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## TECHNIQUE

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# A Technique for Automatic Tubing Occlusion in Response to Air Bubble Detection When Using a Centrifugal Pump

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### Abstract

A double acting pneumatically powered cylinder, energized by an electrically activated solenoid valve, is used to occlude the outflow line from a Bio-Medicus (a) constrained vortex pump. The cylinder is mounted on a tubing guide that is fastened to a pole clamp. A Sarns (b) air bubble detector, placed on the pump inflow line is used to provide the signal to activate the solenoid valve. The outflow occluder is capable of 100% occlusion of 3/8 x 3/32 inch Tygon tubing up to pressures of 2586 mmHg. The occluder system is able to work with many types of bubble detectors and is applicable to any form of non-occlusive pump.

### Introduction

Stopping blood flow to the patient to prevent air embolism is a typical response to the detection of air bubbles in an extracorporeal circuit. The standard methodology of turning off power to the pump, or immediately halting rotation of the head, is acceptable in the case of an occlusive roller pump. However, there is no way of immediately halting the rotation of a centrifugal pump by turning off power to the console due to the pump speed, mass of the drive system and the inertia of the blood. This problem is particularly serious in our predominate application for the centrifugal pump, that of heparinless veno-venous bypass for liver transplantation. Our necessarily simple circuit (composed of 3/8 inch tubing collecting blood from the femoral and portal veins; the centrifugal pump head, and 3/8 tubing returning blood to the axillary vein) permits blood flow through the circuit without pump rotation due to the high abdominal venous pressure to axillary vein pressure gradient. While this type of pump is not capable of continuously pumping massive amounts of air into the outflow line, it may deliver a significant amount of air as foam or microbubbles. In addition, the act of removing air from such a simple circuit with

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continuous baseline flow requires extreme care, and embolization may result without the prompt appropriate use of tubing clamps.

In general, the importance of automatic tubing occlusion following detection of air in a centrifugal pump line was emphasized by Vivian et al. (1), who incorporated an occlusive roller pump, controlled by a bubble detector, in series with the centrifugal pump during cardiopulmonary bypass.

Our applications for centrifugal pumps are limited to veno-venous bypass for liver transplantation and biventricular support. Therefore, a system applicable to both forms of pump assisted perfusion was devised to occlude the outflow line from the pump head to the patient in response to air bubble detection.

### Methods

The design goal was to develop a system that would immediately and effectively occlude the pump outflow tubing, without causing damage to the tubing, in response to the detection of air in the centrifugal pump inflow line. Rapid and complete release of the occlusion following resolution of the problem was also desirable. The occluder had to be controlled by a commonly accepted, reliable and readily available bubble detector.

Considering the force required to effectively occlude 3/8 inch i.d. by 3/32 inch wall thickness Tygon tubing without damage, a pneumatic cylinder, powered from a readily available gas source in the operating room or at the patient's bedside in the intensive care unit, was determined to be the best actuator of the occluder. The minimum cylinder size was determined to be 1.0625 inch bore, with a 1.5 inch stroke when operated from a 50 psi pressure source. A double acting cylinder was chosen to guarantee automatic complete unocclusion of the tubing when the bubble detector was reset. The cylinder was purchased from a local distributor for the American Cylinder Company (c). The

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a. Bio-Medicus, Eden Prairie, MN 55344

b. Sarns, Inc., Ann Arbor, MI 48106

c. American Cylinder Company, Inc., Peotone, IL 60468

Figure 1a. Picture of the occluder, in the unoccluded position, with 3/8 inch Tygon tubing in place.

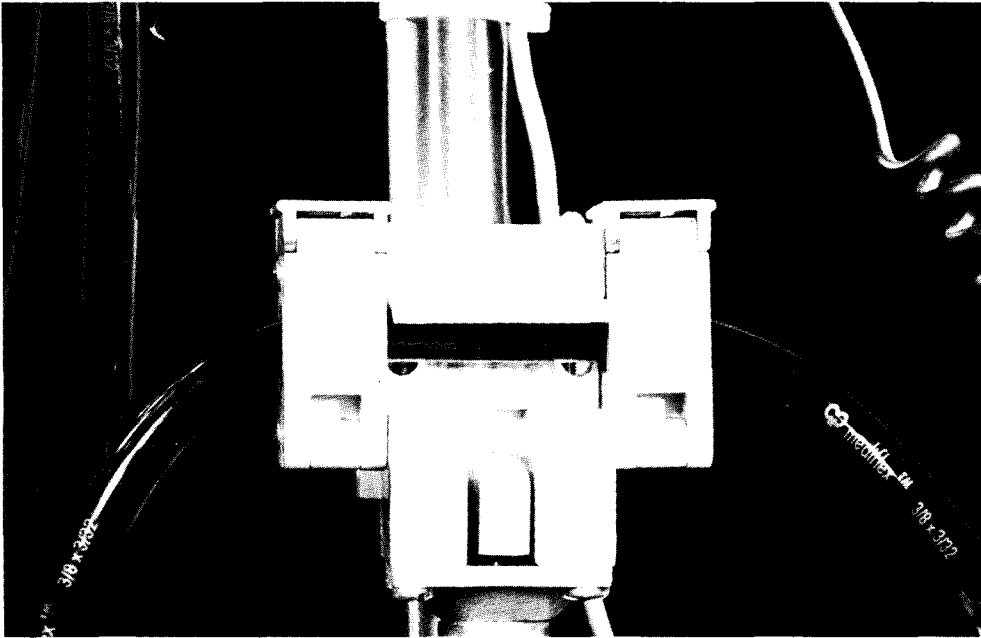


Figure 1b. Picture of the 3/8 inch Tygon tubing being occluded by the device.

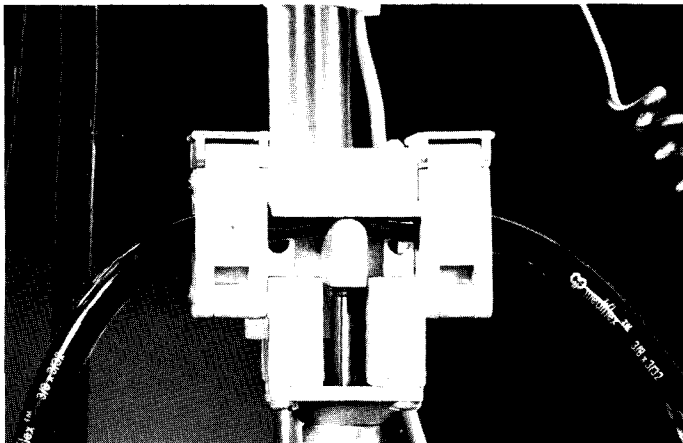
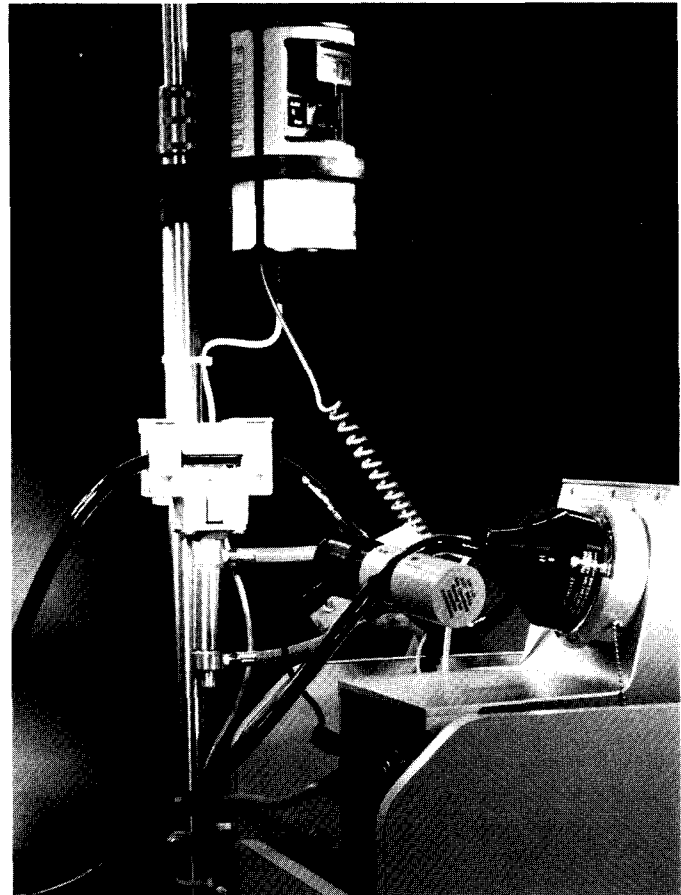


Figure 2. Picture of the bubble detector on the pump inflow tubing and the occluder on the outflow line.



cylinder was powered from a 50 psi medical air source, but could be powered from an oxygen source if care is taken to disassemble the cylinder and replace completely the petroleum-based lubricant with a silicon-based vacuum grease acceptable for oxygen rich environments.

A parabolic-shaped occluder head for the shaft of the pneumatic cylinder was formed from a rectangular block of solid aluminum. Solid aluminum blocks were also used to construct the tubing guide, back plate and cylinder holder assembly. Sarns 7000 pump tubing clamp assemblies were modified and attached to each side of the occluder to hold the outflow tubing in place. The entire occluder assembly was mounted to a pole clamp that permits necessary adjustments to align the tubing path with the pump head.

A four-way direct individual body solenoid valve with nonlocking recessed operator, activated by 120 volts AC, was chosen to provide gas pressure to the appropriate ports on the cylinder. The deenergized solenoid (normally open port) supplied gas pressure to maintain the cylinder in the minimum stroke (unoccluded) position. The solenoid, when activated by power from the bubble detector circuitry, switches the gas pressure to the opposite port on the cylinder resulting in maximum permissible piston stroke and complete occlusion of the tubing. This arrangement was chosen so that an electrical power failure or failure of the gas supply would not result in unintentional tubing occlusion. The solenoid valve was purchased from a local distributor for MAC Valves (d).

The occluder system was tested in order to determine the ability of the system to completely stop flow in 3/8 inch x 3/32 inch and 1/2 inch x 3/32 inch Tygon tubing by varying intraluminal pressures. The tubing was pressurized with air for 100% occlusion testing instead of blood or crystalloid to provide an easy mechanism of pressure control and a simple method of leak detection. The open end of the tubing, distal to the occluder, was placed 3 to 5 cm under water so that incomplete occlusion would be obvious from bubble formation. Since air is less viscous than blood or crystalloid, this form of testing provides more robust leak detection.

The 3/8 inch tubing was occluded 25 times in succession to evaluate the potential for damage to the tubing by the occluder mechanism.

## Results

The occluder was capable of completely stopping the flow of air in the 3/8 inch tubing, even at intraluminal pressures of 50 psig (2586 mmHg). However, the 1/2 inch tubing presented the occluder with considerable difficulty. The occluder was capable of completely stopping flow at only 3 psig (155 mmHg) on the first compression of the tubing. Following three compressions of the 1/2 inch tubing, the occluder was capable of completely stopping flow up to 15 psig (776 mmHg).

There was no readily apparent damage to the tubing following 25 repeated occlusions.

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d. MAC Valves, Inc., Wixom, MI 48096

## Discussion

The occluder was intended to be used with virtually any bubble detector by merely choosing the appropriate operating voltage of the solenoid valve to match the voltage provided by the detector. If the bubble detector provides only a simple switch closure in response to air detection, then a low voltage DC power supply and appropriate solenoid should be chosen to activate the occluder.

An important point to consider is that the overall effectiveness of the occluder system to prevent air embolization is dependent upon the detectors' ability to sense bubbles. For this reason, we have chosen a well recognized, commonly available, and accepted detector system.

Figures 1a and 1b illustrate the operation of the occluder with standard 3/8 inch Tygon tubing. Figure 2 illustrates the entire system as it is used routinely for veno-venous bypass with the bubble detector on the inflow tubing and the occluder on the outflow tubing.

The occluder system has been in routine use for more than a year. The ability to effectively occlude the 3/8 x 3/32 Tygon pump outflow tubing, at intraluminal pressures of 2586 mmHg, without interfering with pump console operation or damaging the tubing has been achieved. Complete occlusion of 1.2 x 3.32 inch tubing was obtained only at low intraluminal pressures of 155 mmHg on the first attempted occlusion. Because the 1.2 inch tubing requires exercising by the occluder in order to provide 100% occlusion at intraluminal pressures above 155 mmHg, a larger cylinder may be required to provide a comfortable safety margin for complete occlusion.

The application of this system is limited to centrifugal or other non-occlusive pumps because they cannot generate excessive pressures that might rupture tubing or connections during occlusion of the pump outflow.

## References

1. Vivian WA, Stander KH, Smith RG: An air embolism detection device for use with a non-occlusive arterial pumphead. *JECT*, 19(4):406, 1987.