

indicated, special sacral radiographs can often be obtained, along with radiographs of the pelvis and hips, with minimum extra cost or inconvenience to the patient.

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Error in a Pipeline Gas Concentration: An Unanticipated Consequence of a Defective Check Valve

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We found a major threat to patient safety resulting from a defective check valve in the air flowmeter of an IMV Emerson Ventilator simultaneously coupled with a 24 per cent decrease in the air pressure of the hospital's central pipeline system. These simultaneous failures caused a gross increase in oxygen concentration in the air pipelines.

The decrease in air pressure resulted from an open circuit breaker in one of the two main air compressors. An auxiliary air compressor was activated by a pressure switch in the air line preset to turn on at 40 psig. The pressure was 38 psig in the surgical intensive care unit (SICU) and in the newborn intensive care unit (NICU).

The IMV Emerson Ventilator (Model #3-MV) with an air-oxygen blending device, contained a defective check valve in the air flowmeter, which resulted in oxygen at 50 psig flowing backwards through the flowmeter into the central compressed air pipeline (fig. 1).

PROBLEM IDENTIFICATION AND CORRECTION

Air pressure in the SICU was recognized as being low because low-pressure alarms on blenders were being activated. The NICU was then checked, because both areas were supplied by the same riser. In the

NICU, a nurse complained that the oxygen concentration in an infant hood was too high. Even with the oxygen flow turned off, the oxygen concentration remained above 21 per cent. With a calibrated oxygen analyzer (IMI Model #3300), the actual oxygen concentration in the air supply was measured at 33 per cent, later increasing to 40 per cent in the NICU and 80+ per cent in the SICU.

Because no new pipelines had been repaired or installed, oxygen was assumed to be entering the air lines from an external source connected to both air and oxygen high-pressure lines. All air-oxygen blenders in use were suspected as a possible source for crossover. After all air-oxygen blenders were disconnected, and the air compressor circuit breaker was closed, the problem was corrected.

Somewhat fortuitously, a new IMV Emerson ventilator was singled out for closer evaluation. To test its blender, equipment was set up as shown in figure 2. When air pressure was decreased, using the variable regulator, oxygen flowed backwards through the air flowmeter and control valve, and the oxygen percentage in the "air" line exceeded 80 per cent.

The check valve was removed from the air flowmeter and was found to be incompetent. The internal spring was broken and did not close the valve, as shown in figure 3. Because the valve looked identical to the check valve in an automobile tire, a tire valve stem was inserted in the rear of the air flowmeter. Although it fit well, the spring tension was greater, and 50 psig from the wall outlets would push a maximum flow of only 10 to 15 l/min of air through the valve. Thus, substitution was impossible. This valve has been replaced with an original from the J. H. Emerson Company, and additional check valves (Puritan-Bennett 255465) have been installed immediately behind the Emerson check valves.

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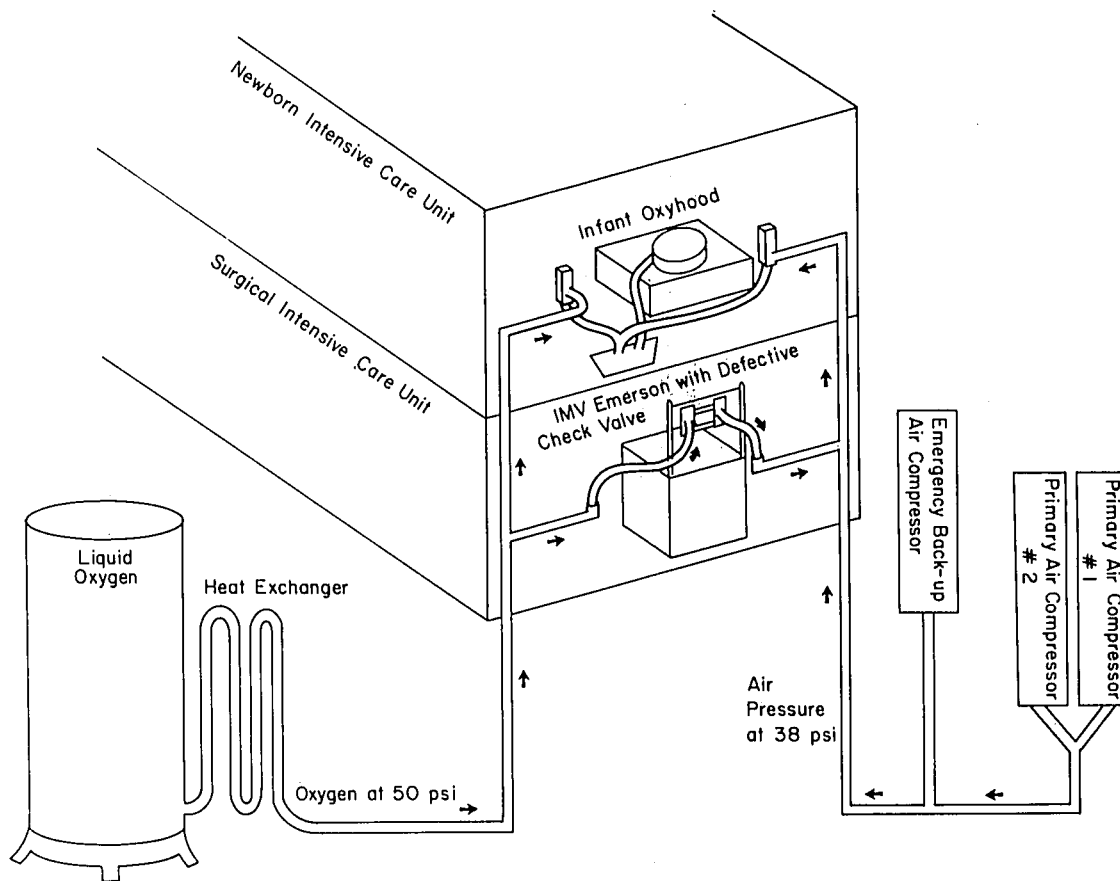


FIG. 1. Oxygen at 50 psig passes through the IMV Emerson ventilator in the surgical intensive care unit, entering the hospital air lines at 38 psig, where it was delivered to the newborn intensive care unit above.

The valves supplied by Emerson not only have weaker springs than do tire valve stems, but also are said to differ in their ability to tolerate water vapor or condensation, as they are made of stainless steel.[§] The air and oxygen valves in the defective blending device were compared. The air valve was slightly corroded compared with the oxygen valve. Another similar blender was tested, and although its air valve worked correctly, it too was found to be slightly corroded. Like a valve stem in a tire, these valves are closed for almost all of their functional life. However, when the valve is used in one of these flowmeters, the open position during all ventilator use adds to the stress on this expansion spring. The valve on the air side is exposed to water vapor from the water seal pumps used in the compressed air system, whereas the valve on the oxygen side is exposed to dry gas only. Our plan now is to replace these valves frequently and to use additional external check valves or to replace this blending device with another. We also added a refrigerated air dryer to remove

moisture from the compressed air lines, since moisture may be contributing to corrosion of the valves.

DISCUSSION

Feeley and Hedley-Whyte,¹ in 1976, reviewed reports of accidents involving medical gas pipelines in hospitals approved for anesthesia training. The 73 specific problems included six involving crossed pipelines. In all six incidents the pipelines were crossed internally rather than externally through blending devices. Dinnick² suggested that nitrous oxide piping systems are too dangerous to warrant their being installed in hospitals. When discussing compressed air pipes, he stated, "it does not matter much if these are crossed with oxygen pipes." We disagree with both of these comments. The proper use of pipeline sources is cost-effective and convenient, but their use must be accompanied by meticulous assembly and rigorous testing.

Arrowsmith³ suggests that after completion of established cross-connection tests for hospital piping systems, further tests should be carried out by a

[§] Emerson J: Personal communication, 1980.

EQUIPMENT USED TO REPRODUCE THE PROBLEM

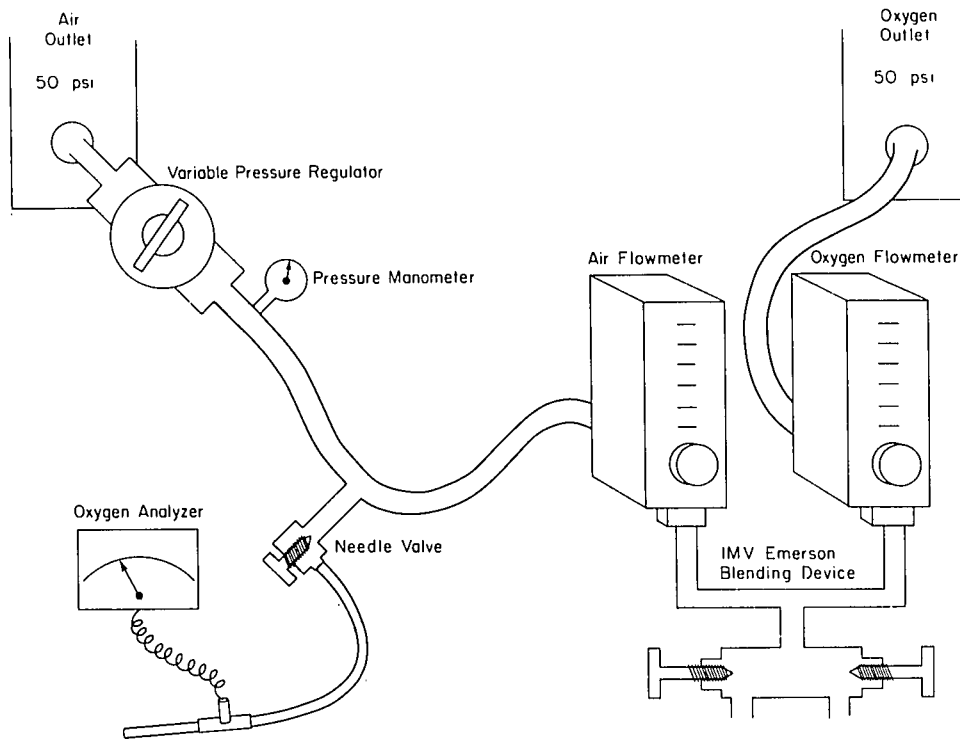


FIG. 2. IMV Emerson air-oxygen blending device. When 50-psig air pressure passed unreduced through the pressure regulator on the air outlet, the oxygen analyzer read 21 per cent. When the air pressure was reduced at the wall, oxygen flowed backwards through the blending device and the oxygen analyzer read between 80 per cent and 90 per cent.

suitably trained person. One of these tests, a secondary pressure test, would ensure the satisfactory closure of the self-sealing valves at wall outlets. Although self-sealing, these are not check valves. Even when they function properly, they are not designed to prevent backflow once a connection is made to the outlet.

Canadian standards (CSA Standard Z-305.1, currently voluntary⁴) in most provinces state that a

“special care unit must henceforth be supplied with its own isolating valve at the riser.” Had this been in effect in our hospital, it would not have prevented gas mixing within the SICU in which the defective apparatus was located, but it would have prevented it in the NICU. In the United States, check valves in medical gas systems are required only downstream of the last pressure regulator.⁵ Obviously, when these are defective, they fail to provide security against gas mixing.

Even assuming all current pressure and alarm standards for gas delivery systems are met, there could still exist a problem with blending of gases, when an external defective check valve is in use. Keeping the oxygen pressure slightly higher than that of nitrous oxide would prevent nitrous oxide from entering the oxygen, but would then allow oxygen to enter nitrous oxide. With air and oxygen lines, detection of a cross-connection problem would probably be more apparent if oxygen had the higher pressure. When a patient's Pa_{O_2} is being monitored, unusually high Pa_{O_2} s would cause suspicion, while low Pa_{O_2} s would be attributed to worsening pulmonary problems. However, if air were being used to deliver humidity only, it is likely that Pa_{O_2} would not be checked routinely, so that unusually high Pa_{O_2} might go unnoticed for quite a while.

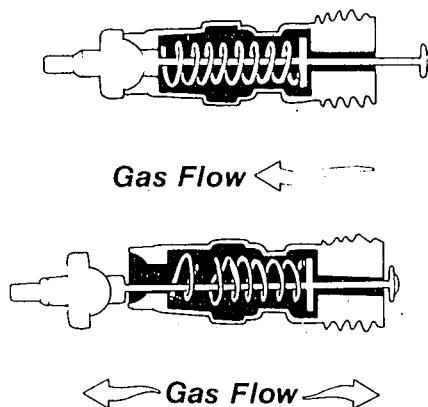


FIG. 3. The lower defective check valve was removed from the air flowmeter. Instead of being closed by spring tension, as in the check valve removed from the oxygen flowmeter, it was wide open, allowing gas to flow in either direction.

When the air pressure decreased, the low-pressure alarm for compressed air was not connected to the critical care areas or central switchboard, as required by NFPA-56F.⁵ This alarm, along with other medical gas alarms, is being connected to a hospital central alarm system (Johnson Control Alarm System, Model 81). Fortunately, the low air pressure was detected quickly, but not because of an alarm in the critical care areas. This same standard⁵ calls for a refrigerated air dryer when local atmospheric conditions make it necessary. We have installed such a dryer since this episode, but not solely to prevent deterioration of these check valves. It may be noted, however, that whether it is necessary depends among other things on the volume of gas used, ever increasing in our experience.

Although this incident produced no evident injury to patients, owing to its rapid detection, the potential obviously existed for such complications as retro-lental fibroplasia, pulmonary oxygen toxicity, or the

diminution of hypoxic drive to respiration. Prevention depends on thoughtful design of apparatus, adherence to standards, anticipation of modes of failure, and careful checking of equipment before use. Oxygen analyzers of adequate reliability should, however, ultimately be included as integral components of all devices other than the most rudimentary for the respiratory and anesthetic care of patients.

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Use of the Flexible Fiberoptic Bronchoscope to Change Endotracheal Tubes in Critically Ill Patients

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In critically ill patients absolutely dependent upon mechanical ventilatory support safely changing an endotracheal tube can be very difficult, especially in the presence of upper airway edema or anatomic abnormalities. Often these patients cannot tolerate prolonged periods of hypoventilation or loss of positive end-expiratory pressure (PEEP), and they may be impossible to ventilate via a face mask. An endotracheal tube may have to be changed for many reasons, including a leaking cuff and the inability to permit passage of a flexible fiberoptic bronchoscope or suction catheters. The flexible fiberoptic bronchoscope is fre-

quently used to facilitate the placement of endotracheal tubes in spontaneously breathing patients.¹⁻³ We describe here a technique using the flexible fiberoptic bronchoscope to change an endotracheal tube in a critically ill patient while maintaining ventilation and control of a difficult airway.

REPORT OF A CASE

A 44-year-old obese man was scheduled for an elective tonsillectomy. After induction of anesthesia, intubation of the trachea was very difficult because of his short, fat neck and small jaw. Many attempts were necessary before an oral endotracheal tube 8 mm in internal diameter (ID) was successfully passed. Bronchospasm then developed, but resolved with deep halothane anesthesia. The operation proceeded, with the surgeon having some technical difficulty because of tissue swelling and bleeding. At the end of the operation breathing was spontaneous, and the trachea was extubated. Air exchange, however, was not adequate because of upper airway obstruction and recurrent bronchospasm. With considerable difficulty a 7-mm-ID endotracheal tube was passed transnasally, and the patient was transferred to the intensive care unit, where mechanical ventilation was begun. Over the next two days, severe bronchospasm persisted, despite therapy that included sedation with morphine and diazepam, antibiotics, steroids, aminophylline, isoetharine, aerosolized atropine, and careful fluid balance guided by pressures obtained with a pulmonary-artery catheter.

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