ANNEX 5 – Life-Cycle Testing – Flowrate Data

Annex 5.1 – Average Flow Data

Run 1	Dates: 11/24/03 – 11/26/03				
Test set-up run for 1611.4 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Edson International	1611.4	26.9	10,197	6.3	
Exstar International	1611.4	26.9	9,553	5.9	
Keco	1611.4	26.9	17,239	10.7	
Peristaltic Units					
EMP M300	1611.4	26.9	38,011	23.6	
EMP EV405	1611.4	26.9	39,546	24.5	
Edson International	756.2	12.6	17,150	22.7	Circuit breaker tripped
Keco	1611.4	26.9	41,969	26.0	
Vacuum Units					
Chesapeake Bay Marine	0.0	0.0	0	0.0	Vacuum pump fuse blew
Edson International	1611.4	26.9	19,399	12.0	
Keco	1611.4	26.9	41,076	25.5	
Waubaushene AVR60	1611.4	26.9	16,753	10.4	
Waubaushene LD125	855.5	14.3	17,188	20.1	Unit shut down on tank high level

Run 2	Dates: 12/1/03 – 12/08/03				
Test set-up run for 4875.5 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Edson International	1318.4	48.8	11,601	8.8	Diaphragm failed twice
Exstar International	2580.8	69.9	18,252	7.1	Suction hose developed a leak
Keco	4875.5	108.1	55,654	11.4	
Peristaltic Units					
EMP M300	4875.5	108.1	109,976	22.6	
EMP EV405	2378.0	66.5	68,049	23.9	Circuit breaker tripped 4 times
Edson International	3482.5	70.6	73,040	21.0	Circuit breaker tripped 3 times
Keco	4875.5	108.1	122,069	25.0	
Vacuum Units					
Chesapeake Bay Marine	0.0	0.0	0	0	Vacuum pump fuse blowing frequently
Edson International	4875.5	108.1	58,785	12.1	
Keco	3502.4	85.2	89,082	25.4	Shutdown on F1 Function
Waubaushene AVR60	4875.5	108.1	47,796	9.8	
Waubaushene LD125	3502.4	72.6	66,762	19.1	Vacuum pump filled with water and seized up

Run 3	Dates: 12/08/03 – 12/09/03				
Test set-up run for 527.4 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Edson International	0.0	48.8	0	0	Unit removed from study at request of manufacturer
Exstar International	527.4	78.7	3,947	7.5	
Keco	527.4	116.9	6,237	11.8	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Fuse in control circuit blew
EMP EV405	527.4	75.3	12,949	24.6	
Edson International	527.4	79.4	11,487	21.8	
Keco	527.4	116.9	12,865	24.4	
Vacuum Units					
Chesapeake Bay Marine	0.0	0.0	0	0	Vacuum pump fuse blowing frequently
Edson International	527.4	116.9	6,474	12.3	
Keco	527.4	94.0	13,043	24.7	
Waubaushene AVR60	527.4	116.9	4,790	9.1	
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Run 4	Dates: 12/10/03 – 12/13/03				
Test set-up run for: Set 1– 2009.5 minutes Set 2 – 1999.7 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	1999.7	112.0	14,055	7.0	
Keco	2009.5	150.4	21,241	10.6	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	2009.5	108.8	49,344	24.6	
Edson International	1392.6	102.6	32,874	23.6	Circuit breaker tripped 1 time
Keco	1999.7	150.2	48,379	24.2	
Vacuum Units					
Chesapeake Bay Marine	0.0	0.0	0	0	Vacuum pump fuse blowing frequently
Edson International	2009.5	150.4	26,619	13.2	
Keco	1999.7	127.3	50,409	25.2	
Waubaushene AVR60	1999.7	150.2	21,044	10.5	
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Run 5	Dates: 12/15/03 – 12/21/03				
Test set-up run for 4169.0 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	1442.7	136.0	10,170	7.0	Speed reducer shaft sheared
Keco	4169.0	219.9	46,719	11.2	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	4169.0	178.3	96,109	23.1	
Edson International	3621.7	163.0	83,775	23.1	Circuit breaker tripped 1 time
Keco	4169.0	219.7	100,185	24.0	
Vacuum Units					
Chesapeake Bay Marine	1999.9	33.3	16,079	8.0	Replaced vacuum pump during run – pump fuse blew with new pump
Edson International	2855.6	198.0	37,827	13.2	Minor icing in inlet check valve – reduced flowrate on last night of run
Keco	3432.7	184.6	86,979	25.3	Shutdown on F1 Function
Waubaushene AVR60	3432.7	207.4	36,314	10.6	Minor icing caused reduced flowrate on last night of run
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Run 6	Dates: 1/02/04 – 1/06/04				
Test set-up run for 2844.3 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	136.0	0	0	Speed reducer on order
Keco	2844.3	267.3	25,401	8.9	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	2844.3	225.7	64,223	22.6	
Edson International	2844.3	210.4	69,853	24.6	
Keco	1939.3	252.0	47,938	24.7	Repair of leak on discharge piping reduced run time – not a unit repair
Vacuum Units					
Chesapeake Bay Marine	0.0	33.3	0	0	Vacuum pump fuse blew
Edson International	2844.3	245.4	36,368	12.8	
Keco	2844.3	232.0	69,516	24.4	
Waubaushene AVR60	2844.3	254.9	29,972	10.5	
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Run 7	Dates: 1/12/04 – 1/15/04				
Test set-up run for 2159.0 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	136.0	0	0	Speed reducer replaced – need new motor due to wear on shaft at keyway
Keco	2159.0	303.3	21,079	9.8	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	1681.4	253.7	37,047	22.0	Circuit breaker tripped 1 time
Edson International	1323.4	232.5	31,553	23.8	Circuit breaker tripped 1 time
Keco	2159.0	288.0	51,141	23.7	
Vacuum Units					
Chesapeake Bay Marine	139.3	35.7	989	7.1	Unit run with replacement oiler to check operation – still blowing fuse
Edson International	2159.0	281.4	31,100	14.4	
Keco	2159.0	267.9	52,818	24.5	
Waubaushene AVR60	2159.0	290.8	23,336	10.8	
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Run 8	Dates: 1/18/04 – 1/19/04				
Test set-up run for 716.4 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	136.0	0	0	Motor on order
Keco	716.4	315.2	7,589	10.6	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	716.4	265.6	15,657	21.9	
Edson International	716.4	244.4	17,077	23.8	
Keco	527.4	296.8	12165	23.1	Internal tube developed leak - **Note 1**
Vacuum Units					
Chesapeake Bay Marine	189.0	38.8	630	3.3	Another test run – flowrate reduced
Edson International	716.4	293.3	10,484	14.6	
Keco	716.4	279.9	17,603	24.6	
Waubaushene AVR60	716.4	302.8	8,401	11.7	
Waubaushene LD125	0.0	72.6	0	0	Vacuum pump being reconditioned

Note 1: Unit running intermittently due to the automatic shutdown feature when tube leakage is detected. Slightly lower flowrate during the run.

Run 9	Dates: 2/10/04 – 2/15/04				
Test set-up run for: Set 1– 3582.8 minutes Set 2 – 3571.9 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	1412.9	159.6	10,846	7.7	Replaced motor and restarted 2/13/04
Keco	3582.8	374.9	36,436	10.2	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	2806.8	312.4	55,734	19.9	Circuit breaker tripped 1 time
Edson International	3582.8	304.1	81,475	22.7	
Keco	1412.9	320.4	42,150	29.8	Internal tube replaced on 2/13/04
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	3582.8	353.0	45,240	12.6	
Keco	3571.9	339.4	88,832	24.9	
Waubaushene AVR60	3571.9	362.3	36,742	10.3	
Waubaushene LD125	0.0	72.6	0	0	Unit repaired & restarted 2/13/04 - **Note 1**

Note 1: Vacuum pump returned from manufacturer after being reconditioned and unit was restarted on 2/10/4. Vacuum pump immediately filled with water and the unit was shutdown to prevent the pump from seizing. Troubleshooting to determine why failure recurred.

Run 10	Dates: 2/19/04 – 2/21/04				
Test set-up run for: Set 1– 1233.4 minutes Set 2 – 1224.1 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Pump shaft separated from diaphragm plunger
Keco	1233.4	395.5	11,278	9.1	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	1233.4	333.0	29,355	23.8	Flowmeter malfunction - **Note 1**
Edson International	1233.4	324.7	29,135	23.6	
Keco	1224.1	340.8	37,161	30.4	
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	1233.4	373.6	18,189	14.7	
Keco	1224.1	359.8	31,648	25.9	
Waubaushene AVR60	1224.1	382.7	11,966	9.8	
Waubaushene LD125	0.0	72.6	0	0	Troubleshooting second failure of pump

Note 1: Flowmeter began to indicate erratic flow on unit. Unit was evaluated to see if it may have a problem that would be causing erratic flow such as a ruptured internal tube, but no problem was identified with the unit. Troubleshooting flowmeter. Total Volume Pumped was estimated using the flowrate measured on the unit when the flowmeter was reading accurately during Runs 17-20 (23.8 gallons/minute) multiplied by the Run Time of the unit.

Run 11	Dates: 2/21/04 – 2/27/04				
Test set-up run for: **Set 1– 4264.5 minutes** **Set 2 – 4243.8 minutes**	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Pump shaft on order
Keco	4264.5	466.6	41,656	9.8	
Peristaltic Units					
EMP M300	0.0	108.1	0	0	Troubleshooting control circuit
EMP EV405	0.0	333.0	0	0	Troubleshooting flowmeter malfunction
Edson International	4264.5	395.8	96,660	22.7	
Keco	4243.8	411.5	95,746	22.8	
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	4264.5	444.7	65,714	15.4	
Keco	3686.6	421.3	91,878	24.9	
Waubaushene AVR60	0.0	382.7	0	0	Unit tripped breaker - **Note 1**
Waubaushene LD125	0.0	72.6	0	0	Troubleshooting second failure of pump

Note 1: Unit breaker was reset and the unit was restarted. Vacuum pump will not produce vacuum or suction. Troubleshooting problem.

Run 12	Dates: 2/29/04 – 3/12/04				
Test set-up run for: Set 1– 8781.9 minutes Set 2 – 8771.8 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Pump shaft needs repair – parts received
Keco	8781.9	612.9	78,111	8.9	
Peristaltic Units					
EMP M300	5768.2	204.3	135,693	23.5	Repaired control circuit and restarted 3/4/04
EMP EV405	6464.3	440.7	153,850	23.8	Troubleshooting flowmeter problem - **Note 1**
Edson International	8781.9	542.1	209,347	23.8	
Keco	8771.8	557.7	235,961	26.9	Flowmeter malfunction - **Note 2**
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	7369.3	567.5	108,283	14.7	
Keco	1472.1	445.8	38,026	25.8	Unit shutdown due to low flowrate - **Note 3**
Waubaushene AVR60	0.0	382.7	0	0	Troubleshooting unit
Waubaushene LD125	0.0	72.6	0	0	Troubleshooting second failure of pump

Note 1: Flowmeter was changed out on 3/3/04 with the flowmeter that had been in use for the Edson International Diaphragm Unit (unit removed from study). Flowrate is still erratic on new flowmeter. Troubleshooting unit and flowmeter. Total Volume Pumped was estimated using the flowrate measured on the unit when the flowmeter was reading accurately during Runs 17-20 (23.8 gallons/minute) multiplied by the Run Time of the unit.

Note 2: Flowmeter began to exhibit erratic readings during the unit run cycle and during the unit off cycle. Reset "zero" on flowmeter to correct problem during unit off cycle. Total Volume Pumped was estimated using the flowrate measured on the unit when the flowmeter was reading accurately (26.9 gallons/minute) multiplied by the Run Time of the unit.

Note 3: Unit found to have greatly reduced flowrate during daily flow check. Troubleshooting problem with manufacturer.

Run 13	Dates: 3/13/04 – 3/22/04				
Test set-up run for: Set 1– 6594.9 minutes Set 2 – 6584.8 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Pump shaft needs repair – parts received
Keco	4297.3	684.5	37,313	8.7	Diaphragm developed leak
Peristaltic Units					
EMP M300	6594.9	314.2	153,422	23.3	
EMP EV405	4297.3	512.3	102,276	23.8	Troubleshooting flowmeter problem - **Note 1**
Edson International	2238.1	579.4	53,336	23.8	Circuit breaker tripped 1 time, and tube failed
Keco	6584.8	667.4	177,131	26.9	Flowmeter malfunction - **Note 2**
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	6594.9	677.4	100,416	15.2	
Keco	0.0	445.8	0	0	Unit shutdown due to low flowrate - **Note 3**
Waubaushene AVR60	0.0	382.7	0	0	Troubleshooting unit
Waubaushene LD125	0.0	72.6	0	0	Troubleshooting second failure of pump

Note 1: Flowrate is still erratic on new flowmeter. Troubleshooting unit and flowmeter. Small amount of water leaking out of unit at drain from internal tube cavity. EMP consulted and drainage is believed to be condensation and not internal tube leakage. Total Volume Pumped was estimated using the flowrate measured on the unit when the flowmeter was reading accurately during Runs 17-20 (23.8 gallons/minute) multiplied by the Run Time of the unit.

Note 2: Flowmeter continues to exhibit erratic readings during the unit run cycle and during the unit off cycle. Reset "zero" on flowmeter to attempt to correct the problem during unit off cycle. Exercised engineering judgment to estimate the Total Volume Pumped by using the flowrate measured on the unit when the flowmeter was reading accurately during Run 12 (26.9 gallons/minute) multiplied by the Run Time of the unit during Run 13.

Note 3: Unit found to have greatly reduced flowrate. Troubleshooting problem with manufacturer.

Run 14	Dates: 3/26/04 – 4/09/04				
Test set-up run for 10046.0 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Replaced pump shaft – speed reducer mounts failed overnight – unit removed from study
Keco	2824.5	731.6	21,939	7.8	Diaphragm replaced and restarted, then speed reducer mount failed – repair completed
Peristaltic Units					
EMP M300	10046.0	481.6	240,072	23.9	
EMP EV405	0.0	512.3	0	0	Shutdown to investigate erratic flowrate
Edson International	2018.8	613.1	58,782	29.1	Internal tube replaced and restarted
Keco	1372.4	690.3	36,699	26.7	Internal tube replaced again by Keco - **Note 1**
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	10046.0	844.8	153,064	15.2	
Keco	0.0	445.8	0	0	**Note 2**
Waubaushene AVR60	596.7	392.7	6,335	10.6	Restarted unit 4/8/04 after lubrication of pump
Waubaushene LD125	0.0	72.6	0	0	Troubleshooting second failure of pump

Note 1: A representative of Keco made a site visit to change out the internal tube due to concerns that the original internal tube may have come from a defective lot. The original replacement tube came from this same lot. Flowmeter initially exhibited erratic readings during the unit run cycle and during the unit off cycle. Allowed tube to run for a break-in period of 5092.5 minutes to see if the flowmeter readings would stabilize the unit flowrate and make the flow readings less erratic. At the end of the break-in period, the flowmeter "zero" was reset and accurate flow measurement was restored.

Note 2: A representative of Keco made a site visit to troubleshoot the low flowrate on the unit. One of the unit's two transfer tanks had a crack around the bottom perimeter of the cylindrical tank. Replaced tank and restarted unit on 4/5/04. Unit shutdown overnight for an unknown reason. Troubleshooting problem.

Run 15	Dates: 4/09/04 – 4/17/04				
Test set-up run for 5510.2 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Exstar International	0.0	159.6	0	0	Replaced pump shaft – speed reducer mounts failed overnight – unit removed from study
Keco	5510.2	823.5	55,111	10.0	
Peristaltic Units					
EMP M300	5510.2	573.4	133,871	24.3	
EMP EV405	616.6	522.6	14,939	24.2	Crack on discharge union of pump - repaired
Edson International	4306.8	684.8	121,060	28.1	Circuit breaker tripped 1 time
Keco	4744.1	769.4	125,622	26.5	**Note 1**
Vacuum Units					
Chesapeake Bay Marine	0.0	38.8	0	0	Consulting manufacturer for assistance
Edson International	5510.2	936.7	73,342	13.3	
Keco	686.3	457.2	19,376	28.2	**Note 2**
Waubaushene AVR60	1253.2	413.5	12,890	10.3	Circuit breaker tripped 6 times
Waubaushene LD125	0.0	72.6	0	0	Restarted following fuse replacement and solenoid valve cleaning – unit found shutdown the following day.

Note 1: Flowmeter "zero" was reset during the run to ensure accurate flow measurement.

Note 2: Keco provided a new control box for the unit to be used to troubleshoot the intermittent operation of the unit experienced in Run 14. Installed new control box on 4/10/04 and restarted the unit to see if the issue would recur with the new control box. The other tank on the unit developed a similar crack around the bottom perimeter of the cylindrical tank.

Run 16	Dates: 4/17/04 – 4/21/04				
Test set-up run for 2764.2 minutes on each set of units	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Keco	0.0	823.5	0	0	Troubleshooting unit - **Note 1**
Peristaltic Units					
EMP M300	2764.2	619.5	62,863	22.7	
EMP EV405	0.0	522.6	0	0	Breaker tripped 1 time – erratic flowrate
Edson International	2764.2	730.9	77,453	28.0	
Keco	0.0	769.4	0	0	Shutdown due to leak on discharge flex-hose
Vacuum Units					
Chesapeake Bay Marine	0.0		0	0	Consulting manufacturer for assistance
Edson International	2764.2	982.7	34,946	12.6	
Keco	0.0	457.2	0	0	Shutdown due to leak on second tank
Waubaushene AVR60	0.0	413.5	0	0	Troubleshooting unit – trips breaker frequently
Waubaushene LD125	0.0	72.6	0	0	Unit restarted and spider coupling between motor and vacuum pump failed

Note 1: Unit is not producing vacuum following periodic flow checks on 4/17/04. After consulting Keco, determined that the discharge check valve on the discharge pump had failed.

Run 17	Dates: 5/04/04 – 5/15/04				
Test set-up run for: Set 1– 7696.6 minutes Set 2 – 7680.7 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Keco	0.0	823.5	0	0	Replaced discharge check valve – suction piping leak prevented restarting unit
Peristaltic Units					
EMP M300	1928.9	651.7	43,576	22.6	2 shutdowns: 1) leak on discharge piping at 45-degree elbow, and 2) failure of internal tube
EMP EV405	1988.2	555.7	48,910	24.6	**Note 1**
Edson International	5698.2	825.9	148,913	26.1	Two leaks on discharge flex-hose
Keco	3425.5	826.5	90,776	26.5	**Note 2**
Vacuum Units					
Chesapeake Bay Marine	7680.7	166.8	54,178	7.1	Unit restarted after repair by manufacturer
Edson International	1988.2	1,015.9	24,608	12.4	Completed life-cycle testing
Keco	0.0	457.2	0	0	Shutdown to repair leak on second tank
Waubaushene AVR60	0.0	413.5	0	0	Cleaning pump internals with WD-40 again – circuit breaker tripped 4 times
Waubaushene LD125	1133.7	91.5	17,403	15.4	Unit restarted and spider coupling between motor and vacuum pump failed for a second time

Note 1: Changed out the flowmeter on the EMP Industries EV405 unit with the flowmeter that had been in use with the Mariner Technologies Peristaltic unit to monitor the unit's performance using a new flowmeter. The unit's flowrate is now more stable.

Note 2: Repaired leak on discharge flex-hose and restarted, but developed another leak on hose. Unit still exhibits erratic flowmeter readings. Total Volume Pumped was estimated by using a flowrate of 26.5 gpm (measured during Runs 15 and 20). Run 15 data was collected using the original flowmeter and Run 20 data was collected using the flowmeter that was originally installed for the EMP Industries M300 to compare the performance of the two flowmeters. Both Runs yielded a flowrate of 26.5 gpm.

Run 18	Dates: 5/15/04 – 5/21/04				
Test set-up run for: Set 1– 4443.0 minutes Set 2 – 4432.9 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Keco	0.0	823.5	0	0	Shutdown for repair of suction piping leak
Peristaltic Units					
EMP M300	0.0	651.7	0	0	Waiting for internal tube replacement parts
EMP EV405	3061.1	606.8	73,456	24.0	Circuit breaker tripped 1 time
Edson International	1143.3	844.9	30,038	26.3	Repaired discharge flex-hose leak and restarted, then developed leak on 45-degree elbow
Keco	2534.6	868.7	2534.6	26.5	Erratic flow on flowmeter - **Note 1**
Vacuum Units					
Chesapeake Bay Marine	4432.9	240.7	31,682	7.1	
Keco	1401.6	480.6	34,760	24.8	Second tank replaced and restarted - **Note 2**
Waubaushene AVR60	0.0	413.5	0	0	Consulting manufacturer for assistance
Waubaushene LD125	0.0	91.5	0	0	Waiting for replacement spider coupling - **Note 3**

Note 1: Total Volume pumped was estimated by using a flowrate of 26.5 gpm (measured during Runs 15 and 20). Run 15 data was collected using the original flowmeter and Run 20 data was collected using the flowmeter that was originally installed for the EMP Industries M300 to compare the performance of the two flowmeters. Both Runs yielded a flowrate of 26.5 gpm.

Note 2: Erratic flowrate on the unit after tank repair from slugs of air in the discharge piping. Consulted Keco and the problem was identified as air leaking on suction manifold at the check valves. Tightened valves and corrected air leakage. Estimated "Total Volume Pumped" by using a flowrate of 24.8 gpm (obtained in Run 19) and the Run Time on unit.

Note 3: Received replacement spider coupling on 5/19/04. Attempted replacement of spider coupling but could not remove key from the motor shaft so that the sprocket could be moved back down the shaft and into position.

Run 19	Dates: 5/22/04 – 5/27/04				
Test set-up run for: Set 1– 3486.8 minutes Set 2 – 3474.8 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Keco	675.5	834.7	6,620	9.8	Repaired suction piping leak - developed leak at discharge union – **Note 1**
Peristaltic Units					
EMP M300	0.0	651.7	0	0	Waiting for internal tube replacement parts
EMP EV405	2851.1	654.3	68,868	24.2	Circuit breaker tripped 1 time
Edson International	2165.5	881.0	55,196	25.5	Circuit breaker tripped 2 times
Keco	2066.2	903.1	54,754	26.5	Developed discharge 45-degree elbow leak – repaired and restarted – erratic flow - **Note 2**
Vacuum Units					
Chesapeake Bay Marine	3474.8	298.6	24,918	7.2	
Keco	2610.5	524.1	64,740	24.8	Second tank replaced and restarted - **Note 3**
Waubaushene AVR60	0.0	413.5	0	0	Consulting manufacturer – tested circuit breaker
Waubaushene LD125	1976.8	124.5	38,152	19.3	Replaced spider gear and used Lock-Tite on motor shaft to prevent sprocket from moving

Note 1: Due to difficulty with measuring the flow on the unit during this run, “Total Volume Pumped” was estimated using a flowrate of 9.8 gpm, which was the average flowrate produced by the unit during life-cycle testing.

Note 2: Total Volume pumped was estimated by using a flowrate of 26.5 gpm (measured during Runs 15 and 20). Run 15 data was collected using the original flowmeter and Run 20 data was collected using the flowmeter that was originally installed for the EMP Industries M300 to compare the performance of the two flowmeters. Both Runs yielded a flowrate of 26.5 gpm.

Note 3: Erratic flowrate on unit after tank repair from slugs of air in the discharge piping. Consulted Keco and the problem was identified as air leaking on suction manifold at the check valves. Tightened valves and corrected air leakage. Estimated "Total Volume Pumped" by using a flowrate of 24.8 gpm (obtained during the final portion of Run 19) and the Run Time on unit.

Run 20	Dates: 5/27/04 – 6/04/04				
Test set-up run for: Set 1– 5754.4 minutes Set 2 – 5744.4 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Diaphragm Units					
Keco	0.0	834.7	0	0	Repair needed on discharge union
Peristaltic Units					
EMP M300	0.0	651.7	0	0	Waiting for internal tube replacement parts
EMP EV405	3160.2	706.9	71,570	22.6	Circuit breaker tripped 1 time
Edson International	2216.1	918.0	57,263	25.8	Rubber coupling between motor and pump failed
Keco	5674.8	997.7	150,382	26.5	**Note 1**
Vacuum Units					
Chesapeake Bay Marine	5744.4	394.4	42,341	7.4	
Keco	5744.4	619.8	144,910	25.2	
Waubaushene AVR60	0.0	413.5	0	0	Consulting manufacturer - breaker tripping
Waubaushene LD125	5744.4	220.2	113,924	19.8	

Note 1: The final portion of Run 20 data was collected using the flowmeter that was originally installed for the EMP Industries M300 to compare the performance between this flowmeter and the original flowmeter installed for the Keco Peristaltic. A flowrate of 26.5 gpm was measured with the new flowmeter installed. This corresponds well with the flowrate measured with the original flowmeter in Run 15, when a flowrate of 26.5 gpm was also measured. Total Volume Pumped was estimated by using a flowrate of 26.5 gpm (measured during Runs 15 and 20) and the Run Time on the unit.

Life-cycle testing was concluded on all units except for the Chesapeake Bay Marine unit on June 4, 2004. Life-cycle testing was continued on the Chesapeake Bay Marine unit because the unit did not operate with the vacuum pump lubricant (Mobil EAL-224H) that was chosen for use in all vacuum pumps in the study. The problem with this lubricant in the Chesapeake Bay Marine unit was not identified until May 3, 2004. After consultation with Kevin Atkinson (SOBA), the Chesapeake Bay Marine unit was allowed to continue to be run in the study until such time as the unit had been run for 1000 hours, or until a failure occurred.

The following additional runs were conducted on the Chesapeake Bay Marine unit.

Run 21	Dates: 6/04/04 – 6/10/04				
Test set-up run for 4291.9 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Chesapeake Bay Marine	4291.9	465.9	31,555	7.4	

Run 22	Dates: 6/10/04 – 6/25/04				
Test set-up run for 10,769.0 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Chesapeake Bay Marine	10,769.0	645.4	80,503	7.5	

Run 23	Dates: 6/25/04 – 7/02/04				
Test set-up run for 4928.0 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Chesapeake Bay Marine	4928.0	727.5	35,887	7.3	

Run 24	Dates: 7/12/04 – 7/23/04				
Test set-up run for 7630.3 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Chesapeake Bay Marine	7630.3	854.7	54,255	7.1	

Run 25	Dates: 7/23/04 – 8/05/04				
Test set-up run for 9317.9 minutes	Run Time (minutes)	Cumulative Run Time (hours)	Total Volume Pumped (gallons)	Average Flow (gallons/minute)	Comments
Chesapeake Bay Marine	9317.9	1,010.0	65,573	7.0	

Annex 5.2 – Total Flow Data

The Total Run Time (in hours) and Total Volume Pumped by each unit in the study is shown in the Table below.

	Total Run Time (hours)	Hour Counter Readings (hours)	Total Volume Pumped (gallons)	Average Flowrate (gallons/minute)
Diaphragm Units				
Edson International	48.8	No hour counter	21,798	7.4
Exstar International	159.6	237.0	66,853	7.0
Keco	834.7	No hour counter	489,623	9.8
Peristaltic Units				
Edson International	918.0	No hour counter	1,355,467	24.6
EMP M300	651.6	701.2	917,484	23.5
EMP EV405	706.9	854.6	990,709	23.4
Keco	997.7	No hour counter	1,550,260	25.9
Vacuum Units				
Chesapeake Bay Marine	1,010.0	1,196.6	455,213	7.5
Edson International	1,015.9	No hour counter	850,858	14.0
Keco	619.8	No hour counter	934,696	25.1
Waubaushene AVR60	413.5	524.8	267,689	10.8
Waubaushene LD125	220.2	317.7	253,429	19.2

Annex 5.3 – Periodic Test Flow and Vacuum Check Data

Periodic Test #1 **Date: 12/09/03**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Edson International	----	----	Unit inoperable – diaphragm failure
Exstar International	11.5	2:22	
Keco	11.5	1:55	
Peristaltic Units			
EMP M300	----	----	Unit inoperable – control circuit failure
EMP EV405	28.5	1:12	
Edson International	27.0	0:59	
Keco	27.5	1:06	
Vacuum Units			
Chesapeake Bay Marine	24.0	2:12	
Edson International	18.5	1:10	
Keco	24.0	0:41	
Waubaushene AVR60	25.5	0:53	
Waubaushene LD125	----	----	Unit inoperable – vacuum pump failure

Periodic Test #2 **Date: 1/02/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Edson International	----	----	Unit inoperable – withdrawn from study
Exstar International	----	----	Unit inoperable – speed reducer failure
Keco	14.0	1:59	
Peristaltic Units			
EMP M300	----	----	Unit inoperable - control circuit failure
EMP EV405	28.5	1:10	
Edson International	28.0	1:27	
Keco	28.0	1:06	
Vacuum Units			
Chesapeake Bay Marine	26.5	2:37	
Edson International	18.5	1:37	
Keco	25.0	0:55	
Waubaushene AVR60	25.5	1:07	
Waubaushene LD125	----	----	Unit inoperable - vacuum pump failure

Periodic Test #3 **Date: 2/21/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Exstar International	----	----	Unit inoperable – pump shaft failure
Keco	11.0	2:02	
Peristaltic Units			
EMP M300	----	----	Unit inoperable – control circuit failure
EMP EV405	28.5	1:12	
Edson International	26.5	0:59	
Keco	27.0	1:00	
Vacuum Units			
Chesapeake Bay Marine	----	----	Unit inoperable – troubleshooting unit
Edson International	18.5	0:46	
Keco	25.0	0:47	
Waubaushene AVR60	25.5	1:07	
Waubaushene LD125	----	----	Unit inoperable – troubleshooting vacuum pump failure

Periodic Test #4 **Date: 3/13/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Exstar International	----	----	Unit inoperable – pump shaft needs repair
Keco	11.0	1:48	
Peristaltic Units			
EMP M300	25.0	1:00	
EMP EV405	29.0	1:14	
Edson International	28.0	0:57	
Keco	25.0	1:11	
Vacuum Units			
Chesapeake Bay Marine	----	----	Unit inoperable – troubleshooting unit
Edson International	18.5	0:41	
Keco	----	----	Unit inoperable – troubleshooting low flowrate
Waubaushene AVR60	----	----	Unit inoperable – troubleshooting unit
Waubaushene LD125	----	----	Unit inoperable – troubleshooting vacuum pump failure

Periodic Test #5 **Date: 4/09/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Exstar International	----	----	Unit inoperable – withdrawn from study
Keco	11.0	1:48	
Peristaltic Units			
EMP M300	26.5	1:07	
EMP EV405	26.5	1:17	
Edson International	26.5	0:54	
Keco	27.5	0:57	
Vacuum Units			
Chesapeake Bay Marine	24.5	1:04	Troubleshooting unit – run only for flow check
Edson International	19.0	0:45	
Keco	23.0	0:54	
Waubaushene AVR60	24.5	1:03	
Waubaushene LD125	25.0	0:35	

Periodic Test #6 **Date: 4/17/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Keco	13.5	---	Unit stopped producing vacuum following vacuum measurement – discharge valve failure
Peristaltic Units			
EMP M300	28.0	1:08	
EMP EV405	28.5	1:17	
Edson International	27.0	0:54	
Keco	27.5	0:59	
Vacuum Units			
Chesapeake Bay Marine	----	----	Unit inoperable – troubleshooting unit
Edson International	19.0	0:45	
Keco	----	----	Unit inoperable – tank failure
Waubaushene AVR60	27.5	0:58	
Waubaushene LD125	26.0	0:43	

Periodic Test #7 **Date: 5/15/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Keco	---	---	Unit inoperable – suction piping leak
Peristaltic Units			
EMP M300	---	---	Unit inoperable – internal tube failure
EMP EV405	27.0	1:15	
Edson International	---	---	Unit inoperable – discharge hose leak
Keco	27.5	0:38	
Vacuum Units			
Chesapeake Bay Marine	23.0	0:55	
Edson International	19.0	0:45	
Keco	23.5	0:49	
Waubaushene AVR60	28.0	1:00	
Waubaushene LD125	---	---	Unit inoperable – spider coupling failure

Periodic Test #8 **Date: 5/27/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Diaphragm Units			
Keco	11.5	1:44	
Peristaltic Units			
EMP M300	---	---	Unit inoperable – internal tube failure
EMP EV405	26.5	1:12	
Edson International	25.5	0:59	
Keco	27.0	0:59	
Vacuum Units			
Chesapeake Bay Marine	23.0	0:57	
Edson International	18.5	0:49	
Keco	24.0	0:40	
Waubaushene AVR60	27.0	1:03	
Waubaushene LD125	27.0	0:48	

The following additional Periodic Flow Checks were conducted on the Chesapeake Bay Marine unit.

[Note: Life-cycle testing was concluded on all units except for the Chesapeake Bay Marine unit on June 4, 2004. Life-cycle testing was continued on the Chesapeake Bay Marine unit because the unit did not operate with the vacuum pump lubricant (Mobil EAL-224H) that was chosen for use in all vacuum pumps in the study. The problem with this lubricant in the Chesapeake Bay Marine unit was not identified until May 3, 2004. After consultation with Kevin Atkinson (SOBA), the Chesapeake Bay Marine unit was allowed to continue to be run in the study until such time as the unit had been run for 1000 hours, or until a failure occurred.]

Periodic Test #9 **Date: 6/10/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Chesapeake Bay Marine	23.5	1:00	

Periodic Test #10 **Date: 7/12/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Chesapeake Bay Marine	27.0	0:57	

Periodic Test #11 **Date: 7/23/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Chesapeake Bay Marine	26.0	1:03	

Periodic Test #13 **Date: 9/14/04**	Vacuum Measurement (inches of Hg)	Time required to pump 30 gallons of Test Media (minutes:seconds)	Comments
Chesapeake Bay Marine	24.0	1:07	