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DEVELOPMENT OF A SYNTHETIC FUEL RECIPROCATING CHARGE PUMP

Quarterly Technical Progress Report

for the period of:

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DISCLAIMER NOTICE

1.0 INTRODUCTION

The following report marks the third quarter of the third phase of the reciprocating charge pump improvement program. The program was begun in 1982 for the purpose of improving the operating life of packings and plungers used in 3000 psig, 300F coal/solvent slurry pumps employed in synthetic fuel generating plants. The previous phases of the program developed the floating piston seal, which is a metallic floating piston barrier placed in front of each plunger to keep the hot slurry separated from a cool clean buffer liquid around the plunger and packing. A metered amount of cool clean flush water is injected into each buffer volume during each suction stroke. This causes each floating piston to bottom early before the end of each plunger discharge stroke, causing a slight pressure rise and flushing of the floating piston seals, and synchronizes the position of each floating piston for the next suction stroke.

The testing to be performed during this phase has been modified since the last quarterly report. The floating piston seal will be oriented vertically and operated at a 50 fpm sliding speed. This will be created by operating the pump at 150 rpm. The test duration will be 210 hours in order to cycle the seals the same amount ($\approx$ 1.9 million cycles). The next test will re-orient the floating piston seal horizontal to test for the effects of gravity on the wear rate at the same operating speed. The last test scheduled will also remain horizontal and will simulate accelerated floating piston seal wear. Reduced diameter seal rings will be used. This test will measure the effects of slurry migration past the floating piston seal and the time to wear the packing and plunger beyond the acceptable limit. The amount of flush will be less than 3 percent throughout these tests.

2.0 TECHNICAL PROGRESS

The last quarterly report mentioned some observations made during the initial testing of the FPS. First, the corrosion seen inside the FPS cylinder bore still occurs. However, the operation on slurry removes it, and it does not effect anything. Secondly, the variable operation of the pump discharge and suction valves when pumping slurry has since become a major problem. This will be discussed more fully. Lastly, the pressure rise in the buffer volume during the bottoming phase of the stroke has continued to effect the buffer volume relief valve setting. At this time, the relief valves have been removed in order to eliminate any leakage through them. Over pressure is still protected with a relief valve on the discharge manifold.

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The major problem with the valves has been their inability to seal shut when pumping slurry. The average flow velocity per plunger is lower than the calculated critical velocity to maintain sand in solution (1.7 fps @ 105 rpm, and 2.4 fps @ 150 rpm per plunger, versus 2.3 fps to keep sand in solution per the Durand equation). This effect, plus the valve ball and seat wear, plus the changing flow directions combines to have sand settling in the working volume between the valves. The valves then jam up, the effect compounds, the volumetric efficiency declines, the FPS piston can also jam up, and the discharge pressure decays (the discharge pressure has been see to decay at 20 to 130psig/hr). The valve balls have been measured to wear 0.001 - 0.004" diametral/10 hrs. The valve seats have been measured to wear 0.003 - 0.005" depth/10 hrs. Ovality and egg-shaped wear also occurs to increase the loss of sealing.

The geometry of the working volume, the orientation of the flow within it with respect to gravity, and the orientation of the valves is important. The orientation should attempt to keep the valves from being submerged coaxially in the slurry flow direction. Instead, forcing the slurry to flow vertically against gravity and then making a right angle turn across the valve will keep the valve less submerged. However, the test pump valve arrangement is fixed and cannot be changed in this manner.

The effect of flow rate on the valve problem was tested. The testing schedule was modified to operate at 150 rpm instead of 105 rpm, increasing the flow 40 percent. The flow rate does reduce the valve problems, but it does not eliminate them. The resultant discharge pressure was improved to the desired 3000 psig. The time before sand settling caused a jam was also delayed.

The effects of increasing the valve spring rate, and of changing to an unguided valve configuration were tested. The increased spring rate with the guided configuration required excess NPSH which was not available from the slurry test loop. The original spring rate was reinstalled. The unguided configuration caused the valve ball wear to increase because the ball would not rotate. The ball is always in contact with the valve spring and cannot float as in the guided configuration (see Figure 1). The rotation evens the ball wear. Also, the timing was not precise using the larger diameter balls with the existing springs. This caused a severe loss of volumetric efficiency and discharge pressure. The original guided valve will be reinstalled.

The buffer volume flush injection volume per suction stroke was increased from 0.3 to 1 percent (percent of plunger displacement) for the higher sliding speed (50 fpm instead of 35 fpm, due to the increased operating speed). This amount may be increased to 2 percent if the FPS piston seals wear too quickly.

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The FPS seals and guide lands have worn at a higher rate than previously reported. This is attributed to the sand jams in the working volume forcing higher concentrations of sand into the seal gaps, and to the higher sliding speed. The first WC seal (closest to the slurry) has been measured to wear 0.0025 - 0.0028" diametral/10 hours, the second WC seal at 0.0019 - 0.0023" dia./10 hours., the first WC guide land at 0.0014 - 0.0022" dia. /10 hrs, and the second WC guide land at 0-0.0022" dia./10 hours. The corresponding borided steel cylinder bore wear has been measured according to depth as follows:

Location	Wear from	In. Dia./ 10 hrs.
1	Seal 1	0.0035
2	Seal 1 & 2	0.0035
3	Seals 1 & 2 & Land 1	0.0029
4	Seal 2 & Land 1	0.0014
5	Land 1 & 2	0.0019
6	Land 2	0.0009

It has been found that the No. 1 plunger/FPS location (located closest to the suction into the suction manifold) has had the most valve and FPS wear. Conversely, the No. 3 location (located farthest from the suction but closest to the discharge from the discharge manifold) has had the least valve and FPS wear. Because of this observation extensions have been added to the opposite (dead) ends of the suction and discharge manifolds. The extensions will prevent excess sand buildup at the dead end of the manifolds from restricting the flow at those valves. It must be noted that the previous phase tests at Princeton were conducted with the No. 1 location left empty (no FPS). The above reported observation may have caused the "unprotected" plunger to wear excessively in the Princeton tests, making the wear appear extraordinarily less on the "protected" plungers.

Another effect associated with the valve problems has been the inability to keep sand flowing with the water. It is felt that because the sand settles rapidly and has inertial resistance, it does not flow easily with the water in the working volume.

This requires the physical push of the FPS piston or the high concentration of other sand particles to motivate the slurry. This implies that the local concentration of sand is normally greatest at the piston face, promoting higher wear in the reciprocating seal gaps. In response to this effect, the concentration of the sand will be reduced from 35 percent wt. to 20 percent wt. for further testing.

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Another idea considered was to increase the viscosity of the slurry and improve the suspension of sand particles in the water. Sodium carboxymethylcellulose (CMC) was considered as the viscosity improver but was not used. Samples were prepared with fractions of 1 percent wt. of high and low viscosity CMC and water. Relative sand settling measurements were made. The conclusions were that the cost to constantly maintain the correct concentration of CMC and slurry would exceed the small gain of reduced settling velocity. The viscosity with 1/8 percent wt. CMC/water increased dramatically, > 4 x water alone. However, the settling velocity decreased only 20-30 percent. Also, the increased temperature- and flow-dependent viscosity, due to the pseudoplasticity of the CMC, would cause the discharge pressure to vary more than it already does.

A direct comparison test was made using spare parts from the original Princeton FPS tests. The inability to create and maintain the desired 3000 psig discharge pressure was also observed. This confirmed the present design and test setup are not the cause for the valve problems.

The low pressure injection feed has been removed. It was optional as specified by the Princeton testing. It consisted of a pressure-regulated clear water supply to check valves at each buffer volume. It would supply water on demand, when the buffer volume pressure was 2-4 psid less than the supply pressure, such as during suction or when displacing air in the buffer volume. It was an easy way to fill the buffer volume, but became a problem during regular operation. It would tend to overfill the buffer volume, causing the relief valves to exhaust, reducing the amount of pressure rise and subsequent seal flushing. Air is now relieved via the plunger packing by operating the pump several minutes at slow speed (70 rpm).

Table 1 is a summary of all testing to date, 456 hours total at this time with 72 hours on 35 percent wt. slurry. It denotes the valve problems seen with rapid pressure decay when pumping slurry. Throughout this time, 33 specific and different equipment failures and operational problems occurred that delayed the testing.

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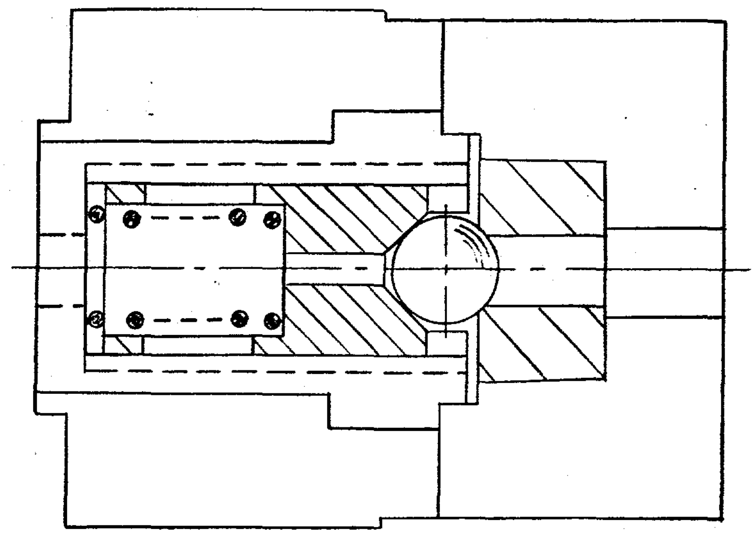
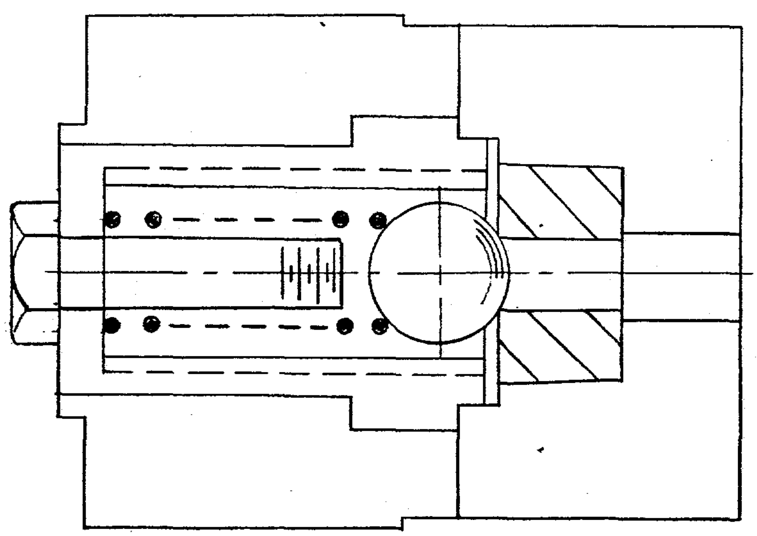


GUIDED VALVE BALL



UNGUIDED VALVE BALL

FIGURE 1

SCALE ≅ 3/4

Recip Slurry Pump Operational Log Summary
(0-448hrs, 3 [illegible]c 86 through 12 Feb 87, 8 [illegible]s)

TABLE 1

Time	Psuct	Pdisch	Speed	Fluid	Injection
hrs	psig	psig	rpm	% slurry	%
0	30	2600	105	0	
60	30	1200	105	0	
106	30	1200	105	0	
107	30	2000	105	0	
note: no. 1 discharge valve cleaned					
110	30	1900	105	0	
114	30	2300	105	0	
note: buffer volume deaerated, rv's reset					
115	30	2100	105	0	
179	30	2050	105	0	
194	30	850	105	0	
note: no. of pressure gags reduced					
194	30	200	105	5	0.3
231	30	1500	105	0	
note: no. of pressure gags increased					
232	30	1500/300/0	105	12	0.3
232	30	1400	105	0	
232	30	1400/500/0	105	12	0.3
232	30	1400	105	0	
295	40	2500	150	0	
295	30	1000	150	12	0.3
295	30	300	105	12	0.3
295	30	1000	105	0	
310	30	1000	105	0	
330	30	1800	105	0	
note: no. of pressure gags increased					
330	30	3500	150	0	
350	30	1800	105	0	
374	30	2000	150	35	0.3
381	30	2500	150	35	0.3
note: no. of pressure gags @ max.					
403	30	2000	150	35	0.3
note: avg. 23 psi/hr pressure drop due to valve wear					
427	30	0	150	35	0.3
note: valves stuck, fps leakage, hole in main loop					
note: original Princeton fps installed					
428	30	1900	105	0	
428	30	1900/1500	105	35	0.3
428	30	3000	150	0	
428	30	3000/2000	150	35	0.3
note: reverted back to P'burg fps; no difference noted in operation on slurry					
430	30	3200	150	35	1.0
431	30	2500	150	35	1.0
445	30	600	150	35	1.0
note: valves stuck, fps no. 1 & 2 jammed with sand					
note: higher spring rate added to valves					
447	35	3000	150	0	
447	35	3000/1500	150	35	1.0
447	35	1500/500	150	35	1.0
note: cavitation problems, reverted suction valves back to original spring rate					
448	30	2000	150	0	
note: no. 1 plunger leaking excessively					

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18 Feb 87

Problems with the Recip Slurry Pump and Test Loop
(0-448hrs, 3 Dec 86 through 12 Feb 87)

Equipment failures:
1. Varidrive speed control handle/dial
2. Crankcase oil pressure switch
3. Cooling water valve S12
4. Suction hose
5. Flush pump belt drive, including:
   a. drive shaft collar
   b. pulley flange
   c. pillow block bearing
6. Overflow water valve S11 relay
7. Packing lube pump reservoir fill control valve
8. Sand silo, including:
   a. screw conveyor
   b. bucket elevator
   c. feed pipe sand/humidity plugs
   d. feed valve S14
9. Pipe wall breakthrough
10. Stuffing box, including:
    a. jammed throat bushing
    b. main packing leakage
    c. main packing spring
11. Flush flow tube elbow
12. Buffer volume relief valve spring
13. Suction pressure gauge
14. Suction low pressure switch

Operational problems:
1. Low pressure injection
2. Suction and discharge valves, including:
   a. sticking
   b. uneven wear/not closing
3. FPS cylinder bore corrosion
4. Sand dispersion in loop
5. Slurry piping, including:
   a. suction hose surging
   b. suction takeoff point from main loop
   c. low pressure injection connection to main loop
6. Buffer volume relief valve setting
7. Sand disposal
8. Slurry flow velocity (sand settling between suction and discharge valves)
9. Pressure ports plug with sand