Hospital Topics

Automatic Electronic Oxygen Supply

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Summary

An automatic electronic oxygen system has been devised to supply an intensive care unit with a "fail-safe" supply of continuous oxygen. All parts of the system are fitted with alarms, as the oxygen powers gas-driven ventilators. Since the system is cheap it can be installed in hospitals where finance is limited.

Introduction

The following is an account of the construction of an oxygen supply to a four-bedded intensive care unit. The limitations of the design were set by (1) no facility for a supply of liquid oxygen; (2) a small working area and therefore no space for storing and manipulating cylinders; (3) difficulties in cleaning and covering the cylinders before they were carried to the unit; (4) oxygen wastage due to premature replacement of cylinders on gas-powered ventilators; (5) insistence on a "fail-safe" system in the oxygen supply; and (6) the cost of available automatic commercial systems far exceeded the available finance.

The design consists of an oxygen source provided by six cylinders housed outside the intensive care unit and the automatic switch-over (manifold) and alarm systems (electronics) in separate instrument cases (Fig. 1). The whole of the system is enclosed in one cupboard. An auxiliary indicator panel (showing the number of empty oxygen cylinders) is fitted in a near-by porters' room. Within the intensive care unit the

oxygen is supplied at 45 lb/in² (3.2 kg/cm²) via $\frac{1}{4}$ -in (0.6-cm) copper tubing with brass fittings piped in a ring. This system is within the scope and price range of the financial and technical aid available to a small intensive care unit. It is hoped that it might be suitable to other small units with similar problems.

Construction

The system is divided into three sections (Fig. 2).

(1) The *running bank* contains up to 10 cylinders plus the emergency cylinder, each cylinder being fitted with a two-stage regulator (preset to 44 lb/in²; 3.1 kg/cm²) and connected to the manifold by high-pressure rubber tubing. An emptied reservoir cylinder is also included, fed from the manifold, to provide a compensating pressure device during the switching sequence. The reservoir is permanently locked into position and never exchanged for a full cylinder, so avoiding a devastatingly high pressure on the output pipeline.

(2) The *control* unit, which is the electronics of the system, consists of an appropriate number of modules inside a metal case with a front indicator panel. The modules within the control unit are arranged one for each cylinder in the running bank, two for the emergency cylinder, and one each for the pulse generator, counter, and audio-oscillator. The indicator panel shows the working condition of the oxygen cylinders; a series of red lamps indicates "empty," amber signifies "in use," and green "full." The emergency cylinder module has a white lamp, indicating "change," and there are two other lamps, labelled "auto" and "manual," which indicate whether the system is working automatically or manually. The manual system, controlled by a switch, is a completely separate selector module used only in the event of electronics failure.

(3) The *manifold* unit comprises electromagnetic valves (solenoids) and pressure switches, one of each being required for each cylinder, the pressure switch being set at 40 lb/in² (2.8 kg/cm²). Three safety systems are incorporated into this unit to cover mains failure and a low or high pressure state in the oxygen output pipeline.

Operation

The automatic system is started by fitting four or more full cylinders into the running bank, with one full emergency cylinder and an emptied permanent reservoir cylinder. All these cylinders are then opened to the fullest extent, and the electronics are switched on, so setting the unit and allowing the sequence to begin correctly. Cylinder No. 1 (in use) opens into the manifold, leaving the remainder indicating "full." When cylinder No. 1 empties it switches off, indicates "empty," and allows the counter to start sequentially hunting for a full cylinder. Should all the cylinders in the running

FIG. 1—Layout of system.

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FIG. 2—Construction of the three sections of the system.

FIG. 3—Diagram of circuit.

bank become empty the emergency cylinder switches into the manifold, indicating this by lamp and sound. When a cylinder is replaced in the running bank the emergency cylinder switches off and the counter finds this replaced cylinder. The partially-emptied emergency cylinder (now indicating "change") must be replaced to cancel the audio alarm. This ensures a full cylinder in the emergency standby position. Any interruption of the mains supply (switching off or mains failure) is followed by automatic circuit resetting, so allowing the sequence to begin correctly again once the mains supply is restored.

The system is operated manually by switching from "auto" to "manual" (appropriate lamp on), using the same oxygen supply. In manual operation a completely separate power supply is used. During the manual run the oxygen cylinders in the running bank can be changed, the mains supply to the control unit being switched off.

"Fail-safe" Systems

In the event of a mains failure a reversed solenoid in the manifold opens, thus allowing oxygen to flow from the emergency cylinder. Units without an emergency mains generator and using this form of automatic oxygen supply would be advised to parallel-up extra emergency cylinders to cover any prolonged period of mains failure.

Electronics

The diagram of the circuit (Fig. 3) shows it to consist of seven modules.

(1) *Power Supplies Module*.—Within this module are two 24-volt 1.5-amp supplies for the circuits and the solenoid output stages. A third 24-volt 2.5-amp supply provides sufficient current to energize the solenoids of the running bank of cylinders joined in parallel when using the emergency manual selection.

(2) *Automatic/Manual Module*.—This contains two circuits. (a) A relay which can switch individual solenoid inputs to their respective cylinder outputs or, in the case of emergency supply, a common input to all the outputs. This relay also maintains the emergency solenoid in the closed position and energizes the mains failure solenoid to hold closed. (b) Reset circuit employing a timer and output stage so provides a short time delay when switching on and resetting each cylinder module and the counter.

(3) *Cylinder Modules Nos. 1-4*.—These are identical, only one being shown in detail in Fig. 3. This contains three output stages, K, M, and R (21A60 or PA60 according to output load); two gates, J and L, each having two inputs, 1 and 2; and a hold-circuit, P. Inputs are taken from the counter inverter outputs V (counter module). The cylinder module has a pressure switch N, a reset pulse from the automatic manual module, and a manual reset pulse from the cylinder replacement push-button. Each cylinder module has outputs to the three indicator lamps ("empty," "full," and "in use") and also to its individual solenoid. It has two other outputs—the inhibit voltage for gate S (in the pulse generator module) and gate A (in the emergency module).

(4) *Emergency Module*.—In this module are a hold-circuit F; three output stages B, D, and G; two gates A and C; and one pulse-forming circuit E, supplying a reset pulse from a long input voltage change via the pressure switch H.

(5) *Pulse Generator Module*.—This contains a low-speed oscillator U supplying the counter module at one pulse per second. The oscillator is inhibited via gate S and inverter T. The output gate L of each cylinder module supplies an output, which is then fed into gate S.

(6) *Counter Module*.—This contains a twisted-ring decade counter of the shift-register type employing five set/reset bi-stable multivibrators with built-in trigger-gates X. There are also four gates W and four inverters V (one of each per cylinder module). Each inverter output, normally positive, pulses to 0 volts when feeding an input to each cylinder module (input 1 of gate L).

(7) *Alarm Module*.—This contains a high-frequency audio-oscillator Z and an output stage Y. Z is normally inhibited by the output of hold-circuit F in the emergency module; this is overridden by the low-pressure switch Q in an alarm condition, and therefore Z is allowed to run. The output stage feeds a loudspeaker via an output transformer.

SEQUENCE FOR FINDING A FULL CYLINDER

If cylinder No. 1 primarily in use becomes exhausted, then within the cylinder module the following sequence occurs (Fig. 3): pressure switch N closes, thus supplying a positive voltage to hold-circuit P. The outputs of P are then: (a) positive to output stage R, so indicating empty, (b) which allows gate L to close, switching off the output stage M to the oxygen solenoid and the in-use indicator; and (c) which maintains J in the closed state simultaneous with L's reversed voltage output to input of J2. The output of L also opens gate S (in the pulse-generator module), and disconnects the inhibit voltage to the pulse generator, so operating the counter and initiating the selecting sequence. Within the counter module the output signals of the V inverters are 0 volts. Within cylinder No. 2 module, assuming that its hold-circuit P has been reset, gate L2 is already at 0 volts before it receives (from the counter) an 0-volt pulse to L1. On receiving this pulse it opens, gate J closes and switches off the full indicator via output stage K, and the output of L drives output stage M, which allows oxygen to flow into the manifold. Finally, it closes gate S (in the pulse-generator module) and so holds the counter on this selected cylinder (No. 2).

If cylinder No. 2 is empty L2 is positive; therefore when the counter pulse of 0 volts is applied to gate L1, gate L remains closed. Gate S (in pulse-generator module) would not be inhibited, and counting would continue until the next full cylinder held the sequence. When Nos. 1-4 cylinders are exhausted all hold-circuits P feed an 0-volt signal to gate A (emergency-cylinder module) and it then opens.

The outputs of A (a) feed the output-stage B, which energizes the solenoid connecting the emergency cylinder to the manifold, and (b) switch hold-circuit F. Its centre 0-volt output feeds gate C2, so disconnecting the audio-inhibit voltage, allowing the alarm to start, and, as output stage G ceases to conduct, switches off the "full" indicator lamp. An output from A also feeds (c) a positive voltage to gate C1, and this switchover of positive voltage to gates C1 and C2 (C2 has changed to 0 volts) maintains C in a closed state, and therefore prevents feed to output-stage D.

If now with the onset of the alarm a full cylinder is replaced in the running bank and reset, then hold-circuit P has the following outputs: (a) to discontinue the positive voltage to output R, switching off the "empty" indicator lamp; (b) to open gate J and indicate "full" via output stage K; (c) to allow the already pulsing counter output to open gate L, switching on and indicating "in use"; and (d) to allow the centre 0-volt output to close gate A in the emergency module. The emergency module now switches off the emergency cylinder (via output B), and gate C1 changes to 0 volts and opens; this allows output stage D to indicate "change."

Disconnecting the emergency cylinder allows pressure switch H to indicate "empty" and, on replacement, return to "full." This action is accomplished by: (a) a positive voltage from the pressure switch H, triggering the pulse-forming cir-

cuit E, which resets hold-circuit F; (b) the positive centre output of F closing gate C and switching off the "change" indicator lamp via the output stage D; (c) output stage G being allowed to conduct, indicating "full"; and (d) reversing the audio-inhibit voltage, thus switching off the alarm signal.

In the original completely automatic circuits the switching action depended entirely on cylinder pressure. If, however, a high flow of oxygen was being utilized at the time of switching, the exhausted cylinder reclaimed enough pressure to again indicate "full," giving false information to maintenance staff who change the cylinders. This situation was corrected by including an empty-hold circuit on each of the cylinder modules individually reset by a push button after replacing an exhausted cylinder. Alternatively, large differential pressure switches could have been used.

Discussion

The automatic oxygen system described has been in continuous use in a four-bedded intensive care unit for the past six months. Its performance has been found satisfactory. Within

the unit there is one oxygen outlet per bed, with detachable flow-meters. Oxygen has been supplied direct (via a face-mask) to patients breathing spontaneously. It has also been used to drive the Cyclator and Bird ventilators and to feed a gas inlet on the Barnet and Blease ventilators. An oxygen pressure of 45 lb/in² (3.2 kg/cm²) was chosen for the intensive care unit because the gas-powered ventilators in use (Bird Mk 14 and Cyclator Mk 2) are adequately driven at this pressure. Previously in this unit oxygen was supplied from a number of cylinders inconveniently placed at the head of each bed. Since the installation of this system the nurses have been spared anxiety over detecting an empty oxygen cylinder and the inconvenience of replacing it with a full cylinder in a small working area. The system can be cheaply and simply fitted into any hospital ward where a supply of piped oxygen is thought desirable. It was constructed in the physics department at a cost of £180. Patents have been applied for.

We should like to acknowledge our debt to the British Oxygen Company for their information on the oxygen supply regulations, pipelines, and regulators. We should also like to thank Sister M. Small for her help in this project.

Outside Europe

United States Naval Medical Research Units in Africa

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The work of the United States Naval Medical Research Units in Africa (NAMRU III) deserves to be better known. Firstly, because it is good work and is related to practical problems of great importance in the tropics; secondly, because of the help the unit gives to governments in Africa; thirdly, because of the stimulus and example the units afford to other developed countries to help in this way; and fourthly, because of the opportunities provided for affording local nationals and persons from other countries to participate in this important research.

The parent NAMRU III Unit has been established in Cairo for 22 years. It occupies a complex of laboratories, offices and ward accommodation adjacent to the Abbassia Fever Hospital. Members of the unit act in close collaboration with the staff of this hospital, and a number of patients being studied by members of the unit are also housed there. The clinical unit within the NAMRU compound is of about 40 beds and an outpatient clinic is run. Patients in fact come to the unit from considerable distances. The laboratories are very well equipped and in Cairo there are some 25 graduate staff of American and Egyptian nationality.

At Addis Ababa, Ethiopia, a field facility, or subunit of

NAMRU III, was established some five years ago and is now fully operational. This like its parent organization in Cairo is situated adjacent to a hospital, the St. Paul's Hospital, in which the organization has a 22-bedded clinical research unit. Also like the parent organization it is extremely well equipped and with full animal facilities. There are 14 graduate staff.

NAMRU III Unit in Cairo

In the Cairo part of the organization there are departments of bacteriology, haematology, medicine, medical zoology, nutrition and biochemistry, parasitology, pathology, rickettsiology, tropical medicine, veterinary medicine, and virology with the Virus Vector Research Laboratory. The general approach followed is to seek out those conditions causing the greatest problems locally, to describe and record these conditions accurately, and to seek the most effective means of diagnosing and managing them. Much effort goes into the study of zoological and ecological factors relating to endemic and epidemic disease. Thus in Cairo Dr. Harry Hoogstraal has made what is probably the world's finest collection of ticks of medical importance. The programme of the medical zoology department, of which he is head, concerns interrelationships between blood-sucking arthropods, vertebrate hosts, and disease-causing agents in the epidemiology of animal and human diseases. Through the years many correlated studies have developed, including the incidence, biology, and epidemiology of tick-borne viruses, and the biochemistry, physiology, and water balance of ticks in relation to pathogen infections. A great

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