Analysis of Pulse Duplicator Systems

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Contents

1 Document Description

1.1 Purpose

This document will look at different flow meters that could be used in ViVitro's Pulse Duplicator. Analysis of similar products by ViVitro's competitors will be considered when discussing the feasibility of these different methods. This will also take a look at competitors to determine Vivitro's stance in the market.

1.2 References

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[3] Heart Valve Tester, Bose [online] 2015, http://worldwide.bose.com/electroforce/en/web/heart_valve_tester/page.html (Accessed: March 2015)

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1.3 Product Perspective

Vivitro's current Pulse Duplicator provides an electromagnetic flow meter and electromagnetic flow transducer probe with each Pulse Duplicator. ViVitro wants to research feasible technologies for their Pulse Duplicators in attempt improve their current model with regards to cost, efficiency, and integration with the digital domain.

2 Flow Meters

Each flow meter has advantages and disadvantages depending on fluid viscosity, measurement accuracy, and price. We consider the electromagnetic, ultrasonic doppler, and laser doppler flowmeters to be feasible sensors for the Pulse Duplicator. They have no effect on the pressure or temperature of the fluid, have no moving parts, and cannot get clogged which makes them reliable and low-maintenance.

Used for several sensors, the Doppler shift is the change in frequency of waves caused by a moving wave emitter. Sound waves get compressed in front of a moving object, and expanded behind it. This causes a change in frequency depending on the relative position of an observer.

2.1 Electromagnetic

Electromagnetic flowmeters measure the voltage induced when a conductor, in this case a liquid, passes through a magnetic field. An electromagnet generates a magnetic fields using an electric current; electromagnetic flowmeters do the reverse. They produce an electric current by passing a conductor through a magnetic field in what is called electromagnetic induction.

2.1.1 Pros

- There is no moving parts or obstruction of flow
- Almost zero pressure drop because of measurements
- Accurate to +/-0.25% of reading
- Flow range turn-down of 300 to 1 or better
- Available for pipe diameters from 1/10” to 120”
- Relatively unaffected by viscosity, temperature and pressure as long as the magnetic flow meter is designed specific to the purpose it is being used for.
- Can respond well to rapid changes in flow
- Applicable to liquids with heavy particulates
- Available in a wide variety of communication protocols
- Ability to register locally, remotely or to interface with an energy management system
- Service life of 75 years

2.1.2 Cons

- Water must contain a certain amount of Microsiemens (uS), giving it the power to conduct heat and/or electricity. Some magmeters can work down to 2-3 uS/cm, while other require 10 uS/cm or more.
- Accuracy may be affected by air space in the pipe

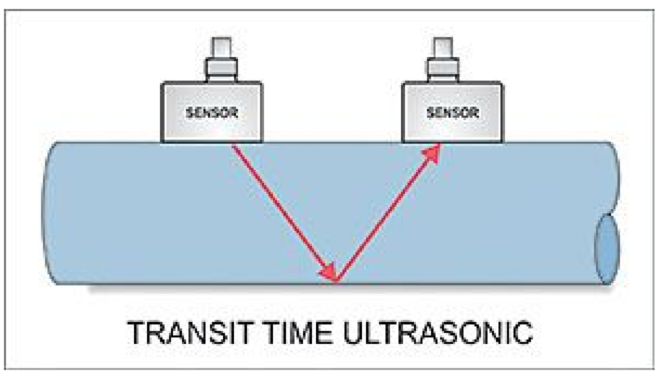
2.2 Ultrasonic

An ultrasonic flow meter is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate volume flow. Using ultrasonic transducers, the flow meter can measure the average velocity along the path of an emitted beam of ultrasound, by averaging the difference in measured transit time between the pulses of ultrasound propagating into and against the direction of the flow or by measuring the frequency shift from the Doppler effect.

2.2.1 Ultrasonic (Transit Time)

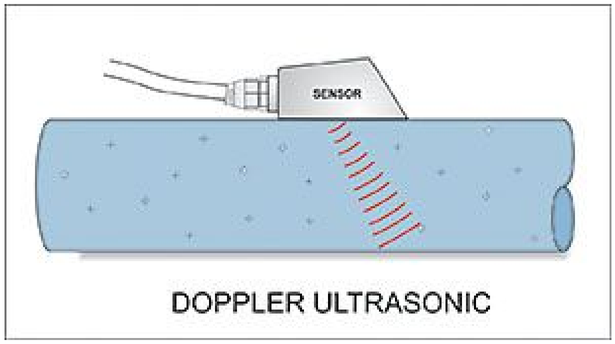
The transit-time ultrasonic flow meter utilizes the propagation time of the ultrasonic signal in the fluid. A pair of transducers are installed on the outer surface of the pipe as shown in the diagram. Each transducer works alternatively as both transmitter and receiver of ultrasonic signals.

When the ultrasonic signal is transmitted toward the upstream side against the flow direction, more propagation time is required. On the other hand, when it is transmitted toward the downstream side with the flow direction, the propagation time is less. That is, the signal is delayed or speeded up by the moving fluid. The difference in time between the upstream and downstream is proportional to the flow velocity, and the flow volume can be calculated by multiplying it by the cross-sectional area, which is obtained by using the pipe diameter and wall thickness.



2.2.2 Ultrasonic (Doppler)

Ultrasonic Doppler flowmeters measure the Doppler shift of sound passed through a moving fluid. An ultrasonic sound is passed through the tube. A reflector, positioned on the other side of the tube, reflects the sound back into a sensor. The speed of the fluid causes a change in frequency from when it leaves, to when it reaches the sensor. The change in frequency can then be measured to calculate the rate of flow.



2.2.3 Pros

- Low costs associated with installation. Your system would not need to be shut down and your piping would not need to be altered.
- Device will not obstruct flow or contaminate processes
- Minimal maintenance
- Flow range typically 100:1
- Can be used with corrosive fluids
- Zero pressure drop
- Operates on pipe diameters from 1/2” to 200” (may require 2 or 3 different sets of transducer depending on pipe size and range transducers cover)
- Insensitive to changes in temperature, viscosity, density or pressure, however sensors chosen must be able to work with desired temperatures
- Available in a wide variety of communication protocols (Transit Time)
- Ability to register locally, remotely or to interface with an energy management system (Transit Time)
- Since the output is electrical, the read-out can easily be analog or digital

2.2.4 Cons

- The accuracy of ultrasonic flow meters becomes much less dependable when the flow rate drops below 2 ft/s
- Any number of unknown internal piping variables can shift the flow signal and create inaccuracies
- The scaling, pitting, and fouling that can occur over time in older piping systems can be problematic
- Accuracy may be affected by air space in the pipe

- Accuracy may be affected by the size distribution of particles and any relative velocity between particles and the water (Doppler)

2.5 Laser Doppler Velocimeter

A laser doppler flowmeter works similarly to the ultrasonic doppler flowmeter, but uses the doppler shift of light, rather than sound. A laser is passed through a moving fluid, and the light's frequency is changed by the doppler shift. Often, two laser's are used: a measurement beam, and a reference beam.

2.2.1 Pros

- No obstruction of flow
- Very high frequency response
- Very high accuracy when used correctly

2.2.2 Cons

- Sufficient transparency is required between the laser source, the target surface, and the laser receiver.
- Accuracy is highly dependent on alignment of emitted and reflected beams.
- Expensive (Prices have dropped due to commercial lasers maturing)

3 Competitors

3.1 BDC Labs HDT-500 Pulse Duplicator System

3.1.1 Key Features

The HDT-500 Pulse Duplicator System is a aortic and mitral heart valve test system. Heart valves can be changed in the machine without draining the system fluid. No second heart valve implant is needed for testing so it provides a highly repeatable test environment. The customizable system valve fixture accommodates up to 70mm in diameter.

3.1.2 Specifications

Flow Monitoring:	Ultrasonic or Electromagnetic Technology
Working Fluid:	Water, PBS, Blood Analog
Flow Rate:	0-10 L/min
Frequency:	2-240 bpm
Temperature:	up to 40 °C

3.2 Dynatek Pulsatile Ventricular Assist Device (PVAD)

3.2.1 Key Features

The PVAD is a real time testing machine that can simulate all the necessary physical conditions to completely test artificial hearts and assist devices. It uses a compliant aortic section, the fluid dynamics of this tester can emulate *in vivo* conditions for flow rates and pressures. The test fixture provides mechanical equivalents for the left ventricle, aortic valve, compliant aorta, atrium, and mitral valve, completing a closed cardiovascular loop.

3.2.2 Specifications

Overall Dimensions:	18″L x 18″W x 71″H (minus control system)
Power Requirements:	115V AC
Maximum Fluid Displacement:	300mL.
Number of Samples:	up to 3
Volume Capacity:	28.4 liters
Temperature Range:	ambient to 40°C
Temperature Accuracy:	-1°C +0.3°C
Speed:	Computer controlled stroke from 1 to 120 beats per min.
Dry Weight:	203lbs

3.3 Bose Heart Valve Tester

3.3.1 Key Features

- Automatically adjusts settings to key target test conditions and reduces overshoot of target transvalvular pressures by means of closed-loop feedback control.
- Bose® DuraPulse™ test instrument supports frequencies higher than 30Hz and facilitates shortened overall testing time.
- Fast filling and draining process

3.3.2 Specifications

Frequency:	15 - 30+ Hz
Temperature:	Up to 40°C
Valve Size:	Up to 40mm
Valve differential pressure:	Up to 500mmHg
Number of Samples:	2, 4 or 6
Data Acquisition Rate:	5kHz

4 FM501 Specifications

Here you can find the specifications for the current flow meter used by Vivitro. These are here for an easy comparison to other flowmeter options.

4.1 Accuracy

Electrical Zero	Non-occlusive zero reference
Calibrate Signal	-1.0V±5mV and 0.1V±2mV on mean and pulsatile outputs, toggle switch operated to calibrate external recorders and indicators
Flowmeter Calibration	Accuracy ±5% after 30 minute warm-up (Includes the effect to gain and excitation variation.)
DC Drift	±5% after 30 minute warm-up, cold start ±10mV
Linearity	±1% maximum full scale

4.2 Safety

Probe Leakage	Protection Probe current is removed if more than 200 μA leakage to ground occurs.(The CME Model 701D CLINIFLOW II is recommended for use on human subjects since its leakage is less than 20 μA.)

4.3 Input Characteristics

Probe Excitation	500 Hz square-wave, 0.5 Ampere ±2%. Limited to ±15V open circuit. 50% duty cycle on 20mm and smaller probes
Amplifier Input	Differential 20MΩ plus 300pf. Maximum input voltage 2V p-p. Common mode signals lower than 350Hz produce an output 20dB below that produced by carrier reference. Signals in the range of 250Hz are approximately 40dB below carrier reference.

4.4 Output Characteristics

Flow Range	5 milliliters/min to 19.99 liters/min depending on probe selected.
Gain	Analog Model – 500K (at P.F. 500) .2μV p-p input produces 1.0VDC output, mean and pulsatile channels (Digital Model – 50K).
Flow Indicator	Model 501D – Digital Readout. Model 501 – Panel Meter. Both calibrated in milliliters/min and liters/min.
Outputs	Simultaneous mean and pulsatile single-ended analog outputs capable of ±5V swing. Normal full-scale mean output +1.0, -0.2VDC for analog model; ±1.999VDC for digital model.75Ω output impedance, short circuit protected. Minimum load impedance 1kΩ.

Frequency Response	DC – 100Hz, ±3dB.
Output Noise	50mV typical (0.1μV RMS referenced to shortened input @ 25K overall gain).

4.5 General

Power Requirements	115V±10V, 50-60Hz, (501, 40 Watts) (501D, 42 Watts). Optional 100VAC, 230VAC.
Operating Temperature	15ºC to 27ºC (60ºF to 80ºF) Ambient
Size & Weight	21 x 21 x 28 cm HWD (8.25 x 8.25 x11 in. HWD). 5.5kg (12 lbs.).
Colors	Burgundy with gray trim.