AKRON
FIREFIGHTING EQUIPMENT

DISCHARGE TABLE FOR WATER FLOW TEST KIT—STYLE 9015
PRESSURE–PSI FLOW–GPM

CAUTION—BE SURE TO READ INSTRUCTIONS MANUAL BEFORE USING.

PITOT PRESSURE PSI	TIP DIAMETER FLOW–U.S. GALLONS PER MINUTE									
	3/4"	*15/16"	*1"	1-1/8"	*1-1/4"	1-1/2"	1-3/4"	*1-7/8"	2"	2-1/4"
40	106	166	187	237	294	422	575	661	752	954
42	109	170	192	243	301	432	589	677	770	978
44	111	174	196	248	308	442	603	693	788	1000
46	114	178	200	254	315	452	617	709	806	1021
48	116	181	205	259	322	462	630	724	824	1043
50	118	185	209	265	329	472	643	739	841	1065
52	121	189	213	270	335	481	656	753	857	1087
54	123	192	217	280	342	490	668	768	873	1108
56	125	196	221	285	348	499	680	782	889	1129
58	128	199	225	290	354	508	692	796	905	1149
60	130	203	229	295	360	517	704	809	920	1167
62	132	206	233	299	366	525	716	823	936	1187
64	134	209	237	304	372	533	727	836	951	1206
66	136	213	240	308	378	542	738	849	965	1224
68	138	216	244	313	383	550	750	862	980	1242
70	140	219	247	318	389	558	761	874	994	1260
72	142	222	251	322	394	566	771	886	1008	1278
74	144	225	254	326	400	574	782	899	1023	1296
76	146	228	258	330	405	582	792	911	1036	1313
78	148	231	261	335	410	589	803	923	1050	1330
80	150	234	264	339	416	596	813	934	1063	1347
82	152	237	268	343	421	604	823	946	1076	1364
84	154	240	271	345	426	611	833	957	1089	1380
86	155	243	274	347	431	618	843	969	1102	1396
88	157	245	277	351	436	626	853	980	1115	1412
90	159	248	280	355	441	633	862	991	1128	1429
92	161	251	283	359	446	640	872	1002	1140	1445
94	162	254	286	363	450	647	881	1013	1152	1460
96	164	256	289	367	455	654	890	1024	1164	1476
98	166	259	292	370	460	660	900	1034	1176	1491
100	168	262	295	374	465	667	909	1045	1189	1506
105	172	268	303	383	476	683	932	1070	1218	1542
110	176	274	310	392	487	699	954	1096	1247	1579
115	180	280	317	401	498	715	975	1120	1475	1615
120	183	286	324	410	509	730	996	1144	1303	1649

* Tips not part of standard unit. Only tips in standard units are U.L. Classified.

NOTE: "Accurate to ±3% at tested values in accordance with the classification scope."

ASSUMED COEFFICIENT OF DISCHARGE = .987, .99, .99, .995, .995, .997, .997
PITOT SIZES 15/16", 1-1/4" and 1-7/8" NOT CALCULATED USING COEFFICIENT
PREFERRED TEST RANGE IS 50 TO 100 PSI

[illegible] Test Kit and the tips supplied with the kit.

WaterCar
PUMP CAPACITY REPORT

I am writing this memo to you from the perspective of a fire apparatus operator and tester. Though I offer this collection of my observations and opinions, I do so voluntarily but with the full integrity of my personal and professional experience. The objective of the testing we did was to determine the maximum and practical limitations of your pump and water delivery design. We did not intend to do any certification but I am confident if you choose to do so, you will be able to reproduce the numbers we saw in our tests done on May 16, 2017 at Marine Stadium. This memo is separated into 3 parts. The first describing the testing process and test results. The second portion will be an analysis on the performance and design limitation as is compared to a common fire pump. The third portion will discuss possible water deliver scenarios (largely by opinion) as to what may be the most efficient or effective method for fire ground water delivery from your design.

TESTING:

On May 16, 2017, we ran a series of water output testing on your experimental fire devilry amphibious vehicle. We were using an Akron 2 1/2 inch test apparatus and a calibrated gauge. The experimental vehicle was backed into approx. 3 feet of salt water at approx. 63 degrees fahrenheit. For the first test, water was pumped through a 2 1/2 nozzle to determine the maximum volume output of the pump. The second test was conducted using at 3/4inch nozzle to determine a practical maximum pressure for the pump.

Results:

Test 1.   2 1/2 nozzle volume test.
Output: 2 1/2in nozzle 1065 GPM@50 psi.

Notes: What this test tells us is the practical volume working capacity of the pump. The pump achieved 1065 GPM at approximately 5400 RPM. It should be noted that the pump generated 44 psi at approx. 4500RPM which calculates to 1000GPM. From this we can see the pump nears it's practical volume capacity at or around 1000 GPM. It should be noted that we likely could achieve larger volumes with additional testing and modifications to the procedure.

Test 2. 3/4in nozzle pressure test.
Output: 3/4in nozzle: 176 GPM@120 psi.

Notes: This test reveals the maximum pressure capacity of the pump. In this case we achieved a maximum pressure using a 3/4in nozzle. At approx. 5400 RPM a pressure of 110 psi @ 176 GPM was achieved.

ANALYSIS:

The delivery of water through this experimental vehicle comes through an adjustable redirection of the jet pump (main propulsion) located on the stern of the vehicle. The water is redirected by adjustable plate at a 90 degree angle into the fire plumbing. During the test the full volume of water was directed into the fire plumbing however it should be noted that the operator can direct a portion of the water in the case he must maintain steerage over the vehicle. The output pump is of a pump-jet design. The pump-jet works on the principle of axial flow in which a large volume of water is moved at a high velocity. The design allows for a large diameter output to exit the pump at high velocity regardless of turbulence or aeration. This makes for a good purchase on the static surface water and provides for good "grip." This pump design efficiently moves a large volume of water, but at a lower pressure relative to the centrifugal design. By contrast, a centrifugal fire pump is designed to move a relatively lower volume of water at a higher

pressure. Most municipal fire engines are rated at a minimum of 1500GPM and 300 PSI. The normal working pressures of a fire pump are wide in range but there are several applications that require a higher pressure. It should be noted that a fire pump is a single purpose pump and only operates efficiently in the absence of turbulence or aeration and is usually powered by a large commercial diesel engine (600hp 12 liter Detroit, etc).

Relative to the 300hp gasoline engine, the efficiency of this design is remarkable. The test results confirm the design limitations of the water-jet axial flow pump, but also reveal its remarkable efficiency for volume. In hydraulic flow calculation, the higher the velocity of water, the larger the turbulence, and therefore larger friction loss. <u>The large volume, low pressure efficiency of this pump and apparatus</u> allows for a relatively small power source to generate <u>1000+ GPM.</u> The very design takes full advantage of the existing pump/engine combination. If this design were modified for the purposes of generating pressure, the volume capacity of the pump would be severely affected by the limitation of horsepower alone. By contrast on the pressure side, the maximum pressure at the nozzle we observed was 110psi. It confirms the ability of the water-jet to achieve a higher pressure but at a limited volume.

Applying this data to fire hose is somewhat subjective and would require further testing to verify. However, by theory, this design should easily be able to deliver 300+GPM through two handlines and achieve a nozzle pressure of 50 psi. The basic math and theory behind this is as follows: (2) 100 foot sections of 2 1/2 single jacketed hose tipped with a smooth bore 15/16 in nozzle each would yield 166 GPM (332 GPM combined). This would require the pump to generate approx. 45 psi at the pump. Based on the testing, this is more than reasonable to achieve. As a frame of reference, NFPA standard 1710 requires the first to handlines in a fire to deliver a minimum of 300psi combined. This is a starting point, but you can arrange many scenarios where this design is capable of achieving these numbers so long as the application is at a low pressure.

<u>OPINION/COMMENT</u>

The above Analysis is loaded with subjective opinion, but I tried to keep it as close to what was observed as possible. There is some extrapolation when discussing handlines but I feel confident the numbers I suggested are achievable. Specific to fire water delivery, as a fire apparatus designed for light duty, fast attack, highly mobile, amphibious attack...I feel you have achieved a highly efficient, reliable, and effective design. Outfitting a fire apparatus is a different and highly modifiable discussion. But again, specific to water delivery, this design is only going to be effective as a low pressure, high volume design. This is NOT a limitation for its effectiveness at all. There are some limitations to a low pressure/high volume design that I will cover at the end.

The key to efficiently deploying this design with the current pump performance is to key in on the high volume low pressure delivery model. Fire nozzles come in two basic categories: automatic and manual. An automatic nozzle is designed to absorb sudden changes in pressure by opening its flow orifice under pressure and maintaining a constant pressure with a varying GPM. Practically speaking, they are designed to absorb the felt force by the nozzle operator (nozzle reaction generated by pressure changes). Automatic nozzles are mostly designed to operate at 100psi and will always be rated for a range of GPMs...for example, an automatic nozzle may be rated from 30-350GPM @90-110 psi. There are some automatic nozzles by TFT and Elkheart that are designed to work at lower pressures. By contrast, a fixed gallonage (including a selectable gallonage) nozzle is designed to operate at 50psi at the tip. If you take advantage of this ideal nozzle pressure of 50psi by the use of smooth bore, stacked tip, or select gallonage nozzles, the limitations determined by pressure go away. In the fire service there are departments who use either or both, and there are situations that use either or both. In the case of your design and its application, it simply suggests you design your water delivery around lower pressures.

I want to share the other side of this pressure/volume discussion. Fire ground hydraulics (water deliver) is all about compensating for pressure and friction loss so that we get the targeted (50 or 100 psi) to the nozzle. We talked about friction in hose and in general, the larger the hose, the lower the friction loss. As I mentioned, a

3" hose has a friction loss of 5 psi/100 feet where as an 1 3/4in hose has a friction loss of 30 psi/100 feet. You can see the impact of 300 feet of hose immediately where the total for a 3" hose is 15psi, and for a 1 3/4 is 90psi. Clearly, your design benefits from larger hose. There is a practically here that you have to see as well. Large hose is heavier (more water) and doesn't like being moved. 2" or 2 1/2" or some compromise will have to reveal itself. Further testing and design here maybe. It's somewhat critical as it relates to the practical application of a hose line! If we are talking about the deck mounted nozzle...not at all. Another consideration as it relates to pressure is elevation. For every 10 feet (or one floor) of elevation you loose 5psi to head pressure. In a gentle somewhat ground level application this is meaningless..but imagine pumping up to a house or up to a 3rd floor, or in the case of a high rise, up to a 25th floor. Example: 25 floors = 125psi. House on a 30 foot bluff = 15psi. If your pump is generating 100psi, you have a 100 foot practical vertical lift before you hit 50psi at the nozzle (basic theoretical). Again, it's all about appropriate application and design objectives here.

The deck mounted nozzle and stream from your design and vehicle is excellent. There is little reason here to use a small diameter nozzle unless you are trying NOT to knock something over or destroy it. The reach and quality of the stream with a 2 1/2 in nozzle vs a 1in nozzle will be minimal where as the volume of water in delivery is dramatically different (1000+ vs. 209 GPM).

These are some things I have thought about from the perspective of a firefighter:

1. When on a handline, particularly with a smooth bore nozzle; sudden pressure changes are dangerous, especially with larger bore nozzles. Being able to control the pressure smoothly is key. In the case of your design the control factor is throttle. Some thoughts: Cruise control? Verneer (dash mounted electronic throttle), pressure control device (relief valve). In the case of the relief valve..it is a simple device that would be inline in the plumbing section before the handline output.

2. Hose size. I mentioned it above but there really is a balance here...small and nimble vs heavy, pressure limitations, volume etc. I think 2" or 2 1/2" may be the sweet spot for you. I have attached a friction loss chart...pay attention to the 150 GPM line... you'll see that 2 1/2 has a loss of 5psi where as the 2" is 18 psi.

3. Nozzles: Fixed gallonage, select gallonage, or smooth bore.

4. Realistically, we're over-comparing this design when we look at the NFPA 2710 or at a fire apparatus. What I mean is, this isn't a fire engine. It's not a fire boat. It's a fast attack, highly nimble, highly modifiable amphibious vehicle with a fire pump. It can effectively deliver up to 1000gpm at 50psi and it can do it incredibly quickly. We talked about our lifeguard boats...they pump 1000gpm. Go figure.

Thanks again for the experience and for your invitation to offer some insights. It was my pleasure. If this generates more questions or thoughts, please feel free to follow up with me. I'm open to any discussion or ideas you want to vet out. I believe you have an excellent and inspiring design and that there are many real applications for it.

Best to you and your crew.

John W
Long Beach, CA