Oxygen Gas in the Arts and Industries

By August S. Neumark

"SINCE the discovery of oxygen the civilized world has undergone a revolution in manners and customs. . . . The successful pursuit of innumerable manufactures and trades, and the separation of metals from their ores stand in the closest connection with this fact. It may well be stated that the material prosperity of the world has increased many times in this period, and that the fortune of every individual has been augmented in proportion." Thus remarked the distinguished chemist, J. von Liebig, in his "Letters on Chemistry." This was half a century ago. Since then the application of oxygen in the arts and industries has developed to a remarkable degree.

OXYGEN IN MEDICINE AND SURGERY.

The therapeutic use of oxygen dates back to its discovery. Priestley found that a mouse, confined in a limited quantity of oxygen, lived at least twice as long as in a like quantity of atmospheric air. To-day the gas is widely employed in medical practice and surgery. Among the diseases cured or at least relieved may be mentioned asthma, croup, pneumonia, dyspnea, phthisis (and atomic diseases generally), anæmia, dyspepsia, diabetes, albuminuria, paralysis, and insomnia. The chief method of administration is by inhalation, but injection (subcutaneous) or infusion (intravenous) or introduction into the cavities of the body are also practised. Oxygen inhalation improves the quality of the blood by increasing the red corpuscles. They are of service in the later stages of pneumonia, where there is danger to life from deficient aeration of the blood; further, in chronic bronchitis of old people, and in wasting diseases. Hopeless cases of phthisis have been reported cured. Oxygen acts as a direct stimulant to the respiratory mucuous membrane, increases the force and velocity of the pulse, and has a quieting effect on the heart and respiration. It shortens the period of convalescence in typhoid fever, is beneficial in chlorosis, uræmia, dropsy, diabetic coma, tetanus, and is of distinct value in preventing and curing septic complications in gynecology. The introduction of oxygen directly into the intestinal canal may materially aid digestion, and be of service in functional and organic diseases of the liver. Hypodermic injections are useful in all conditions where the blood is not properly oxidized (sciatica, carbuncles, pleurisy, acute anæmia, pulmonary tuberculosis). It is often given in conjunction with general anæsthetics, viz., chloroform, ether, ethyl-chloride, and especially with nitrous oxide ("laughing gas"), to prolong anæsthesia, relieving cyanosis and safeguarding against cardiac or respiratory failure. Nitrous oxide mixed with 10 to 15 per cent of oxygen produces perfect anæsthesia without reducing the anæsthetic power of the former. According to Dr. G. I. Gwathmey, an anæsthetist of New York, forty thousand administrations of nitrous oxide and oxygen have been recorded without one single fatality. By warming the gases before using them, even nausea may be almost completely avoided. Nascent oxygen (i. e., oxygen at the moment of liberation) is one of the most powerful antiseptics known. Peroxide of hydrogen, which readily parts with some of its hydrogen, or oxygenated water (i. e., water saturated with oxygen) has distinct value in chronic dyspepsia, vomiting, constipation, and headaches, when taken internally. The peroxides of calcium and magnesium can also be used, as they give up their oxygen when they come in contact with the gastric juice. Peroxide of zinc is used as an antiseptic dressing, while hydrogen peroxide is one of the best antiseptic washes for wounds, boils, etc. Oxygen baths, i. e., baths in which nascent oxygen is liberated by the action of a catalytic substance on chemicals which contain oxygen loosely combined (such as sodium peroxide or perborate), have beneficial effects on the circulation; cyanosis and dyspnea has been known to vanish quickly. Oxygen is now much used as a stimulant for athletes. There is no more effective remedy than oxygen gas in cases of asphyxia and in poisoning by exposure to noxious gases such as carbon monoxide, in which the blood loses its oxygen-carrying capacity. It is the universal remedy in threatened death from inhaling poisonous gases, such as illuminating gas, benzine vapor, chloroform, ether, ammonia, sulphuretted hydrogen, smoke, sewer gases, acetylene, and "after-damp" of mines. It has further been used in opium, belladonna, chloral, and aniline poisoning, as well as in the resuscitation of the apparently drowned. The apparatus used for rescue and reviving work will be described elsewhere. The use of oxygen has been suggested for revivifying the atmosphere in public halls. Ozonized air is used in the ventilation of the Chicago Public Library. Ozone is a powerful bactericide and germicide; it purifies the

atmosphere, destroys the bacilli of cholera, typhus, anthrax, etc., produces beneficial action when insufflated on wounds, and sterilizes drinking water. It may also be mentioned here that oxygen is used in Rhodesia, S. A., with marked success to combat the deadly South African horse sickness.

Oxygen gas for therapeutic use need not be chemically pure; medically pure oxygen contains between 5 to 10 per cent of nitrogen, according to the method used for preparing it. As long as nitrogen is the only impurity, it can safely be used, but it should not exceed 10 per cent. Oxygen manufactured by the electrolytic process is often of high purity (98 to 99 per cent), the impurity being hydrogen gas. Liquid air oxygen is usually of 95 per cent purity, while oxygen prepared by the alkali chlorate process contains anywhere between 5 to 10 per cent nitrogen. If not carefully purified, the gas made by the latter method may be contaminated with chlorine, carbonic acid gas, and traces of solid matter. It may hardly seem plausible, but it is nevertheless a fact, that so-called "medically pure" oxygen, as put up by the manufacturers, is very often unfit for certain technical applications (welding of aluminium, copper, brass), while most of the commercial oxygen sold for welding and like purposes could readily be used for medical purposes, being usually of 95 to 98 per cent purity. And while the latter can be bought for 1 to 2 cents per cubic foot, the cost of the former is as high as

15 cents, or even 20 cents per cubic foot. Medical oxygen is supplied in cylinders (Fig. 1) usually of 100 and 200 gallons' capacity; sometimes smaller tanks holding 50 or 60 gallons are put up. The charging pressure is 225 pounds for any of the sizes mentioned. The cylinders are provided with spindle-valves to which is attached a nozzle (Fig. 2) for the tubing connection. The gas passes from the tank to a wash bottle through which it bubbles, and from there to the mouthpiece or mask. The former should be made of hard rubber as glass is liable to break. High-pressure cylinders should be provided with a reducing valve; from there the oxygen flows through a rubber bag to insure constant pressure. In the low-pressure tanks the flow of gas can be regulated by the spindle valve, the bubbles rising in the water of the wash-bottle indicating the force of the current. In most cases the oxygen is inhaled through the mouth, although in some instances it should be administered through the nose, as in heart failure, pneumonia, and asthma, where the act of respiration is interfered with. The gas should be retained in the lungs as long as possible, and should be taken at intervals, and not continuously. In some cases oxygen must be used persistently. The failure to obtain results is often caused by not using the gas freely enough, or by not resorting to it until the patient is in a maribund condition. From four to eight gallons of oxygen can be inhaled without any ill effects, except perhaps a certain nervous exhilaration or a little giddiness; in larger quantities, however, it produces vertigo and narcotism. Compressed oxygen for medical purpose was sold for the first time in New York city by the New York Oxygen Gas Company in 1870, if the writer is correctly informed. This firm used the Motay and Marechal process of manufacturing the gas. Before that time, oxygen was made in the physician's office or at the bedside of the patient, the apparatus consisting of a retort, a wash bottle, and delivery tube; the chemicals used were invariably a mixture of chlor-

ate of potash and manganese dioxide. (Figs. 3 and 4.)

Respiratory devices of various construction are used in the mining and allied industries, in the fire department, in ice and cold storage plants, breweries, and chemical works. Such breathing apparatus are used for rescue work to save life and also to provide against loss of time. In the operation of refrigerating plants accidents occur from time to time, such as the bursting of an ammonia pipe or the breaking of a gage glass, and in such cases respiratory devices are used for rescuing anyone overcome by the deadly fumes and for making the necessary repairs without waiting until the entire charge of ammonia is exhausted. The fire department often has occasion to use oxygen helmets, when the firemen are compelled to enter places filled with smoke and noxious gases. Rescue parties in mine accidents are usually exposed to the dangers incidental to the death-dealing "fire-damp" (marsh gas); therefore emergency breathing devices are kept on hand for instant use. The following incident may be cited to fully illustrate the value of oxygen in gas poisoning: While cleaning a boiler in a German mining plant, six men were overcome by poisonous gases. With no aid in sight, the victims were left unconscious for nearly an hour, when the foreman remembered having noticed two oxygen tanks in the laboratory. These he carried to the scene of the accident, and then emptied the contents of both cylinders into the boiler. Shortly after, the men began

to breathe again, and soon were able to climb unaided through the manhole.

OXYGEN AS A BLEACH.

Oxygen gas (or ozonized oxygen) in the nascent state or in connection with bleaching powder or chlorine possesses most remarkable bleaching power, its use resulting in considerable economy. It is of special value for bleaching paper pulp, wood, straw, jute, cotton cloth and yarn, also wax, starch, ivory, animal fibers, chamois leather, stearic acid and paraffin, oils (olive oil, cottonseed oil, linseed oil) rubber goods, etc. If a stream of oxygen is passed through a mixture of paper pulp and a solution of bleaching powder, the decoloration of the pulp proceeds more rapidly than if the bleaching powder alone were used. Oxygen not only accelerates bleaching, but it also reduces the quantity of the powder necessary very considerably. It has been proved by practical tests that a saving of 35 to 50 per cent of the bleach can be effected, while air has no such action. Hydrogen peroxide solution is sometimes used for bleaching purposes. Ivory, especially the inferior grade used for knife handles and the like, is bleached that way, also straw, textile and fiber, and white chamois leather. Nascent oxygen or peroxide solution has also been employed for the whitening of the paper of books, prints and engravings that have become stained or dingy with age.

THE USE OF OXYGEN IN THE MATURING OF SPIRITS.

If oxygen under pressure is forced into spirits or liquors and left for about two weeks, the spirit becomes mellowed to an extent equivalent to three to five years aging, nearly all of the fusel oil being converted into harmless compounds. Alcohol and wines can be improved by either passing oxygen or organized air through the liquid or by adding easily decomposed peroxides. (English Patent No. 18,422 of 1888.) For maturing whisky, oxygen has a very beneficial effect; bad whisky can be transformed into good whisky in a very short time.

Oxygen is further being used to make solid fish fat, train, and other oils. The last are heated to 90 to 100 deg. C. and then brought into intimate contact with oxygen. It is also used in the production of siccativ oils and blown oils for lubricating purpose, as well as for refining linseed and palm oils. A cake of soap made of palm oil refined by this method is said to be remarkable for the delicate fragrance of its odor and its good color. Oxygen is also extensively used in the oxidation of oils as required for the manufacture of paints, varnishes, and linoleum. It does away with the use of metallic oxides and exposure to atmospheric air, and the reaction can be completed at (or below) the temperature of boiling water in from three to six hours, while before much higher temperatures had to be used for a longer period. There also was the danger from fire in boiling the oil.

The oxidation of linseed oil is effected by passing a current of oxygen in a finely divided stream through the oil (mixed with a small percentage of a drier) placed in a closed vessel, provided with steam jacket and agitator. As soon as the maximum amount of oxygen is absorbed, it is allowed to cool down to a yellow, jelly-like mass which is solid and dry enough to be packed into bags. This forms the chief ingredient of linoleum. It is mixed with rosin and ground cork, rolled on a jute canvas backing and finally seasoned at a temperature of 75 deg. C., whereupon it is ready for use.

Oxygen is being used for the preparation of pure starch derivatives, such as refined starch, soluble

into the barrels. This process was found to be the only way to save many otherwise valueless beer kegs.

OXYGEN FOR THE PURIFICATION OF ILLUMINATING GAS.

The introduction of three-fourths to one per cent of oxygen into coal gas before its admission to the purifiers materially assists the purification. It practically does away with the auxiliary hydroxide of iron purifier which served to remove the sulphuretted hydrogen; the lime being alone sufficient to remove all impurities. It also increases the life of the lime and improves the candle-power of the illuminating gas. At the Ramsgate Gas Works in England, 10,000 cubic feet of oxygen (of 90 per cent purity) are manufactured daily by Brin's process. This is sufficient to purify 1,500,000 cubic feet of coal gas. To sum up, the addition of a small percentage of oxygen results in the following advantages: economy in time, in labor, and in space; simplicity in operation, immunity from nuisance, perfect purification from sulphuretted hydrogen and carbon dioxide, and higher illuminating power.

OXYGEN IN THE MANUFACTURE OF WATER GAS (DAWSON GAS).

Water gas, which in this country has nearly displaced coal gas, or at least is mixed with the latter, is obtained by the action of steam on red-hot carbon (coke). The latter decomposes the steam, forming hydrogen and carbon dioxide, which combines with more carbon to form inflammable carbon monoxide (CO). Water gas therefore is mainly a mixture of hydrogen and carbon monoxide, the gases being rendered luminous by passing the same through chambers

coal gas for lighting purposes. The first burner in which oxygen was successfully used in connection with a gas flame was invented by Nürnberg of Berlin in 1904. In this burner the jacketing tube is provided with an elbow, so that the oxygen meets with some resistance during the passage to the flame and impinges upon the stream of gas at a sharp angle. This not only leads to a more perfect mixing of the gas but also keeps the flame away from that part of the burner which would otherwise suffer most from the heat. Other burners in which oxygen is used in conjunction with illuminating gas, are those of Hildebrandt, Mewes, Trese-reuter and Hecker. The latter uses a burner in which the two gases came from opposite directions. Such lights consume very little illuminating gas and produce less heat than ordinary gas lights, and are more hygienic. They can not contaminate the air as the oxygen is supplied to the flame, and not taken from the air.

Oxygen is also now being used instead of air in various furnace processes. The addition of 5 per cent of oxygen to the blast would reduce the capacity of the blowing engine and would increase the temperature more rapidly above the tuyeres. The escaping gases would be richer in combustibles and therefore better fuel gas. For the production of Bessemer steel the addition of oxygen reduces the time necessary for the operation. The enrichment with oxygen would save about one sixth on the fuel.

An interesting application of oxygen has recently been patented by Messrs. Menne and Zallenkopf of Germany. It consists in a method of perforating masses of metal by fusion and is particularly useful for farming blast-holes, opening of tap-holes, making holes through armor plates, and the like. This is done by connecting one pole of a circuit supplying electric current with the material to be melted through, while the other pole is connected with a pipe through which oxygen is blown. If the pipe is brought in contact with the metal for an instant, while the oxygen simultaneously flows through the pipe, the resulting short-circuit spark produces sufficient heat to start the fusion and the oxygen perforates the plate in a fraction of a minute. No electric arc is formed, as the current of oxygen prevents this, or blows it out if one should be formed. Another way to perforate the metal is to allow the formation of an electric arc for a few seconds and then allow a stream of oxygen to play on the heated place, whereby the electric arc is destroyed and the metal burnt away.

THE COMPOUND BLOWPIPE AND ITS APPLICATIONS.

The fact that immense heat is obtained when hydrogen burns has been known long ago and has given rise to the invention of a device for drawing advantage therefrom. In the year 1801 Dr. Robert Hare constructed a contrivance which he called an hydrostatic blowpipe, better known as the oxy-hydrogen blowpipe. The quantity of heat evolved when hydrogen burns in oxygen—according to Julius Thomson—is 34,116 calories for each gramme of hydrogen burned. By means of this blowpipe a temperature of 4,000 deg. F. can be obtained. Since a mixture of the two gases is liable to very dangerous explosions, they are kept in separate vessels and only allowed to mix a short distance from the tip of the blowpipe. The typical form of such blowpipe (Fig. 7) consists of an outer tubing, in the center of which a finer jet is longitudinally placed, ending a short distance from the tip. Hydrogen is admitted through the larger tube and ignited, then oxygen is directed through the inner tube. There can be no risk of an explosion if the gases are kept separate until nearly reaching the nozzle; there it will at the worst merely be a sharp "snap," which causes a sudden extinction of the flame. The latter yields but very little light, but on account of its intense heating power, has found many uses in the arts. One of these is its application to the melting and refining of the ores and alloys of platinum, which cannot be fused in an ordinary furnace. A furnace or crucible for this purpose must be constructed of a nearly infusible substance, such as calcium oxide or refractory clay. A stream of the burning gases from the blowpipe is forced through an opening in the cover, made of the same refractory material, falling on an interior crucible containing the metal to be melted. While the flame of the oxy-hydrogen blowpipe is but small and itself only slightly luminous, an intense light can be produced by allowing it to fall upon certain substances which can be heated to a high temperature without melting or burning, such as lime, magnesia and other oxides. This fact led to another interesting application of the blowpipe, namely, the *oxy-hydrogen light* (calcium light or lime light, sideral light, Drummond's light, magnesia light, zirconia light). As far back as 1820 attempts were made to obtain a safe and intense light by ignition and combustion of a piece of lime with the aid of the oxy-hydrogen flame. Goldsworthy Gurney has been the first to show that a cylinder of lime could be brought to a state of dazzling brilliancy by projecting the blowpipe flame on the former. How-

starch, dextrin and crystal gum, from common potato starch.

It has further been proposed to use oxygen gas in the manufacture of *nitrogen oxides*, the latter to be transformed into *nitric acid* and *nitrates*. This is done by enriching atmospheric air with oxygen and subjecting the gas mixture to the electric spark, thus producing oxides of nitrogen. In Germany, oxygen is used in the manufacture of *sulphuric anhydride* (SO_3), by passing a mixture of the former with sulphur dioxide (SO_2) over red-hot platinized asbestos or other contact substances.

OXYGEN IN THE MANUFACTURE OF GLASS.

The introduction of pure oxygen gas into the crucible greatly facilitates the melting of the glass; in fact an economy in fuel of 30 per cent is claimed. It hastens the operation and promotes the chemical combination of the different ingredients. It further serves to clarify the melt, resulting in a glass free from air bubbles. Oxygen is also employed in the process of glass blowing and glass marking. In the first place the oxy-coal gas blowpipe can be used to great advantage instead of the ordinary blowpipe. Lead glass can be manipulated without fear of discoloring the glass through reduction of the lead; hard glass can be marked as easily as soft glass. The use of oxygen for *glazing pottery* has also been proposed, as in this process some pottery has to be exposed in ovens (kilns) to an oxidizing agent at a high temperature.

Other applications for oxygen are its use in the production of *fused quartz (silica) vessels*, in the preparation of *natural dyes* and for *cleaning and purifying brewers' foul casks*, which is accomplished by forcing steam and ozonized oxygen under pressure alternating

in which oils are decomposed (carbureting). To maintain the incandescence of the carbon it is necessary to admit air with the steam. This causes a large percentage of nitrogen to be mixed with the escaping gases which greatly impair the heating and illuminating power of the water gas. It therefore would be of the greatest advantage to substitute commercial oxygen for the air, thus reducing the percentage of nitrogen and increasing the calorific value of the gas. It would be especially adapted for incandescent lights and probably result in reducing the size of the service pipes. When oxygen is added to a heavy oil gas while the latter is still hot, the illuminating power of the gas is raised; besides, it actually increases the stability of poor oil gas.

Oxygen, as is well known, is not a combustible gas, but is a supporter of combustion. If in all operations involving combustion where air is used, oxygen gas could be substituted for the latter, it is apparent that this would not only mean a great saving, but would do away with the great waste of heat energy. The development of the application of oxygen is only in its infancy, as it is only in recent years that the cost of the gas has been brought within range of practical commercial work. In a Pictet 650-horse-power plant liquid-air oxygen of 50 per cent strength can be obtained for 1/10 cent per 35 cubic feet, or 90 per cent oxygen for one quarter cent. In Claude's oxygen plants, producing 7,060 cubic feet per hour, the cost of production is three-fifths cent per 35 cubic feet. Since such cheap oxygen has been produced, it has become technically and economically possible to use this gas instead of air in all operations involving combustion. In recent years it has been used in conjunction with

ever, it was Capt. Thomas Drummond who in 1826 first utilized the lime light for practical purposes, by using it for military signals in connection with the trigonometrical survey in Ireland. At first he used oxygen and alcohol vapor (oxy-calcium light, Bude light), but later substituted hydrogen for the latter. Several years passed, however, before the oxy-hydrogen light received general attention and was put to use for the exhibition of dissolving views, for microscopic work, etc. In most cases the cheaper coal gas was substituted for hydrogen, as is still done to-day.

Attempts have been made in Europe to use the blowpipe flame for general lighting purposes. For a time lime light was used in England for lighting the Queen's barracks of the British War Department. The burners had been placed 10 feet high, the light being reflected from mirrors. During the Paris Exposition in 1867 several buildings were illuminated by oxy-hydrogen lights, and these attracted much attention. Among the buildings thus lighted were the Tuileries and the Hotel de Ville. A year later some streets and squares were provided with these lights. Each post was fitted out with five burners, each using 50 liters of hydrogen and 70 liters of oxygen per hour, giving as much light as the old lamps having nine burners and using 170 liters of carbon gas per hour. In 1870 oxy-hydrogen lights were installed at the railroad depot in Vienna. Still, illumination by the blowpipe flame never passed the experimental stage, this being chiefly due to the high cost of oxygen gas. The only other objection that was raised against these lights was that the radiating material had to be renewed daily, however, this drawback was overcome later. With an abundant and cheap supply of oxygen as produced by Claude's, Pictet's, Linde's, Hildebrandt's, and similar processes, we may expect that within reasonable time illumination by oxy-hydrogen or oxy-gas lights is sure to come into general favor. At a meeting of the Pacific Coast Gas Association a few years ago, Prof. G. A. Babrick voiced this opinion and told of some experiments he made with oxy-hydrogen lights. One lamp was placed 25 feet high at a spot where there was no other artificial light. The flame was directed against a cylinder of lime and reflected from a silver-plated mirror 15 inches in diameter. The night was dark, and still the smallest type of newspaper could be read at a distance of 250 yards. The lamp consumed a mixture of 10 cubic feet of illuminating gas and 8 cubic feet of commercial oxygen per hour. Prof. Babrick also thought that calcium light is in many ways superior to the electric arc, being devoid of the disagreeable violet color of the latter. Being exceedingly white, calcium light is well suited for the display of bright and delicate colors. The various shades and tints of a picture or dress, etc., are as plainly discernible as they are by the diffused light of the day. For the same reason lime light can be used for medical purposes, for lighting up body cavities. The intense white color makes it possible to recognize fine color-changes in the reddish mucous membrane, so that diseases can easily be diagnosed.

A piece of quicklime is mostly used as radiator for the oxy-hydrogen light; magnesia can be used instead, but zirconia (zirconium dioxide) excels both, as it compares most favorably with the electric arc. The lime is usually in the form of a cylinder (candle, pencil), the soft lime gives more light than the hard lime, but is inferior in quality and often badly centered. As minute portions of lime become detached and are volatilized from the spot on the lime on which the jet of the burning gases strikes, thus forming small grooves, it is necessary to expose a fresh surface to the action of the flame. For that purpose the lime is set in a revolving cup or dropped on a pin, which has to be turned at intervals of 10 to 15 minutes, the time depending on the pressure of the gases used. The calcium light therefore needs constant attention. A further disadvantage is that the lime cylinders have to be kept in air-tight tins and that they last only a few hours. The cracking or splintering of the lime pencils has been partially overcome. Crooks recommends the use of dalaomite, mineral composed of the carbonates of calcium and magnesium. According to an English patent, the following composition may be used. Magnesia 3 parts, precipitated chalk 6 parts, plaster of Paris 6 parts, calcium oxide 1 part, calcium phosphide 1 part, and prepared chalk 6 parts. This mass is subjected to hydraulic pressure and then baked for 3 to 5 hours. It does not absorb moisture or carbon dioxide and does not give off gas, injurious to health, during incandescence, or undergo combustion, as does quicklime. It has also been proposed to surround the lime cylinder with a tabular metal shield, leaving an elliptical aperture opposite the gas jet. This shield prevents cracking and also the formation of the white and impalpable powder often seen inside the lantern hood, caused by disintegrated calcium oxide. While it is hardly probable that lime light will ever be used for general lighting purposes, it is well adapted for

illumination during brief periods, as required in carrying on important constructions during the darkness of the night, for scenic illumination of the stage, where electric light is not available, for the spectroscopy, moving pictures, for the stereopticons used in illustrated lectures (Fig. 8), for medical purposes and for military operations in the field; also in emergency cases for photographing where no natural light can be obtained and where magnesium would fall owing to the dense fumes evolved. By far the best radiant body for the oxy-hydrogen flame is zirconia. This substance was used for the first time in connection with the blowpipe flame by Tessie du Motay (1860) who used oxygen saturated with a solution of naphthalene in petroleum. Zirconia, if pure, remains absolutely unchanged at the highest temperature, is permanently brilliant, and does not volatilize. It is used in form of disks (buttons) or very small cylinders; their small size is an advantage in rendering them a highly concentrated source of light (Fig. 9). They last a long time and are not subject to atmospheric influences. The zirconia buttons as used by Tessie du Montay, Caron, and Linnemann were unsatisfactory. The disks broke from their base and the platinum mounting often started to melt off when it came in contact with the oxy-hydrogen flame. In 1889 Dr. W. Kochs succeeded in overcoming all difficulties. His cylinders were made by "fitting" the zirconia, using the pure earth mixed with a very small quantity of other substances. These cylinders were porous and yet sufficiently hard to be readily handled. Zirconia disks or cylinders can now be obtained in three different qualities: No. 1, for photometric purposes, lasting only 10 hours, but possessing a most intense incandescence; No. 2, for medical purposes, stereopticons, and the like, lasting 100 hours; and No. 3, for general illuminating purposes, lasting a whole month. Zirconia lights not only are as white and brilliant as the electric arc, but for certain purposes the former are even preferable to the latter, as for instance for the spectroscopy and for microphotographic purposes. It is most essential for microscopic work for the light to be accurately centered and to remain so. Once set right, the zirconia light will remain unchanged for hours and always in the center of the condensing lens. The electric arc has to be "fed" from time to time to regulate the distance between the carbon points, while even in the best lime, pitting or excavation of the surface takes place, which will remove the incandescent point from the focus of the lens. It is of the utmost importance that the burners be constructed properly so that the least amount of gas at the least pressure may produce the greatest amount of heat and light. The chemical union of the gases should take place not further than one-half inch from the tip; the pressure of the oxygen must be 15 times that of the coal gas or hydrogen. Such a burner is not likely to get hot. If the oxygen pressure is not strong enough the flame may beat back and heat up the burner. The tip of the burner should be about one quarter inch from the zirconia (or lime); the angle of incidence being usually 45 degrees. A faulty flame can be easily detected with the aid of a piece of smoked glass. Black spots on the radiator indicate unburned oxygen. For scientific purposes the burners designed by Linnemann are the best on account of their accurate adjustments, for illuminating purposes they are too expensive. Those designed by Wolz are better adapted for such purposes, they consume but eight gallons of oxygen and a like amount of coal gas per hour, are self-regulating, small and most practical. Originally the mixed gases of the two parts of hydrogen and one part of oxygen were condensed by means of a "syringe" worked at a strong pressure into a square metal box from which there issued a long jet of very small bore. This jet passed through a thick oak partition in order that the operator might be protected from the danger incidental to an explosion and bursting of the metal box. This was the form of apparatus originally contrived by Clarke and Newman. Later, the safety jets of Gurney, Henning and others were adapted and the gases delivered separately. The so-called mixed-jet burners (Fig. 10), as used in England, in which the gases are mixed in a chamber—packed with wire gauze—before they issue from the orifice of the tip are to be condemned. In the "blow-through jet" (Figs. 11, 12) the oxygen only is under pressure. In this type of burner, the illuminating gas can be used directly from the service pipe or any convenient source. It also can be used in connection with a saturator. The latter consists of a chamber filled with some porous material—cotton or the like—which is saturated with ether or light gasoline (Ives patent). The saturator method (oxy-calcium light) is said to be the most economical means of producing lime light, being less costly and requiring less oxygen. Acetylene may be substituted for hydrogen or coal gas, but a specially constructed blow jet has to be employed. According to E. H. Amet, acetylene may

be used with the ordinary lime light jet, provided the oxygen is mixed with nitrogen and preferably small quantities of carbon dioxide and carbureted hydrogen. He recommends the following mixture: 18,120 parts of oxygen, 11,868 parts of nitrogen, 6 parts of carbon dioxide, and a like amount of carbureted hydrogen; two parts of this gas mixture to be used with one part of acetylene (*Oxo-carbi light*). The calcium light has been used more extensively in this than in any other country. It played quite an important part during the great Civil War of 1861, where it was used for the illumination of the forts. It has further been used for signal purposes, lighthouses and during the erection of large buildings. During the construction of the Brooklyn Bridge in 1870 and 1871 twelve lime lights were in constant use. Prior to the introduction of the electric arc, they were used for stage lighting purposes. They were the most popular illuminant for the magic lantern. While the latter was looked upon in Europe as merely an optic toy, it was used in this country for educational purposes. And in spite of the introduction of the electric arc, calcium light outfits can still be found in every public school in New York city where they are used in connection with stereopticons for illustrated lectures. They may also be found in some of the public parks, where they are put to use during the concerts in the summer, and in winter for illuminating the frozen lakes for the benefit of the skaters. During political campaigns they may be seen at street corners; dance halls use them for the still popular shadow dances; they are used in the form of spot lights for private entertainments, church fairs, etc., and for moving-picture exhibitions where the electric arc is not available. For lighting purposes they are either provided with silver-plated reflectors or, if a small area is to be illuminated, open lights are used. The calcium-light outfits as seen in New York and elsewhere are, however, of the old-fashioned kind and surely in need of improvement. The uses to which these lights are put are so numerous in large cities that it has become a regular industry there to furnish oxygen and hydrogen (coal gas) in separate cylinders. The latter are of 25 or 50 cubic feet capacity, charged to 225 pounds of gas pressure, the tanks being tested to 600 pounds hydraulic pressure. The oxygen cylinder is painted red, the hydrogen cylinder black. In England the reverse seems to be the case, although for melting purposes oxygen is put up in black cylinders even in this country. It therefore seems to be a good idea to provide the different tanks and fittings with left- and right-handed threads, so that only the gas for which the cylinders are intended can be pumped in, thus preventing the possibility of any accident in filling. This method has been adopted by the British Oxygen Company in England. The cost of oxygen for calcium lights is usually 10 cents per cubic foot; the gas is in nearly all cases obtained by the chlorate process. Oxygen thus manufactured cannot be made for less than \$18 per 1,000 cubic feet, the quantity being limited to 500 to 600 cubic feet per hour, using the largest retort. Therefore, oxygen used for general illuminating purposes will never be produced by chemical means. But by the liquefaction of air and its fractional evaporation we have the means of obtaining industrial oxygen in quantities to meet all requirements. By the Linde process 20,000 cubic feet of gas per hour can be produced, using a plant of 900 horse-power. The cost of oxygen as made by Pictet's method is said to be three fourths cent per 1,000 cubic feet, the gas being of 90 per cent purity; by Claude's process the cost of 1,000 cubic feet of oxygen is 1¼ cents. In the United States nearly all liquid-air oxygen seems to be used for welding and like purposes.

From the theoretical standpoint, illumination by the oxy-hydrogen flame can doubtless be regarded as the most rational system, having many advantages over electric light. Its practical use really only depends on the cost of the oxygen and on how readily this can be procured. Prof. Babrick in an address before the Pacific Coast Gas Association in 1903 declared that the United States Liquid Air and Oxygen Company would soon be able to produce commercial oxygen for 15 cents per 1,000 cubic feet. Using eight cubic feet of illuminating gas and a nearly equal amount of oxygen, a light equal to that of an electric arc consuming one kilowatt per hour can be obtained. The electric arc used for street lighting often does not exceed 1,000 candle-power, while the oxy-hydrogen flame is able to furnish a light of anywhere between 2,000 and 3,000 candle-power. To use Prof. Babrick's figures, an oxy-hydrogen light of over 2,000 candle-power would cost but little more than one half cent per hour, viz.:

8 cubic feet of gas at say 50 cents per	
1,000 cubic feet =	\$0.40
6 cubic feet of oxygen at say 25 cents per	
1,000 cubic feet =	0.15

Cost of combined gases per hour.... \$0.55