APPENDIX F

Reliability of Check Valves and Leak Estimates at Selected Stream Crossings

Reliability of Check Valves and Leak Estimates at Selected Stream Crossings

A commentor expressed concern about valve closure reliability (particularly check valves) and the impact of valve failure on leak volumes. Check valve reliability and potential leak volumes at sensitive crossings are discussed below.

Check Valve Reliability

Limited amount of publicized data are available on the reliability of either remote controlled valves or check valves.

Lees (Lees, 1996) contains limited data on valve reliability. According to Lees, data from the Rasmussen Report (Atomic Energy Commission. Reactor Safety Study: An Assessment of Accident Rates in US Commercial Nuclear Reactors. Rep. WASH-1400, Washington, DC, 1975) indicates that the median failure rate of motor-operated valves is 0.001 failure/demand. Although the liquid in the line was not specified, it was probably mostly treated and untreated water, since these valves were in nuclear power plant service.

The remote controlled block valves in the Longhorn pipeline are gate valves. Smith (Smith, 1985) reported failure rates of 1.5-15 failures/10^6 hours for gate valves in general.

Data on the reliability of check valves also appears to be limited. In Lees (Lees, 1996), data from the Rasmussen Report (AEC, 1975) indicate that check valves in their study failed to open (a less critical failure mode) at a rate of $1x10^{-4}$/demand, and developed severe internal leaks at a rate of $3x10^{-7}$/hour. The types of check valves were not specified, so the specific reliability of swing check valves (as used in the Longhorn Pipeline System) was not determined. Smith (Smith, 1985) reported failure rates of 2-5 failures/10^6 hours for check valves in general.

In 1997, McElhaney (McElhaney, 1997) summarized the results of an Oak Ridge National Laboratory (ORNL) study of check valve performance in nuclear plants. Approximately 21,000 check valves are listed in the Nuclear Plant Reliability Database System (NPRDS). Nearly 60 percent of these valves and 85 percent of the 838 check valve “failures” occurring during 1991-1992 were identified according to valve type.

In the ORNL study, most of the valve failures were discovered by programmatic methods such as seat leakage testing, surveillance testing, in-service inspections or tests, disassembly and inspection, nonintrusive diagnostic testing (radiography, acoustic monitoring, etc.), hydraulic/ pneumatic indication, etc. Most failures were classified as moderate in nature, and they included modes such as failure to seat properly and internal leakage through/around the valve seat. The significant failure mode category includes broken or detached internals, stuck open, stuck closed, etc. There were 288 failures attributed to swing check valves in 1991-1992, and approximately 60 percent of these were considered to be moderate. Eighteen percent of the swing check valve failures were in the “stuck open” mode, while 50 percent of the failures were due to improper seating. The former mode is of most interest in evaluating the potential for high backflow rates through the check valves on the downstream side of the pipeline where it passes across several rivers. Unfortunately, the actual failure rate of swing check valves was not determined, nor can it be estimated from the data available in McElhaney's paper (McElhaney, 1997).

In an earlier paper, however, McElhaney and Staunton (McElhaney, 1998) did provide an estimate of 0.0061 significant failures per year for the overall failure rate of all types of check valves combined. In this study, a "failure" was defined as the degradation of one or more valve functions.

The reliability of check valves in service on the Williams System pipelines appears to be high. According to Williams, to their knowledge, they have never experienced the failure of a check valve to close on demand in the Williams System.

In summary, the available failure rates of both motor-operated valves and check valves are low enough that the probability of a leak occurrence and a valve failure happening simultaneously appears to be very low. Nevertheless, leak volumes at some stream crossings of particular interest to the commentor have been estimated under the assumption that the downstream check valves failed to close in response to an upstream leak. These estimated leak volumes are presented and discussed in the following section.

Estimated Leak Rates at Selected Stream Crossings

In the event of a catastrophic leak along most segments of the pipeline, most of the liquid lost from the leak site would probably be liquid draining from the sections of the pipeline immediately upstream and downstream of the leak site. Using the algorithm described in Appendix 5H of the Environmental Assessment (EA), these drained volumes have been estimated for stream crossings of particular interest. The estimated drain volumes are summarized in Table F-1.

At three of the major river crossings (Colorado, Llano, and Pedernales), the pipeline is equipped with remote-controlled block valves (RCBV) immediately upstream of the crossings and with a check valve and manual block valve (MB+CV) immediately downstream of the crossings. When operating properly, these valves can minimize the volume of liquid that would drain from the pipeline in the event of a large leak at these three crossings. The drain volumes were calculated for the case where the leak was isolated by the upstream RCBV and the downstream MB+CV. These volumes are reported in Table F-1.

The drain volumes were also calculated under the assumption that the check valves immediately downstream of the leak site failed to close, allowing unobstructed flow back through the valves to the leak site. In these cases, the drain volume in the pipeline between the leak site and the next RCBV downstream of the leak was included in the total drain volume.

When a leak occurs, the liquid is forced through the ruptured area by the pressure in the pipeline until the pump(s) upstream of the leak are shut down. In the catastrophic leak scenario presented in this analysis, it is assumed that the pipe is completely ruptured and liquid leaks at the full

Table F-1. Drain Volumes at Selected Stream Crossings

	Crossing		Upstream Valve		Downstream		Maximum Drain Volume			Estimated Drainage at Crossing during a 2-Hour Period		
Crossing	**MP**	**Station**	**Valve Type**	**MP**	**Valve Type**	**MP**	**bbl**	**gal**	**Drained Volume Incl. 10-Minute Shutdown, gal.**	**Liquid Draining Velocity, fps**	**Drained Volume, gal.**	**Drained Vol. Incl. Loss during 10-min. Shutdown Interval, gal**
Colorado River	134.4	709,632	RCBV	134	MB+CV	134.67	1,245	52,292	117,917			
			RCBV	134	RCBV	166.66	16,388	688,287	753,912	3.7	110,000	175,600
Llano River	276.6	1,460,448	RCBV	276.48	MB+CV	276.64	280	11,745	77,370			
			RCBV	276.48	RCBV	295.12	9,253	388,619	454,244	9	268,000	333,700
Sandy Creek	234.8	1,239,744	RCBV	227.79	RCBV	276.48	4,167	175,017	240,642			
Pedernales River	198.7	1,049,136	RCBV	198.68	MB+CV	198.94	408	17,143	82,768			
			RCBV	198.68	RCBV	222.79	12,281	515,781	581,406	7.5	206,300	272,000
Barton Creek	180.9	955,152	RCBV	175.5	RCBV	181.6	3,571	149,977	215,602			
Onion Creek	164	865,920	RCBV	134	RCBV	166.66	4,318	181,352	246,977			
Marble Creek	163.5	863,280	RCBV	134	RCBV	166.66	3,273	137,445	203,070			
Cedar Creek	144	760,320	RCBV	134	RCBV	166.66	9,321	391,481	457,106			
Alum Creek	131.5	694,320	RCBV	63.65	RCBV	134	2,401	100,835	166,460			
Rabb's Creek	112.3	592,944	RCBV	63.65	RCBV	134	6,025	253,036	318,661			
Cummins Creek	99.2	523,776	RCBV	63.65	RCBV	134	8,275	347,548	413,173			
Pin Oak Creek	122.5	646,800	RCBV	63.65	RCBV	134	7,805	327,819	393,444			

Notes:
RCBV = remote-controlled block valve.
MB + CV = manual block valve and check valve.

pipeline flow rate until the line is shut down. After shutdown, the leakage is due to draining. The total estimated leak volume is the sum of the initial volume leaked before shutdown and the volume drained. It is estimated that a catastrophic leak would be identified and the line would be shut down within 5 minutes of the leak initiation. The initial leaked volume was estimated under the conservative assumptions that (1) it would actually take 10 minutes to shut down the line, and (2) that the leak rate would be equivalent to the maximum flow rate of 225,000 bpd (6,560 gpm). Furthermore, although the maximum rate of 225,000 bpd was assumed, the additional pump stations needed to maintain that flow rate were not considered. The presence of these pump stations may well reduce the maximum drain-down volumes at some locations due to the additional valves at these pump stations. The volume lost during the 10-minute period is 65,600 gallons. This volume was added to the drain volume to get the maximum volume that could be lost through the leak site.

It seems reasonable to assume that the actual volume lost through a leak will be less than the calculated maximum. Some of the drained liquid must travel a considerable distance (>20 miles, in some cases) with only the liquid hydrostatic pressure to propel it. Drained volume and total volume losses were estimated assuming that the block valve immediately downstream of the leak at the three river crossings could be reached and manually closed within 2 hours from the initiation of the leak. Using the procedure described in Attachment 1, the velocity of the draining liquid in the pipeline was estimated for the three river crossings. The volumes drained in the 2-hour period were then estimated and these volumes are included in Table F-1.

Several other creek crossings are of particular interest. Maximum leak volumes were calculated for each of these crossings, assuming that drainage occurs from segments of the line between the leak site and the closest upstream and downstream RCBV. These estimated volumes are included in Table F-1.

References

1. Lees, Frank P., *Loss Prevention in the Process Industries*. Second Edition, Butterworth-Heinemann, Oxford 1996.

2. Smith, D.J., *Reliability and Maintainability in Perspective*, 2nd and 3rd editions, Macmillan, London, 1985.

3. McElhaney, K.L., *Performance Characteristics of Check Valves Based on Specific Valve Type Plant Systems/Components Aging Management*, American Society of Mechanical Engineers, Pressure Vessels and Piping Division, PVP v 349, 1997, ASME, New York, New York, p 135-146, 1997.

4. McElhaney, K.L., R.H. Staunton, *Reliability Estimation for Check Valves and Other Components, Seismic Engineering, American Society of Mechanical Engineers*, Pressure Vessels and Piping Division, PVP v 340, 1998, ASME, New York, New York. P 135-146.

ATTACHMENT 1

Procedure for Estimating Velocity of Draining Liquid in the Pipeline

Attachment 1—Estimating Flow Velocities at Leak Locations along the Pipeline

Since the maximum drained volume often comes from a long stretch of pipe, the velocity of the draining liquid in the pipeline can be estimated to project the approximate time needed to fully drain the line. The velocity of the liquid draining from the pipeline segment immediately downstream of a leak site was estimated using the following procedure:

- The high point along the line between the location of the leak and the nearest downstream valve was found from the pipeline elevation profile.
- The distance between the high point and the leak point was defined as the difference in stationing values of the two locations. This distance was assumed to be the total length of pipe, L, from which drainage occurred.
- The head driving the drainage was assumed to be only due to the difference in elevation, ΔE, of the high point and the leak site.
- The system was assumed to be a straight pipe of length L with a slope of $\Delta E/L$.
- The velocity was estimated using the Fanning equation, shown below:

$$V^2 = \frac{\Delta P g_c D}{2fL\rho}$$

where

V = volumetric fluid velocity, feet/sec
ΔP = pressure drop due to friction (head loss), lb/ft^2
g_c = 32.17 lb(mass) ft / lb(force) sec^2
D = inside diameter of pipe, ft
f = friction factor
L = length of pipe, ft
ρ = fluid density, lb/ft^3

- The friction factor, f, is obtained from a chart that shows the friction factor curves for a variety of pipe materials as a function of the Reynolds Number, N_{Re}, where

$$N_{Re} = \frac{DV\rho}{\mu}$$

where μ = absolute viscosity of the liquid, lb / ft sec

- The estimated liquid draining velocity through the pipe is determined through an iterative calculation:

  - A fluid velocity is first estimated;
  - The value of N_{Re} is calculated;
  - Using the N_{Re}, the friction factor is found from the friction factor chart
  - The velocity is calculated from the Fanning equation; and
  - If the calculated velocity is not equal to the estimated velocity, a new velocity is assumed, and the procedure is repeated until the calculated velocity matches the assumed velocity.

- The length of pipe to be traversed by draining liquid is equal to the drained volume divided by the amount of liquid contained in a 1-foot length of pipe.

- The total drain time is then estimated as the length of pipe traversed divided by the liquid velocity.

- The volume of liquid that would drain from the pipeline in 2 hours was then estimated as:

$$\text{Volume (gal/2-hr)} = \text{velocity (fps)} \times 7200 \text{ (sec/2-hr)} \times 12.495 \text{ (gal/ft)}$$