by the oxygen consumption, but by the carbon-dioxide produced. For this reason it appears improbable that any apparatus for use in poisonous gases can ever be devised for use for more than a few minutes at a time with which the wearer will not do any rebreathing whatever. It is especially important, therefore, that the alkali should be so arranged as to absorb as completely as possible the carbon dioxide-exhaled by the subject into the bags before he again inspires the air.

In the former types of Draeger and in the Westfalia apparatus the expired air was drawn through the absorber and into the inspiratory bag by means of an injector through which the oxygen enters the circulation system. Natural circulation, that is, movement of air produced by the subject's breathing, as in the Fluess-Proto apparatus—is to be preferred to automatic circulation induced by an injector. One particular advantage of natural circulation is that if the wearer happens to become imprisoned in "bad air" he can make his oxygen supply last for many hours by turning off the fixed feed on the oxygen cylinder and using the by-pass at intervals to supply the relatively small oxygen consumption during rest hours. Otherwise the supply would run out at the end of two hours, and the man might lose his life. With apparatus of the automatic circulation type, such conservation of oxygen is impossible, for turning off the oxygen feed stops the absorption of carbon dioxide and makes the breathing much harder.

No subject in regard to rescue apparatus has been more debated than the use of the helmet. Many practical mining men insist that the helmet is advantageous in that it allows the wearer to speak more distinctly and to breathe through the nose, a more natural method of breathing than with the mouthpiece and nose clip. It necessitates the wearer's breathing into a "dead space" greater than the volume of an ordinary deep breath. The air that the wearer expires into this space he is obliged, in good part, to reinspire from it. The defects of the helmet are serious, but the greatest objection to its use is the danger of leakage. I am glad to say at this point that the officials of the British Columbia Government, realizing the inefficiency of the helmet, were among the first to install the mouth-breathing apparatus.

The importance of having all valves, tubing, and openings as large and as free from resistance as possible has not, until recently, been adequately appreciated either by the manufacturers or users of breathing apparatus. When one puts on any of the three types of apparatus previously mentioned, he finds that he can breathe quietly back and forth into the bags without noticable effort. Even if directed to breathe vigorously for a few seconds, most subjects declare that they feel no considerable resistance. If, however, the wearer is required to exert himself so vigorously as to induce heavy breathing, he finds a resistance so exceedingly annoying that it soon occupies his mind to the exclusion of everything else, and he is strongly tempted to tear off the apparatus.

Safety demands that when the water of an apparatus is surrounded by an atmosphere containing poisonous gasses there should be no leakage inward. With the injector type of apparatus it is particularly important that no negative pressure should occur at any point where the outside atmosphere may be drawn in. As formerly constructed the injector of the Draeger drew air through the absorber. In case the absorber or the tube leading to it was cracked, poisonous gasses could enter. A life has been lost in this way. This defect has been to a considerable extent remedied by so placing the injector of the Draeger apparatus that the air is forced through the absorber under a slight positive pressure. In any arrangement of this sort, however, there must always be a greater or less area of negative pressure on the side from which the injector draws. This is an additional reason for abolishing the artificial circulation and giving up the injector entirely. A natural circulation depending upon the respiratory movements of the wearer is altogether preferable.

It is an advantage to have a slight positive pressure in the apparatus, although it must of course not be of such amount as to impede the wearer's expiration — above 0.5 centimeter, or at most 1.0 centimeter, water gage. Even the best constructed apparatus is liable to leak slightly, and all leaks should be outward instead of inward. One of the principal reasons for recommending a greater supply of oxygen in the apparatus of the fixed-feed type is the fact that there will then be a continual slight leakage outward of the excess. On the other hand, when the supply is insufficient, and the breathing bags are sucked flat at each breath, the negative pressure so produced may draw in the surrounding poisonous atmosphere.

As regards joints and connections of these three types of apparatus, the Fluess excels both the Draeger and Westfalia. The many joints on the Draeger apparatus require careful inspection to insure their being made fast. Screws having a cross arm for turning admit of making the joint reasonably tight, but thumbscrews with a circular milled head are not so reliable, as a heavy glancing blow will often loosen them. Such screws have frequently been found loose both in training and in actual rescue work. In many instances loosening has been due to the metal part of the tube not having a locked seat so that a slight movement of the metal part has worked the screw loose.

The reducing valves of the former types of apparatus also were frequently a cause of trouble, as a result often of the deterioration of the rubber diaphragm. One of the most serious difficulties in the way of devising and constructing a reliable mine rescue apparatus is the necessity of using rubber. So called pure gum rubber remains soft and elastic in Europe for months, but in the dry and brilliant climate in which most of the American mines are located it becomes stiff and brittle in as many weeks. It appears at present impossible to avoid entirely the use of rubber, but it is evident that the parts composed of rubber should be as few as possible.

Impelled largely by the observations made by Doctors Henderson and Paul, the Bureau of Mines undertook to develop a breathing apparatus that should embody the recommendations of these men, and consequently in 1914 W. E. Gibbs, a mechanical engineer of experience and skill especially suited to the task, started, with their assistance, to design what is now known as the Gibbs apparatus.

Two years later, during a period while Mr. Paul was not connected with the Bureau of Mines, and while he was affiliated with Mr. Clarence Hall, who had previously left the Bureau of Mines service, Mr. Paul took out the patents on the details of construction of an oxygen breathing-apparatus which is now known as the Paul Apparatus.

Both the Gibbs and Paul apparatus have now been perfected, and placed on the market. The machines