ANNEX 3 – Peristaltic Units

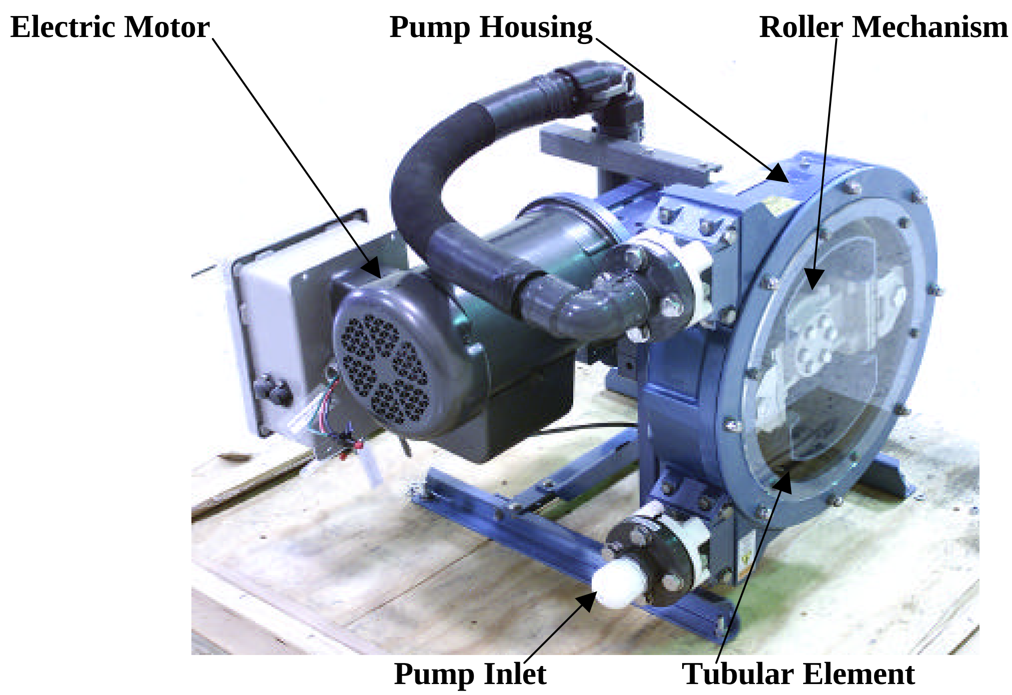
Annex 3.1 - General Information

The table below provides information on the four peristaltic pump-out units evaluated in this study.

Manufacturer	Model
Edson International	286EP-40
EMP Industries	Sanisailor Sentinel - M300
EMP Industries	Sanisailor Sentinel - EV405
Keco	PER900.1PH

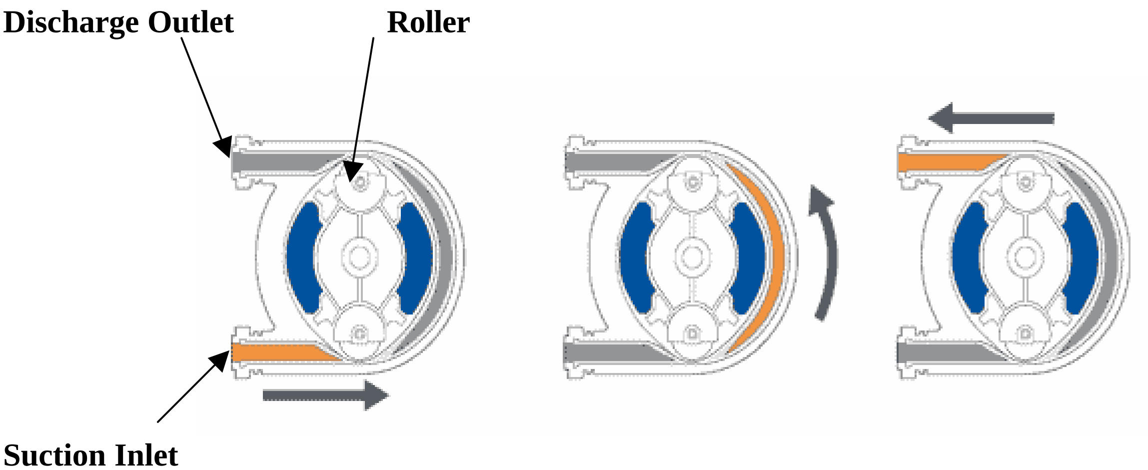
Theory of Operation – Peristaltic Pump-out

The photograph below and the drawing on the next page illustrate the operating mechanism of the Keco PER900.1H Peristaltic Pump-Out unit. The peristaltic pump-out units evaluated in this study utilized self-priming, rotating, positive displacement peristaltic pumps. In Keco's peristaltic unit, two rollers progressively crush a tubular element confined within the pump housing. The alternation between compression and relaxation of the tubular element generates suction vacuum and discharge pressure. The contents being pumped only come in contact with the inner wall of the tubular element. The peristaltic pump is driven by an electric motor through a speed-reducing mechanism. All four peristaltic pump-out units evaluated in this study used this same basic construction and theory of operation.



Internal Diagram of Peristaltic Pump

As the pump rotates, the rollers compress the internal hose. The rollers travel along the outside of the hose moving the hose contents ahead of the rollers to the Discharge Outlet. The hose, expanding behind the roller, creates a vacuum drawing more solution into the pump at the Suction Inlet.



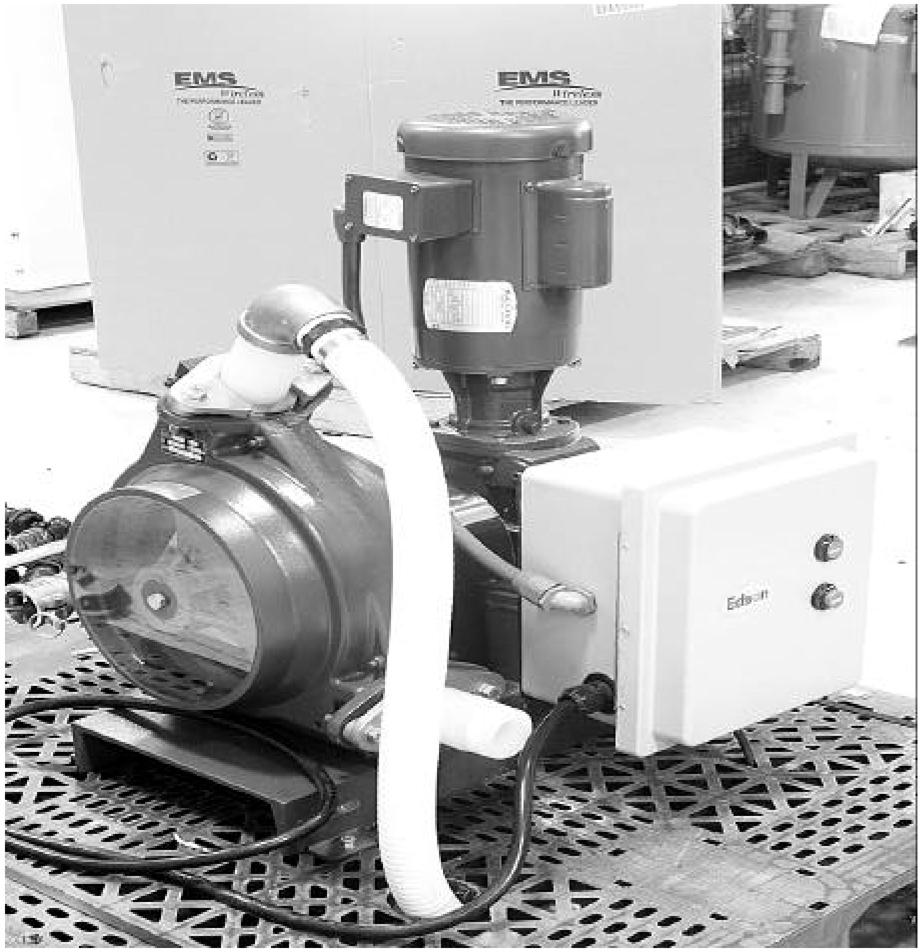
One major difference in the peristaltic pump-out units was the means of lubricating the internal hose (tubular element). Two methods of lubrication were used for the pumps:

1. **Lubricate pump manually –** The Edson International Model 286EP-40 and the Keco Model PER900.1PH are both designed to be lubricated manually. The pump casing is filled with air and the peristaltic pump requires periodic greasing with silicone lubricant that is applied to pump internals using a grease gun. Preventative maintenance instructions from Edson International and Keco recommend lubricating the pump monthly or after every 100 hours of operation.
2. **Pump housing filled with lubricant –** The peristaltic pumps, in use on the EMP Industries Sanisailor Sentinel Models M300 and EV405, are designed such that the pump housing is filled with silicone oil. This design feature eliminates the need for periodic lubrication with a grease gun. Due to aging of the silicone oil, EMP Industries recommends changing the oil in the pump housing once every 3 years.

Annex 3.2 – Manufacturer: Edson International
Model: 286EP-40 (Peristaltic)

Unit Photographs

Internal View



External View of Enclosure

Description of Pump-Out Unit

Serial Number: 27794

Construction: Stainless Steel Hardware
Extruded Aluminum Frame
Molded Solid Fiberglass Enclosure

Peristaltic Pump: Pompes DELASCO Model GZ 40

Rating of Electric Motor: 2 Horsepower, 115 Volts, 23.0 Amps (as configured for testing)
Circuit breaker used in life-cycle testing set-up: 30 Amps
GFCI protection provided by a GFCI circuit breaker

Speed-Reduction: (Note: Electric motor operates at 3450 rpm):

Method: Speed-reducer
Ratings of Speed-reducer: Speed: 90 rpm
Ratio: 19.42
Maximum Torque: 1000 in-lbs

Summary of Life-Cycle Testing Performance

The Edson International 286EP-40 Pump-Out unit operated for a total of 918.0 hours in the life-cycle testing set-up and suffered two failures during testing:

1. Tubular element failure – internal tube developed a leak;
2. Failure of the rubber coupling between the speed reducer and the peristaltic pump

The unit did not complete a the full 1000 hours of operating time in the life-cycle testing set-up due to the circuit breaker for the unit tripping 11 times during life-cycle testing and, therefore, some potential run time was lost while the unit was powered off.

Summary of Repairs

Edson International
Model: 286EP-40

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Replace internal hose	579.4 **Note 1**	Internal hose	$440.00	1	1	18 **Note 2**
Replace rubber coupling between speed-reducer and pump	918.0	Rubber coupling	$48.00	**Note 3**	0.75	**Note 3**

Note 1: The Mariner Technologies Peristaltic Pump-out unit, which was eventually removed from the study, had an identical peristaltic pump (Pompes DELASCO Model GZ 40). This unit also developed an internal tube leak on 3/19/04 after 560.5 hours of operation.
Note 2: Delays encountered in the repair were not due to Edson International.
Note 3: Failure occurred during the last week of life-cycle testing, so the repair was not made until after life-cycle testing was completed.

Results of Environmental Testing

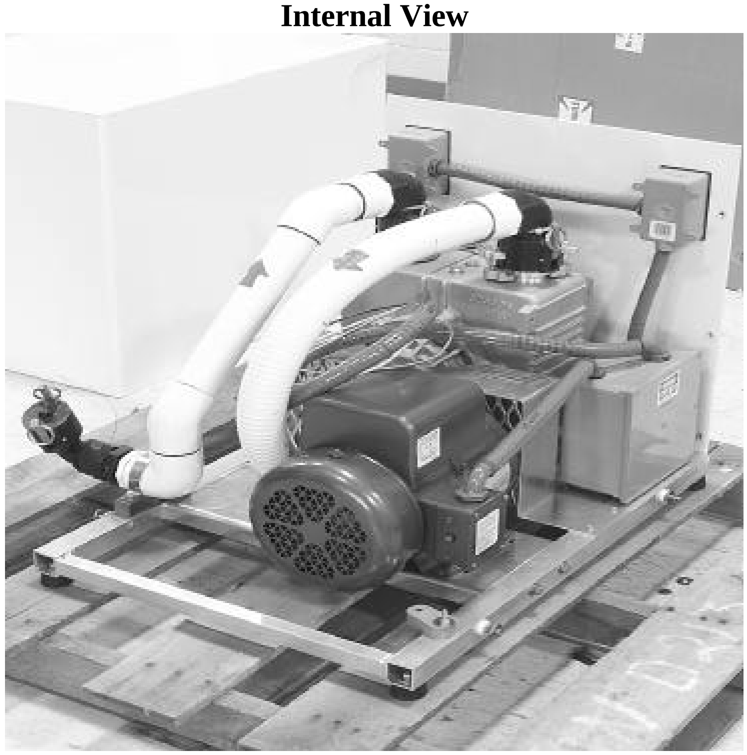
1. Corrosion Resistance: A sample of the Extruded Aluminum Frame was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have superior corrosion resistance.
2. Ultraviolet Exposure Resistance: A sample of the Molded Solid Fiberglass Enclosure for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.

Annex 3.3 – Manufacturer: EMP Industries
Model: Sanisailor Sentinel - M300 (Peristaltic)

Unit Photographs

External View

Internal View



Description of Pump-Out Unit

Peristaltic pump: Alfa Laval "M" Range (Serial Number: 207139)

Construction: Stainless Steel Hardware
Aluminum Frame
Polyvinyl Chloride (PVC) Enclosure

Rating of Electric Motor: 3 Horsepower, 115 Volts, 28.0 Amps (as configured for testing)
Circuit breaker used in life-cycle testing set-up: 40 Amps
GFCI protection provided by a GFCI circuit breaker

Speed-Reduction: (Note: Electric motor operates at 1725 rpm):

Method: V-belt and pulley system connected to the peristaltic pump and gearbox on the peristaltic pump

Summary of Life-Cycle Testing Performance

The EMP Industries Sanisailor Sentinel – M300 Pump-Out unit operated for a total of 651.6 hours in the life-cycle testing set-up, and suffered two failures during testing (See *Summary of Repairs* below):

1. A failure of the time delay relay in the control circuit for the unit – This failure of the time delay relay also caused a failure of the following components: unit timer, secondary transformer, and relay contactor in the control circuit.
2. Tubular element failure – internal tube developed a leak

The unit did not complete a the full 1000 hours of operating time in the life-cycle testing set-up due to:

1. Extensive troubleshooting was required on the control circuit for the failure outlined in the Summary of Repairs (below); and
2. The internal tube replacement kit was not received until after the end of life-cycle testing.

Summary of Repairs

EMP Industries
Model: Sanisailor Sentinel - M300

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Time delay relay failed - causing failure of secondary components	108.1 **Note 1**	Time delay relay, transformer, timer, relay contactor	$234.85	1	2 **Note 2**	85 **Note 3**
Replace internal tube	651.6 **Note 4**	Internal tube replacement kit	$496.00	**Note 5**	2.0	**Note 5**

Note 1: 154.9 hours on unit hour counter. Run time on unit was calculated from the calibrated timers used on the test set-up.
Note 2: Although extensive troubleshooting was required to identify the cause of the problem in the unit (approximately 15 hours), the actual repair only took about 2 hours to perform.
Note 3: Delays encountered in the repair were not due to EMP Industries.
Note 4: The hour counter installed on the unit indicated 701.2 hours of operation at the end of life-cycle testing. Run time on unit was calculated from the calibrated timers used on the test set-up.
Note 5: Delays encountered in the repair were not due to EMP Industries. Parts were not received until after the end of life-cycle testing.

Results of Environmental Testing

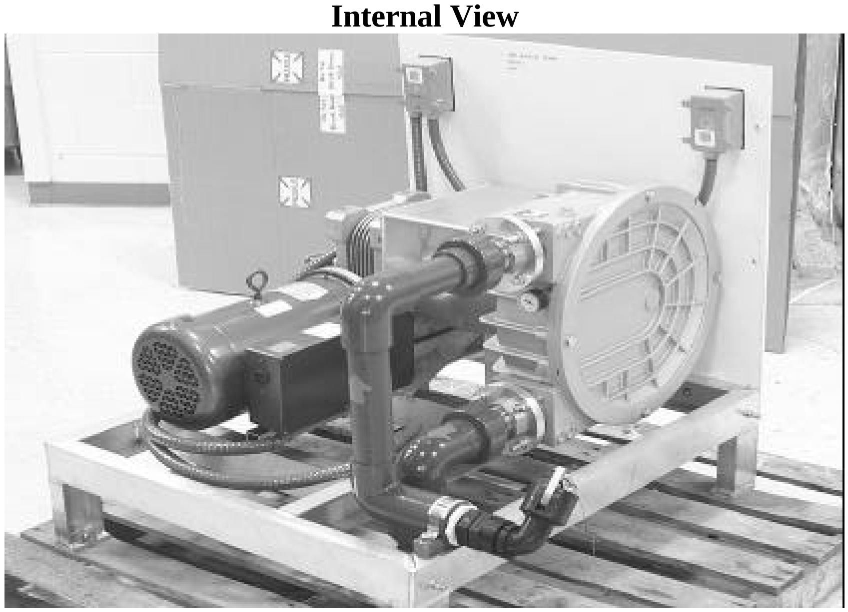
1. Corrosion Resistance: A sample of the Aluminum Frame was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have superior corrosion resistance.
2. Ultraviolet Exposure Resistance: A sample of the Polyvinyl Chloride (PVC) Enclosure for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.

Annex 3.4 – Manufacturer: EMP Industries
Model: Sanisailor Sentinel - EV405 (Peristaltic)

Unit Photographs

External View

Internal View



Description of Pump-Out Unit

Peristaltic pump: Alfa Laval IP400 (Serial Number: 204746)

Construction: Stainless Steel Hardware
Aluminum Frame
Polyvinyl Chloride (PVC) Enclosure

Rating of Electric Motor: 5 Horsepower, 230 Volts, 23.0 Amps (as configured for testing)
Circuit breaker used in life-cycle testing set-up: 30 Amps
GFCI protection provided by a GFCI circuit breaker

Speed-Reduction: (Note: Electric motor operates at 1725 rpm):

Method: Gearbox on the peristaltic pump

Summary of Life-Cycle Testing Performance

The EMP Industries Sanisailor Sentinel – EV405 Pump-Out unit operated for a total of 706.9 hours in the life-cycle testing set-up and suffered one failure during testing. The discharge union on the pump developed a crack requiring that the union be replaced (See *Summary of Repairs* on page 58).

The unit did not complete the full 1000 hours of operating time in the life-cycle testing set-up due to:

1. The circuit breaker for the unit tripped 9 times during life-cycle testing, and some potential run time was lost while the unit was powered off.
2. Faulty flowmeter (at no fault of the manufacturer) - Issues were encountered with measuring the unit's flowrate during life-cycle testing. The unit began to exhibit erratic flow on the flowmeter. The unit was shutdown and troubleshooting was performed on the flowmeter to see if it was the source of the problem. The electronics on the flowmeter were reset and the pump-out unit was restarted, but the flowrate became erratic again and the unit was shutdown for troubleshooting. To further investigate the problem, a spare flowmeter (that had been installed for a pump-out unit that was removed from the study) was installed and the unit was restarted to check the flowrate with the spare flowmeter. The spare flowmeter did not indicate erratic flow, so the problem was isolated to the original flowmeter in the system. The spare flowmeter was used for the remainder of life-cycle testing. The flow data for the pump-out unit was evaluated to ensure that the performance of the unit was properly accounted for in light of the problem with the flowmeter. Since the flowrate measured on the two flowmeters was very similar, (except during the episodes of pulsation on the original flowmeter) the Total Volume Pumped during a portion of life-cycle testing for this unit was estimated using an average flowrate for the unit when the flowmeters were providing accurate readings. Some potential run time was lost while the unit was powered off.

Summary of Repairs

EMP Industries
Model: Sanisailor Sentinel -EV405

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Replace discharge union due to crack	440.7 **Note 1**	2-inch PVC union	$21.76	1	1	3

Note 1: The hour counter installed on the unit indicated 854.6 hours of operation at the end of life-cycle testing. Run time on unit was calculated from the calibrated timers used on the test set-up.

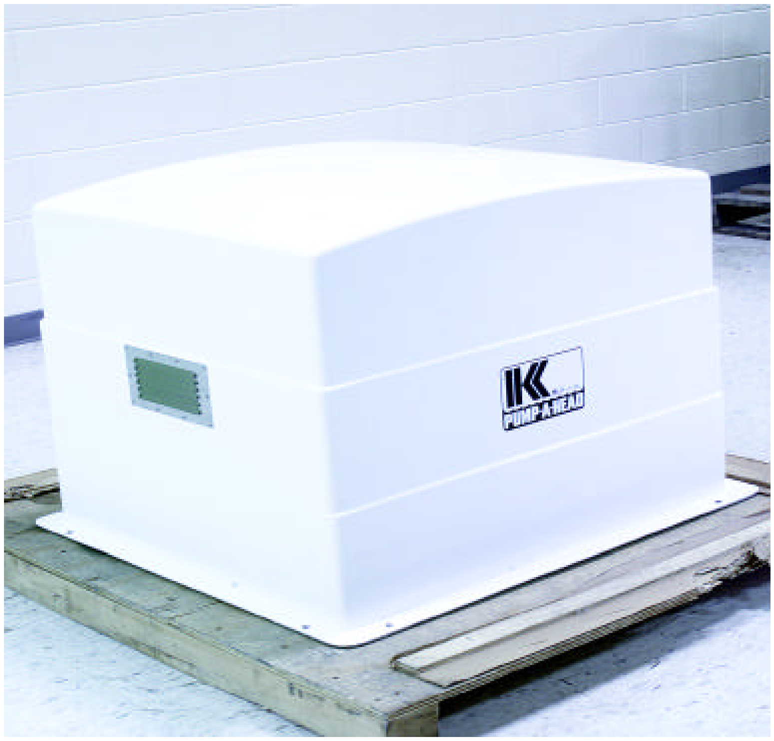
Results of Environmental Testing

1. Corrosion Resistance: A sample of the Aluminum Frame was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have superior corrosion resistance.
2. Ultraviolet Exposure Resistance: A sample of the Polyvinyl Chloride (PVC) Enclosure for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.

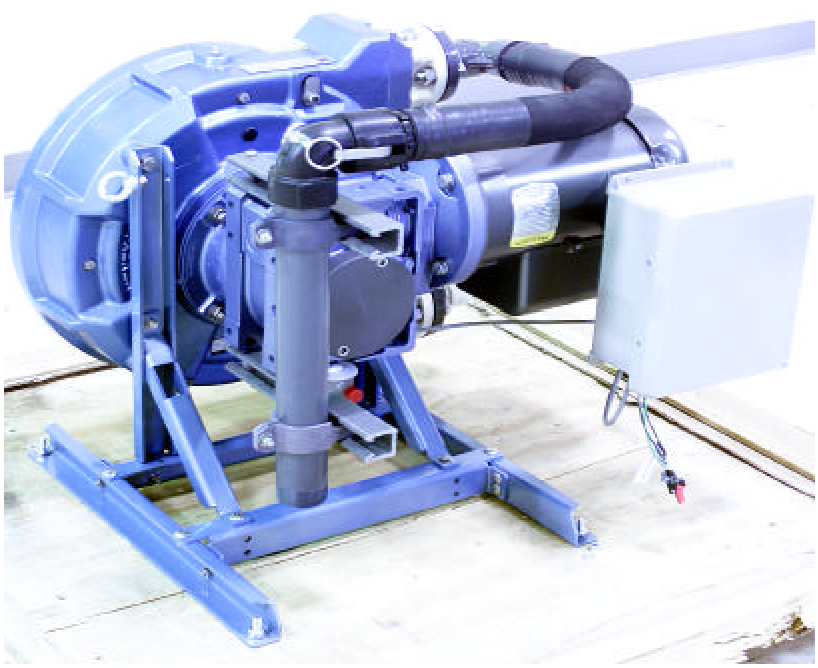
Annex 3.5 – Manufacturer: Keco
Model: PER900.1PH (Peristaltic)

Unit Photograph

External View



Internal View



Description of Pump-Out Unit

Peristaltic pump: Ragazzani (Serial Number: P2012)

Construction: Stainless Steel Hardware
Painted Steel Frame (zinc-based primer used for corrosion resistance)
Molded Solid Fiberglass Enclosure

Rating of Electric Motor: 3 Horsepower, 230 Volts, 14.0 Amps (as configured for testing)
Circuit breaker used in life-cycle testing set-up: 20 Amps
GFCI protection provided by a GFCI circuit breaker

Speed-Reduction: (Note: Electric motor operates at 1725 rpm):

Method: Gearbox on the peristaltic pump
Standard ratio: 20:1
Input: 3 Horsepower (max) @ 1750 rpm
Service Factor: 1.0

Summary of Life-Cycle Testing Performance

The Keco PER900.1PH Pump-Out unit completed 1000 hours of operation in the life-cycle testing set-up and suffered one failure of the internal hose (tubular element) during testing (See Summary of Repairs Section on page 61). The Keco Peristaltic unit has a unique leak detector feature that acts to stop the peristaltic pump in the event of a leak on the internal hose. This leak detector is a safety device that is wired to stop the electric motor that drives the pump when a float-switch mechanism is actuated by leakage of liquid into the pump housing. The leak detector functioned as intended in this instance.

Some issues were encountered with measuring the Keco Peristaltic unit's flowrate during life-cycle testing that were similar to the experience with the EMP Industries Sanisailor Sentinel - EV405 Peristaltic Pump-out unit. In both cases, the problem was erratic flow indicated on the flowmeter and the source of the problem was eventually isolated to the flowmeter. The original flowmeter, in use with the Keco Peristaltic unit, was changed to a spare flowmeter (that had been installed for a pump-out unit that was removed from the study) and the spare flowmeter was used for the remainder of life-cycle testing. The flow data for the Keco Peristaltic unit was evaluated to ensure that the performance of the unit was properly accounted for in light of the problem with the flowmeter. Since the flowrate measured on the two flowmeters was very similar (except during the episodes of pulsation on the original flowmeter), the Total Volume Pumped during a portion of life-cycle testing for this unit was estimated using an average flowrate for the unit when the flowmeters were providing accurate readings.

Summary of Repairs

Keco
Model: PER900.1PH

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Replace internal hose	296.8	Internal hose	$450.00	3	1.75	23 **Note 1**

Note 1: Delays were encountered in the repair which were not due to Keco.

Results of Environmental Testing

1. Corrosion Resistance: A sample of the metal frame was subjected to the Salt-Spray Exposure described in *Section 2.3.* The sample was found to have inferior corrosion resistance. The sample displayed pronounced corrosion on bare metal surfaces of the sample. The painted surfaces of the metal sample also exhibited corrosion under the surface of the paint.
2. Ultraviolet Exposure Resistance: A sample of the Molded Solid Fiberglass Enclosure for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.

Annex 3.6 – Conclusions regarding Peristaltic Pump-Out Units

1. The most common repair for the four peristaltic pump-out units was replacement of the internal hose (tubular element).

2. The peristaltic pump-out units tripped their individual power circuit breakers more often than either the diaphragm or the vacuum pump-out units. The tripping of the circuit breakers during operation was most likely due to an over-current condition on the units due to the continuous cycling of the units in the 10 minutes on, and 10 minutes off sequence.