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Oxygen Partial Pressure Sensor

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Abstract. The polarographic oxygen partial pressure sensor consists of two electrodes immersed in an electrolyte supported in a nylon case. The electrodes and electrolyte are separated from the atmosphere by a teflon membrane. Oxygen passes through the membrane and is reduced at a noble metal electrode. This reduction produces a current proportional to the amount of oxygen present. At 100% oxygen the current is approximately 55 microamperes. Tests to determine the operating characteristics are discussed.

There has long been a need for a method to determine the presence of one gas in a mixture of gases, and also its partial pressure in the system. One of the methods for determining the partial pressure of oxygen is by use of polarographic technique. An oxygen partial pressure sensor was desired which would have the following characteristics: (1) high sensitivity (large change in current); (2) reasonable output; (3) stability; (4) long life; and (5) portable, small size. With these objectives, a sensor was designed.

The sensor consists of two electrodes, an electrolyte, a permeable membrane, and case. The outer case is machined nylon; the insert is also of the same material. The electrodes are gold and cadmium; the membrane is teflon. The oxygen gas penetrates the membrane and the reduction of the oxygen at the noble metal electrode produces a current proportional to the partial pressure of the oxygen present. Thus, when oxygen enters the system, the following reaction takes place: $O_2 + H_2O + 2e^- \rightarrow H_2O_2 + 2OH^-$. The electrolyte further reacts and the following reaction takes place: $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$. The overall reaction may be written:

$$O_2 + 4e^- + 2H^+ \rightarrow 2OH^-$$

The sensor was assembled using an electrolyte of 0.2% KCl and 0.2% HCl. A 3% solution of agar-agar was added to form a gel. When the electrolyte is in paste or gel form, the output is not affected by vibration and shock as it would be if it were a liquid. The unit was tested with various gases and it was found to respond only to oxygen. The output was read on a Hewlett Packard 412A VTVM. A system using manometers to indicate pressure was set up to determine the output as a function of the partial pressure of oxygen.

Since manometers were used, the system was purged with oxygen and evacuated, then purged again with oxygen. The

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output was found to be a linear function of the partial pressure. The output at 760 mm Hg pressure was 54 microamperes. At 150 mm Hg the output was 14 microamperes, and at 0 mm Hg the output was 5 microamperes.

The response time of the sensor was defined to be the time required to indicate a drop of 200 mm Hg pressure. The response time was checked, using a stop watch, and was found to be 5.0 seconds. The effect of temperature was also considered. The sensor was placed in an insulated box and several thermocouples placed near and on the sensor to indicate temperature. The temperature was varied from 65°F to 80°F. It was found that there was a change of about 0.7 microamperes per degree at 760 mm Hg of oxygen partial pressure. A thermistor was placed in the output to compensate for the change in output.

A life test was set up to determine how long the sensor would remain sensitive to changes in oxygen partial pressure. First tests indicated a life of about 8 to 16 hours. This was much too short and a method was sought for lengthening the life of the sensor. One of the methods tried included the use of ion exchange resins, since it was felt that the hydroxyl ions were causing the decrease of current with time. A series of tests indicated that the ion exchange resins did not improve the life of the sensor. The electrolyte was tested with varying concentrations of KCl and HCl. The life was not considerably improved. However, when the electrodes and all parts of the sensor were precision machined, it was found that the life was longer and at times exceeded 48 hours. The sensor was stored in nitrogen and was found to have a good shelf life.

A series of tests were conducted to determine a load impedance which would give long life and yet good response. It was found that 2,500 ohms was the optimum impedance.

This sensor does not require an external source of e.m.f. since the potential due to the electrodes is sufficient to reduce the oxygen. This feature makes the sensor particularly suited for portable operation and aerospace applications.

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