Engine Testing & Pump Development

Company:

Compiled By: Justin Palmer

Title: Global Applications Manager

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1) OBJECTIVE

The purpose of this testing was to determine the maximum performance output of the Fyr Pak pump when built with higher horsepower engines and to determine what next steps are required to improve the performance output. The Fyr Pak currently underperforms in the market relative to the and . There has been customer demand both domestically and overseas for a competitive product to sell against the aforementioned units. Revision A of this report captures the most recent test results and recommended next steps.

2) PROCEDURE

The testing was performed by Andy Anderson of and Justin Palmer of The testing was performed on the Fyr Pak or 20FP-C8P configuration of the 20FP pump assembly and was performed on 16-Mar-2016 through 17-Mar-2016. A total of (12) performance tests were run on (4) different pump/engine combinations to determine the maximum performance output of the pump in its current configuration as well as its output when coupled to higher horsepower prototype engines.

The table below shows the (12) configurations that were tested:

- The “B” engine is a digital-ignition equipped engine comprised of standard components previously used for testing in October 2015.
- The “1” engine is a slightly “hot-rodded” version of the baseline engine that is representative of what the standard 8 HP engine could become in the future. This engine was built with larger reed valves to allow the engine to ingest more air during operation. The cooling fins on the cylinder walls/head are also larger to allow the engine to run cooler during operation.
- The “2” engine was the first of two engines built with an increased stroke crankshaft, larger reed valves and larger cylinder wall/head cooling fins. This engine used a standard Fyr Pak carburetor.
- The “3” engine was the second of two engines built with an increased stroke crankshaft, larger reed valves and larger cylinder wall/head cooling fins. This engine used a special Tillotson carburetor with a velocity stack inlet to improve air flow.

The table below also describes the air cleaner and muffler, the high speed (HS) carburetor setting, the pump impeller and the ignition module used for each test. Each test was performed using a calibrated discharge gauge and a calibrated, cart-mounted Rosemount flow meter.

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Test #	Engine #	Engine Description	Air Filter	Muffler	HS Carb. Setting	Impeller	Ignition Module/RPM Control
1	B	Baseline (Production)			1-3/4	Production 4.88" Dia.	Digital / ~8300
2	B	Baseline (Production)			1-1/2	Production 4.88" Dia.	Digital / ~8300
3	B	Baseline (Production)			1-1/2	Production 4.88" Dia.	Digital / ~8300
4	B	Baseline (Production)			1-3/4	Production 4.88" Dia.	Digital / ~8300
5	1	Updated 820			1-1/2	Production 4.88" Dia.	Digital / ~8300
6	1	Updated 820			1-1/2	Production 4.88" Dia.	Digital / ~8300
7	2	Super 960 V1			1-1/2	Production 4.88" Dia.	Digital / ~8300
8	3	Super 960 V2			1-1/2	Production 4.88" Dia.	Digital / ~8300
9	3	Super 960 V2			1-1/2	Production 4.88" Dia.	Analog / No Speed Control
10	3	Super 960 V2			1-1/2	Modified 4.75" Dia.	Analog / No Speed Control
11	3	Super 960 V2			1-1/2	Production HP100	Analog / No Speed Control
12	3	Super 960 V2			1-1/2	Production 4.88" Dia	Analog / No Speed Control

Engine "3" was originally built with a digital speed control as shown in test #8 but this was removed due to the pump bouncing off the rev limiter and the engine module retarding the ignition timing. The analog ignition module allowed for higher revs to be achieved and since testing was being performed with the higher revs were allowed. Per the engine can comfortably rev to 9,000-10,000 RPM providing the fuel mixture is appropriate and the overspeed control can be reprogrammed for Hale as needed.

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3) RESULTS

The results of the individual tests are shown below.

Test #1			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	190	7120	-
10	175	6950	-
20	160	6650	-
30	145	6350	-
40	125	6100	-
50	105	5830	-
60	75	5580	-
70	50	5340	-

Test #2			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	210	7410	-
10	190	7130	-
20	175	6890	-
30	160	6600	-
40	140	6310	-
50	115	6010	-
60	90	5650	-
71	80	5460	-

Test #3			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	230	7830	-
10	220	7610	-
20	195	7280	-
30	170	6920	-
40	150	6540	-
50	125	6240	-
60	100	5970	-
75	60	5600	-

Test #4			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	220	7750	-
10	205	7420	-
20	185	7100	-
30	170	6820	-
40	155	6440	-
50	125	6170	-
60	95	5830	-
74	40	5490	-

Test #5			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	245	8110	353
10	230	7710	357
20	205	7440	363
30	190	7130	363
40	165	6820	341
50	145	6450	363
60	110	6100	333
77	40	5730	344

Test #6			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	230	7800	327
10	210	7600	332
20	195	7310	336
30	180	7030	340
40	155	6680	341
50	135	6300	342
60	100	6010	339
77	40	5700	325

Test #7			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	255	8360	345
10	220	7760	340
20	200	7440	336
30	190	7320	351
40	175	7170	359
50	155	6960	363
60	135	6640	363
70	105	6400	363
84	40	6180	344

Test #8			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	255	8350	334
10	250	8350	339
20	240	8150	347
30	225	7860	349
40	200	7530	339
50	170	7120	342
60	140	6800	344
70	105	6480	349
85	50	6300	350

Test #9			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	275	8600	371
10	260	8400	350
20	235	8110	345
30	220	7800	350
40	195	7430	350
50	175	7160	355
60	140	6840	345
70	115	6600	340
85	50	6340	323

Test #10			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	268	8720	359
10	250	8480	357
20	228	8100	346
30	200	7770	354
40	180	7400	364
50	160	7200	363
60	140	6930	359
70	110	6700	348
84	50	6460	325

Test #11			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	250	8500	374
10	240	8130	372
20	225	7870	370
30	205	7530	361
40	180	7100	345
50	160	6730	337
60	125	6430	333
70	100	6280	324
83	55	6110	302

Test #12			
Flow	Pressure	Engine Speed	CHT
US GPM	PSI	RPM	°F
0	280	8550	363
10	270	8480	364
20	240	8150	366
30	220	7780	367
40	200	7500	359
50	160	6980	359
60	130	6610	355
70	110	6410	353
82	50	6150	343

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Comparing tests #1 & #2 to tests #3 & #4 proves the standard air cleaner used on the Fyr Pak is incredibly restrictive and reduces maximum engine speed by approximately 400-500 RPM. This translates to a maximum output pressure loss of approximately 20-40 PSI at shutoff based on the current engine and pump configuration. It is also important to note that there is approximately 20 PSI to be gained by simply changing the high speed (HS) carburetor setting from 1-3/4 turns out to only 1-1/2 turns out. The current factory motors are set to 1-3/4 to improve fuel economy but per 1-1/2 is acceptable and does not risk damage to the engine.

Tests #5 & #6 are also of importance as they highlight the potential performance increase to be had from a slightly modified 8 HP engine when used with a high performance air cleaner. This engine could potentially replace the standard 8 HP unit currently used in the base model Fyr Pak (and Dinglee DP-F8) to create a more competitive in the marketplace against the .

Test #7 was performed on a moderate stroker engine with a stock Fyr Pak carburetor to highlight the performance improvements of the larger displacement engine before moving on to the main event, which is the engine used for tests #8 through #12.

Test #8 was initially performed with a factory installed digital ignition module utilizing the current RPM speed setting of 8300 RPM. However, the pump wanted to spin faster than 8300 RPM due to the extra power of the engine so this module had to be changed out to an analog module without a speed limiter. Test #9 shows just how much flow and pressure is available from the current Fyr Pak hydraulic set when used with a high performance engine, air cleaner and carburetor and a stock Fyr Pak muffler.

Test #10 was performed to see if additional pressure was available by using a smaller diameter impeller. The results show engine speed increased but pressure actually decreased.

Test #11 was performed to see if maximum flow could be increased beyond 85 GPM. This test utilized an HP100 impeller (016-0980-00-0) that was modified to fit on the engine. The results show flow actually decreased slightly and pressure and engine speed were significantly lower than in test #9.

Test #12 was performed to see if any additional performance was available by using a muffler. This muffler is essentially a Fyr Flote muffler on a Fyr Pak exhaust pipe. Although a slight improvement in pressure was seen at lower flows, this pressure increase diminished as flow was increased.

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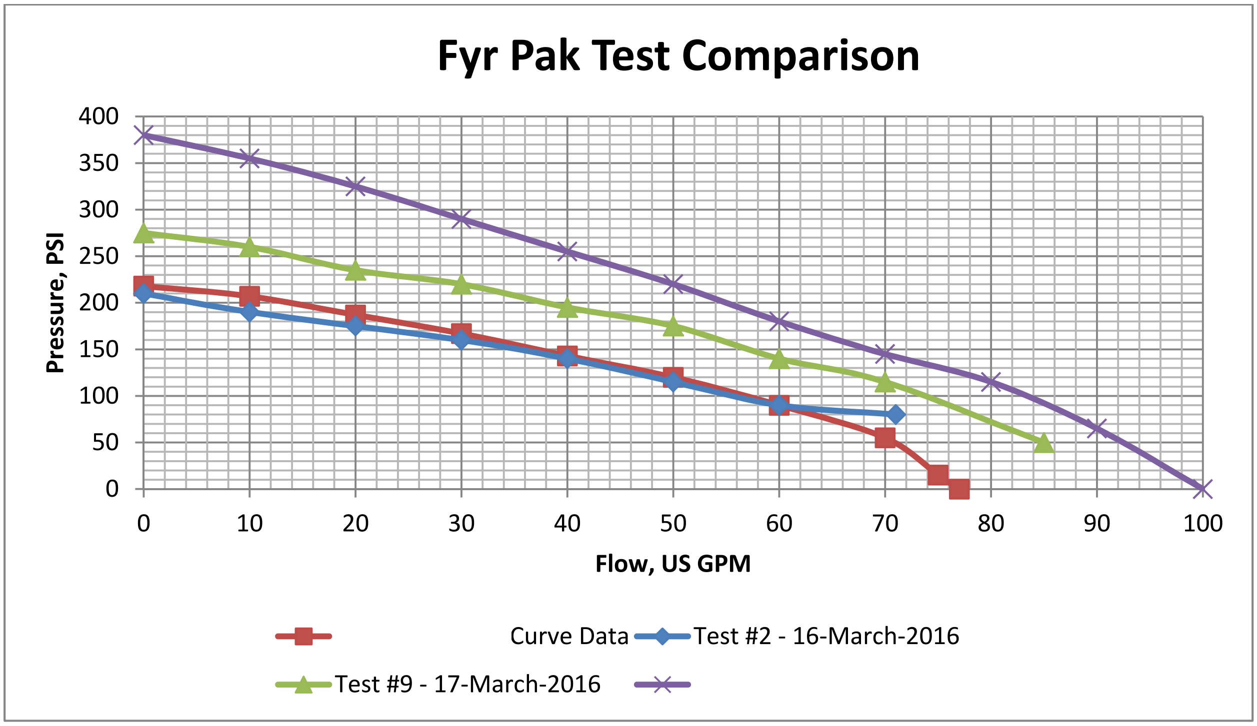
Below is a graph comparing the following:

- 20FP-C8P released curve data
- Test #2 data from 16-March-2016
- Test #9 data from 17-March-2016
- and data from published curves



This graph highlights the enormous performance improvement achieved by simply changing to a higher horsepower engine but also highlights how much further we need to go to be competitive against the and .

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4) CONCLUSIONS

a) The standard Fyr Pak hydraulic set is a robust performer when coupled with a high performance air cleaner on a stock engine and an even better performer when mated to a higher horsepower engine.

b) The standard Fyr Pak air cleaner underperforms significantly compared to a high performance paper/wire mesh air filter.

c) With the current volute machining, the standard impeller at 4.88" diameter is ideal as it allows for maximum pressure and engine speed while maintaining high flows.

d) Minor volute changes can be made within the current product envelope to increase performance to levels closer to the and

5) RECOMMENDATIONS

a) Additional endurance testing/tweaking on the Super 960 V2 engine (engine #3) needs to be completed by . This work has already been committed to but without a definitive timeline.

b) Additional testing needs to be performed on the high performance air cleaner. It has already been proven that it improves pump performance but a concern is its ability to protect the engine in wet environments. This can possibly be remedied with the use of a protective shroud attached to the engine. Additional benefits of this air cleaner are improved carburetor mounting (air cleaner won't rattle off during operation) as well as paper/wire mesh, over-molded rubber and stainless steel construction (won't rust like the current air cleaner).

c) Calculations need to be run to determine the optimum size throat inlet and outlet for use with the higher horsepower engine to be more competitive against the and products. Multiple test volutes need to be machined and tested to confirm analytical findings. Impeller diameters may also need to be modified depending on the results from the volute changes.

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