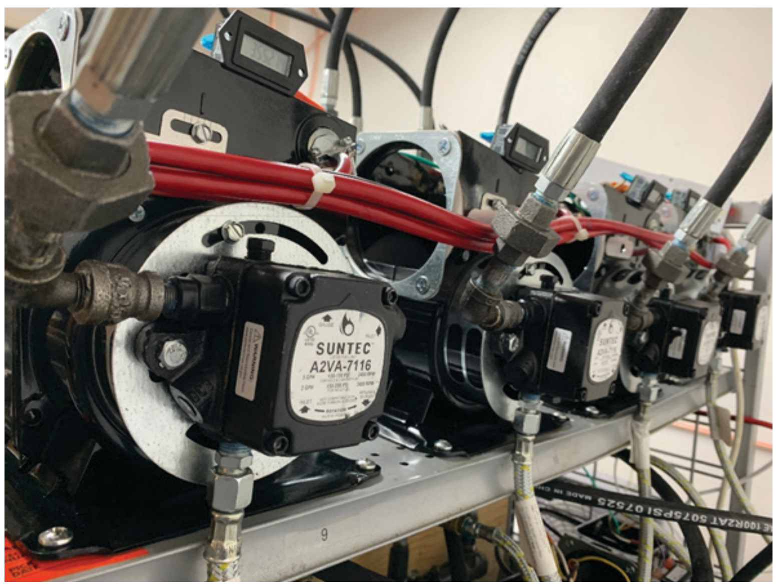
Report on Pump Cycling Test

July 30th, 2020



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Introduction

The use of biodiesel in the heating oil industry has been steadily increasing over the last decade or so. This is mainly the result of a push to reach climate goals of carbon emissions reduction. While there are many biofuels that could serve that purpose, biodiesel has emerged to be the most popular in the industry. A few major companies in the Northeast have already implemented a use of 20% biodiesel blend with heating oil (hereby referred to as B20 or BXX for any blend), while some deliver their customers with up to B80.

While the fuel similarities to the petroleum-based heating oil, it is chemically different. This has raised concerns as to how existing equipment will react when using higher blends of biodiesel. A particular topic of discussion is the fuel pump, which consists of various sub-components with elastomers that contribute to its overall operation. For example, the piston, which is responsible for controlling outlet pressure and providing clean cutoff, has an elastomer material on its "face" that could be damaged. This study investigates the effects prolonged exposure to biodiesel may have on this and other parts of the pump by cycling up to 500,000 cycles with various blends of biodiesel up to B100. The same tests have also been performed on pumps with heating oil (which can contain up to 5% biodiesel in the Downstate New York area, hence it will be called B5) as a control. There were also scheduled break points along the way to 500,000 cycles to determine the condition of the pumps visually and on a test to determine cutoff behavior.

Experimental Setup and Test Procedures

All tests took place at the National Oilheat Research Alliance lab in Plainview, NY. A test stand containing two sides, each with 8 burner chassis mounted on them is used for cycle testing. This provides the ability to test 16 pumps at once. Each side contains its own power and fuel supply. The top row (with 4 pump setups) of one of the sides is shown below:

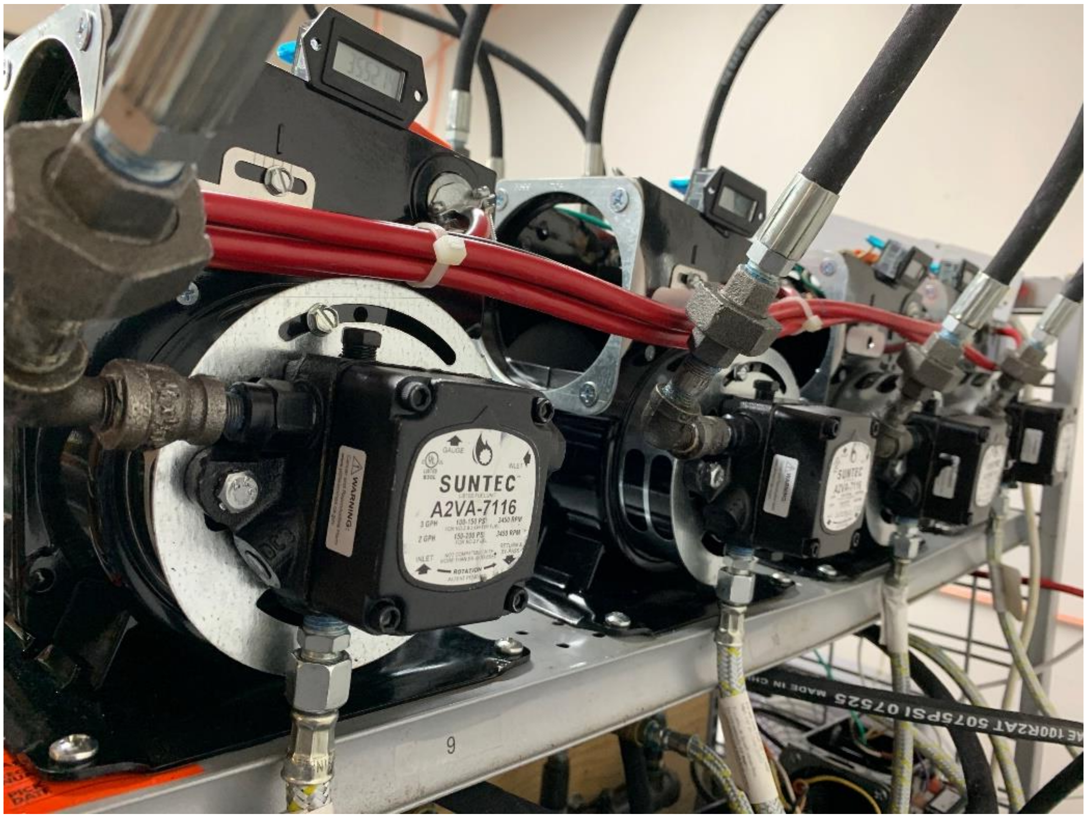

Figure 1: One row of pumps connected to their respective fuel chassis and fuel lines

There is another set of 4 pumps underneath the row shown in *Figure 1*. All 8 pumps in each side receive fuel from a common fuel reservoir, which also collects fuel discharged by the pumps via gravity feed through a common return piping system.

A Crouzet EMER8 time relay switches power on and off for cycling the pumps for each row. The timer provides power (when switched on) to a relay, which then distributes it to each of the 4 motors in the row.

Every pump used for this study is a Suntec A2VA-7116. This pump is quite common in the field and shares similar parts with other popular pumps. According to the test plan, the above setup was used to cycles the pumps at intervals of 5 seconds on and 5 seconds off. Each pump was cycled up to 500,000 times, with scheduled removals for testing and inspection at 100,000 cycles, 200,000 cycles, 350,000 cycles. At each interval, the pumps were inspected visually, and pictures were taken of the piston face and the seat of the diaphragm valve. It must be noted that diaphragm seat pictures were not taken at the intermediate intervals for all pumps. After removal, each burner was also put on a burner to fire and perform a cutoff test. This test records cad cell resistance at high frequency to determine how long it takes the pump to stop the flow of fuel after the burner has turned off. A properly performing pump will have a cut-off time less than 1.0 seconds. The fuel in each reservoir was changed once a week since circulation through the system over time would degrade very rapidly. This was done as a precaution to avoid degraded fuel from causing failure, since it would be hard to distinguish from any other causes of failure.

Results

The pumps were removed from the test stand at the scheduled breakpoints. The cutoff time for each pump was determined based the cad cell resistance signal at the end of a steady-state cycle of operation. These cutoff times for each pump from each removal period (including the final one) is shown in *Table 1*.

The cutoff times above should not be taken as a comparison between one pump to another, but instead used as a general guideline to determine if the piston (and other related parts) are operating properly. A cutoff time of 1.0 second or greater was chosen to be a range above which the cutoff system would be deemed problematic for this study. All results determined were below that range. The worst-case scenario from the data are cutoff times of 0.5 and 0.6 seconds. These numbers are not out of the ordinary for pumps without a solenoid valve.

Table 1: Cutoff times for all pumps at each pit stop

		Cutoff Time (s)			
Fuel	Pump Number	100,000	200,000	350,000	500,000
B0	1	0.3	0.3	0.4	0.4
	2	0.4	0.4	0.5	0.3
	3	0.2	0.2	0.3	0.3
	4	0.4	0.4	0.1	0.2
	5	0.1	0.2	0.4	0.1
	6	0.2	0.1	0.4	0.3
	7	0.4	0.2	0.2	0.1
	8	0.4	0.4	0.4	0.1
B100	9	0.4	0.4	0.4	0.2
	10	0.2	0.3	0.3	0.2
	11	0.3	0.5	0.4	0.2
	12	0.1	0.2	0.5	0.2
	13	0.4	0.3	0.2	0.2
	14	0.3	0.3	0.1	0.6
	15	0.3	0.5	0.1	0.6
	16	0.5	0.2	0.2	0.2
B20	17	0.3	0.1	0.2	0.2
	18	0.3	0.1	0.4	0.4
	19	0.2	0.2	0.2	0.4
	20	0.4	0.2	0.2	0.3
	21	0.2	0.2	0.3	0.3
	22	0.3	0.4	0.3	0.4
	23	0.2	0.3	0.3	0.2
	24	0.2	0.2	0.4	0.3
B50	25	0.2	0.3	0.2	0.1
	26	0.3	0.2	0.2	0.2
	27	0.2	0.2	0.1	0.1
	28	0.3	0.5	0.2	0.1
	29	0.3	0.1	0.2	0.2
	30	0.3	0.1	0.4	0.2
	31	0.4	0.2	0.2	0.3
	32	0.2	0.1	0.3	0.3

Along with the test, pictures of the piston face were taken at every scheduled breakpoint. The pumps with the worst results from the cutoff tests were examined very closely but were determined not to contain more damage than other pumps that had performed better in the cutoff test. The piston faces that showed the most physical damage after 500,000 cycles are shown below:

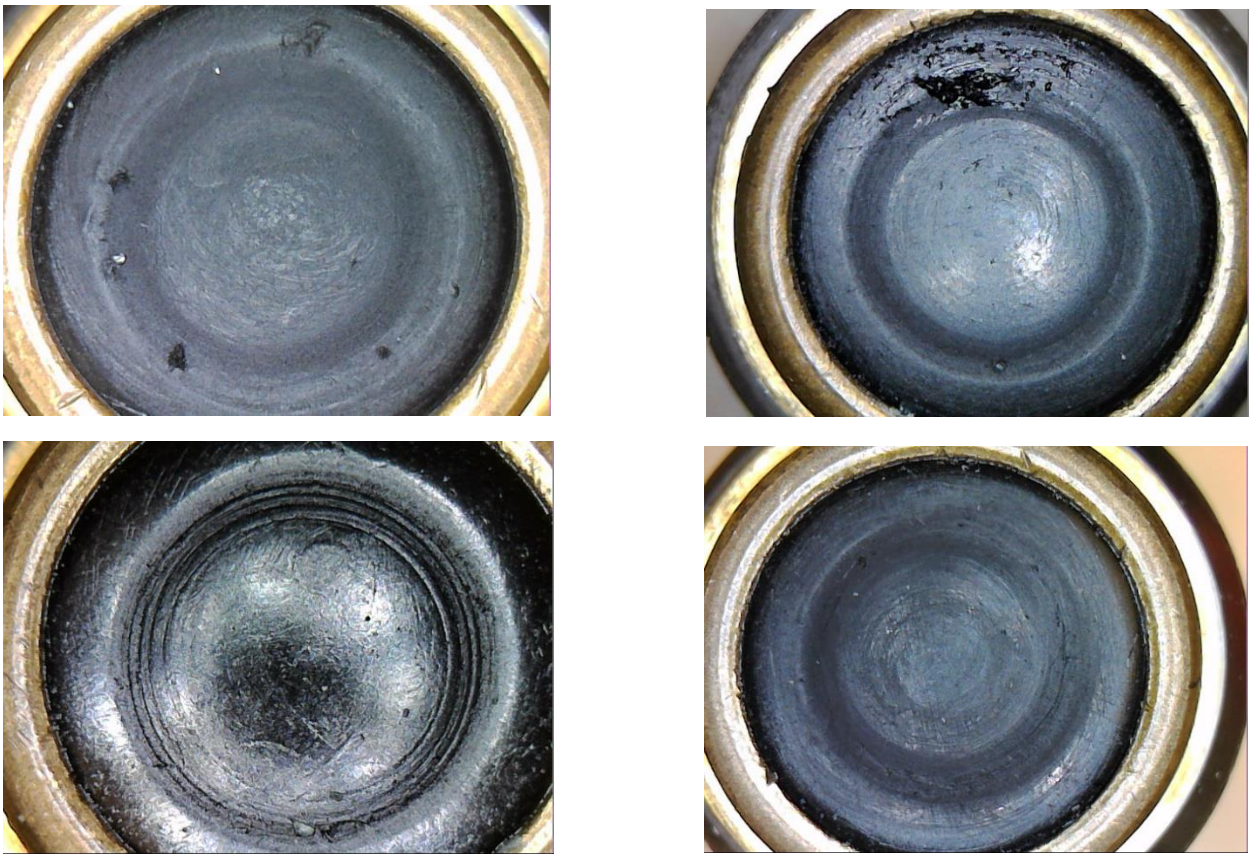

Figure 2: Piston faces with most apparent wear and tear after 500,00 cycles of pump with B5 (top-left), B100 (top-right), B20 (bottom-left) and B50 (bottom-right)

Diaphragm seat pictures were also taken during the scheduled stops, but only for the pumps that tested with B5 and B100. Those pictures for the pumps that were tested with B20 and B50 were only taken after 500,000 cycles were completed. The following are pictures of the diaphragm seats after 500,000 cycles:

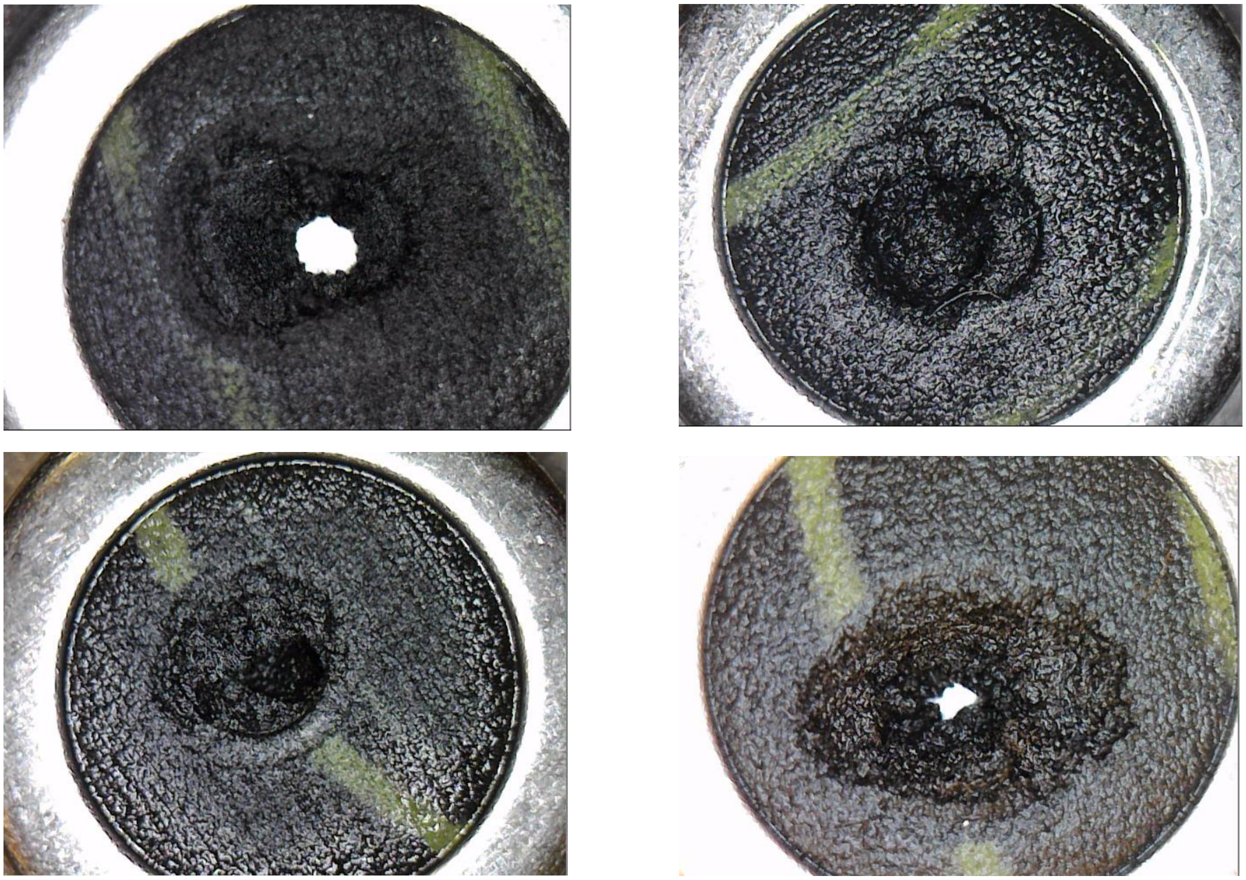

Figure 3: Diaphragm seats with most apparent wear and tear after 500,00 cycles of pump with B5 (top-left), B100 (top-right), B20 (bottom-left) and B50 (bottom-right)

Discussion

The cutoff times would have been expected to increase over time because of wear and tear. For example, even though the cutoff time increased for pump 15 from 100,000 cycles to 200,000 cycles, it was lower at 350,000 cycles. This occurred for many other pumps, as seen in *Table 2*. There is also no obvious sign that cutoff times increased with higher biodiesel blends. This can be better illustrated by the average cutoff times for each set of 8 pumps at every stop, as shown below:

Table 2: Average cutoff times at the scheduled stops

	Average Cutoff Times			
Fuel↓ - Cycles→	100,000	200,000	350,000	500,000
B5	0.3	0.28	0.34	0.23
B20	0.26	0.21	0.28	0.31
B50	0.28	0.21	0.23	0.19
B100	0.31	0.34	0.28	0.3

Comparing the average cutoff times across each row (i.e. same fuel, increasing cycles) provides no discernable pattern. The same is true when the analysis shifts down each column (i.e. increasing biodiesel blend after the same number of cycles).

The worst-case scenario pictures of the piston faces show more damage to those belonging to pumps that were tested with B5 and B100, while those tested with B20 and B50 have no damage that is of note. However, it must be considered that the piston faces from the other pumps in the B5 and B100 groups appear to have similar amount of wear and tear as those of the B20 and B50 groups shown. Based on this, it appears that the "extreme" cases here may just be exceptions.

The worst-case scenario pictures of the diaphragm seat show considerable amount of damage. After a prolonged period of exposure and contact under pressure with the diaphragm, some of the elastomer material deteriorated, as seen in the pictures. This deterioration leads to a hole in the seat, which can be seen for the samples shown from the B5 and B50 groups. Only one other diaphragm seat has shown this level of damage and that is also from the B50 group. In previous tests, a damage of this sort has caused failure to produce pressurized discharge from the pump despite being able to draw fuel from the reservoir, which was not seen in this test. Further operation, however, would most likely have led the pumps with torn diaphragm seats to fail fairly rapidly. There was one failure in the entirety of the test, which was suspected to be a failure of the diaphragm seat which, after performing a vacuum test, turned out to be a shaft seal leak. This pump was part of the B5 group and was then replaced by another pump, which completed 500,000 cycles.

Conclusions

Based on conservative estimates, an average pump in the field goes through ~10,000 cycles a year. According to that metric, all pumps that completed this test simulated ~50 years of operation in the field. The cutoff times obtained after testing at intervals show little to no effect as number of cycles increased. Increasing blends of biodiesel after any period of time also did not have any effect on the cutoff time for any of the pumps tested. Some parts of the pump, however, did show some wear and tear, including the elastomers on the piston face and diaphragm seat. There was, however, no indication that higher biodiesel blends caused such damage. It could then be concluded that use of higher biodiesel blends for prolonged periods of time with legacy Suntec A2VA-7116 pumps should not cause issues related to the parts and properties that were examined.