Comparison of Exhibited Wear in Tefzel®, Kynar®, and UHMWPE Valve Seats Exposed to Cyclic Operations with Abrasive Slurry - 17519

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ABSTRACT

Pacific Northwest National Laboratory (PNNL) conducted abrasive-wear testing of ball valves used for double valve isolation in nuclear waste process lines. The valve seat materials consisted of Kynar®, Tefzel®, and ultra-high-molecular-weight polyethylene (UHMWPE). Cycle testing was conducted for 1500 operating cycles for the Kynar® and Tefzel® valve seats and 5500 cycles for the UHMWPE valve seats. A valve operational cycle consisted of slurry flow, slurry gravity drain, flush water flow, and flush water gravity drain. Both two-way and three-way valves were evaluated, and valves were configured in simulated manifolds so the impact of serving various operational functions (e.g., slurry, flush, or drain control) could be evaluated as some valves are flushed prior to being cycled and others are not. Testing was conducted in PNNL's Multi-Phase Transport Evaluation Loop Facility using a performance-based simulant developed by PNNL specifically for this test program to emulate abrasive slurries for Hanford Tank Farms Waste Transfer System during single-shell tank retrieval and waste feed delivery to the Hanford Tank Waste Treatment and Immobilization Plant. Pre- and post-test valve teardown evaluations were conducted to observe changes in the condition of internal components for the various seat materials. The various forms of physical wear observed for the different seat materials are presented. The wear results can be used to assess seat materials and valve configurations for application to waste transfer operations, and the observed wear mechanisms can provide insight into assessing valve service life. This information will be used to identify and select additional valve designs that should be evaluated for certification for future use.

INTRODUCTION

This paper presents post-test observations of internal conditions for a sample of the safety-significant isolation valves used for double valve isolation (DVI) at the Hanford tank farms following extended testing with abrasive slurry. Pacific Northwest National Laboratory (PNNL) conducted testing to assess the leak rates and associated operating torques as a function of operational history using an abrasive simulant developed to represent the Hanford waste [1, 2]. The suite of valves was made up of two-way and three-way valves and consisted of:

- Two-inch valves with ultra-high-molecular-weight polyethylene (UHMWPE) seats and 316 stainless steel balls manufactured by Flow-Tek.

- Three-inch valves with Tefzel®[1] seats and electroless nickel-plated balls manufactured by Pittsburgh Brass Manufacturing (PBM) Inc.
- Three-inch valves with Kynar®[2] seats and 316 stainless steel balls manufactured by PBM Inc.

The existing Hanford Tank Farms Waste Transfer System (WTS) contains DVI ball valves that have been installed for up to 10 years. The DVI valve seat materials were selected to be abrasion-resistant, based on the valve manufacturer's data, to provide additional wear protection from tank waste fluids that may be abrasive and erosive. Past operational valve testing performed by Washington River Protection Solutions (WRPS) evaluated wear performance characteristics using representative (two-way and three-way) DVI ball valves in wet cycling (valve flooded with water) and dry cycling (no liquid against the ball and seat) combinations. Following the operational cycling, the test valves were subjected to seat leak tests, and all valves passed.

A later evaluation by WRPS [3] concluded that the materials used for the DVI valves can withstand the postulated failure modes due to operation in the WTS. However, this evaluation also concluded that the past WRPS DVI valve testing using water did not address the documented safety analysis (DSA) concern that valve life can be limited by exposure of valve seats to abrasive particles in the waste. To address DSA valve life concerns regarding abrasive tank waste, PNNL conducted the additional DVI valve testing using abrasive simulant [4].

The objective of the test program was to determine whether valves currently in use for the WTS might develop excessive leak rates over extended periods and with repetitive cycling in abrasive service. Newly purchased valves of the same makes and models as those currently installed in the WTS were tested. Testing was conducted for up to 1500 operating cycles for PBM valves and 5000 cycles for Flow-Tek valves.

The purpose of this paper is to present the observations from the teardown inspections of the valves following the completion of cycle testing. The focus of the results presented is a comparison of the physical wear observed for the different seat materials tested.

SIMULANT DESCRIPTION

The test effort used a performance-based simulant developed by PNNL [4]. The simulant performance focused on valve wear from abrasive slurry based on representative Hanford waste particulate characteristics (e.g., density, hardness, size) as well as the hardness of the valve body and seat surface exposed to abrasive slurry, and on pipeline slurry transfer. The composition and physical properties of the simulant developed for DVI valve testing are presented in Table 1.

[1] Tefzel is a registered trademark of E.I. du Pont de Nemours and Company, Wilmington, Delaware.
[2] Kynar is a registered trademark of Arkema Inc., Philadelphia, Pennsylvania.

The average undissolved solid density of this composition is approximately 3.17 g/mL.

TABLE 1. Composition of the DVI test simulant.

Component	Crystal Density (g/mL)	Mohs Hardness (VHN)[a]	Volume Fraction[b]	Mass Fraction[b]	Approximate Percentile Particle Size (µm)	
					50th	90th
Gibbsite	2.42	3 (157)	0.240	0.185	80	158
Zeolite	2.15	3.75 (270)	0.182	0.125	53	309
Hydroxyapatite	3.14	5 (535)	0.115	0.116	4.7	12
Bismuth Oxide	8.9	4.5 (418)	0.021	0.060	8.7	24
Boehmite	3.01	4 (315)	0.221	0.212	8.5	21
Large Gibbsite	2.42	3.4 (213)	0.081	0.062	8.8	20
Large Sand	2.65	6.5 (982)	0.030	0.025	394	592
Zirconium Oxide	5.7	8 (1567)	0.091	0.166	13	30
Stainless Steel[c]	8	5.5 (669)	0.02	0.051	59	152
			0.017	0.043		
			0.001	0.004		

a Different references provide similar but not equivalent conversions from Mohs to Vickers Hardness No. (VHN). Data provided at http://www.cidraprecisionservices.com/mohs-conversion.html, in general agreement with the ranges provided in [5], was used for this analysis.
b Values differ slightly from those reported by Wells [4] due to difference between vendor-reported values for density and those of received material.
c Three stainless steel products were obtained to create stainless steel constituent equivalent to that defined by Wells [4].

Throughout testing, changes in the simulant condition (e.g., simulant degradation and attrition) were monitored based on characterization of slurry line samples drawn at the start and end of each test run. A methodology was formulated, based on simulant degradation test results, for monitoring the simulant particle size distribution based on key relative particle sizes (i.e., size percentiles d(50) and d(90)) [1, 2]. The simulant was dressed or replaced as needed to maintain the simulant bulk properties within test specifications over the course of testing.

DESCRIPTION OF VALVE TEST MANIFOLD

An automated test system was configured for conducting the valve cycle operations at PNNL's Multi-Phase Transport Evaluation Loop Facility. The test system was designed to provide four flow conditions through the valves that mimic the WTS operating conditions. The four flow conditions, in order of occurrence during automated valve cycle operations, consist of slurry flow, slurry gravity drain, water flushing to clean out remaining slurry transfer residuals, and flush-water gravity drain.

The 10 DVI test valves, plumbed into one of three test manifolds, were each assigned a unique test valve number (TV#) along with an associated valve type (A through F) from Table 2. Each manifold contained valves of a single seat material. Multiple valves of types B, D, and E were tested. Fig. 1 provides a schematic of the test manifolds, associated TV numbers, designated valve types, and indication of test loop hose connections (slurry, flush, and drain). For the three manifolds containing the test valves, the operational valve positions within the manifolds are designated as follows:

- Slurry – upstream valve that controls slurry flow and does not experience flushing prior to cycling. For the configurations having a three-way valve in this position, the valve also controls the flush water supply to the line. (TV1, TV4, and TV8)
- Drain – downstream three-way valves that control the routing of the discharge fluid from the manifold (e.g., slurry, slurry drain, flush water, flush water drain) and experience flushing prior to cycling. (TV3, TV7, and TV10)
- Middle – midline two-way valve that experiences flushing prior to cycling. (TV2, TV6, and TV9)
- Flush – upstream two-way valve that controls the supply of flush water and does not experience flushing prior to cycling. (TV5)

OPERATING CONDITIONS

Each test valve underwent a pretest teardown and inspection followed by an acceptance leak test (0 cycles) prior to being subjected to cycle testing with slurry. The allowable pretest (0 cycles) leakage was ≤ 4 mL/min (0.001 gpm) for the 2-inch Flow-Tek valves and ≤ 0.2 mL/min (5.3×10^{-5} gpm) for the 3-inch PBM valves. The threshold leak rate for valves in service is 379 mL/min (0.1 gpm).

The following operating conditions were maintained for the cycle operations:

- Slurry conditions – bulk density: 1.08 to 1.13 g/mL, solids concentration: 13 to 18 wt%, temperature: 43°C to 49°C, volumetric flow for 2-inch valves: 341 to 417 L/min (2.6 to 3.2 m/s), volumetric flow for 3-inch valves: 530 to 795 L/min (1.8 to 2.7 m/s), flow duration: 160 to 200 sec
- Flush water conditions – temperature: ambient, volumetric flow for 2-inch valves: 341 to 417 L/min (2.6 to 3.2 m/s), volumetric flow for 3-inch valves: 379 to 568 L/min (1.3 to 2.0 m/s), flow duration: 55 to 65 sec
- Valve rotation – 7.5 to 3.7 rpm (90° of rotation in 2 to 4 sec)

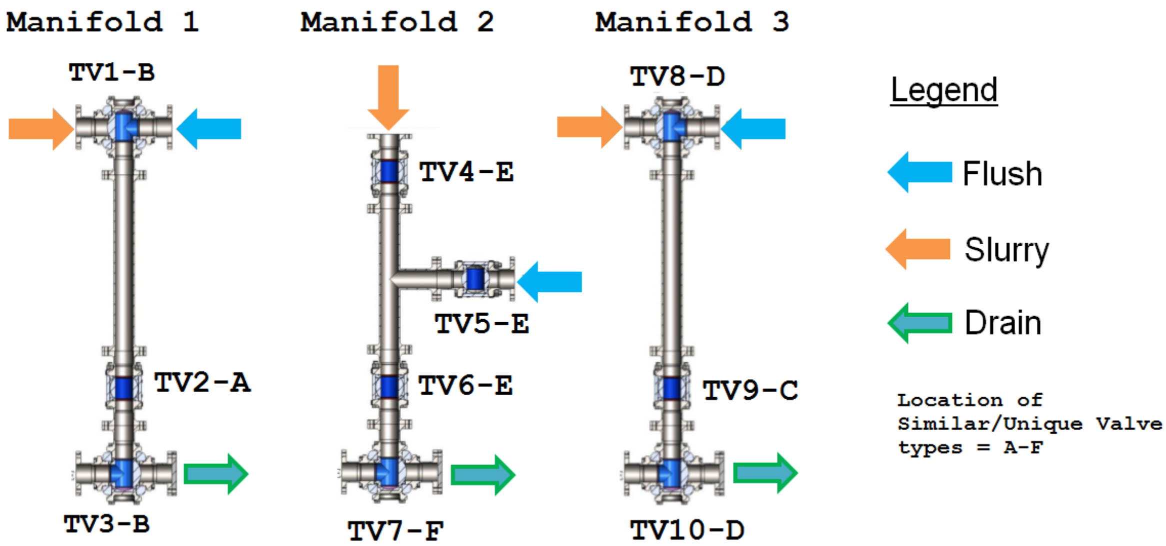

Fig. 1. Configuration of test manifolds with indication of flow stream into and out of manifolds as well as TV numbers used to define system configuration.

Table 2. Description of test valve types presented in Fig. 1.

Valve Type	Manufacturer	Type	Seat Material	Ball Coating
A	PBM	3-in 2-Way	Tefzel®	Electroless nickel plating
B	PBM	3-in 3-Way	Tefzel®	Electroless nickel plating
C	PBM	3-in 2-Way	Kynar®	None
D	PBM	3-in 3-Way	Kynar®	None
E	Flow-Tek	2-in 2-Way	UHMWPE	None
F	Flow-Tek	2-in 3-Way	UHMWPE	None

TEST RESULTS

The PBM valves (Kynar® and Tefzel® seats) and the Flow-Tek valves (UHMWPE seats) that were tested for 1500 and 5500 cycles, respectively, underwent post-test inspections following the final leak tests [2]. This section discusses the common findings that were observed for all the valves. Unique findings for the Kynar®, Tefzel®, and UHMWPE seated valves are presented in follow-on sections.

Relative assessments of the surface conditions were made via visual inspection and surface texture, and the record of the assessment consists of observation notes and photographs. Photos were taken as components were disassembled to capture deposited materials and any changes in the mating surfaces between components. The teardown evaluation focused on components associated with sealing (e.g., seats, O-rings, and ball surface) and on any accumulation of solids within the valve body.

The seat face mating with the valve ball has a non-uniform profile due to an annular relief groove depicted in the left image in Fig. 2, where the valve seat cross-section is represented in yellow. The concave portion of the seat profile allows for a reduced friction between the ball and the seat at lower pressures. As the force between the ball and seat increases, the seat profile is compressed to increase the contact surface between the seat and the ball. For comparison purposes, Fig. 3 presents photos of a used UHMWPE port seat and a Kynar® blind seat.

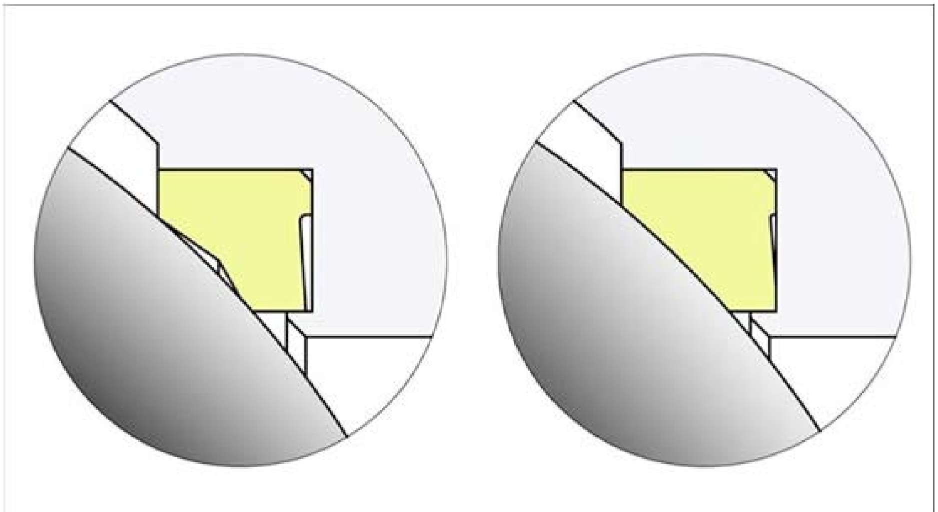

Fig. 2. Cross-section of a valve seat (highlighted in yellow). Left: Seat and ball mating surfaces in low-pressure condition (i.e., concave portion of seat surface does not fully contact valve ball). Right: Seat and mating surfaces in higher-pressure condition (i.e., valve seat surface in full contact with ball).

Observations made during the teardown inspection are as follows:

- Ball alignment – The ball alignment pertains to the concentric alignment of the ball penetration with the opening of the valve port. Alignment was concerned with two aspects:
  - Rotation of the ball is within the original specification of ± 2° of the indicated fully open position. An out-of-tolerance condition would indicate slippage of the linkage between the valve stem and the valve actuator. This would be observed in an offset of the ball at the side of the valve port. All of the valves evaluated were found to have maintained their horizontal alignment.
  - Vertical ball port rotation, which would be observed by an offset of the ball port with respect to the top or bottom of the valve port. All of the Kynar® and UHMWPE valves maintained their vertical port alignment. For the Tefzel® seated valves, the slurry valve (TV1) was found to have a slight vertical offset.

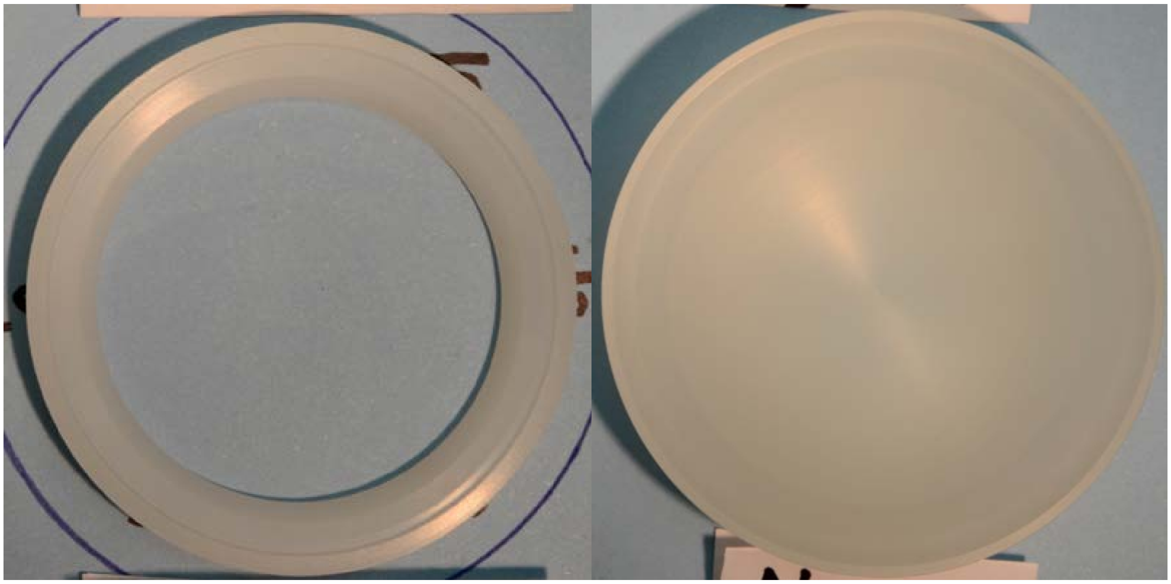

Fig. 3. Left: Unused UHMWPE port seat for 2-inch, three-way, Flow-Tek valve. Right: Unused Kynar® blind seat for 3-inch, three-way, PBM valve.

- Stem wear – Stem wear refers to the valve stem, which includes the keylock with the top of the valve, the stem shaft, and the components encircling the stem. For all of the valves tested, no stem leakage was observed over the course of cycle and leak testing. Only minor wear marks were observed on the stem shaft and no other indication of wear associated with the stem was seen or felt.
- Ball wear – Interior and exterior ball wear were evaluated.
  - Interior ball wear refers to any erosive wear occurring within the ball penetrations as a result of the slurry flow. For all the valves evaluated, the interior ball penetrations appeared pristine, and based on surface texture, no wear was detected.
  - Exterior ball wear refers to abrasive wear observed on the outside of the ball resulting from ball rotation. For all of the valves tested, some form of exterior ball wear was observed.
- Solids holdup/accumulation – Refers to the amount of simulant material (i.e., particulate) that was observed within the valve interior upon disassembly. Removed components were rinsed over a single basin to capture all of the solids retained in a single valve.
- Cavity filler – Wear on the cavity fillers was dependent on the configuration of the cavity fillers, which varied between valve designs, and whether the cavity fillers surfaces were exposed to the rotation of the ball.
- Sealing surface of the seat – The sealing surface of the seat is that face that is in contact with the ball; refer to Fig. 2. Observations included type of wear observed on the seat face, the degree of wear observed, and the ease with which the seat was removed from its retaining channel.

For the comparison of teardown observations listed in Table 3, the following qualitative terms are applied:

- None detected – No observation of wear is seen or detected/felt. Component or portion of component could pass for new.
- Negligible – Wear markings are visually observed, but no wear is detected. Component appears unused or to have had limited service but could not pass for new.
- Minimal – The initiation of wear is observed and/or detected but appears to be the result of limited service.
- Moderate – Wear is observed and detected and provides evidence of sustained service, but it is readily apparent that part has significant service life left.
- Extended – The observed and detectable wear are pronounced, but examination of the component by itself would not lead one to consider the component had failed.
- Significant – The observed and detectable wear are pronounced, and examination of the component by itself could lead one to conclude that the part may have no service life left. Based on examination, the part should be replaced.

Table 3. Comparison of internal component post-test conditions.

Valve Component	**UHMWPE Seat Valves**		**Kynar® Seat Valves**		**Tefzel® Seat Valves**	
	2-way	3-way	2-way	3-way	2-way	3-way
Stem wear	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Ball interior wear	None detected	None detected	None detected	None detected	None detected	None detected
Ball exterior wear	Moderate	Moderate	Moderate	Moderate	Minimal - Reduced due to nickel plating	Minimal - Reduced due to nickel plating
Cavity filler wear	Minimal	Moderate	Minimal	Moderate	Minimal	Moderate
Type of seat wear observed	Plastic scoring	Plastic scoring	Brittle scoring with small chip/flake removal – appear-ance of brittle surface behavior	Brittle scoring with small chip/flake removal – appear-ance of brittle surface behavior	Minimal plastic scoring	Plastic deformation

Valve Component	UHMWPE Seat Valves		Kynar® Seat Valves		Tefzel® Seat Valves	
	2-way	3-way	2-way	3-way	2-way	3-way
Degree of seat wear based on appearance	Moderate	Extended	Minimal	Significant roughing of surface and embedded solids	Minimal	Significant large amount of embedded particulate and deformation of original shape
Post-test seat removal	Readily removed	Readily removed	Readily removed	Significant tightening of fit in retaining channel – seats were the most difficult to remove of any valves	Readily removed	Tightening of fit in retaining channel
Relative solids holdup in internal region of valve	Minimal	High	Moderate	High	Minimal	High

Observations for UHMWPE-Seated (Flow-Tek) Valves

The Flow-Tek valves with UHMWPE seats consisted of three two-way valves (slurry, flush, and middle valve positions) and one three-way valve in the drain valve position (TV7). The wear and solids accumulation for the three two-way valves were similar, with the slurry valve (TV4) having indications of greater wear and solids holdup compared with the flush (TV5) and the middle (TV6) valves. The design of the sealing components is significantly different for the two-way Flow-Tek valves with UHMWPE seats compared with the other two-way and three-way valves tested. For the two-way UHMWPE valves, the cavity filler and the valve seat form a single (combined) part. The sealing seat surface is the annular region on the inside of the cavity filler surrounding the hole/port through the cavity filler. The configurations of the UHMWPE seats for the three-way drain valve (TV7) are similar to the Kynar® and Tefzel® seats for the three-way PBM valves.

The UHMWPE seat faces (i.e., annular surface) exhibited visible and detectable scoring, but no evidence of material loss was observed; no removed or partially attached pieces of seat material were noted. Based on the observations, the scratches were possibly the result of plastic deformation of the seat face. The wear observed in the seats of the three-way, UHMWPE-seated valve was greater than anything observed for the seats of the three, two-way, UHMWPE-seated valves. Refer to Figs. 4 and 5, respectively. The degree of wear observed in the UHMWPE seats was significantly less than that observed in the Kynar® and Tefzel® seats.

The blank, drain, and blind UHMWPE seats of the three-way Flow-Tek drain valve showed wear around the entire circumference based on the appearance of embedded material and apparent discoloration. In contrast, based on appearance, the upstream port seat of the three-way drain valve only exhibited wear around the lower third of the sealing surface (Fig. 4). The degree of roughness corresponded to the regions with the most embedded material and greatest amount of discoloration. The blank and blind ports had significantly smoother surfaces at the top and bottom of the seat faces that corresponded to regions with minimal embedded particulate. A similar surface existed at the bottom of the seats for the drain and upstream ports.

Based on appearance and texture, the lower portions of the TV7 seats experienced greater wear than the upper regions, with the upstream seat experiencing the least amount of detectable wear. The surface condition of the center region of the blind seat appeared unchanged.

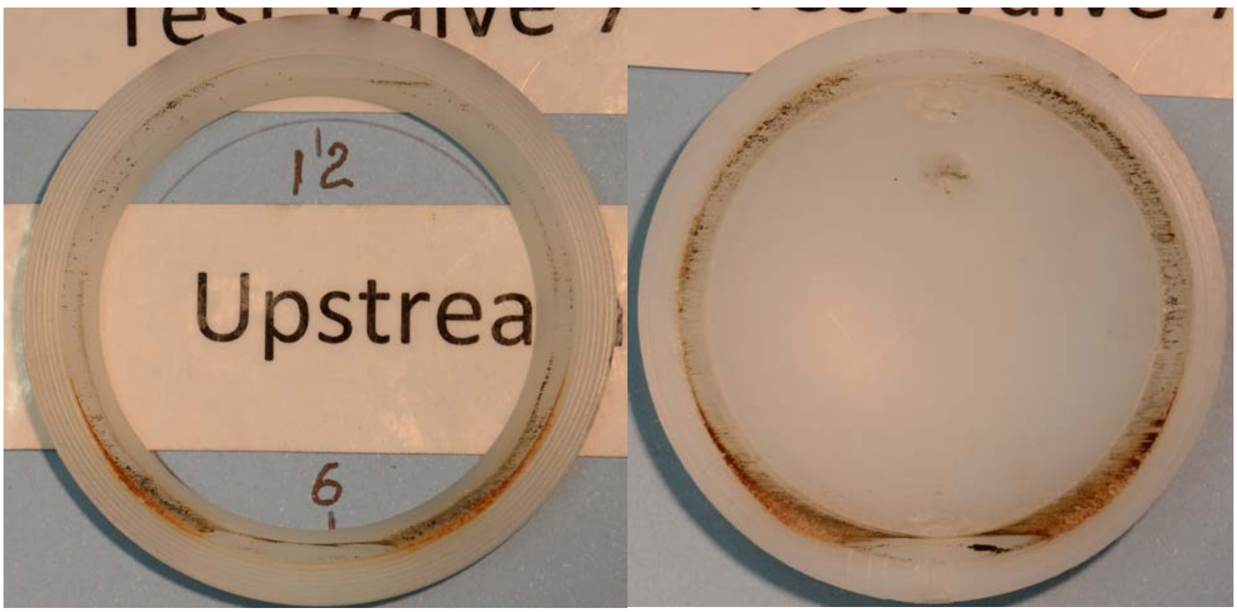

Fig. 4. Left: UHMWPE seat from upstream port of three-way, Flow-Tek, 2-inch drain valve (TV7) after being rinsed. Right: UHMWPE blind seat for three-way, Flow-Tek, 2-inch drain valve (TV7) after being rinsed. (Note: Blemish in upper portion of center region is a hole made to extract blind seat from valve flange stem.)

For the two-way Flow-Tek valves with UHMWPE seats, wear was predominantly greater on the lower half of the seats due to the influence of gravity. However, based on surface texture, the wear was not symmetrical around the circumference of the seats or between opposite sides. The lowest portion of the seats had a very smooth region that contained minimal embedded particulate (lighter dimple area seen in Figs. 4 and 5.). The seat faces of the two-way valves each had one side that felt smoother than the other. The rougher side of each seat corresponded to the side over which the ball penetration passed during valve rotation, exposing that side of the seat to less contact with the ball's outer surface.

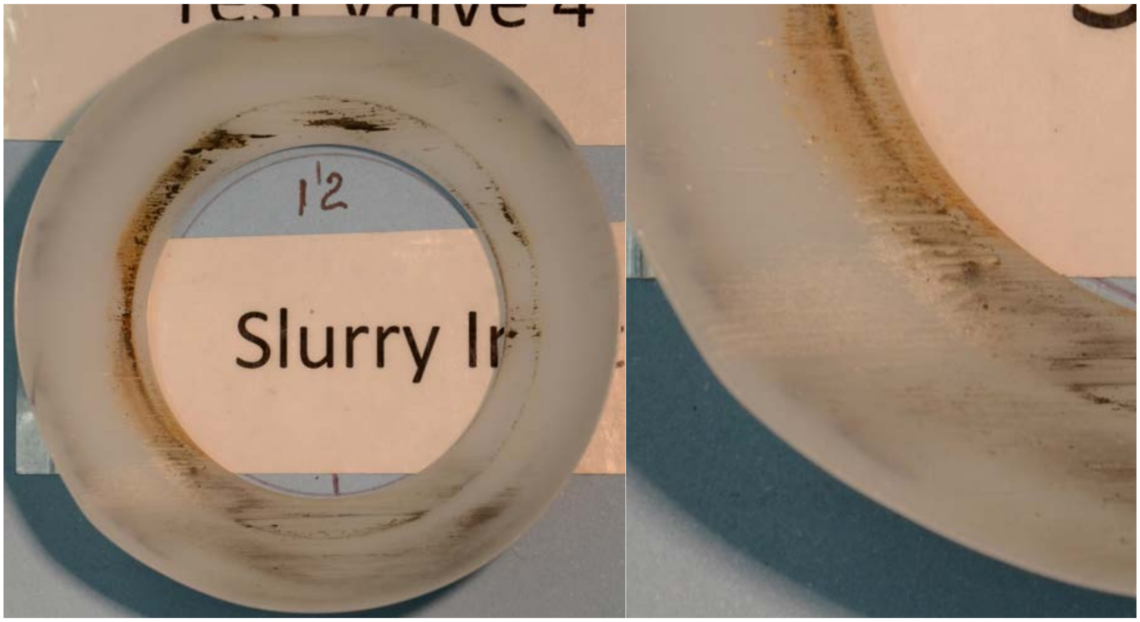

Fig. 5. Upstream UHMWPE cavity filler/seat from two-way Flow-Tek Slurry valve (TV4) after being rinsed. Seat (i.e., sealing surface) consists of annular inner region of component. Image on right is of lower left section of seat.

Observations for Kynar®-Seated (PBM) Valves

The seats of the Kynar®-seated, three-way valves contained significant scratches/grooves in the direction of the ball rotation, and small deposits of the Kynar® flakes were observed within the valve internals. The scratches also contained small flakes of Kynar® material, giving the appearance that the scratches had been slowly formed by continual removal of small pieces of material. Refer to Fig. 6. The rough appearance of the wear marks and the small flakes of material gave the impression that material removal occurs via localized chipping away of the seat material as in a brittle fashion, as opposed to a ripping away of longer threads of material.

The Kynar® seats from the two-way middle valve had also been scored. However, the scratches did not exhibit the partially torn away small flakes of material still attached to the seats, nor were deposits of Kynar® material found during the teardown inspection.

The scoring of the seats generated relatively deep scratches that created a very rough surface. Wear on seat faces appeared symmetrical and similar at each valve port, with symmetrical wear marks from ball rotation on each side of the seat faces. No evidence of the relief groove remained in the face of the seats.

The top and bottom regions of the seats were worn smoother than the sides of the seats. The black marks on the faces of the seats are embedded particulate. While the Kynar® seats experienced the embedding of particles, based on relative comparison of surface texture, the roughness resulting from scoring was greater than that resulting from particle embedment. The interior, central region (i.e., the region corresponding to valve/ball port) of the blind flange had no visual or tactile indications of wear. Refer to Fig. 7.

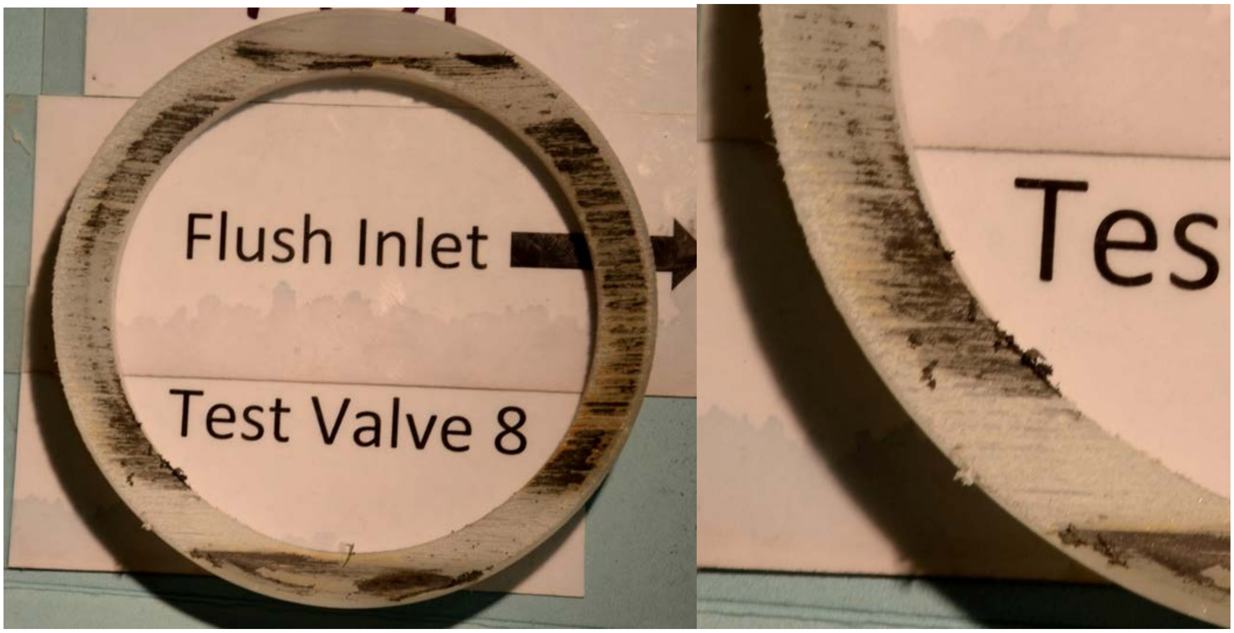

Fig. 6. Flush-port Kynar® seat from PBM, 3-inch slurry valve (TV8) after being rinsed. Image on right is of lower left section of seat.

Fig. 7. Kynar® blind seat for three-way, PBM, 3-inch slurry valve (TV8) after being rinsed. Image on right is a close-up of left side of the blind seat.

Observations for Tefzel®-Seated (PBM) Valves

The seats of the two-way PBM middle valve with Tefzel® seats (TV2) showed minimal wear, maintained an intact relief groove in each seat, and contained no embedded material within the relief groove. Most of the relief groove was smooth with a few spots of roughness that were not uniformly or symmetrically distributed. The ridges of the relief groove felt rough and exhibited circumferentially uniform wear except at the bottom of the seat faces.

The seats from the Tefzel®-seated, three-way valves displayed a plastic material creep/deformation in which the outside lip of the seats was extruded beyond the edge of the retaining channel for the seat. Examples of the observed deformation are presented in Fig. 8. The side of the seats displaying the greatest amount of deformation corresponded to the direction of valve rotation (i.e., side in constant contact with exterior of ball).

There was no evidence of material loss from the seats, just a reshaping of the seats, which eliminated the relief groove in the face of the seat to form a continuous surface. It is unclear whether its absence was the result of deformation or having been worn away.

The Tefzel® seats for the three-way valves experienced the greatest degree of particle embedment. The embedding of the particles was what increased the roughness of portions of the Tefzel® seat faces as opposed to the scoring observed in the Kynar® and UHMWPE seats.

For the three-way slurry valve (TV1), embedded particulate was observed over the entire face of the seats except for small cleared areas at the top and bottom of the seats. The small cleared areas were the smoothest surfaces. The surface texture around the circumference of the seats was not uniform or symmetric. The face of the thin lip of seat material protruding from the flange-stem retaining channel at the outer edge of the seats was smooth. The amount of black embedded material observed corresponded to the degree of surface roughness/wear.

The center of the blind seat for slurry valve (TV1) contained some indication of scoring and particle embedment into the surface, which was not observed for any of the blind seats of the other seat materials tested. The deformation and appearance of the seats for the three-way drain valve (TV3) were similar to that observed for the slurry valve (TV1).

CONCLUSIONS

The most noteworthy difference observed between the valves based on the post-test teardown inspections was the condition of the valve seats and the apparent method by which the wear occurred. All of the two-way valves displayed significantly less wear than the three-way valves. The degree of observed seat wear from most to least was Kynar®, Tefzel®, UHMWPE, respectively.

Fig. 8. Left: Tefzel® seat of three-way, PBM, 3-inch slurry valve (TV1) still in retaining channel of flush port flange stem. Right: Tefzel® blind seat still in retaining channel of flange stem from three-way, PBM, 3-inch drain valve (TV3). Note: Original installation of both pictured seats had the top of each seat flush with the top of the retaining channel.

Fig. 9. Right: Tefzel® seat from flush port of three-way, PBM, 3-inch slurry valve (TV1) after being rinsed. Left: Tefzel® blind seat from three-way, PBM, 3-inch drain valve (TV3) after being rinsed.

All valves tested maintained leak rates below the threshold limit (379 mL/min [0.1 gpm]) throughout the extended duration of cycle operation (1500 cycles for 3-inch valves, 5000 cycles for 2-inch valves). The relative degree of observed wear of the seats corresponded to the measured leak rates. Results indicate that the 3-inch and 2-inch valves installed at Hanford for DVI have a service life in excess of 1500 and 5000 operating cycles, respectively. The seats maintained sealing integrity despite the observable wear to the sealing surfaces.

The faces of the Kynar® seats in the three-way valves experienced a material loss due to cutting/abrasive wear from ball rotation that resulted in fine shavings being cut from the seats, leaving a scored surface. The residual seat material provided clear evidence that the faces of the Kynar® seats for the three-way valves experienced material loss. While the Kynar® seats of the two-way valves had been scored, it is unclear whether material loss occurred. While the Kynar® seats experienced the embedding of particles, based on surface texture, the roughness resulting from scoring was greater than that associated with particle embedment.

The faces of the Tefzel® seats appear to experience a plastic deformation, causing the seat to extend/protrude from the confines of the flange-stem retaining channel. While the faces of the Tefzel® seats had been deformed, it was unclear if seat material had been worn away. The Tefzel® seats for the three-way valves experienced the greatest degree of particle embedment, which increased surface roughness.

The design of the Flow-Tek valves, with UHMWPE seats, minimizes the volume of internal voids, reducing the ability to capture solids. This design provides a better chance that the valve will be flushed clean and reduces the opportunity (i.e., based on volume of solids present) for solids to migrate into the valve internals and contribute to valve wear.

The UHMWPE seat faces experienced less visible wear than either the Kynar® or Tefzel® seats despite having been operated for 3500 more cycles. The UHMPWE seats did not appear to experience any deformation and they were readily removed upon post-test disassembly. While the seat faces contained score marks, there is no evidence of appreciable material loss, and the degree of scoring was significantly less than that observed on the face of the Kynar® seats.

The multi-manifold automated test setup assembled for this test effort allows head-to-head comparative testing and extensive test procedures have been developed that should be considered for any future valve testing to assure a standardized approach and corresponding results [2].

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