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OUTDOOR INSTALLATION OF TRANSFORMERS FITTED WITH OIL CONSERVATORS

(See article, "A New Form of Tank for Static Transformers," page 756)

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GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE   Editor, JOHN R. HEWETT

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MAIN OFFICE BUILDING, GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

GENERAL ELECTRIC REVIEW

THE VALUE OF RESEARCH

It is befitting that a story on lamps should shed some light on our story of human progress. Mr. Morrison's article, written around the report of the Lamp Committee of the National Electric Light Association, with its accompanying tables, tells those who will spend the time to study it a more encouraging story of human progress than many books written to extol the genius of man and his mastery over the resources of nature. A sermon might well be preached taking Table I in this article as the text.

In 1907 the domestic sale of incandescent lamps included only 0.1 per cent of tungsten lamps. These lamps were then a new invention. They were three times as efficient as the old carbon lamp; that is to say, for each watt of energy expended the user gets three times the amount of light with a tungsten lamp that he would get by using the same energy in a carbon lamp. In 1918, of all the lamps sold for domestic use, 89 per cent were of the tungsten type, so within a little more than a decade the use of a new invention had grown from 0.1 to 89 per cent. This shows an astonishing rate of progress.

It is this rate of progress that interests us. Let us compare it with the rate at which inventions and discoveries previously became useful assets in our daily life. The birth of electrical science took place about 600 B. C. when Thales, a Greek philosopher, discovered that amber when rubbed possessed the astonishing property of attracting small particles of certain materials. The very word electricity came from this discovery, being derived from the Greek word for amber. Great as this discovery was, the purely imaginative philosophy of the Greek, which made this era so rich in poetry, art, and literature, could not turn it to practical purpose. We know of no advance made in the science of electricity during the whole time that the Roman Empire flourished. Science of a sort was in fashion, men discussed the laws of nature learnedly and literature flourished, but experimental science had not been born. Then the dark ages came (those years of barbarian invasion and conquest); the world moved backward rather than forward. We could expect no advances then and we certainly got none. The next real step came in the reign of Queen Elizabeth when Gilbert published his famous book, "De Magnete," in the year 1600. Indeed, so marked was Gilbert's work that it can be considered as having given birth to our modern science of electricity and magnetism— not on a purely speculative basis, but founded on the sure footing of experiments and inductive reasoning.

The next great step was in 1799, when Volta, a contemporary of Galvani, by his famous invention of the electric pile first produced an electric current. The next milestone was reached when Faraday, in 1831, discovered the induction of electric currents and the creation of electric currents by the motion of conductors in a magnetic field. These great discoveries usher in our era of modern electrotechnics. We now begin to visualize the fruits of invention and discoveries for the useful service of man. In 1865, Clark Maxwell enunciated his electro-magnetic theory of light and then we pass into our own times when the invention of the dynamo electric machine paved the way for our modern electrical industry; and the development of electrical theories and the absolute quantitative measurement of electrical energy established electrical engineering as a great world asset.

We recite these facts to bring home one point: The rate of progress used to be very slow—

Thales 600 B.C.—Gilbert 1600 A.D.	2200 years
Gilbert 1600 to Volta 1799	199 years
Volta 1799 to Faraday 1831	32 years
Faraday 1831 to Clark Maxwell 1865	34 years
Maxwell 1865 to Present Time	54 years
Thales to Present Time	2519 years

All these discoveries are related; in all probability, each one had some bearing on the next. Of course, we cannot say that a succeeding step would not have been taken had the first been omitted, but, especially since Volta's time, one discovery has led to another.

After Thales' discovery 2200 years elapsed before the next step was taken by Gilbert. Men had not learned the value of experiments. Gilbert experimented—but the rest of the world was slow to know his work or to follow his methods. His work had great potential value, but little practical use. One hundred and ninty-nine years later Volta produced something that could do something useful, and only 32 years elapsed before Faraday paved the way for an industry. By this time the world was learning the use of experiments and governments had begun encouraging science as a possible national asset.

Now, in our own times science has built up mighty industries and industries have built up mighty research facilities, so that when a new invention is discovered, experiments are made, a new product is produced and in a single decade can come into general use.

In 1907 one tenth of one per cent of the lamps made for domestic use were tungsten lamps. In 1918 of the 186 million lamps made 89 per cent were tungsten lamps. Each tungsten lamp gives three times the amount of light per watt when compared with the older form of carbon lamp, so if we assume the cost of current at 10 cents per kw-hr., we can calculate that the public is getting this additional light at a saving of over two million dollars per day.

This additional light is literally not figuratively making the world a better world. The world is intellectually, morally, and physically better for it. Men, women and children are working, playing and spending their leisure hours the better for it. Not in relation to lamps alone is this true, but of motors, generators, turbines, and the thousand and one electrical devices we are making and supplying the world with day by day. They are making a better world.

We are living at a terrific pace and we sometimes wonder where the world is heading. Each factor which makes our rate of progress so great—research, invention, manufacture, advertising, distribution—are organized and practiced on an intensive basis in the manufacturing world until we wonder where it will all lead. We sometimes wonder if we are the better off for all these modern advancements, and it is just because we sometimes wonder these things, that we felt that a sermon might well be preached from the Table we have referred to. It shows that we are better off; the public, the whole world are getting the benefit of all this work. Not from lamps alone, but from everything that is produced that saves labor and gives better working and living conditions.

We have labor troubles. It seems paradoxical, but the only cure is more work to save labor. Labor wants better working conditions, more money, shorter hours. The only answer is, more machines to save labor; more machines to do harder kinds of work that men do not like doing; more devices that will do hard work in factory, farm and home.

Discontent is a virtue if tempered with a reason that stimulates work to gain what is desired. It is a vice when it leads to grumbling and does not instill the ambition and strength to accomplish more work to make conditions satisfactory. If the reader doubts that machines are the best cure for labor trouble—in fact, the only thing that can cure it—by giving men easier means to produce more and thus improve their laboring conditions, let him ask a man to thrash his wheat with the flail, to carry or to wheel his trunk to the railroad depot in a barrow, or to act like a galley slave and row him a score of miles in a boat. These and a hundred and one back-aching, laborious jobs that a century ago men were doing by sweating toil, today are performed better, quicker, cheaper, by machines. Those who would be toiling on these uninteresting, unelevating, laborious tasks, but for the advent of the machine, are the ones who have been the greatest gainers by the change. Just as they have gained in the past, they are going to gain in the future, by more inventions, more discoveries and more machines.

So there is a purpose in our work. The factory is making the world a better place to live in. It is giving the working man better conditions. If we compare what a working man earns today for a given task, the food he eats, the clothes he wears, the home he lives in and the pleasure he can get out of life in this age of machines, with the conditions a century ago without machines, it will give us faith in the usefulness of our work. We shall realize that the work of the inventor, the research man, the manufacturer, the man at the bench, at the machine, and in the office, are all part of one great organized plan to improve the world. Of course, there are some who may work harder than others, but we all work and those who are going to get the most out of life are those who work the hardest and get pleasure in their work. For

"Not enjoyment and not sorrow
Is our destined end or way;
But to act, that each tomorrow
Find us further than today."

It is encouraging that the importance of research is becoming so generally recognized. A recent resolution of the American Federation of Labor is of much interest in this connection:

"Resolved, by the American Federation of Labor in convention assembled, that a broad program of scientific and technical research is of major importance to the national welfare and should be fostered in every way by the federal government, and that the activities of the government itself in such research should be adequately and generously supported in order that the work may be greatly strengthened and extended; and the secretary of the federation is instructed to transmit copies of this resolution to the President of the United States, to the President pro tempore of the Senate, and to the Speaker of the House of Representatives."

J. R. H.

CHINA

Mr. Oudin's address to Chinese students on the development of China, published in this issue, presents a peculiarly interesting problem to the world today. In the times of ancient history, when civilizations could flourish without means of inter-communication with other people, China reached a high state of development. During this period she did many notable things that have materially added to our store of [illegible] world-wide advance. [illegible] mariner's compass, gunpowder [illegible] are three examples cited by Mr. Oudin.

In modern times, while other nations [illegible] been advancing, China's environment [illegible] handicapped her development. Hemmed in to the north, east, and south by mountain ranges and deserts, and having for her neighbors, immediately beyond the barrier, only the more backward peoples of the earth, she has been out of touch with the rest of the world. It is only her western coast that is washed by the ocean and this is her most remote boundary from other civilizations, but, at the same time, it must serve as her only inlet from the rest of the world. Added to these handicaps China developed so passive a spirit that she was exploited by many nations.

We have ample evidence that China has undergone a great change in recent years; for one thing she has become a democracy, and added to this she is now sending out her sons broadcast to other lands to learn science and engineering. We believe that these will prove the best kind of missionaries that any land has ever sent out, and we hope they are to play an important part in the future of their country by becoming leaders in her engineering developments. The characteristics of the Chinese, coupled with adequate railway facilities, power houses, and industries run on modern lines, will, we believe, lead to China taking the place that belongs to her in the sisterhood of nations.

J. R. H.

The General Electric Company in the Great World War

PART IV. OTHER WAR WORK

By John R. Hewett
Editor General Electric Review

In Parts I, II and III of this story we have outlined some of the more important large war work that the Company did, but still have given no adequate idea of the immense total. In this issue we give some notes on other war work, mentioning some of the Company's larger plants, but the reader can well imagine that the story is still far from complete when he realizes that the Company's army of 65,600 men were devoting 95 per cent of their energy to work that was designed, either directly or indirectly, to end the war.—Editor.

After having written, in the last three issues of the Review, some memoranda concerning what at first appears as the Company's most notable war work; such as the more important items of research, including the work done on submarine detection, X-rays, radio, electric welding, and other items, and the apparently larger and more important contracts such as those for turbines for ship propulsion, electric furnaces for various purposes and searchlights, the writer finds that he has not begun to tell the story of what the 65,500 war workers of the Company did. There is such a variety of work, and it is so far spread all over the country, that the truth is, it never will be collected together into an article or a series of articles. So perhaps the most practical way will be to give brief mention of some of the other notable work that was carried out in some of the Company's more important factories, dealing more particularly with special developments, and leaving any attempt to show how the Company helped the country as a whole to carry on its intensive war work to be dealt with under the heading of General War and Industrial Activities.

Schenectady

Much of the special war work already cited was carried out at the large Schenectady plant, such as most of the research activities and the production of a great number of the large turbines, gearing and searchlights. The large induction motors for battleships and cruisers were also made at the Schenectady Works and other large induction motors were produced in great quantities for driving the powder dryers at the Dupont Powder Company's plants.

Some small idea of the production of the Schenectady plant may be gained from the fact that it was using a thousand tons of cast-iron per week during the war, and that 40 carloads of finished products were leaving the factory daily. In this connection it should be pointed out that had pre-war methods of packing and loading been used rather than the new intensified method of loading, this figure would have reached 80 carloads leaving the Schenectady factory every day.

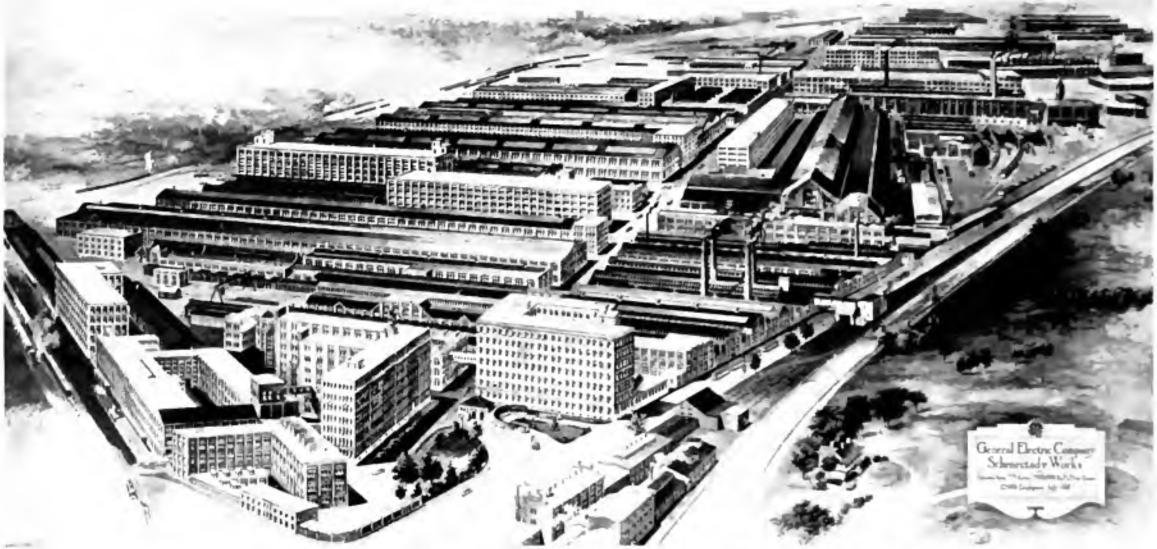
Schenectady did some most interesting work on the manufacture of submarine motors which called for much development work to meet the rigid requirements of so special a service. These were direct current motors and were quite powerful units presenting many interesting problems in their construction; it is unwise to go into details, but there can be no harm in stating that the service conditions called for very rigid and special requirements, particularly so in the matter of insulation, lubrication and quiet running. The Company met all the conditions imposed and were complimented by the government officials for their achievements in connection with these motors. Twelve motors were actually built, and had the war continued in all probability this number would soon have been increased to 44.

A special 70-kw. capacity generator was developed for operating tanks and gun mounts.

If each department could tell the story of its own war work it would be an interesting romance, but too long to read. The Switchboard Department made so many panels that, although each was only 24 inches wide, if stood up side by side they would reach for a distance of more than five miles; if laid end on end they would pave a sidewalk 100 miles long.

This department made many special developments during the war, one notable example being the development of shock-proof switching devices for use on shipboard, that would stand battle service. These devices were perfected to a point where they would trip on the prescribed overload, yet would remain closed when subjected to a direct blow from a hammer.

Thirteen acres of floor space were always busy in fulfilling war orders for switchboards



The General Electric Company's Works at Schenectady, N Y Ground Area 340 Acres Floor Space 5,800 000 Sq Ft 23,000 Employees. This huge plant was devoting ninety five per cent of its activities, either directly or indirectly, to war work Most of the largest turbines, generators and motors built by the Company are produced here. During the war new buildings were erected and equipped to meet the Government's requirements for apparatus, and over forty car loads of finished products were leaving the factory daily.

during the period of war, and no less than 50 cars of switchboards left the factory every week. In common with practically all other departments some of the best men were devoting all, or part of, their time to helping the different government departments with their expert knowledge and advice. The Switchboard Department should also be credited with doing some special development work on a gun pointing mechanism which gave promising results.

The Railway Equipment Department developed a high voltage, high current, contactor for controlling the propulsion motors on battle cruisers, battleships and cargo boats, special drum controllers for heavy army tractors, controllers for tanks and an electromagnetic control system for submarines, as well as adapting many standard devices for the special requirement of the navy.

As is but natural, the engineers of the Power and Mining Department were making use of their varied experiences in the solution of war problems as well as supplying the country with apparatus to meet her industrial needs. Indeed, some of the developments already cited and some still to be written of are either in whole, or in part, the work of this department. There are some special war problems that they undertook and solved which call for special mention. Among these are the following. The development of motors for electrically-driven woodworking machinery for making rifle stocks and air-plane struts, which increased the output of rifle stocks fourfold over the old method, and increased the rate of making airplane struts in the ratio of eighty to one. A new method of making adapters for gas shells was devised which absolutely seals the shell and met all the conditions required. Very important work was done in developing a method for salvaging defective shells. This alone led to the reclaiming of an enormous number of shells which would otherwise have been wasted. Of course most work of this nature was done in co-operation with the engineers of the different government institutions. For instance, in co-operation with the Watervliet Arsenal, our engineers developed a method of salvaging gun parts which had been machined wrong or were defective from other causes. This work secured enormous economies. As an example, a practically completed 8-inch gun spoiled by a mistake in machining was salvaged in about half a day. The system developed for doing this work should find an extensive use. It is now being used in many other arsenals throughout the country.

Another very interesting engineering development was that of the cast steel anchor chain for merchant ships which, in point of saving time, permitted the production of these chains 37 times faster than was previously the case. About 30,000 tons of chain are now being made in this way. Particularly valuable war work was done in the development of cast steel guns, most of this work being carried out on the French 75 type. Tests are now continuing and give every promise of success. If this method of making guns should finally prove feasible it would revolutionize the manufacture of ordnance especially in the smaller sizes. Another development in connection with artillery was the electric welding of gun liners, that is to say, the welding of the liner to the jacket in such a way as to prevent movement when the explosion takes place. It will be interesting to the reader to know that approximately half a million dollars' worth of ammunition has been expended in testing several guns that the Company's engineers welded and that in no case has a flaw occurred. Work was also done in developing a new method of pressing in and out gun liners. This work also proved successful.

Perhaps one of the most novel mechanical developments undertaken by our engineers was a new method for broaching the rifling in cannon. Previously a given piece of work took a day and a half, while with the new method the same work was done in fifteen minutes.

A great deal of experimental work was done in such things as the centrifugal casting of electric steel for turbine discs, gears, etc., and on the development of heavy spot welders for the fabrication of ship parts.

The Illuminating Engineering Laboratory not only fitted out a special testing ground for searchlights and did development work on high intensity searchlights, but also did a considerable amount of research work and photometric testing for the General Engineering Depot of the U. S. Army. They also rendered considerable help by working with the Illuminating Engineering Societies Committee on war service in the solution of such problems as the lighting of aviation camps, flying fields, and protective lighting of various kinds.

Just to cite an example of how much work was done on some things which are apparently standard products, it may be mentioned that the production of special cable for men-of-war was increased sevenfold between April and November, 1917, and for general navy purposes the monthly output of 200,000 feet went up to 1,000,000 feet. The call for wire

The River Works of the General Electric Company at Lynn, Mass
Ground Area 100 Acres Floor Space 207,418 Acres 7,919 Employees

The Federal Street Works of the General Electric Company at Lynn, Mass
Ground Area 13 Acres Floor Space 667,991 Sq. Ft. 3,083 Employees

and wiring supplies was incessant and the facilities for production were strained to the utmost between July and the end of August. Wire and wiring supplies for sixteen cantonments were produced and installed. In all such work as this it often happened that a certain amount of development work was required to meet the special requirements.

Lynn

The Company's large works at Lynn were carrying their full share of the burden of war work all the time. Among the particularly interesting war developments carried out at Lynn were some of a most scientific nature in connection with submarine detection apparatus, concerning which we are not permitted to publish details. They also developed a special motor for driving torpedoes, details of which must not be given at present.

The Turbine Department at Lynn was very busy in producing turbines. Some of this work has already been mentioned in connection with ship propulsion, but much of the development work done in connection with turbines was not mentioned.

Lynn assumed an order for 210 especially designed 10-kw. turbo-generators for use as lighting sets in the Eagle boats. About 70 of these were delivered. A 50-kw. ship lighting turbo-generator set was developed for ships being built on the Pacific Coast.

Lynn did some interesting investigation work in connection with the Lombard centrifugal guns and was also called into consultation by the National Research Department concerning another centrifugal gun. Some of the engineers from Lynn did a great deal of work in connection with some of the problems of submarine detection, and much of the production work of the Nahant developments was done at the Lynn factory.

Among the other developments that Lynn undertook are to be found such interesting items as superchargers for airplane work, army ordnance projectile tests, the design of turbines and mercury turbines for airplane engines.

One contract that was assumed was of very special interest, namely, that for the wholesale production of compasses for our airplanes. This was an entirely new development for America and the English design was altered to suit our manufacturing conditions. There were many special problems to be overcome in this work which was carried out by the Meter Department in Lynn. The work was entirely new to those who undertook it, but the call was very urgent, and it is pleasant to record that the speed with which production followed the first inquiries astonished the officials in Washington. A shipment of 1000 compasses was made before the contract was signed. The rate of production amounted to 500 a week. One order for 10,000 compasses was completed and of another order for 20,000, 1300 were completed when the armistice was signed.

The Meter Department at Lynn also developed a compass for use with trench signal lamps and undertook to make 2000 daylight signal lamps for signalling from ships to airplanes. These devices were similar to their English prototypes, but of course a considerable amount of work was necessary before the parts could be produced according to American manufacturing processes.

Hot wire thermo electric elements were developed at Lynn for radio work which were capable of measuring frequencies of between 2000 and 3000 and such instruments were actually constructed, also a very small hot wire instrument of an English design was produced. One order called for 3300 of these instruments.

Mention should be made of the work of the street lighting department of the Lynn factory. Of course it must be understood that a great deal of this development work was done in conjunction with the government departments who required this special apparatus. They designed a special headlight for army trucks and made about 2000 of these and also designed a headlight for the Liberty truck, making about 1200 of the reflectors, the regular automobile headlight manufacturers making the other parts.

The proper lighting of aviation fields called for a lot of work which was carried on in conjunction with army representatives. The Company designs for lighting outfits for this work, which comprised large projectors mounted on 11-inch tripods, were accepted and 864 were ordered. Some novel and useful development work was done on the lighting equipments for airplanes for night flying. This work was carried out in co-operation with army officers. An equipment was arranged for range and landing lights which resulted in the Company being asked to make 6000 devices and to supply 21,000 incandescent lamps.

Signal projectors of various types received a great deal of attention, especially those for use in trench and airplane land work, also for naval applications both from the water and aircraft. The Company took a trial order for

The General Electric Company's Works at Pittsfield, Mass.
Ground Area 88 Acres—Floor Space 2,000,000 Sq. Ft.—7,000 Employees

The General Electric Company's Works at Fort Wayne, Ind.
Ground Area 27 Acres—Floor Space 1,000,000 Sq. Ft.—4,000 Employees

350 6-inch projectors using a 6-volt 2-ampere incandescent lamp connected to a dry battery through an ordinary telegraph key. It is interesting to note that with this device communication can be carried on in daylight for distances of from 3 to 5 miles.

Investigations were also carried out on a suitable projector for submarine chasers.

A great deal of work was naturally done on the illumination of government and industrial plants. Some of the special searchlight developments have already been mentioned.

Erie

The Company's Works at Erie, where quite a lot of the important work already mentioned was carried out, like some of the Company's other plants, were busy at war work for the allied cause before America entered the war, having assumed extensive contracts for the machining of shells.

No sooner had America entered the war than Erie received its first order from the government for 200 25-kw. gas engine electric generator sets. The rate at which these were required called for a production of 40 units per month, and eventually Erie was asked to assume the production of 80 per month.

We have already cited the work done at Erie in the rapid production of geared turbine sets for the propulsion of torpedo boat destroyers; this and so much of the other work must largely be classed as development work as so much had to be done to meet the special requirements.

Four hundred railway motors were made at Erie for equipping the lines running between Philadelphia and the great Hog Island shipyard, and besides this the Railway Motor Department developed a 25-ton and a 15-ton storage battery locomotive for the Newport News Shipbuilding Yard. This work was done for the Navy Department.

A large amount of work was done at Erie toward the development of a special type of oil engine on listener boats in connection with the anti-submarine campaign. Gas electric trench locomotives of 14 tons and 60 tons capacity were laid out and propositions made for the government, and it is likely that much work would have been assumed in this direction had the war continued.

Fort Wayne

The Fort Wayne Works did some very interesting work, in conjunction with others, in building 103 winch drives for operating captive ballons from the ships, as it is now generally known balloons attached to ships did valuable service in hunting submarines as well as in directing gun fire at the battle front. They also made 2600 bomb releasing mechanisms for the U. S. Government. These devices are used on bombing planes and provide for releasing 10 bombs, five carried on each side, the bombs being dropped alternately from either side to preserve balance. It is gratifying to note that this entire order was accepted without one device being rejected.

Many dynamotors and motor generating sets were also built by the Fort Wayne factory for special war purposes; for instance, 400 navy type dynamotors were made for the flying boat service, 100 dynamotors were furnished the navy for supplying the current on hydroplanes for both the wireless telegraph and telephone, as well as for providing current for both day and night signalling devices, land lights, and for the heating devices used in aviators' garments. The Marconi Wireless Telegraph Company was supplied with 650 dynamotors for seaplane service, and Fort Wayne also built 600 lighting generator sets which were used by the Emergency Fleet for ship lighting and radio work.

A large number of amplifiers used in connection with submarine listening devices were made at Fort Wayne which included various combinations of transformers and pliotron tubes. In addition to these, a large number of motor driven condensers and dynamotors were made for wireless work.

Another distinctly new development, which the Meter Department at Fort Wayne undertook, was the manufacture of ship logs for the Emergency Fleet. The original contract called for 5000, but was subsequently reduced to 2500. Fort Wayne made the entire device, with the exception of the cord. Like all of our other factories, over and above the special work which Fort Wayne did and which involved the usual amount of engineering work incident to undertaking work of this nature, they were at the same time very active with their standard products and carried their full share of the load in supplying such large apparatus as synchronous motors, battery charging sets, crane motors, a great number of ice making machines, 175 of which were used on submarines and destroyers, a large number of lighting sets, motors, radio apparatus, rock drills, transformers and turbo-generators.

Pittsfield

The Pittsfield Works, although primarily engaged in filling large orders for their stand-

The General Electric Company's Works at Erie, Pa.
Ground Area 68 Acres Floor Space 1,100,000 Sq. Ft. 5,000 Employees

The Sprague Electric Works of the General Electric Company at Bloomfield, N. J.
Ground Area 30 Acres Floor Space 620,762 Sq. Ft. 1,6[illegible] Employees

The National Lamp Works of the General Electric Company at Cleveland, Ohio
Ground Area 152 Acres—Floor Space 2,000,000 Sq. Ft.—9,500 Employees

A Group of the Edison Lamp Works of the General Electric Company. The center picture shows the Works at Harrison with a Ground Area of 23 Acres, a Floor Space of 1,500,000 Sq. Ft. and Employing 8,000 People ard products on direct government orders and priority orders for such important things as transformers, regulators, lightning arresters, choke coils, motors, compensators, reactances, fans, submarine ranges and other heating devices and controllers, also did such specific war work as making 27,000 gas check pad containers for the U. S. Government; for the British Government 750,000 gaines; for the British Thomson-Houston Company approximately 50,000 molded parts for magnetoes; for the Russian Government 363,500 three-inch shell cases and parts for a half million fuses.

To cite just one example of how these standard products were helping the great tasks of the country all the time it may be noted that the Company furnished 20,000 electric fans to the Emergency Fleet Corporation and 10,000 to the U. S. Navy for battleships, submarines, submarine chasers, destroyers and shipyards, etc. Many thousands of fans were furnished the army cantonments, base hospitals, Red Cross, etc., etc. Fans also were supplied in enormous quantities to plants and factories of all kind and were thus doing their mite in stimulating the production of munition factories, powder mills, woolen mills, packing plants, and shoe factories, and found a host of other applications in adding comfort and giving better ventilation for the war workers throughout the length and breadth of the land. These fans were made at Pittsfield.

Sprague Works

Again the Sprague Works, like all our other factories, was doing its full quota to help win the war very largely by supplying its output to the different divisions of the War Department for use both in this country and by the American Expeditionary Force in France. Large quantities of conduit material were used by the U. S. Navy and the Emergency Fleet, and like so much of this work, the special conditions required a certain amount of development work on otherwise standard products. Great quantities of conduit material were used on the transports which carried the American army across the ocean and on cargo vessels as well as on the fighting ships of the navy such as battleships, destroyers and submarine chasers, and much of this same product went to the War Department for its munition plants, cantonments and warehouses. To meet the special requirements of the U. S. Signal Corps large quantities of especially covered cable were made for signalling in the field, the cable being [illegible] ground and connection [illegible]

The Sprague panel board and [illegible] were used in large numbers in [illegible] Navy Yards, on the ships of the [illegible] Fleet in the U. S. Army Bases in France and at the different Quartermaster [illegible] throughout the country. One [illegible] board of special interest was developed [illegible] on the U. S. Navy hydroplane for controlling the lights, searchlights, and the electrically heated clothes that the pilots and [illegible] navy planes wore.

About eighty per cent of the electric [illegible] made at the Sprague Works were used for special war purposes in shipyards, motor truck, and airplane factories, chemical works, railroads, power plants and by food producers. Large numbers were used in navy yards and a small electric winch was developed for raising and lowering the periscopes of submarines. Ninety-eight per cent. of the dynamotors made by the Sprague Works were used for war purposes, and we find such interesting applications as dynamotors for testing the engines of airplanes and those used by the Bureau of Standards and the Experimental Station at McCook field and at other plants engaged in important war research work. Sprague dynamotors were used in the development of the Liberty engine, several plants building these engines having installed these dynamotors for their production testing. They also found application in a host of other work such as the testing of U. S. Standard trucks, tractor engines for heavy artillery, engines used in army tanks and for testing engines for tractors which were being constructed to help with the intensive production of food products.

Lamp Works

Of course all of the Company's lamp works were busy turning out their standard products as well as helping wherever they could by doing special work for war purposes. In fact, this is a most striking example of how the Company's manufacturing activities were all the time helping others to do their bit. During the first nine months of 1918 they made 103,000,000 incandescent lamps of the larger sizes. If we include all sizes the production of these nine months amounts to 148,000,000 lamps. Who can estimate what this contribution did toward helping the whole country speed up its war work? The Company was employing more than 16,000 people in helping to light the work shops, offices, camps, homes, etc., of America during all this period.

(To be continued)

A New Form of Tank for Static Transformers

By W. S. Moody

Engineer, Transformer Department, General Electric Company

The conservator type of tank for static transformers is a particularly valuable development as it simultaneously accomplishes three purposes that increase the reliability of the unit. The entrance of moisture into a transformer reduces the dielectric strength of the insulation, the collection in the top of the tank of any combustible gases produces an explosion risk, and the contact of the hot oil with air causes the oil to sludge and the operating temperature to be increased. The author explains in detail how the new form of tank reduces to a minimum the possibility of moisture entering, removes any combustible gases as soon as formed, and prevents the hot oil from coming into contact with air.—Editor.

Moisture

Entrapped moisture is perhaps the greatest deleterious agent affecting high-grade insulation. The presence of an exceedingly small amount of moisture will reduce the dielectric strength of solid insulation to a mere fraction of its original value, by so changing the distribution of the dielectric stress as to cause a failure of what would ordinarily be a dielectrically strong structure.

In the early days indoor transformers were not even encased and outdoor transformers were placed in cases that were water-proof only under favorable conditions. As operating potentials increased, the necessity for a greater degree of protection against moisture was met by the use of oil and later by the impregnation of the fibrous insulation with moisture proof compound previous to the immersion of the transformer in oil.

The sensitiveness of oil to water has long been known; the effect on the dielectric strength being shown clearly in Fig. 1. Satisfactory transformer oil when shipped from the factory should stand a test of at least 22 kilovolts between one-inch discs spaced 1/10-in. apart and is unsatisfactory for high-voltage or large transformers when the dielectric strength is less than 75 per cent of this value: that is, when it is below 16½ kilovolts. By reference to the curve it will be noted that oil of the standard strength, that is, 22 kilovolts, should have not more than eight parts of water in one million parts of oil; and that the addition of 10½ parts of water giving a total of 18½ parts per million will reduce the dielectric strength to the lowest permissible limit. With increasing capacity and higher voltage, the necessity of almost absolute protection of oil against moisture was appreciated. With the demand for outdoor installations the details in design of tank, cover, and lead construction were developed to avoid the possibility of the entrance of snow, rain, or merely atmospheric moisture.

Evidently the most completely effective method of accomplishing the necessary protection against moisture is to have the tank cover and terminals air tight. This requires not only an expensive tank construction but also a large idle space air filled above the oil level to limit the possible internal pressure due to the expansion of the oil resulting from increase in temperature.

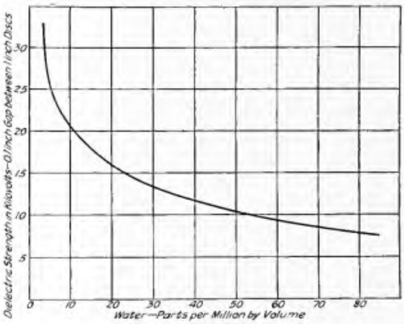


Fig. 1. Effect of Water on Dielectric Strength of Transformer Oil

Explosion

Due to chemical action in the transformer oil, caused by arcing or static discharges or heavy overloads, combustible gases (mostly hydrogen and light hydro-carbons) are sometimes set free, and in the ordinary tank these gases mix with the air above the oil so that a highly explosive mixture may be formed. This gas may be ignited by sparks of a static or dynamic character occurring along the leads, causing a dangerous explosion. While all General Electric high-voltage leads are provided with grounded shields that make this impossible under ordinary circumstances, an abnormally low oil level may expose the transformer terminals thus neutralizing the protection of the shields.

Sludging

Hot oil, even if carefully selected, will very slowly decompose when in contact with oxygen, and a precipitate will be thrown down. This decomposition or sludging, while it does

TRANSFORMER OIL

Test at 130 deg. C. for 18 days

A
Natural Oil
Before Heating

B
Air Excluded
from Hot Oil

C
Air in Contact
with Hot Oil

Fig. 5. Effect of Air on Hot Oil

not affect the dielectric strength of the oil, increases the viscosity and thus retards the transfer of heat from the core and coils to the cooling surfaces. Even more deleterious is the fact that the deposit settles on the coil surfaces, in the ducts, and on the cooling coils. This acts as a heat insulator on all surfaces and also will in time clog up the ducts.

The result is that the operating temperature gradually increases with consequent acceleration of the sludging. The remedy is found, first, in a method of oil refining that minimizes this action and, second, in a periodic renewal or filtering of the oil and thorough cleaning of the core and coil surfaces. The oil regularly supplied with General Electric transformers is of such a quality as to practically exclude sludging under normal conditions, yet continued service with occasional overloads will eventually produce sludge.

An exhaustive series of tests has demonstrated that when air is not present the oil can be operated continuously at a temperature that would prove disastrous if air were present, with practically no sludge resulting. Fig. 5 (on colored plate insert) shows the results of one very severe test where the oil was subjected to a temperature of 130 deg. C. for 18 days.

Sample *A* shows the natural color of the oil. Sample *B* shows that when air was not present no sludge resulted—only a slight discoloration taking place. Sample *C* shows that when air was in contact with the oil a heavy sludge was produced. This test is representative of many others, and shows conclusively that for any permissible temperature sludging will not take place in oil so long as air is excluded.

Until recently, the most generally accepted solution of the problem provided for (a), the use of a tank substantially air tight at all joints with a single vent or breathing point for the interchange of air between tank and the outside atmosphere; this opening being connected by a vent pipe to a chemical drying chamber to remove moisture from the air passing through it, (b) ground shield above the oil level, and (c) the operation with conservative temperature rise.

This construction, until recently the best available, has the following possibilities for improvement.

Fig. 2. High-voltage Side of a Larger High-voltage Three-phase Transformer Provided with Oil Conservator

Fig. 3. View showing Conservator and Method of Support

(1) An immediate indication of the oil-tightness of all joints thus insuring absolute protection against the entrance of moisture.

(2) The elimination of all air space between the cover and the oil level.

(3) The reduction in the amount and temperature of the oil in contact with the air.

The indication of oil-tightness of joints will be a source of assurance to any operator of outdoor units. The elimination of the air space will insure protection against explosion due to the ignition of this atmosphere from corona or static between live parts and ground. The coolness of the air-exposed oil and the small surface in contact with the air will avoid the possibility of the oil sludging.

These refinements in tank construction, which will materially reduce the possibility of failure even of apparatus as reliable as the best transformers, are all found in a valuable but simple addition to transformer tanks now extensively

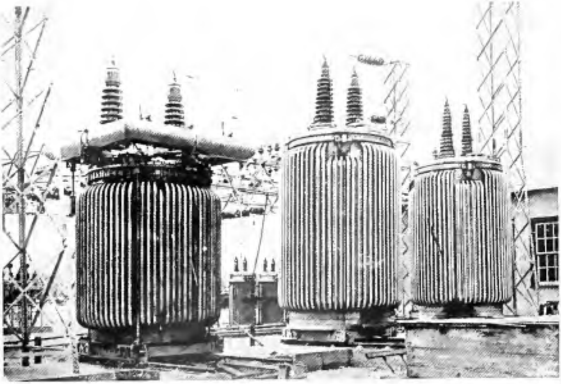


Fig. 4. Initial Installation of Transformer Provided with Oil Conservator, at Laurinburg, N. C.

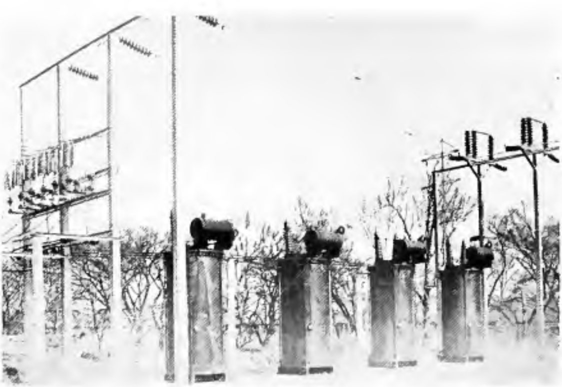


Fig. 7. Outdoor Installation of Conservator-type Transformers of the Virginia Railway and Power Co., Richmond, Va.

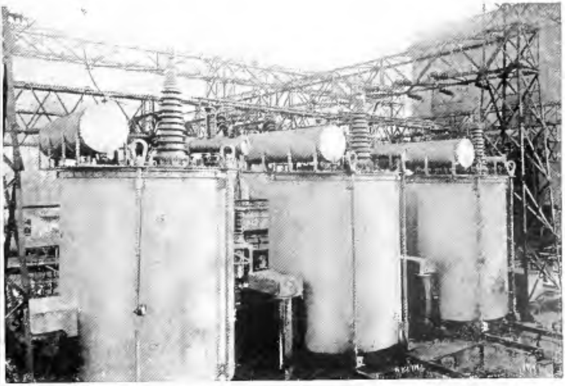


Fig. 6. Transformers with Oil Conservators at the Windsor Power Plant of the American Gas and Electric Co.

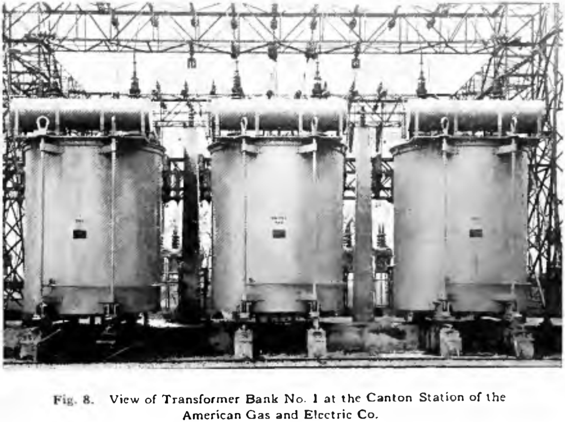


Fig. 8. View of Transformer Bank No. 1 at the Canton Station of the American Gas and Electric Co.

used by the General Electric Co. This device is sometimes called the Oil Conservator. Figs. 2 and 3 show the general appearance of conservator-type transformers.

The engineers of this Company have been testing this conservator construction in service during the past three years and are now generally recommending it for all large outdoor units. The conservator consists primarily of an auxiliary tank connected to the top of the main transformer tank by a suitable pipe and mounted somewhat above the level of the oil in the main transformer tank. When the auxiliary tank is supplied with oil the main tank and connecting pipe are completely filled, and the only oil that comes in contact with the air is that in the conservator. This is shown diagrammatically in Fig. 9.

The size of the conservator tank is governed by the expansion and contraction of the oil due to its changes in temperature. At the lowest operating temperature, the oil must not contract so as to allow air to enter the main transformer tank, and at the maximum operating temperature the oil must not overflow the conservator. Transformer oil increases in volume about 4 per cent with a temperature rise of 50 deg. C. and this with other necessary allowances brings the volume of the auxiliary conservator tank to about 8 per cent of that of the main tank. In practice, various refinements and auxiliary devices are provided such as suitable oil gauges, oil valves, chloride breather, and sump.

Even a superficial consideration will show that this simple equipment fulfills the general requirements previously enumerated and a closer study reveals the fact that, even in detail, a better solution of the problems involved could hardly be desired.

Transformer Tank Completely Filled with Oil

The fact that, except through extreme carelessness of the operator, the transformer tank will always be completely filled with oil has many advantages. The reduction in the necessary size of the tank, and consequently of the bushings, has evident advantages. The elimination of the air space is of greater importance because with it is eliminated the chance of an explosive mixture of gas and air being trapped above the oil, for with the oil conservator any gas that may form immediately escapes into the air-seal tank, and there is, of course, no possibility of ignition.

Cool Oil in Contact with Air

Since there is only one oil connection, of limited size between the conservator and

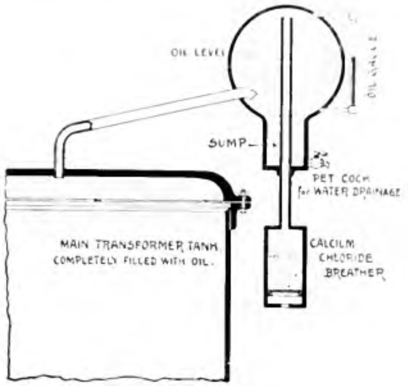


Fig. 9. Diagrammatic Sketch of Oil Conservator Connected to Transformer Tank

transformer tank, there is no circulation and the interchange of oil is limited to that due to the gradual expansion and contraction of the whole body of oil. The result of this is that the oil in the conservator is only slightly warmer than the outside air. To cite a typical test on a 95,000-volt conservator-type transformer of 3000-kv-a. capacity: the oil in the main tank reached a temperature of 73 deg. C. while the oil in the conservator was only 38 deg. C. Since the ambient temperature was 24 deg. C. the temperature rise of the oil in the main tank was 49 deg. C. against 14 deg. C. for the oil in the conservator—three and a half times as great a rise. The importance of this on the sludging of oil can hardly be over estimated.

Figs. 4, 6, 7, and 8 are installation views that give some idea of the appearance of the conservator-type transformer in service. Fig. 4 is of especial interest as it shows the initial installation of the oil conservator in 1916 at Laurinburg, North Carolina.

Methods for More Efficiently Utilizing Our Fuel Resources

PART XXX. *NATURAL GAS (Cont'd)

By Samuel S. Wyer

Consulting Engineer, Columbus, Ohio

The first installment of this article on natural gas appeared in our August issue and described the methods employed in producing, transmitting, and distributing the gas. The present and concluding installment treats of the wastes of gas involved in these operations and in the present method of manufacturing carbon black. These wastes are attributed to the present low price of the fuel; and the conclusion is drawn that adequate conservation will be brought about only by raising the price. Such a procedure would render profitable the expense that would have to be incurred by the utility company to save its wastes and would induce the consumer to use the fuel efficiently.—Editor.

WASTE AND CONSERVATION OF NATURAL GAS

Definition of Conservation

True conservation is not hoarding, but the wise use of natural resources, and it implies not merely the preserving in unimpaired efficiency, but also a wise and equitable exhaustion with a maximum efficiency and a minimum waste. The heart of the natural gas conservation problem is the conflict between the present and the future. The individual land owner is interested primarily only in immediate present personal returns. That is, he is thoughtless and indifferent with respect to the future. The public—at least the 2,000,000 domestic natural gas consumers and the 10,000,000 people dependent on natural gas for their cooking, heating, and lighting purposes—are interested in conserving the supply and bringing about a slow, wise, and economical exhaustion, so as to insure continuity of service for the future.

Conservation, therefore, demands intensive rather than extensive use, takes cognizance of equitable distribution, aims to bring about social justice, and means the greatest good to the greatest number and that for the longest time.

Most of the supply and service problems of today are the inevitable result of waste in producing and handling natural gas. The annual reports of the conservation committee of the Natural Gas Association of America are stinging indictments of a criminal system, fostered by both the gas companies and the public, that has resulted in wasting more gas than has ever been utilized.

In West Virginia only eight years ago not less than 500,000,000 cubic feet of this precious gas was daily escaping into the air from two counties alone, practically all of which was easily preventable by a moderate expenditure for additional casing.

The various forms of waste may be grouped under drilling, well operation, transmission, and utilization operations.

Drilling Wastes

1. *Not closing wells promptly.*—Much gas is wasted on account of delay in closing wells, caused primarily by poor judgment and failure to supply material promptly. In many cases the rock pressure over quite a district has been materially lowered by the delay in closing promptly a single large well in that section.

2. *Improper casing.*—There is much underground waste by improper casing methods which allows gas or water to migrate from their original strata into other strata. This is an especially important feature in the West Virginia fields, where in many instances several gas-bearing formations are superimposed with intervening barren formations.

3. *Waste of gas to air.*—As a result of improper casing methods gas frequently works up around the packer or into the casing above the packer and is wasted in the air.

4. *Gas waste in well-drilling boilers.*—Most gas burning appliances used in well-drilling boilers are crude and inefficient, and the gas is handled as if it had practically no value and were of little use to other people.

5. *Waste of gas in torches.*—A large number of open flame (flambeaux) torches are still in use. Not only is this an inefficient and therefore wasteful method of securing illumination at night, but in many instances the torches are not shut off during the day.

6. *Offset wells.*—The drilling of offset wells is not only frequently a waste of capital, but very frequently results in marked waste of gas.

* The first portion of this article was published in our August issue.—Editor.

7. *Improper plugging.*—Where a well is abandoned and the casing pulled, if the hole is not properly plugged, it may result in the ruination of other gas bearing formations by the migrating of gas or water from one to the other, or the very great waste of gas leaking into coal veins or coming up and passing out into the air.

Well Operation Wastes

1. *Wasting gas to get oil.*—Where oil and gas are found in the same field it is quite a general practice for oil operators to blow off the gas, that is, waste it, in order to procure the oil. This is the principal cause of the depletion of many gas fields, and is responsible for a greater volume of gas waste than probably all other causes put together.

In tests on over 1000 oil wells in West Virginia it was shown that the waste of natural gas of each well was at the rate of 12 M cubic feet a day, or 4380 M cubic feet of natural gas a well per annum. There are at least 16,000 oil wells in West Virginia, and at this rate the annual waste from this source would be at least 70,000,000 M cubic feet of natural gas, equivalent to about one third of all the natural gas used for domestic consumption in the United States.

2. *Excessive blowing.*—Where wells are blown into the atmosphere for water freeing purposes the gas must, of course, be wasted. However, in many cases the wells are blown longer than necessary, and in others it would be feasible to install siphons for the removal of the water so as to curtail this form of waste.

3. *Salt water troubles.*—In some instances salt water exists in the gas-bearing formation and in others it works in from other strata, due primarily to improper drilling and casing methods. This results in a large waste of gas when the wells must be watered to free them of the salt formation below in the tubing.

4. *Too rapid lowering of the rock pressure.*—The irregular or too rapid lowering of the rock pressure by exceedingly rapid production will always produce undesirable operating conditions, and must ultimately result in a large waste of the total amount of gas that might have been removed with more rational operating methods.

Transmission Wastes

1. *Leakage.*—The structural conditions accounting for much of the leakage along gas lines are discussed later under the heading "Gas Leakage." The leakage in the consumer's house piping beyond the meter is very much larger than ordinarily supposed. In a number of houses where the leakage has been checked it has been found that in these instances the leakage averaged 19 M cubic feet of gas a year for each house.

2. *Measuring devices inaccurate.*—In many instances measuring appliances are not used for measuring the gas either into the line or out of the line. The more extensive use of measuring devices would reveal an enormous waste in many lines that are now supposed to be tight.

3. *Blowing drips.*—If the gasolene and water vapors are not removed by drying the gas, considerable gas must be wasted where these vapors, after they have been precipitated in liquid form, must be blown out along the transmission system. The installation of gas drying plants will therefore practically eliminate this form of waste in addition to conserving the gasolene.

Utilization Wastes

1. *Flat rate.*—Much natural gas is still sold at a flat rate of so much per consumer, or so much for each fire or other fixutre. This puts a premium on waste and results in the destruction of an enormous amount of gas that might be conserved for more intelligent and appreciated future use.

2. *Cheap gas for manufacturing.*—When natural gas is sold at low prices for industrial use, there is no incentive to use the gas in an efficient manner, and it is therefore quite frequently used without regard to efficiency or conservation. This is probably the largest form of waste in connection with utilization of natural gas.

3. *Free gas.*—In many cases boom towns in the gas fields have held out the inducement of supplying either free gas or the gas has been sold at ridiculously low prices for industries that would locate there. This feature has been especially troublesome in West Virginia and has resulted in depriving many domestic consumers of an adequate supply of the best fuel available for household use.

In an extensive investigation the amount of gas consumed by domestic consumers in West Virginia having free gas service privileges, on account of having gas wells or gas lines on their farms, it was found that the average consumption per free consumer a year was 480 M cubic feet. This is a waste of at least 350 M cubic feet for each free consumer a year. There are at least 4400 free consumers in West Virginia, and at this rate of waste this item alone amounts to 1,540,000 M cubic feet a year. This is more than half the amount of gas used in Louisville.

4. *Carbon black.*—This is a form of improper use rather than absolute waste. The carbon black industry in West Virginia uses 50 per cent more gas than is furnished to all of the domestic natural gas consumers in that state.

5. *Inefficient use.*—In many cases natural gas is used without mixers. The marked difference between the use of natural gas in the fire pot of an ordinary coal furnace and a correctly designed natural gas furnace, and the cooking stove and lighting efficiencies, emphasize the need of improvements in gas-using appliances.

6. *Thermostat control.*—Thermostats for controlling house-heating appliances are out of the experimental stage, and the large number in use demonstrates their reliability and usefulness. In addition to ministering to the comfort of the house occupants, they aid very materially in conserving the gas consumption by preventing overheating. Where natural gas is sold at low prices the practice is still all too common of lowering the temperature of an overheated room by opening a window rather than by lowering the gas fire.

7. *Discount for low pressure stimulates waste.*—This has the immediate practical effect of lowering the price of gas during the peak load period and stimulates waste, for the well-known human nature reason that what is made cheap will not be saved.

Offset Wells

After a well has been drilled on one farm, the term "offset well," in a narrow sense, means a well drilled on a contiguous farm, directly opposite from the first well and substantially the same distance across from the farm line.

It is not necessary in all cases that the offset well be either directly opposite to or the same distance from the property line as the well that it is to offset. Thus one well may be an offset to two or more contiguous wells. The offset well is drilled for purposes of protection.

> In gas territory the lessee may sink many wells and find gas in them all, but he can utilize only such of them as have a volume and pressure sufficient to enable him to transport the gas through his line and deliver it to the purchaser. If no one of them has the requisite pressure, then none of them can be utilized and the lessor is entitled to no royalty. What is the proper way to operate a gas lease is therefore a question beset with some difficulty. Its settlement requires some general knowledge of the business and some knowledge of the local field. The lessee may have a good well, from which he can utilize the gas with profit. He may put down another on the same farm and so reduce the pressure in the first as wholly to destroy its value, without getting a sufficient pressure at the second to enable him to utilize that. The gas, if coming from one well, would be of great value. Divided in such manner that the whole volume and pressure at each is below the necessary standard, the whole is lost.*

It is a matter of common observation in natural gas mining that offset well locations are frequently dry holes. This is because most natural gas pools are not strictly continuous, but are made up of many small local pools, frequently surrounded in whole or in part by a gas rock of low porosity. For this reason, if a producing well has been drilled into one of these small gas pools, there is a large chance that the offset well location may go beyond the limits of the pool and therefore be a dry hole.

The fact that offset natural gas wells are frequently of lower capacity than the wells that they offset may be accounted for as follows:

If the offset well is drilled at the extreme edge of a small local pool its capacity would naturally be smaller than the original well drilled more nearly in the center of the pool. Furthermore, when the first well is drilled into the pool the rush of gas has a marked tendency to open up numerous channels of low resistance so that the gas in the sand can get to the well opening with a minimum of friction. The high initial rock pressure aids substantially in first creating such lines of least resistance and then in freeing them of loose particles of sand which are blown out through the well. Even though an offset well is afterwards drilled in the same pool, the initial rock pressure will probably be lower than for the first well, and the lower gas pressure wil not be near as likely to produce favorable conditions for flowing to the bottom of the offset well as were produced in the first well.

The crux of the entire "offset well-drilling question" is whether the decision to make the additional investment, providing the increased annual operating cost and cutting down the reserve acreage, shall be made by the farmer—with no risks involved and no obligation to the public—or the party who must provide the money, assume the financial risk and operating duty. All of such increased burdens represent an unnecessary waste which will ultimately be paid for by the public.

* Pennsylvania Supreme Court. McKnight *versus* Manufacturers Natural Gas Co. (146 Pa. St., p. 185.)

The following analysis gives the reasons for the drilling by one company of 429 wells in West Virginia during 1916, and emphasizes the offset well burden, as well as the large number that were drilled on the demands of the lessors.

Reason for Drilling	No. of Wells
To save lease	96
Offset	68
For oil	74
For gas	52
Wildcat	4
Requirements of lease	5
Demand of lessors	130
Total	429

Gas Leakage

The difficulty in keeping gas joints tight is not ordinarily appreciated and results in an enormous waste from defective joints and minute openings in gas-carrying equipment. The laws of gas leakage may be stated as follows:

1. The relative leakage tendencies of two fluids under the same conditions are inversely proportional to the square roots of their densities. Natural gas has a density of about 0.64. That is, the leakage tendency of natural gas will be $1 \div 0.8 = 1.25$ times that of air under similar conditions. Water has a density 819.5 times that of air; hence the leakage tendency of natural gas is much greater than that of water at the same pressure. This accounts for the universal difficulty in keeping gas confined.

2. The quantity of leakage through a given opening will vary directly as the square root of the differential pressure.

3. Amount of leakage is independent of the quantity or velocity of gas passing through the main.

A typical gas main joint coupling, as shown in Fig. 12, has four surfaces adjacent to the rubber where leakage may be possible. On a 16-inch main each coupler presents about 17 linear feet of potential leakage surface. The magnitude of this in a large system is evident when we consider that about 270 couplers will be required to the mile, thus making 4590 ft of possible leakage surface.

Welded gas mains are coming into use, but the welded process can not be used except on new work or in main line installations where the entire line can be shut down and drained of gas before welding.

* U. S. Geological Survey Statistics. Natural Gas in 1916, p. 662.

† J. B. Garner, "The Chemical Possibilities of Natural Gas." Paper, Natural Gas Association of America, Pittsburgh meeting, May 23, 1918.

Carbon Black Manufacture

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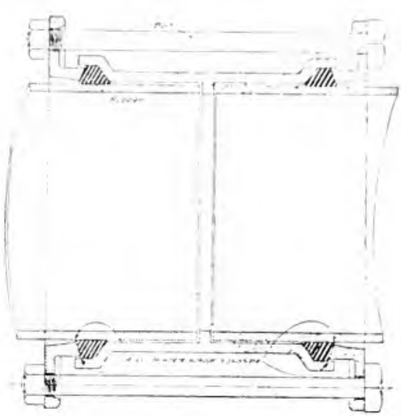

Fig. 12. Longitudinal Section of a Natural Gas Pipe Coupler showing Four Possible Leakage Joints

Carbon black is now made by the wasteful process of incomplete combustion of natural gas. That is, the gas is simply burned in the open and the flame impinging against a metal plate makes the black deposit. From $1\frac{1}{4}$ to $1\frac{1}{2}$ pounds of carbon black are made to each M cubic feet of gas burned. The only product obtained is the carbon black, and this utilizes only a very small percentage of the total carbon content of the gas.

The total annual quantity of natural gas used for carbon black manufacture is more than 26,000,000 M cubic feet. This wastes about 10 times as much gas as was used in the city of Louisville, or the equivalent of one eighth of the domestic natural gas consumption in the United States.

Dr. J. B. Garner, of the Mellon Institute of Industrial Research, Pittsburgh, Pa., has demonstrated that with correctly designed appliances the yield of carbon black can be made three times as high as that usually obtained and in addition save a usable commercial gas.†

Carbon black manufacture may be more attractive than public utility service for the following reasons:

1. It is not subject to the many phases of

Fig. 13. Two 4-in. Pipes Wasting 5,000,000 Cu. Ft. of Natural Gas in Order to Get Oil

Fig. 15. Natural Gas Main Line River Crossing Under Construction

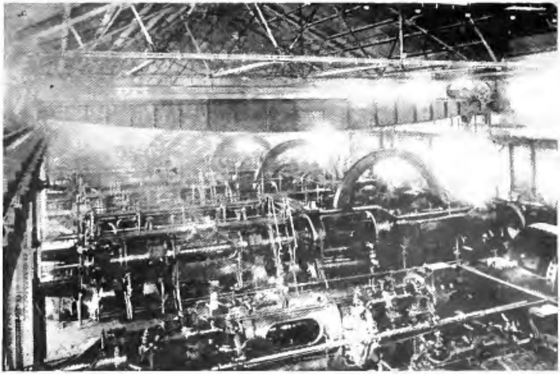

Fig. 14. Interior of a Natural Gas Compressing Station

Fig. 16. Typical Natural Gas Main Line Construction Conditions

public regulation that control the marketing of natural gas as a public utility service.

2. The price is not controlled by rate fixing bodies.

3. The plants are located in the field close to the leases, and sometimes on the leases themselves, so that the ordinary gathering lines are the only transmission equipment necessary, and these are so short as to not even require the use of gas compressors.

4. A natural gas plant operating as a public utility has a load factor of only about 34 per cent. The carbon plant load is uniform.

5. The proximity of the carbon plants to the wells makes it possible to carry lower well pressures than can ordinarily be reached by contiguous public utility companies having their wells discharge into intake lines to compressor stations.

6. In a number of instances carbon plants have been located where it would not be feasible, with present prices for natural gas, to lay lines in order to transmit the gas into the public utility transmission systems.

7. The carbon black plants do not carry reserve acreage, as a general rule.

8. The plant hazards are much less than those in a public utility plant.

9. The investment necessary for each 1000 cubic feet of natural gas handled will be about 10 times larger in a public utility plant than in a carbon black plant.

Relative Investment Required by a Natural Gas Public Utility Plant

It is not ordinarily appreciated that the investment necessary to render natural gas service is very much greater to each consumer than for any other utility service. That is, the investment to each consumer in natural gas properties, from gas leases to domestic meters, is:

1. Three hundred per cent more than in electric plants.

2. One hundred and fifty per cent more than in waterworks plants.

3. One hundred per cent more than all of the Bell Telephone toll lines and Bell exchanges in the United States.

4. Fifty per cent more than in ordinary manufacturing gas plants.

The investment from reserve acreage to consumer's meters in a natural gas plant rendering public utility service and selling on an average of about 100 M cubic feet of natural gas to each domestic consumer a year will be about $220 to each consumer, or $2.20 for each M cubic feet of gas delivered a year.

Competition Always Economic Waste

Competition in a [illegible] is a duplication of [illegible] Unbalanced operating [illegible] coordination [illegible] field. [illegible]

Under competitive conditions [illegible]

Under ordinary drilling [illegible]

Critical Need of the Natural Gas Industry

The natural gas industry is in a transition stage, going from the large volume and low-priced basis of the past to the small volume and inevitably higher price of the future. Strong individualism dominated the past. Public policy will ultimately require that legalized and regulated collective co-operation, rather than cut-throat competition, dominate the future. The greatest need of the industry today is the adequate recognition of the dominating factors in the natural gas conservation problem, which are:

1. Mandatory pooling of field operations coupled with an adequate market price.

2. Education of the natural gas producers, and of the public, coupled with national constructive legislation. Any legislation, of course, to be of value to the public must be so framed as to stimulate production and the constant search for new supplies.

The present governmental attitude in preventing unity of action in the gas field causes a decrease in the life of the leaseholds, stimulates waste, and increases the cost of the gas to the public. Gas field operating conditions should be regarded as a natural monopoly, so that in the development of the field one company, or one "operating pool," could space the wells properly, and drain the field only at the rate of its best working capacity, thereby greatly increasing and strengthening the life of the field.

The economic fallacy of competition between utilities is now thoroughly established. Competition, either as a guarantor of good service or regulator of rates, has failed. The doctrine that the public is served best by a legalized and regulated monopoly has become a fixed part of American public utility jurisprudence, and ought to be applied to the mining operations in the natural gas field.

Provincial Thinking Cause of Most Waste

The provincial habit of looking at natural gas from the dwarfed viewpoint of local use and the immediate present is the primary cause of our acute natural gas service problems of today. The history of the industry has been one of unrestrained waste and profligate disregard for the public's interest. This has been emphasized by creating provincial aspects rather than recognizing the national and interstate nature of the business. The selfish motive of trying to keep the natural resources of a state within the state boundaries, so as to make consumers locate within the state boundaries in order to enable them to use the resource, has been the dominating feature.

Natural gas prospectors are optimists, with individualism as the dominating characteristic. They are over-sanguine, but if it were not for this characteristic they would not be searching for new supplies of gas. They do things in a big way, take large risks, are good sportsmen and, therefore, good losers. However, the gains must in the end be more than the losses or they will not continue in the hunt for gas supplies for future service.

Natural gas can be found only by diligent prospecting. After it is found the service can be maintained only by further searching for new supplies. In this development the prospector must figure on many dry holes. The average for all drilling in the entire United States is that every fourth hole is dry. In opening up new fields this may be much higher.

Since the hazards are greater than in any other mining enterprise, the profits ought to be correspondingly greater. This element of profit is the only incentive which impels men to engage in so speculative an enterprise.

Natural gas has never been equaled by any man-made product for many high-grade utility services. The only thing that will effectively conserve the supply for future use and insure continuity of service is price commensurate with the value of the service. Therefore, the public is served best when natural gas mining is made profitable.

The feasibility of conserving wastes or developing new supplies and connecting these with a market depends on the co-ordination of various factors.

In no case would it be prudent business or good judgment to attempt to conserve a waste of gas or develop a new supply that would not take care of the fixed charges and the operating cost during the life of the gas that is saved or developed on the basis of the volume of gas that can be obtained from such an enterprise and delivered through the consumer's meter. An adequate price is therefore the crux of the natural gas conservation question. Unless it is made worth saving by the public it will not be good business judgment to attempt to save it.

A Review of the N.E.L.A. Lamp Committee Report

By G. F. Morrison

Vice-President General Electric Company

The Lamp Committee Report of the National Electric Light Association is always [illegible] to the lighting industry; this year's report is no exception. Mr. Morrison's article summarizes [illegible] emphasizes the most important parts. The statistical data is well worthy of close study. No [illegible] doubt the progressiveness of the lamp manufacturer after studying the tables accompanying the [illegible]—Editor.

Following its established custom, the Lamp Committee has issued its annual report, giving statistics and a record of progress of incandescent lighting equipment, which serves as a valuable guide in planning the activities of the lighting industries.

An outstanding feature of this year's convention was the Lighting Exhibit, which is described in a separate article. It included the typical standard and new lighting appliances, and presented the opportunity of visualizing the most modern practice in the application of equipment in important fields of lighting service. The exhibit presented its lessons so effectively that they could not well be overlooked. Concerning the exhibit, the report says: "This production which may be considered the main portion of your Committee's report, has been possible only by reason of the generosity of the lamp manufacturers and the co-operation of the Lighting Sales Bureau of the Commercial Section."

The statistics of the report are with special reference to the calendar year of 1918, although for purposes of indicating the trend, figures for previous years are included.

TABLE I

DOMESTIC INCANDESCENT LAMP SALES, 1907-1918 INCLUSIVE

Year	Per Cent Carbon and Gem	Per Cent Tantalum	Per Cent Tungsten
1907	99.2	0.7	0.1
1908	92.7	1.8	5.5
1909	84.1	2.1	13.8
1910	78.0	3.5	18.5
1911	71.9	2.7	25.4
1912	59.0	1.0	40.0
1913	43.3	0.1	56.6
1914	29.5	...	70.5
1915	21.1	..	78.9
1916	16.3		83.7
1917	13.0		87.0
1918	11.0		89.0

Lamp Sales

Excluding miniature lamps, 186 million lamps were sold for domestic use. The percentage increase in number of lamps sold over the preceding year was 9.4, whereas 1917 had shown 17 per cent increase.

Of the 186 million lamps, 166 million were of the tungsten filament type, an increase in numbers of 12 per cent over 1917.

The distribution of lamps between the tungsten and carbon classes, as reported in Table I and Fig. 1, shows a transfer of 2 per cent from the carbon to the tungsten, so that now nearly 90 per cent of the lamps are of the tungsten class.

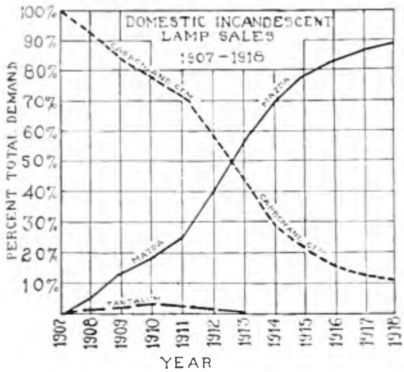

Fig 1

Of these tungsten filament lamps, 142 million, or 85½ per cent, were of the vacuum type and 24 million, or 14½ per cent, were of the gas-filled type. This represents an increase for the year of 8.5 per cent for vacuum lamps and 37 per cent for gas-filled lamps.

Gem and Carbon Lamps

The report records the passing of the Gem or metallized filament, which had first come into use in 1905 and had proved useful in the transition from the carbon to the tungsten filament lamps. As explained later on in the report, the war's demand for the most efficient lamps was a dominating influence in the withdrawal of the Gem lamp.

The carbon lamp, due to its low cost and sturdy construction, is still used for severe service where lamp breakage is a predominating factor of lighting costs. Such lamps are largely used for temporary lighting and industrial construction which, on account of the requirements of the war period, has maintained about the same demand as for the past two or three years.

The Committee anticipates a decline in the use of carbon lamps, especially in view of the recent development of the mill type tungsten filament lamp, which is treated more fully in a later reference.

Miniature Lamp

Miniature lamps are practically all now of the tungsten filament types. Their use has witnessed a considerable growth due to the increased numbers of automobiles and flash-

TABLE II

1918 DISTRIBUTION BY VOLTAGES OF TOTAL LAMPS SOLD

Voltage Group	Per Cent of Total Sales
110-125 volts	82.1%
220-250 volts	7.6%
Street Series (4.0, 5.5, 6.6 and 7.5 amperes)	1.3%
Street Railway (5 in series on 525-650 volts)	3.8%
30 and 60 volts (Train and Farm Lighting)	4.0%
Miscellaneous	1.2%
Total	100.0%

TABLE III

DETAIL DISTRIBUTION OF MULTIPLE TUNGSTEN LAMP SALES

Lamp	PER CENT OF GROUP SALES			PER CENT OF TOTAL TUNGSTEN SALES		
	1916	1917	1918	1916	1917	1918
Multiple Mazda B Lamps						
Signs	8.8	7.6	5.9	7.8	6.4	4.9
15 watts	6.1	5.0	6.7	5.3	4.2	5.5
20 watts	2.0	1.2	....	1.7	1.0	....
25 watts	25.7	27.1	27.1	22.4	23.0	22.4
40 watts	29.0	29.5	29.4	25.2	25.0	24.3
50 watts	6.0	8.5	10.2	5.2	7.0	8.4
60 watts	17.9	17.3	16.2	15.6	14.8	13.3
100 watts	3.8	3.2	2.4	3.3	2.7	2.0
Miscellaneous	0.7	0.6	2.1	0.6	0.5	1.7
Total Multiple "B"	100.0	100.0	100.0	87.1	84.6	82.5
Multiple Mazda C Lamps						
75 watts	25.0	31.0	32.1	1.9	3.1	4.1
100 watts	46.0	39.0	36.9	3.5	3.9	4.7
150 watts	....	2.1	3.6	....	0.2	0.4
200 watts	14.5	15.3	15.6	1.1	1.5	1.9
300 watts	5.5	4.2	4.0	0.4	0.4	0.5
400-500 watts	4.0	4.2	4.1	0.3	0.4	0.5
750-1000 watts	2.5	2.1	1.3	0.2	0.2	0.3
Miscellaneous	2.5	2.1	2.4	0.2	0.2	0.3
Total Multiple "C"	100.0	100.0	100.0	7.6	9.9	12.7

lights, for which these lamps form the exclusive light sources. On central station circuits miniature tungsten lamps are being employed in increasing numbers for candelabra and Christmas tree lighting.

Distribution of Types and Sizes

Tables II, III and IV show the distribution of the 1918 lamp sales among the various types and sizes. More than 82 per cent of all lamps sold were of the 110-125 volt group, while 7.6 per cent were of the 220-250 volt groups. The 40 watt is shown to be the most popular lamp of the 110-125 volt group of tungsten filament lamps, representing more than a quarter of the sales in this group. The 25 and 60 watt are second and third respectively.

The 50 watt lamp which was put on the market four years ago has shown the greatest gain among the vacuum lamps of this group, having an increase of 30 per cent over 1917.

The demand for sign lamps shows a falling off of 33 per cent, largely, no doubt, on account of the government restrictions of sign lighting during the year.

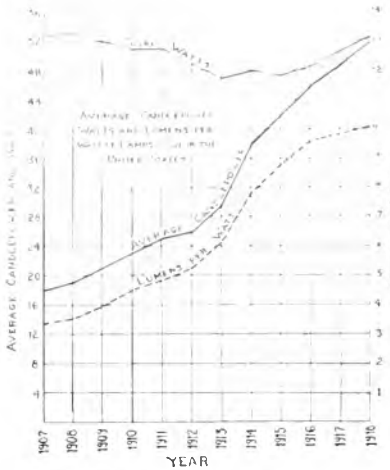

Fig. 2

TABLE IV

DISTRIBUTION OF TUNGSTEN LAMPS OF THE 110-125 VOLT GROUP

Size of Lamp	Per Cent of Group Sales 1917	Per Cent of Group Sales 1918	Per Cent Increase or Decrease in Actual Sales 1918 over 1917
Vacuum Class			
Sign	4.5%	2.7%	Decrease 33%
10-watt S-17 bulb	2.7%	2.4%	No chang
15 watt	6.9%	5.8%	Decrease 7%
25 watt	24.3%	23.5%	Increase 7%
40 watt	25.0%	25.5%	Increase 13%
50 watt	7.5%	8.8%	Increase 30%
60 watt	15.1%	14.0%	Increase 3%
100 watt	3.0%	2.1%	Decrease 21%
Miscellaneous	0.9%	1.8%	....
Total Vacuum Class	89.9%	86.6%	Increase 7%
Gas-Filled Class			
75 watt	3.2%	4.4%	Increase [illegible]
100 watt	4.0%	4.9%	Increase [illegible]
150 watt	0.3%	0.5%	Increase [illegible]
200 watt	1.4%	2.1%	Increase 57%
300 watt	0.4%	0.5%	Increase 41%
400-1000 watt	0.6%	0.7%	Increase 37%
Miscellanoues	0.2%	0.3%	
Total Gas-Filled Class	10.1%	13.4%	Increase 47%
Grand Total	100.0%	100.0%	Increase 11%

The 75, 100 and 150 watt gas-filled tungsten lamps appeared to be replacing the 100 watt vacuum lamp, the sales of the latter having decreased considerably.

Considering lamps of 110-125 volts, the number of vacuum tungsten lamps sold has increased 7 per cent, while for the gas-filled lamps the increase in nearly 50 per cent.

The most popular of the gas-filled lamps is the 100 watt size, which is closely followed by the 75 watt.

Gas-filled lamps represent numerically 13.4 per cent of the 110-125-volt tungsten group, but in wattage they represent 36 per cent. A calculation based on the figures given in the report indicates that the gas-filled tungsten lamps represent over 40 per cent of the candle-power of all large incandescent lamps sold during the year.

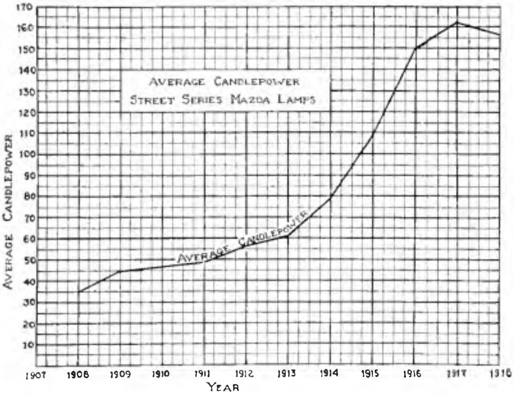

Fig. 3

Average Candle-power, Watts and Efficiency

As shown in Table V and Fig. 2, the average size and efficiency of lamps continues to increase at a reasonable rate. It is noted that the average lamp efficiency for 1918 is over three times what it was in 1907, when tungsten filament lamps were first introduced.

Street Series Lamps

Street series lamps have, due to the reduced use of the higher candle-power sizes, fallen off nearly 2 per cent in average candle-power, as shown in Fig. 3. Considering only the smaller sizes, that is, lamps less than 250 c-p., the average candle-power for 1918 is 74 c-p., or an increase of nearly 3 per cent over 1917. The comparison of candle-power size for 1917 and 1918, in Table VI, shows the tendencies mentioned above. The table shows that 53.2 per cent of the series lamps are 6.6 amperes.

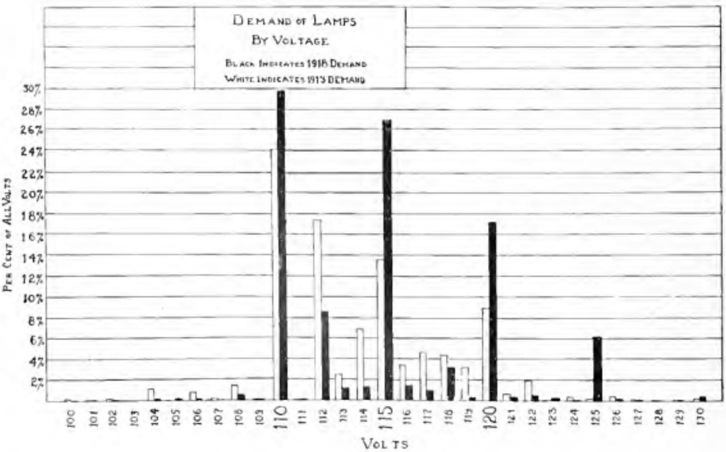

Fig. 4

Since a large majority of the 15 and 20 ampere lamps are actually operated on 6.6 ampere circuits, through individual transforming devices, the dominance of the 6.6 ampere circuit is evident. Circuit amperages other than 6.6, 7.5 and 5.5 are negligible.

TABLE V

AVERAGE CANDLE-POWER, WATTS AND EFFICIENCY

Year	ALL LAMPS		
	Average Candle-power	Average Watts	Average Lumens per Watt
1907	18.0	53.0	3.33
1908	19.0	53.0	3.52
1909	21.0	52.0	3.96
1910	23.0	51.0	4.42
1911	25.0	51.0	4.80
1912	26.0	49.0	5.20
1913	29.4	47.0	6.13
1914	38.2	48.0	7.80
1915	42.2	47.4	8.71
1916	45.8	48.6	9.60
1917	48.7	50.7	10.56
1918	51.5	52.7	10.30

Voltage Standardization

The sub-committee did no active work during the war period, but it is noted that over 82 per cent of all lamps were of the voltage group of 110-125, and nearly 75 per cent of these fall in the voltages recommended by the committee, namely 110, 115 and 120.

Progress towards standardization is indicated by the fact that in 1917, 65 per cent of the 110-130 volt lamps were of the three recommended voltages, while in 1913 the percentage was only 45. Fig. 4 is a graphical comparison of voltage distribution between 1913 and 1918, while Table VII shows the percentages for 1917 and 1918.

Colored Lamp Bulbs

Although no extended activity has been carried on in the past year, a sub-committee has been endeavoring to secure a reasonable agreement among central stations, which may lead to the standardization of a yellow or amber bulb, and thus taking advantage of the economic possibilities opened up by the increased lamp efficiency. Although a considerable range of preference still exists, the weighted average of some 80 observers points to an approximation of the color of the kerosene flame as most generally acceptable.

Superficially colored lamps, said to be permanent as to color, have been submitted to the committee and found pleasing. Further progress seems to depend upon indication of an actual demand.

TABLE VII

DEMAND OF LAMPS BY VOLTAGES

Voltage	PER CENT OF TOTAL	
	1917	1918
100-109	1.2%	0.3%
110 (Standard)	25.0%	29.9%
111		
112	10.0%	8.7%
113	3.0%	1.2%
114	2.5%	1.4%
115 (Standard)	21.7%	27.0%
116	2.0%	1.5%
117	2.0%	1.0%
118	4.0%	3.3%
119	2.0%	0.2%
120 (Standard)	15.5%	17.7%
121-124	2.3%	1.3%
125	4.5%	6.1%
126-130	1.3%	0.4%
Total 100-130 Volts	100.0%	100.0%

TABLE VI

STREET SERIES LAMPS

BY CANDLE-POWER SIZES		
Candle-power	Per Cent 1917	Total 1918
Under 60	14.5	13.3
60	22.6	22.7
80	11.0	10.8
100	25.5	29.3
250	11.0	11.7
400	8.2	6.2
600	6.3	5.1
1000	0.9	0.9
Total	100.0	100.0

BY AMPERE RATINGS		
Amperes	Per Cent 1917	Total 1918
4	11.3	11.8
5.5	9.6	10.9
6.6	53.3	53.2
7.5	16.7	15.5
15 and 20	9.1	8.6
Total	100.0	100.0

In connection with this feature of the report, it should be noted that a division of the demand among different shades, types and sizes might seriously limit the practicability of furnishing and distributing such lamps.

Country Home Lighting Outfits

Attention is called to the extended introduction of these gasolene electric generator storage battery sets. These are considered beneficial rather than detrimental to central station business. By educating people as to the advantages of electric lighting they make them better prospects for future central station service. Such users are usually connected to central station service when the extension of lines renders it available.

Price Changes

Fig. 5 shows the initial prices and later changes of 110-125 volt Mazda lamps, including the changes of October, 1918.

Lamp Development

The energetic work on improvements, particularly of the gas-filled lamps, is mentioned with the expectation that announcements of the results can be made at an early date.

50-Watt White Mazda Lamp. One of the latest and most important lamp developments of the year, namely, the 50-watt white Mazda lamp was announced too late for inclusion in the printed report. It was, however, displayed at the Lighting Exhibit, during the latter days of the convention and attracted much favorable attention.

The 50-watt lamp is made in the 110-volt range, provided with a tipless PS-20 bulb in diffusing white glass only, and is of the Mazda C type.

While sufficiently dense as to conceal the filament and appear uniform, the diffusing glass is of low absorption, being about 8 per cent in excess of clear glass. As a result, the overall efficiency of the lamp is slightly better than that of the clear glass 50-watt Mazda B lamp. The lamp is rated at 1.28 watts per mean spherical candlepower.

The dimensions of the lamp are such that it is interchangeable with the 40 and 50-watt regular Mazda B lamps, i.e., its length overall is $5^1/_8$ in. and its diameter is $2\frac{1}{2}$ in. It

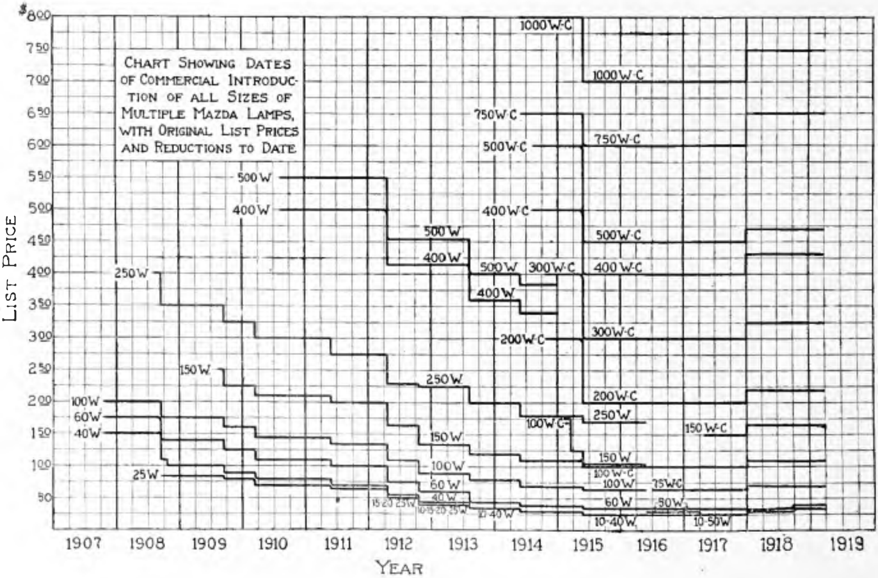

Fig. 5

can, therefore, replace such lamps without change of equipment.

The manufacturers regard the diffusing glass as an important feature, since the lamp is likely to receive wide application in homes where the lamp will present a pleasing appearance and emit a soft diffused light.

As exhibited in the home lighting booth and the portables, in the foyer of the exhibit, the lamp attracted much favorable comment on its appearance and lighting effect.

The Mill Type Lamp which was placed on the market October 1, 1918, was developed to meet the need for a more rugged, high efficiency lamp for special service, where the strength of the ordinary tungsten lamp had proved insufficient. Fig. 6. While the need for such a lamp had been recognized for several years, and considerable work had been done, the efforts of the manufacturers were quickened by the war emergency. Its adoption was also hastened by the efforts of the Fuel Administration to bring about the substitution for the carbon lamp, of a lamp combining ruggedness and efficiency.

Many difficulties were encountered and some of the early samples, issued for practical service, proved fragile. Means of overcoming these difficulties have been found and while in some minor respects the lamp is still in a state of development, it is now well worthy of trial where an especially sturdy lamp is required.

The special features of the mill type lamp are the flexible steel wire by which the filament mount is supported, and the additional anchors for the filament. The former absorbs vibrations. The cooling of the filament, due to the additional anchors, reduces the efficiency of the lamp about [illegible] per cent. The mill type lamp is made in 25 and 50 [illegible] (120 [illegible])

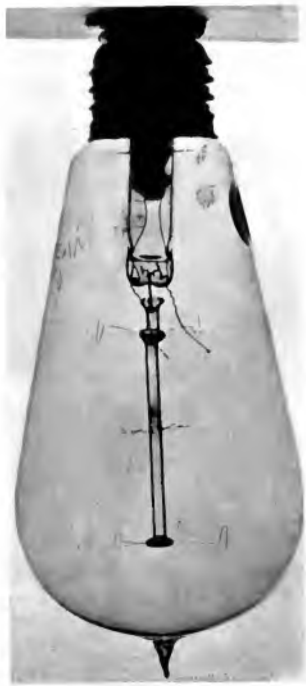

Fig. 6. Mill-type Lamp

TABLE IX

CENTRAL STATION COMPANIES REPORTING VARIOUS LAMP POLICIES

Figures Indicate Per Cent of Companies Reporting in Each Group

Company Lamp Policy	NUMBER OF LIGHTING CONSUMERS SUPPLIED: Less than 1000		1001 to 5000		5001 to 10000		10001 to 50000		Over 50000		Total	
	1917	1919	1917	1919	1917	1919	1917	1919	1917	1919	1917	1919
Free Renewals Only	0	0	0	1	2	0	2	0	0	6	1	1
Merchandise Only	85	80	63	80	32	83	32	71	17	59	63	79
Free Renewals and Merchandise	12	2	31	9	56	11	56	13	66	35	30	8
Do Not Handle Lamps	3	18	6	10	6	6	6	16	0	0	5	12
Give Renewals—Make Lamp Service Charge	0	0	0	0	4	0	4	0	17	0	1	0
Total	100	100	100	100	100	100	100	100	100	100	100	100

25-Watt Lamps in S-17 Bulb. The 25-watt lamps, formerly employing the S-19 bulb, are now being made in the S-17 bulb, excepting lamps of the 220-250-volt group. It is expected that the change will be complete and all the larger bulb lamps disposed of by fall. The pur-

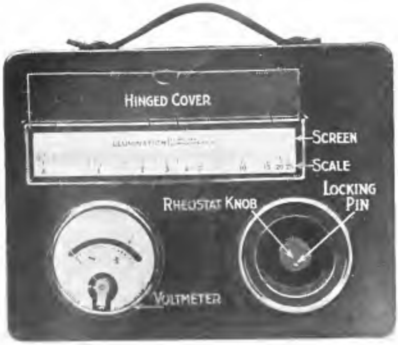

Fig. 7. Foot Candle Meter

pose of this change is to standardize one size of bulb for the lower wattage lamps and secure economies in packing and storing lamps.

Lamps for Motion Picture Machines. Supplementing information of previous reports, the standardization of the 600 and 900-watt lamps for *motion picture* projection is recorded. Both lamps are in T-20 bulbs.

The 900-watt, 30-volt, 30-ampere lamp is generally recommended, and the 600-watt 30-volt, 20-ampere lamp is only recommended for short throws and small screens and where available power is limited.

Industrial Lighting Codes

The progress in the establishing of industrial lighting codes is briefly reviewed. Mention is made of the five states which adopted lighting codes, namely, Pennsylvania, New Jersey, New York, Wisconsin and Oregon, as well as four other states in which codes are definitely under preparation, namely, Ohio, Massachusetts, California and Oklahoma.

The code is being promulgated by the United States Bureau of Standards and the Committee of Labor of the Advisory Commission of the Council of National Defense, as well as by the Illuminating Engineering Society, which Society originally prepared it.

The enforcement of the codes will not only improve the utilization of artificial light, but usually increase the amount of light used, with resultant advantages to the workman, to the industrial establishment, and to the central station.

In this connection, it is worthy of note, that the report of the Industrial Lighting Committee of the Lighting Sales Bureau, presented at the Atlantic City Convention, pointed out surprisingly large gains in manufacturing efficiency, resulting from lighting, far above the usual standards of intensity.

Foot Candle Meter

The foot candle meter, which has been described in the technical press, is a simple, portable instrument recently designed for measuring illumination intensities commonly found in artificial lighting installations, that is 0.05 to 25 foot candles. The instrument, which is of small size, is self-contained, the standard lamp being energized by a flashlight battery. The foot candle meter is being used with considerable success, especially in connection with industrial lighting. This instrument is an important factor in the industrial lighting code situation, and by providing a means of recording actual intensities of illumination, will undoubtedly hasten the progress toward effective standards of "productive" illumination.

Fig. 8. Tag which may be attached to the service meter indicating the voltage of the circuit. These tags should, to a large extent, prevent the use of Mazda lamps of incorrect voltage rating

The foot-candle meter is shown in Fig. 7, along side of which is an interior view of the meter.

Fuel Conservation Program

The Lamp Committee co-operated with the Lamp Committee of the Association of Edison

Illuminating Companies and with the National Committee on Gas and Electric Service, in carrying out the program of conservation for the Fuel Administration.

The substitution of more efficient lamps wherever practicable was successfully urged upon the member companies.

The Society for Electrical Development assisted in the Publicity Campaign for conservation.

Since the withdrawal of the request for voluntary restrictions, the association has received from the Fuel Administration an expression of thanks for the co-operation.

Company Lamp Policy

Company lamp policy continues to be a subject of animated discussion. The Committee undertook to recanvass the membership and secured reports from 50 per cent, covering every State in the Union, which it believed representative of the industry.

Table IX shows a summary of results in percentage, as to the four principal practices classified with regard to the number of lighting consumers supplied.

Comparison with 1917 shows a tendency toward merchandising among companies of all sizes; 79 per cent of the companies are so operating, as compared with 63 per cent in 1917. The change has apparently been somewhat accelerated during the war.

There are still many notable examples of the free renewal policy. The committee regards it as a local question and expresses no opinion as to the wisdom of the various policies.

The disappearance of the Gem lamp from the market is recorded, only three companies having reported its use this year as against 83 in 1917. The ultimate disappearance of the carbon lamp through the development of the sturdy tungsten filament lamp is predicted.

Table X compares the policy as to lamp sales price with that of 1917.

New Channels of Lamp Distribution

In view of the tendency of central stations to go to a merchandising basis, attention is directed to the rapid development of lamp distributors. Companies are urged to participate in organized efforts so as to supervise the distribution of lamps to their customers and insure their obtaining the best quality of lamps.

An outline is given of the practice of lamp manufacturers in appointing and developing agents. The education of agents is furthered by the use of booklets and other printed matter, personal calls and lectures before contractor-dealer associations and by sales promotion magazines.

Agents are further [illegible] ing, especially through [illegible] printed material [illegible] used [illegible] promotion and [illegible] preparation of [illegible] window display [illegible]

TABLE X

SALE PRICE

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	72	77	[illegible]	[illegible]
[illegible]	11	21	22	25
[illegible] lamp [illegible]	17	[illegible]	2	—

Central Station Co-operation

When three eastern central [illegible] the merchandising policy, a co-ordination of the three branches of the industry [illegible] successfully worked out in consultation with the lamp manufacturers. The importance of preserving proper standards was impressed upon the contractor-dealers through their associations. Special attention was given to supplying lamps of proper voltage.

To further assure proper selection as to lamp voltage, these lighting companies are about to adopt and place on all meters a tag as shown in Fig. 8, furnished by the lamp manufacturers. This tag, called to the customer's attention by suitable advertising, is expected to induce them to secure lamps of correct voltage.

One of the large manufacturers is further distributing a voltage map among dealers and agents.

Forms of Lamp Contract

No important changes have been made in the form of lamp contract offered by the manufacturers. The Committee recognizes that local conditions enter into the selection of the most desirable form. While making no general recommendations, the committee feels that the trend is toward a general merchandising policy.

The importance of co-operation with lamp distributors, where such a policy is in effect, is pointed out, with the recommendation that the central station take an active part in supervising the distribution of lamps.

Conclusion

In conclusion, the Committee expresses appreciation of aid from sources too numerous to mention.

National Electric Light Association Lighting Exhibit

By G. F. Morrison
Vice-President General Electric Company

This contribution is closely associated with Mr. Morrison's other article appearing in this issue. It describes the lighting exhibits which were considered as a part of the Lamp Committee report. The author, in describing the more important exhibits, tells of the features in the art of lighting which each exhibit was designed to bring before the public's attention.—Editor.

The report of the Lamp Committee presented at the 1919 convention at Atlantic City, characterizes the lighting exhibit as the main portion of the report. Both are exceedingly important, each in its own way. The exhibit in particular was unique and a source of special incentive to an aggressive extension of lighting service.

Fig. 1. View of Entrance and Foyer, Lighting Exhibit, N.E.L.A. Convention, showing General Arrangement of Rooms and Motion Picture Screen in the Background. The lighting of this area was accomplished by means of portable lamps of the direct and indirect types

The convention exhibits, as a whole, stand out as probably the finest collection ever presented to an N. E. L. A. Convention, and the lighting exhibit was conspicuous both as to interest and excellence of display. Prepared, as it was, under the auspices of the Lamp Committee and the Lighting Sales Bureau, with the active assistance of the lamp manufacturers and the co-operation of other branches of the industry, it was truly representative. The best of modern lighting practices and equipment were presented. "The New Spirit of Lighting" was the title, and this was unquestionably exemplified by the pertinent suggestions so vividly presented to the attention of the visitors.

The exhibit was located on the Million Dollar Pier at the end of the long avenue of commercial exhibits, just beyond the point where one turned to enter the convention halls. The visitor was confronted by a roomy alcove of rich, substantial appearance, flanked on either side by the more brilliantly lighted exhibit rooms. At the further end of this foyer was a screen on which motion pictures and stereopticon slides followed each other almost continuously. Besides exemplifying the use of

Fig. 2. View of the Industrial Lighting Exhibit, showing the Condemned or Poor Lighting. Such illumination represents a type of practice far too common which causes direct glare, sharp shadows, reflected glare and low intensity at the work. No one would be comfortable working in a room lighted in this manner.

Fig. 3. View of the Industrial Exhibit with the "Good" Lighting System Turned On. This is designed to produce productive intensity. There is an absence of direct and reflected glare. Such shadows as are produced are soft and luminous. There is a high intensity of illumination on the work in both the horizontal and vertical planes.

Fig 3 View of the Industrial Exhibit with the [illegible] Lighting System. A slight intensity of general illumination is provided, supplemented by properly shielded local lamps. The distribution of light is not very even. There is considerable reflected glare and poor illumination on vertical surfaces.

Fig [illegible] General View of the Room Devoted to the Indoor Lighting [illegible]. The diversity of the exhibit is quite apparent [illegible] multiplicity of types of fixtures and [illegible] incandescent lamps in moving picture and automatic stereopticon projection, the screen carried interesting illustrations of lamp manufacture, equipment and application.

Throughout the alcove were clustered comfortable chairs and sofas, which were generally occupied by social groups. On either side of the entrance were located reception rooms of the Lamp Committee and Lighting Sales Bureau respectively.

Industrial Lighting

As one entered the foyer, the first exhibit to attract his attention was that devoted to industrial lighting. The room, approximately 16 x 30 feet, was fitted as an automobile repair shop with benches, assemblying areas and machine tools. A very important point in connection with proper industrial lighting is the correct painting of walls and ceilings. Half of this room was finished in light tones with high reflective power and the other half in characteristic dull, dingy finish, too often found in industrial plants. Three systems of illumination were provided. The first, typical-poor lighting with drop lamps, unshielded, glaring and ineffective. The second represented fair practice. A low intensity of general illumination was provided by means of overhead units, supplemented at points demanding special lighting by suitably shielded, local or drop lamps. The third change represented good, modern, high intensity illumination. Overhead units, of the RLM standard dome type with the proper size Mazda C lamps and diffusing shields were symmetrically spaced so as to exemplify "productive lighting."

A great deal of data have been presented showing that high intensity general illumination will produce increase in production, and show tangible economic advantages to manufacturers. Increases of 15 per cent or more in production have been secured by good lighting which cost less than 5 per cent of the payrolls affected. Such increases justify very much larger expenditures for lighting than have until recently been thought economically practicable. The contrasts between the different systems of lighting shown in the exhibit were self-evident, as was the effect of wall finish. It was a simple matter to change from one system to another by hand or when the installation was not being demonstrated by the man in charge an automatic flashing device carried through the cycle. In this room, as in all the others, charts, illustrations and data were displayed on the walls, assisting the actual demonstration.

A large working model of the foot candle meter for measuring illumination permitted one to read, at a glance, the comparative intensities at a central point, while a number of standard foot candle meters facilitated a study of intensities throughout this and other exhibits.

Home Lighting

Directly opposite was the exhibit devoted to home lighting. Very attractive living and dining rooms were arranged with appropriate and artistic furnishings. The rooms were so wired that various combinations of lighting were obtained, and from day to day the types of fixtures installed were varied. Direct, semi-indirect and totally indirect illumination were all utilized. Ceiling outlets, wall brackets and portable lamps were available. The flexibility of electric service was evidenced by a multiplicity of baseboard and floor outlets, which served for heating and cooking devices, an electrical fountain, electrically driven victrola, fan and other equipments. Precautions were taken to insure harmony of fixtures, glassware and room furnishings. Special emphasis was laid on the methods of providing eye protection and comfort. The new 50-watt White Mazda lamp was first shown to the trade at the convention, and typical examples of its application were to be seen in this residence demonstration.

Indoor Lighting Equipment and Newer Lamp Applications

The next two rooms were devoted to indoor lighting equipment and newer lamp applications respectively. Typical fixtures were installed with individual control for demonstration and the latest types of reflectors, portable lamps, industrial units and accessories, color matching units, moving picture projectors and similar devices were here available. No important field of lighting was overlooked, even to the latest developments in stage appliances, utilizing high candle-power lamps.

Show Window Lighting

A full size, standard show window attracted considerable attention. This was constructed in such a manner as to be typical to the window in a high grade department store and appropriately dressed by a professional display man. A rather elaborate installation

Fig. 6. In This Space, Devoted to Newer Lamp Applications, were Grouped Some Very Interesting Appliances for Projecting Light and Adapting It to Other Special Purposes

Fig. 8. View of the Dining Room with a Semi-indirect Unit Installed. This is supplemented by a number of attractive wall brackets. The cooking devices and the electric fountain will be noted on the serving table and buffet respectively

Fig. 7. View of the Living Room in the Residential Exhibit. Silk shaded central and wall fixtures harmonize with the portable and desk lamps. The room is thoroughly comfortable, artistic and pleasing.

Fig. 9. There ... Wide Variety ... able Ingenuity was Necessary ... this Display Representative ... the Committee having ... their purpose.

of lighting equipment enabled a number of features to be readily demonstrated.

The lighting effects were manipulated from a control table and automatically operated when not being specially exhibited. In connection with this control board, illuminated signs presented full data on the essential feature of the lighting at all times. Standard mirrored and prismatic window lighting reflectors were used as the principal lighting units. Small mirrored reflectors with low candle-power lamps furnished a slight amount of foot lighting, and two standard stage spotlights were suspended overhead.

Color effects were obtained by the use of gelatine screens mounted in frames such as are used for theatrical spot lights.

A wide variety of lighting effects were demonstrated, of which the principal variations were briefly the following:

(a) Variation of intensity, showing the value of high intensity.
(b) Variation of color of light, including approximate daylight (Mazda C_2), red, green, etc.
(c) Variation of direction and distribution of light, including portable stand lamps, spot lights, and foot lights.

The display on exhibit was of wicker furniture and the window arranged somewhat like a summer porch. The combination of lighting which seemed to give the most pleasing results with this particular display consisted of green general illumination, a low intensity of unmodified foot lighting, table and floor lamps, and the overhead spotlamps which were equipped with purple and orange color screens respectively.

In demonstrating the window, it was pointed out that the future in show window lighting lay in the use of color effects and that all window displays should not be treated in the same manner, but each picture receive separate attention. To obtain the numerous lighting effects a considerable number of circuits were provided. This duplication is not necessary nor desirable for the average show window, although a modification of it might well be applied to the central station show room for purely spectacular and demonstration purposes.

In the ordinary store, however, color screens should be available which can be attached to the regular window lighting equipment and spotlamps which could be plugged in to suitably located receptacles. As each display is created, suitable color screens should be applied and spotlamps correctly placed.

Outdoor Lighting Equipment

Adjoining the show window was a room devoted to the display of outdoor lighting equipment. This material included street lighting units, floodlighting projectors, signs, reflectors for tennis court lighting and spectacular applications. Enlarged photographs showing some of the material in use were suitably placed about the walls. This exhibit called the attention of the industry to the wide field for this type of business which is again available. The latest types of devices served to awaken interest and promote much valuable discussion.

Central Station Lamp Practice

In the booth devoted to the exhibit of central station lamp practice were to be seen the findings of the two surveys of the Lamp Committee in 1917 and 1919. The methods of handling lamps in use by member companies were graphically portrayed. Interesting charts, maps and tables showed the trend of lamp practice. This exhibit was of great value to the central station representative as it embraced the experience in lamp merchandising, free renewals, parcel post delivery and similar phases. A representative of the Lamp Committee was in constant attendance to give full information on all the data.

Educational

The entire exhibit was devoted to educational purposes. In addition to the features already mentioned there were some which might be considered as more directly in the educational class. This included racks showing a complete line of all standard lamps, bulletins dealing with practical lighting problems, detail information on educational courses on lighting available at the different universities, the correspondence courses conducted by the N.E.L.A., transactions and publications of the Illuminating Engineering Society, all the modern text books on lighting subjects and similar literature. The illustrated lecture, "As An Aid to Selling," was demonstrated by means of an illuminated display, and the text of typical lectures, issued by the various manufacturers and institutions, were available. A number of interesting charts were used to

Fig. 10. Ordinarily, Dry Statistical Data was made into an Appealing yet Comprehensive Display in the Room Devoted to Central Station Lamp Practice. Instead of one's having to wade through pages of printed data the essential facts were vividly portrayed in chart, diagram and table

Fig. 12. Close up View of the Show Window with the Artistic Lighting Combination in Effect. Green overhead tints, portable lamps, low intensity of foot lights and overhead spotlights, paint in light a most artistic picture. The effect of a spotlight in bringing out an object to a particularly high intensity of tinted illumination, will be noted on the chair at the left.

Fig. 11 View of the Full Size Display Window with the High Intensity Uniform Lighting Turned On. Every detail of the display is [illegible] revealed. The control table for manipulating the [illegible] automatically, is visible in the immediate foreground.

Fig. 1[illegible] In the E[illegible] of Lig[illegible] Hall [illegible]
The cost and [illegible]
these at [illegible]

show the effect of color of walls and ceilings on the resultant illumination

No one could make even a hasty survey of this lighting exhibit without being impressed by the ground covered and the importance of lighting to the electrical industry. The magnitude of the field is very great and an exhibit of this character served to emphasize this to the delegates. It was rather remarkable to note the manner in which the lighting exhibit was inspected in comparison to the average display at a show or convention. The visitor was first drawn to the attractive surroundings. Once in the area devoted to this exemplification of the "new spirit of lighting," he did not leave it with merely a hasty glance. The exhibits were so vividly portrayed and so attractively arranged, that he at once became interested and paused to give the subject the attention which it justly deserved. Naturally, very few were interested in the minute details of all phases, but it is safe to assume that practically no attendant at the convention went away without having given rather serious thought to at least one field of lighting. It is doubtful if any other one event in recent years has given such a marked impetus to advancement in illumination or called the attention of the industry to the possibilities of lighting in such a striking manner.

Chinese Students and American Training

By M. A. Oudin

Vice-President, International General Electric Company

Recently a joint convention was held between the Science Society of China and the Chinese Engineering Society. During the convention the Chinese students visited the Schenectady plant of the General Electric Company. In the evening of the same day a social meeting was held at the Edison Hall, where the students were the guests of the Company. On this occasion Mr. Oudin presided and addressed the meeting. The Editor being much impressed with Mr. Oudin's remarks prevailed on him to write them for the Review. The human interest in China's struggle to "find herself" as a modern nation reconstructed on modern lines will appeal to the reader.—Editor.

It is an honor to be asked to preside at this session of the joint convention of Chinese Engineering Society and the Science Society of China. It is also a pleasure to welcome the members of these Societies on behalf of the Company whose Works they have visited today. I am especially pleased to greet you because of the deep interest which I, in common with a great many Americans, take in China and her many problems. Especially are Americans interested in the undoubted awakening of China and her progressive dedevelopment along modern lines.

There are I believe about 1600 Chinese students in American colleges. It is fitting that young Chinese should come to America for their professional studies, especially those relating to engineering and science. In the first place, one of the advantages of education and training in this country is the freedom of that education and that training from the suspicion of any endeavor to influence the views of students from abroad. Again, it is our good fortune that there is no restraint on the free expression of free views. These views are judged quite as much by their undoubted sincerity of purpose as by their soundness. It is in this atmosphere and under these conditions that the foreign student acquires a correct understanding of the American people which with the knowledge acquired here makes of lives a valued friend and a useful citizen on his return home.

Another advantage of the United States as a place of training for engineers and men of science from abroad is the superiority of that training. In foreign universities theory is studied in a degree rarely known here and then only to graduate students. Here rough and ready methods have long prevailed. They were necessary in building up this great country. The quickest solution of engineering problems was usually sought. In the early days bridges were needed and they were built rather than designed. Experience in construction, more than refined calculations of stresses and strains, made the structures safe. So it was with prime movers, both steam and water; so it was with dams, with water works, with buildings and the great variety of mechanical applications on a large scale. Such methods explain the miracle of America's development in the space of one hundred years and the speed with which a continent was filled from the Atlantic to the Pacific with splendid cities and great public works.

In these later days there has been more time for refinements in Engineering. You can see that with such a wealth of experience to support it theory became like a living vital thing. Europe was practically built up when engineering science loomed large in the world, so practice and theory did not go hand in hand to the same extent they did in America.

The problems to be solved in China are curiously similar to those already solved in this country; for the two countries physically present many similarities. The development of China is a continental problem just as it was in America.

As to the study of science, I need not remind you that the opportunities and advantages in America are enhanced by its commercial, collegiate and governmental research laboratories, especially the former. Our industrial development is intimately dependent upon the work done in these commercial laboratories.

In considering the achievements of the youngest great country and its advantages as a seat of learning, we must not overlook the record of the oldest living civilization in engineering, science and culture. Since almost the beginning of China's history there were two constant dangers to the perpetuation and prosperity of the country, viz., the invasion of the country by hordes of barbarians and the inundation of the alluvial plains of Central China by the floods of the Yellow River. These dangers were met by two of the greatest engineering feats in history—the building of the Great Wall, one of the world's wonders, and the control of the Yellow River, in which was included the Grand Canal. History records the work of the great Engineer Yu. Because of his success in controlling the Yellow River, it will be remembered, he was elected Emperor by a grateful people and has been held in reverence ever since. In our own days there is the remarkable engineering work of Dr. Jieme Tien-yu, who was educated at Yale. His success as a builder of Railways under extraordinary engineering difficulties without foreign assistance placed him as one of the foremost, if not the foremost, of Asiatic engineers of recent times. His recent death at Hankow was a national loss.

The contribution of China to the world's store of scientific knowledge and progress, such as the compass, printing and gun-powder, is too well known to require more than mention. The return by Germany of the stolen astronomical instruments as provided for under the terms of the peace treaty invites attention to the early advances made by China in the study of the heavenly bodies.

In art, literature and philosophy the Oriental nations have gone to school at the knees of China. Chinese art has powerfully influenced that of the West. The philosophy of Confucius contains the wisdom of the world although twenty-five centuries have elapsed since that sage wrote his classics.

A few weeks ago I had the pleasure of lunching with his 75th lineal descendant. That link with the remote past is an astonishing fact. It is difficult for those nations with relatively short histories to realize the continuity of Chinese history and civilization. The annals of ancient China appear in their true and hoary perspective only when compared with dates and events with which we are familiar.

For instance, Confucius was a contemporary of the last of the fabulous line of Roman Kings. His was a great name in the land before the battles of Thermopolae and Marathon were fought. Confucius lived nearly two centuries before the Great Age in Greece; before the Parthenon was built and before Xenophon wrote his Anabasis. Still longer a time was to elapse before Alexander was to conquer the world. Uninterruptedly Chinese history goes back two thousand years before Confucius. Not so sure and authentic as it might be, however, until coming down the ages, we reach the 18th Century B.C., when the Shang dynasty ruled China and kept at bay the Huns on the Northern and Western frontiers.

If I appear to dwell unduly upon Chinese history and chronology, it is because I wish to emphasize the fact that modern Chinese development has its roots deep in the past. This ancient civilization which has persisted in all its essential features and has resisted the shocks of time and wars for over 4000 years is a vigorous stock on which the stem of present day culture is grafted. Intellectually then we might expect to find and do find the Chinese people the equal of any of the more modern peoples. Chinese students who have been trained abroad exemplify this fact. American educators with whom I have spoken confirm my own experience that the average ability of Chinese students in the United States is high and the attainments of some of them are exceedingly brilliant. I would not have it understood that American students suffer by comparison, for Chinese students I fancy on the whole are selected and sent here or abroad for special reasons.

These men on their return have made the best possible use of the knowledge they have acquired abroad. Returned Chinese have been numerically weak but mighty in patriotism. They were the first revolutionists and largely brought about the Republic of China.

In engineering and industry lie the best material opportunities for the future constructive efforts of those Chinese who have had a foreign training. In these spheres of activity they can render immense service to their country, for both are essential to the upbuilding of a powerful nation.

On account of her unparalleled natural resources, China has been called the commercial prize of the world and as such has been exploited by the commercial nations. Her possibilities as an industrial country are greater and infinitely more important to China herself. For within herself and for herself if she wishes lies the largest single market of the world. Her labor is tractable, intelligent and low-priced. With Chinese labor and supervision in co-operation with American experience, industry in that country offers unexampled opportunity for capital investment and the employment of high-class Chinese assistance. There should theoretically be no easily reached limit to the industrial development of China. The cost of unit-production is so low that China does not need a tariff for protection however great the need for revenue may be and however great the justice of a tariff of her own making without interference from other nations.

America takes a very friendly interest in China and has shown that interest for the past sixty years. The first great foreign advisor to China was Anson Burlingame, a man held in grateful remembrance today. Then came that versatile diplomat, Rockhill, who always upheld China's cause. For five years this country has been represented by a scholarly man whose name does not suffer by comparison with that of any diplomat who has ever gained the good-will, respect and confidence of the Chinese Government, Dr. Reinsch. Those interested in the welfare of China have learned with regret of his recent resignation as Minister to China. His withdrawal from Peking will be a blow to American interests in that country.

In the last few months there has been a good deal of public discussion of China. Some of it has been intelligent and illuminating; some of it wide of the mark and misdirected. On the whole this discussion has contributed to a better understanding of China and her problems. As a result, the merely friendly interest of America has been changed to one that promises to be beneficial and of practical value to China. The active interest and good wishes of America and other nations will avail most when, as the President of the United States has suggested, in a spirit of the utmost friendship, China composes her internal differences. The pressure of international forces working today upon all countries, especially the weaker ones, makes it necessary, if China is to become again as she was in the past the most powerful nation on the Asiatic Continent, that she present a unified front to the world.

No nation has been powerful that has not possessed the consciousness of nationalism. Without that the strength of a nation is as a rope of sand. In the past nationalism has largely gone hand in hand with the martial spirit, and it is not likely that this spirit will be replaced by cosmopolitanism, at least not for a long while. Fortunately the spirit of democracy is leavening the world. The people of China have always been democratic at heart and for many centuries were warlike. Observers of far Eastern conditions state that the dormant martial spirit is now awakening.

What is more important China is now struggling to become truly republican. That is the initial step towards a great China.

No one realizes this better than those Chinese who have been trained in America and have absorbed its political ideas. On these students then falls the responsible duty of upholding and applying at all costs the democratic principles on which the Republic of China was founded.

Centrifugal Compressor Installation at Newport News Shipbuilding and Dry Dock Co.

By Dr. L. C. Loewenstein

Turbine Engineering Department, Lynn Works, General Electric Company.

This article describes an unusual installation of a turbine driven centrifugal [illegible] output of an existing reciprocating air compressor plant. The turbo compressor is operated [illegible] steam from the reciprocating engines and precompresses the air delivered to the reciprocating [illegible] The output of the compressor plant was in this way increased by about 30 per cent with [illegible] additional expenditure for fuel, as the reciprocating engines were operated non-condensing, a portion [illegible] steam being exhausted to the air.—Editor.

A very novel installation of a centrifugal compressor has been made at the plant of the Newport News Shipbuilding and Dry Dock Company, Newport News, Va. It is probably the first time in this country, and, as far as we know, the first time anywhere, that a centrifugal compressor has been installed for precompressing the air supplied to the cylinders of a number of reciprocating compressors in order to increase their output.

The original installation of reciprocating compressors was found to be inadequate for supplying the shipyard with enough air at 100 lb. pressure to take care of the demand. Most of this air was used in air-riveting hammers, and the remainder in usual work demanding compressed air about a plant of this kind. In April, 1915, a centrifugal compressor was installed which was to take atmospheric air and compress it to about 24 lb. per sq. in. pressure. This compressed air is delivered to an air cooler, and after proper cooling is admitted to the intake of the air cylinders of the reciprocating compressors. The previous total capacity of all four of the reciprocating compressors was 7820 cu. ft. of free air. By the new arrangement, the admission of compressed air into the intakes of only three of the reciprocating compressors increased their air delivery to

TABLE I

INITIAL PERFORMANCE OF RECIPROCATING COMPRESSORS

	Unit No.	Stroke	Cylinder Diameter: Steam H.P.	Cylinder Diameter: Steam L.P.	Cylinder Diameter: Air L.P.	Cylinder Diameter: Air H.P.	R.P.M.	Cu. Ft. Displacement	Cu. Ft. Free Air
Ingersoll-Sargeant	1	24	22		30.00	18.25	94	1800	1530
Laidlow-Dun-Gordon	2	30	24	44	36.00	22.00	86	3000	2550
Laidlow-Dun-Gordon	3	30	24	44	36.00	22.00	86	3000	2550
Ingersoll-Sargeant....	4	36	14	26	22.25	13.25	94	1400	1190
Total air, cubic feet, per minute..									7820

TABLE II

PERFORMANCE AFTER INSTALLATION OF CENTRIFUGAL COMPRESSOR

	Unit No.	Stroke	Cylinder Diameter: Steam H.P.	Cylinder Diameter: Steam L.P.	Cylinder Diameter: Air L.P.	Cylinder Diameter: Air H.P.	R.P.M.	Cu. Ft. Displacement	Cu. Ft. Free Air
Laidlow-Dun-Gordon	2	30	24	44	32.00	22.00	86	2360	4030
Laidlow-Dun-Gordon.	3	30	24	44	32.00	22.00	86	2360	4030
Ingersoll-Sargeant...	4	36	14	26	20.00	13.25	94	1190	2030
Total air, cubic feet, per minute									10,090

10,900 cu. ft. of free air; and by running the fourth reciprocating compressor the total possible output is increased to 11,620 cu. ft. of free air.

Fig. 1. Mixed Pressure Curtis Turbine-driven Centrifugal Compressor

Another very interesting feature is the driving of the centrifugal compressor by the exhaust steam of the reciprocating blowers, as these were designed to operate non-condensing. The steam turbine driving the centrifugal blower is, therefore, primarily taking steam at a few pounds above atmosphere and exhausting it into a condenser. The turbine, however, is provided with high-pressure steam should the low-pressure steam supply fail or be insufficient.

The original plant equipment consisted of the reciprocating type air compressors listed in Table I.

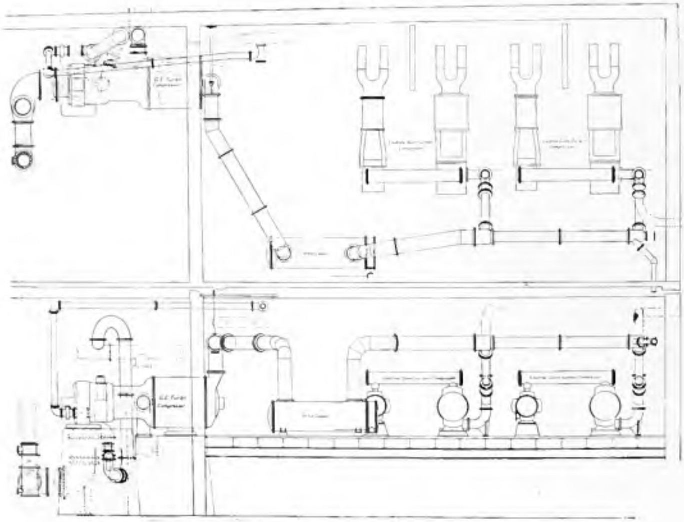

Fig. 2. Plan and Elevation of Installation of Curtis Turbo Centrifugal Compressor

With this equipment the air pressure was 90 lb. per sq. in. The engines were operated non-condensing on 120 lb. per sq. in. initial steam pressure and 3 lb. per sq. in. gauge back pressure. The exhaust steam from the engines was partly used in a low-pressure turbine generator and the remainder wasted to atmosphere.

The centrifugal air compressor was installed to supply air at about 20 to 21 lb. gauge pressure to the reciprocating compressors and to supply air directly for the pipe [illegible] forges. The centrifugal compre[illegible] Fig. 1, has four stages and is capable of supplying 11,500 cu. ft. of atmospheric air per minute against 21 lb. per sq. in. pressure. The compressor is driven by a two-stage Curtis steam turbine of the mixed-pressure type. The turbine is arranged to use all the available low-pressure steam from the exhaust of the reciprocating air compressors and other sources, except for the steam supplied to a

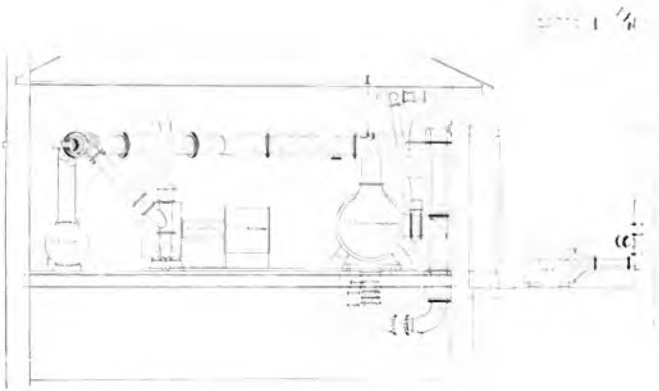

Fig 3. End Elevation of Turbo Compressor Installation

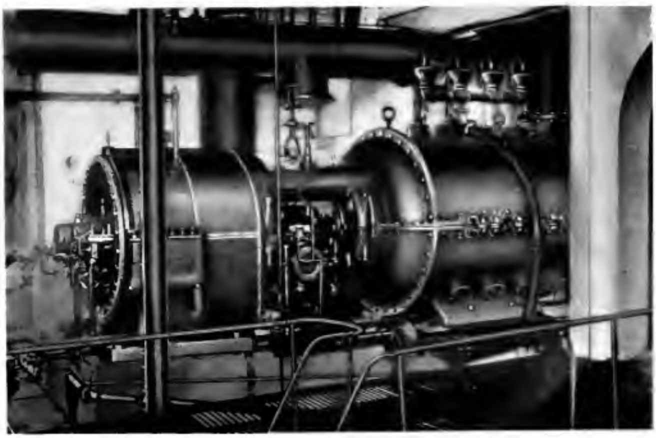

Fig. 4. Photograph of the Turbo Compressor as Installed

small low-pressure turbine-generator set. If, at some time, there is not a sufficient supply of low-pressure steam, the governor on the turbine driving the compressor will automatically admit sufficient high-pressure steam to carry the load. A concrete conduit is provided to supply clean air from outside the engine room to the centrifugal compressor. An inter-cooler is located between the centrifugal compressor and the reciprocating compressors to cool the compressed air before it enters the reciprocating compressors. The low-pressure air cylinders of the two Laidlow-Dun-Gordon compressors and the smaller of the two Ingersoll-Sargeant compressors were bushed so as not to overload the steam cylinders and to more nearly balance the work between the low-pressure and the high-pressure cylinders.

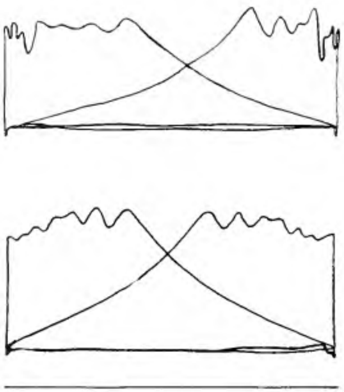

Fig. 5. Indicator Diagram Taken on Smaller Ingersoll-Sargent Compressor Before Installation of Turbo Compressor

The rearrangement of the plant with the installation of the centrifugal air compressor supplying air, at 20 lb. pressure and 150 deg. F. temperature, to the reciprocating compressors gave the outputs listed in Table II.

The larger of the Ingersoll-Sargeant compressors was not arranged to receive air under pressure as it was planned to operate this unit when the load was very light or as a spare unit, the centrifugal and the other reciprocating compressors being shut down.

By comparing the tabulations giving the outputs before and after the installation of the centrifugal compressor, it will be noted that the total output of high-pressure air is increased from 7820 to 11,620 cu. ft.

In the operation of the plant during regular working hours it was planned to operate only two Laidlow-Dun-Gordon compressors to carry the normal load, which would give 8060 cu. ft. of air per minute at 90 lb. pressure; and in this case there would be available for use in the forges and ovens any quantity up to about 3000 cu. ft. of air per minute at 20 lb. pressure supplied from the centrifugal compressor.

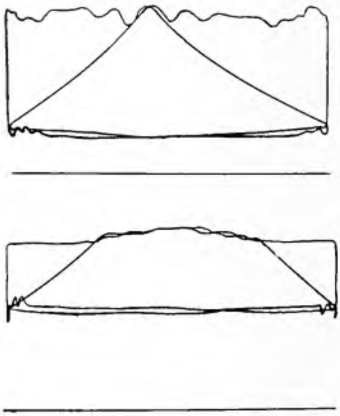

Fig. 6. Indicator Diagram Taken on Smaller Ingersoll-Sargent Compressor After Installation of Turbo Compressor

The general layout of the compressor plant is shown in Figs. 2 and 3. The installation of the centrifugal compressor is shown in Fig. 4.

Fig. 5 shows the indicator diagram taken on the smaller Ingersoll-Sargeant compressor in its original condition taking air at atmospheric pressure. Fig. 6 shows the indicator diagram taken on this compressor after the low-pressure cylinder was bushed and receiving air at 20 lb. pressure. The indicated air horse-power was slightly greater after the change, but not enough to affect the operation as the steam cylinders had sufficient power to take care of slight variations.

The Arrangement of Electrons in Atoms and Molecules

PART III

By Irving Langmuir
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*In this, the concluding installment, the author deals with the application of [illegible] to the compounds of sodium, magnesium, aluminum, silicon, phosphorus, sulphur and chlorine [illegible] in its simplest form will not, however, apply to elements of higher atomic weight than [illegible] author discusses in what respects his theory has to be modified to fit the [illegible], which are [illegible] by the ordinary theory of valence, but for which a theory has been developed by Werner. [illegible] points out the relation between his theory and that of Werner, showing that what he designates [illegible] is identical in most cases with Werner's co-ordination number.—*Editor.

Second Short Period

The atoms of the elements beyond neon easily give up electrons and revert to the form of neon. The first two elements *Na* and *Mg* have properties which are practically wholly dependent on this giving up of electrons. With increasing numbers of electrons the larger electrostatic forces make it more and more difficult for the atom to revert to that of neon, but tend rather to make the atom take up additional electrons to form a structure like that of argon. According to ordinary potential theory electrons uniformly distributed throughout a spherical shell should exert no forces on electrons inside the shell, but should repel those outside the shell as though the electrons in the shell were concentrated at the center. On the other hand, an electron in the spherical shell itself is repelled by the others in the shell as if one half of the other electrons were removed altogether, while the second half were concentrated at the center. Thus let us consider a carbon atom ($N=6$) which has taken up four extra electrons and has completed its octet. An electron in the outside shell is thus attracted by the nucleus which has six positive charges, is repelled by the two electrons in the first shell as though they were concentrated at the center, and is repelled by the electrons in the outside shell as if four of them were concentrated at the center. The repulsion of the electrons is thus only just able to neutralize the attraction by the nucleus nothwithstanding the fact that the whole atom has an excess of four negative charges. If, instead of taking carbon, we had considered nitrogen, there would have been a large resulting force tending to hold the electrons even after three extra ones had been taken up by the atom. These considerations indicate one of the reasons why the symmetrical arrangements of electrons corresponding to the inert gases have such very great stability and why the elements like oxygen and especially fluorine have such very great tendencies to take up electrons.

According to the above calculation, carbon might just be able to hold four electrons, while boron could not do so. In the crude theory just given, however, we have neglected to take into account the formation of pairs when electrons are shared between octets or between these and hydrogen nuclei. This will greatly increase the tendency of an atom like that of carbon to take up electrons to complete its octet. For this reason we also find a few boron compounds such as HBF_4, metaboric acid, etc., in which the boron atom has an octet. These same arguments apply to such elements as aluminum and silicon.

Atomic Volumes

The properties of the elements lithium, beryllium, and boron are not closely related to those of sodium, magnesium and aluminum as these are to potassium, calcium and scandium. Instead we find very marked resemblances between lithium and magnesium, beryllium and aluminum, and boron and silicon. These differences and similarities are due, I think, to the small atomic volumes of lithium, beryllium and boron in their compounds. Before considering these elements individually a discussion of atomic volumes will not be out of place.

The periodic relationships between the atomic volumes of the elements are usually based on the volumes of the free elements in solid or liquid form.* Because of the radically different structures which occur among these substances these measurements give very little information in regard to the real volume of the atoms. Thus the structure of fluorine with its diatomic molecules is so different from that of metallic sodium that

* Tables and curves giving these atomic volumes have been given by Harkins and Hall, *Jour. Amer. Chem. Soc.*, 38, 196 (1916).

effects due to the difference in constitution may mask any real changes in the volume of the atoms. This difficulty is largely avoided if we consider the volumes of the atoms in the form of similarly constituted compounds.

In view of the very great stability of the octet in neon it seems probable that the volume of this octet is not materially different from the complete octets in the fluorine and sodium ions. The closeness to which two octets can be made to approach each other, however, should depend on how great the forces are which draw them together. In liquid neon these forces are weak, so the atoms should be at comparatively great distances. The atomic volume (*i.e.*, atomic weight divided by the density of the liquid) of neon is 19.2. Sodium fluoride consists of sodium and fluorine ions held together in a space lattice by the positive and negative charges. Both ions contain complete octets which differ from those of neon only because of the slightly different charges on the kernels. It may be assumed that the fluorine and sodium octets contribute equally to the molecular volume of sodium fluoride which is 15.2. Thus while in liquid neon the volume was 19.2 in sodium fluoride the volume occupied by each octet is 7.6. It is probable that the volume of the octet itself, that is, the volume of the cube formed by the electrons, is not materially different in the two cases but the strong forces in the sodium fluoride draw the octets closer together. Magnesium oxide whose molecular volume is 11.0, consists of oxygen atoms with a double negative charge and magnesium atoms which have lost two electrons—in both cases giving a simple octet with a structure like that of neon. The volumes occupied by each octet is thus 5.5 as compared to 7.6 in sodium fluoride and 19.2 in liquid neon. These results give a measure of the extent to which octets may be made to approach each other more closely by strong forces. Comparing magnesium oxide and sodium fluoride the relative distances between the atoms are as the cube roots of their volumes or as 1 is to 1.114. The ratio of the forces acting between the atoms, taking account of the double charges of the magnesium and oxygen atoms, is as 1 is to 4.98. Thus for a five-fold increase in the force the volumes occupied by the octets has decreased 27 per cent (7.6 to 5.5). The atomic volume of metallic sodium is 23.7 greater than even that of neon, notwithstanding the fact that the charges on the electrons and the positively charged sodium ions might be expected to exert strong attractive forces compared to those in liquid neon. It is not reasonable to suppose that the actual volume of the octet of the sodium atoms in metallic sodium is much different from that in sodium fluoride. The large volume of metallic sodium must then be due to a specific repulsion between a completed octet and a single free electron which keeps the electron from approaching the octet. It is probable that this same repulsion is the cause of the remarkable and apparently perfect elasticity of the collisions between electrons and the atoms of the inert gases, or nitrogen.* The fact that nitrogen is similar to the inert gases in this respect is additional confirmation of our theory that the nitrogen molecule has a single octet.

It is especially interesting to compare the volume of sodium fluoride with that of metallic sodium for in each case the substance is held together by the forces between particles having unit charges. The volume occupied by the sodium ion in sodium fluoride is 7.6. The free electron in metallic sodium increases this to 23.7 so that the electron seems to require a volume of 16.1 or more than twice that of the octet. However, the effect is probably not quite as great as this for the distance between the positive and negative charges in sodium is some 15 per cent greater than in sodium fluoride. The actual space lattice arrangement of the atoms also needs to be known and taken into account in any proper treatment of this subject. From the molecular volume of magnesium oxide it appears that the atomic volume of the octet is less than 5.5—it is reasonable to assume that with much larger forces it might approach a limiting value of about 4.0. The volume of a single neon octet is thus 6.1×10^{-24} cubic cm. corresponding to a cube having an edge of 1.9×10^{-8} cm.

Assuming the electrons and the sodium ions in metallic sodium to be arranged like the ions of chlorine and sodium in a crystal of sodium chloride, we find that the distance between their centers must be 2.7×10^{-8} cm. Presumably at distances shorter than this the repulsive forces between a single electron and an octet more than compensate for the attraction between oppositely charged univalent ions.

According to this view the large atomic volumes of the alkali metals are due to the volumes occupied by single free electrons rather than to a large volume of the atom as such.

* Franck and Hertz, Verh. deut physik Ges., *15*, 929 (1913).

Magnesium, although there are two free electrons for each atom, has an atomic volume of 14.0, only a little more than half that of sodium. Comparing this with magnesium oxide, of molecular volume 11, it is clear that the electrons contribute much more to the volume of the metal than does the octet of the oxygen in the oxide. It is probable that the two free electrons form a more or less stable pair and are thus able to occupy a smaller volume than the single electron in sodium.

The atomic volumes of the elements increase at first about in proportion to the atomic numbers and then more slowly. For example, the atomic volumes of the free alkali metals are *Li*, 13.1; *Na*, 23.7; *K*, 45.5; *Rb*, 56.0, and *Cs*, 69.8. The volumes in their compounds are seen from NaF, 15.2; KCl, 37.4; $RbBr$, 51.4, and CsI, 57.5. In these compounds the two elements are chosen so as to have as nearly the same atomic numbers as possible. Half of these quantities should give a measure of the maximum atomic volumes of the inert gases lying between them. In this way we find *Ne*, 7.6; *Ar*, 18.7; *Kr*, 25.7, and *Xe*, 28.7. The molecular volume of lithium fluoride is only 10.0, while that of the fluorine atom alone in sodium fluoride is apparently 7.6. The atomic volume of the lithium nucleus must thus be very small, probably about 2.4. The same rapid increase in atomic volume between the first and second period is observed with the elements in the middle of the period, thus: *B*, 4.7; *Al*, 10.4, and *C*, 3.4; *Si*, 11.7.

It seems as though the total volume of the atom tends at first to increase in proportion to the number of electrons. This means that the cells of Postulate 3 have the same volumes even in different atoms in spite of the increasing attraction of the nucleus. However, with larger atomic numbers the rate of increase of volume is much less, and with certain elements like osmium notwithstanding the high atomic number, the atomic volume is so small (8.5) that the hypothesis of constant cell volume seems untenable. It should be noted that the elements of small atomic volume are those in which there are larger numbers of electrons in the outer shell held by attractive forces (Postulate 6) to the underlying electrons. When there are either too few electrons, or when the electrostatic forces predominate, the atomic volume increases.

Let us now continue with a discussion of the properties of individual elements.

Sodium $N = 11$; $E = 1$. The properties are determined almost solely by the ability of the atom to give up one electron. It is much more electro-positive than lithium because its atomic volume is greater so that the force with which it holds its electron is smaller.

Magnesium $N = 12$, $E = 2$. The properties are largely dependent on the ability to give up two electrons. The double charge makes this process more difficult than with sodium. There is thus a greater tendency to form insoluble salts and for hydrolysis to occur. Lithium, because of its small volume, holds its electrons more firmly than sodium and for this reason resembles magnesium in the solubility of its salts, etc. Magnesium has no tendency to form an octet.

Aluminum $N = 13$, $E = 3$. The difficulty of giving up three electrons to form a positive ion leads to marked hydrolysis and to a tendency to form insoluble salts. In compounds with oxygen, aluminum probably forms an octet as, for example, $KAlO_2$. If we place $n = 3$, $e = 16$, we find $p = 1$ and are led to the formula $K^+ (O = Al = O)^-$. Beryllium with only two electrons in its outside shell, has a kernel of such small volume that it holds its electrons nearly as firmly as aluminum and therefore resembles aluminum in the solubility of its salts and in other ways.

Silicon $Si = 14$, $E = 4$. This element is no longer able to form positive ions but like carbon forms practically only compounds in which its atoms have octets. Boron owing to its small volume holds its electrons about as firmly as silicon and therefore resembles this element.

The chemistry of silicon compounds is complicated by the marked tendency to form second order compounds. The great number of silicates found in nature seem to be compounds of SiO_2 with other oxides. The octet theory is applicable to the formation of SiO_2 and each of the other oxides but not to the minerals resulting from their combination. By far the greater number of such compounds exist in the solid state only. The number of molecules of each of the oxides that can combine together in this way to form crystalline solids is determined mainly by purely geometrical considerations. The writer has already discussed compounds of this kind at some length* and Sosman† has developed a similar theory.

A compound like H_2SiF_6 differs from those we have just considered in that it exists in

* Jour. Amer. Chem. Soc., 38, 2241 (1916).
† J. Ind. Eng. Chem., 8, 985 (1916).

aqueous solutions. The formation of such compounds is explained by Werner's theory of supplementary valence, but without leading to a definite conception of the mechanism

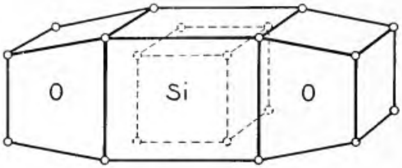


Fig. 14.

Diagram of Silicon Dioxide

of the combination. We have seen that fluorine has a particularly strong tendency to take electrons outright rather than to share them with other atoms. Thus when fluorine reacts with silicon, four fluorine atoms take the four electrons from a single silicon atom. The fluorine ions are then held by electrostatic forces and surround the positively charged silicon kernel probably in a tetrahedral arrangement, but without sharing electrons. The electric field is thus almost entirely enclosed within the molecule so the substance SiF_4 is a gas of rather low boiling point. The silicon kernel having as its second shell an octet like that in neon, has a cubic symmetry. There is thus a tendency for the kernel to take up six rather than four fluorine ions since these ions can fit opposite the six faces of the cube in a very symmetrical way. It may at first seem that a quadrivalent positive ion could not hold six negative ions by electrostatic forces but close examination indicates that this arrangement should be possible. Let us assume that a silicon kernel has taken up six fluorine ions to form the complex ion SiF_6^{--}. What are the forces acting on each fluorine atom? Let us imagine the fluorine ions at the six corners of a regular octahedron with the silicon ion at its center. We will take the distance from the center to the corner of the octahedron as the unit of length. Let us consider the forces acting on one of the fluorine ions which we will denote by A. The attractive force between A and the quadrivalent silicon ion is four. The repulsion force between A and the fluorine ion furthest from A is one fourth since the distance is two. Each of the other four fluorine ions is at a distance $\sqrt{2}$ from A so that the force is one half. But the component in the direction towards the center is only $1/(2\sqrt{2})$. The four fluorine ions thus exert a total replusive force of $2\sqrt{2}$ or 1.41. All five thus repel the ion A with a force $1.41 + 0.25 = 1.66$, while the silicon atom attracts it with a force of four. Thus notwithstanding the negative charge on the complex ion as a whole, each fluorine ion is attracted to the central nucleus as strongly as it would be to a simple positive kernel having a charge of 2.34 units. The SiF_6^{--} ion can exist as such in solution or can attach to itself two hydrogen ions to form H_2SiF_6.

This simple theory indicates how compounds with a co-ordination number of six can be formed because of purely geometrical and electrical factors. The forces causing such combinations as well as those holding complex silicates, etc., together, will be referred to as secondary valence forces.

The marked contrast between silicon and carbon in their tendencies to form second order compounds is probably due to the larger volume of the kernel of the silicon atom. This probably greatly decreases the tendency of the silicon atom to hold an octet when combined with oxygen as SiO_2. We may picture a molecule of SiO_2 diagrammatically as in Fig. 14. When a second octet forms around the silicon kernel it would normally have a larger spacing between its electrons than those usual in an oxygen atom. When the silicon and oxygen atoms hold two pairs of electrons in common the electrons of the silicon atom are drawn over towards the oxygen. This exposes the positively charged silicon kernel so that a large external field results. This effect is like that caused by the double and especially the triple bonds in organic compounds. There is a continuous series of gradations between a structure of this kind and one in which two oxygen atoms, each with a double negative charge, are held electrostatically by the positively charged silicon kernel. In either case, however, the oxygen atoms because of their small number and small volume are not able to surround the silicon kernel and make its field nearly all internal as is the case in the carbon dioxide molecule. The large external field thus causes molecules of SiO_2 to be held very firmly to each other or to any other similarly constituted oxides. On the other hand, when oxygen atoms completely surround a kernel of small volume as, for example, in osmium tetroxide, the weak external field causes the substance to have a low boiling point (about 100 deg. for OsO_4). When the silicon atoms combine with the halogens or with hydrogen the larger number of these atoms allows them more nearly to surround the silicon atom and this leads to the formation of liquid and gaseous products, in which secondary valence forces are much less manifest.

Phosphorus $N = 15$, $E = 5$. The phosphorus atom like that of nitrogen has five electrons in its shell. The peculiar arrangement by which two nitrogen atoms form a molecule with a single octet containing an imprisoned pair of electrons is impossible in the case of phosphorus because of the complexity and large volumes of the kernels. Phosphorus therefore cannot form molecules of the composition P_2 except by the structure $P \equiv P$. It also cannot form P_3 for this involves an odd number of electrons. Let us examine by the octet theory the possibility of forming P_4. Here $n=4$, $e=20$ and $p=6$. The only reasonable ways in which four atoms can be arranged sharing six pairs are represented by

$$P=P=P=P \text{ and } \begin{array}{ccc} P & - & P \\ \| & & \| \\ P & - & P \end{array}$$

Phosphorus vapor actually has the composition P_4. It is probable from reasons of symmetry that its molecule is represented by the second of the above formulas as indicated in Fig. 15.

Let us now apply the octet theory to the various typical compounds of phosphorus. It will be seen that in every case results are obtained in full agreement with the properties of the compounds without any special assumptions in regard to valency. The structural formulas obtained are in most cases quite different from those derived from the ordinary theory.

Phosphorus Hydrides P_4H_2, $n=4$, $e=22$, $p=5$. This gives by analogy with P_4 the formula

$$\begin{array}{ccc} P & = & P \\ | & & | \\ HP & - & PH \end{array}$$

For phosphine PH_3, $n=1$; $e=8$; $p=0$, hence PH_3.

For liquid hydrogen phosphide P_2H_4, $n=2$; $e=14$; $p=1$, hence H_2P-PH_2.

Phosphorus Oxides. The *suboxide* P_4O gives $n=5$; $e=26$ and $p=7$ for which by analogy with P_4 we find the structural formula to be

$$\begin{array}{ccc} P & = & P \\ | & & | \\ P & = & P-O \end{array} \text{ or } \begin{array}{ccc} P & = & P \\ | & & | \\ P & - & P=O \end{array}$$

The *trioxide* has a vapor density corresponding to P_4O_6. This gives $n = 10$, $e = 56$ and $p = 12$. Since this oxide is obtained by the partial oxidation of P_4 and from reasons

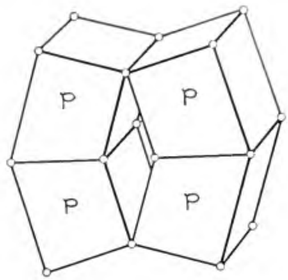


Fig. 15.

Diagram of the Phosphorous Molecule P_4

of symmetry it is probable that its constitution is

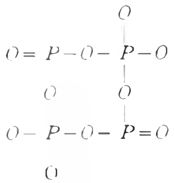
$$\begin{array}{ccccc} & & & & O \\ & & & & | \\ O= & P & - & P & -O \\ & | & & | & \\ O- & P & - & P & =O \\ & | & & & \\ & O & & & \end{array}$$

In this formula there are 12 pairs of electrons held in common in accordance with $p=12$. Each phosphorus atom not only has its octet, but has all four pairs of electrons in each of these octets shared by other atoms. We shall see that in practically all phosphorus compounds just as in carbon compounds there is a strong tendency for the four pairs in the octet of the central atom to be shared. In fluorine we have noticed just the opposite tendency, namely, not to share any of the pairs with the other atoms.

If we represent a molecule of the trioxide by P_2O_3 its constitution can be written $O=P-O-P=O$. This should be rather unsaturated as compared to the ring since only three pairs of electrons around each phosphorus atom are shared. This formula, however, shows the relationship of the trioxide to the acids of phosphorus better than the ring formula. A reasonable transition between the two structures is

$$\begin{array}{ccccccc} O- & P & -O- & P & -O \\ & \| & & \| & \\ O- & P & -O- & P & -O \end{array}$$

Phosphorus Pentoxide. The vapor density indicates the formula P_4O_{10}. This gives $n=14$; $e=80$ and $p=16$. From its derivation form P_4O_6 the most probable constitution is



If the formula of the pentoxide is taken as P_2O_5 we can write its formula $O=\overset{O}{P}-O-\overset{O}{P}=O$. It is readily seen that the octet theory indicates that no oxides higher than the pentoxide should exist.

Acids of Phosphorus. The following table shows the constitution of the various acids as given by the octet theory.

The constitution as determined from the values of p are shown more clearly in Fig. 16. In each case all four pairs of the phosphorus octets are shared by the adjacent atoms. It is significant that these formulas give correctly the number of replacable hydrogen atoms. Thus hypophosphorous acid is a monobasic acid, while phosphorous and pyrophosphorous acids are dibasic. This is readily explainable by the formulas for it is seen that in the first case two of the hydrogen atoms and in the other cases one atom is bound directly by each phosphorus atom and therefore does not show acid properties.

Phosphorus Chlorides. For the trichloride PCl_3, we find $n=4$; $e=26$ and $p=3$. The phosphorus octet thus shares a pair of electrons with each of the three chlorine atoms. Here is one of the few cases in which the phosphorus atom does not share four pairs. It is readily seen from the octet theory, however, that phosphorus could not form a compound PCl_4. Since the chlorine atoms can nearly surround the phosphorus atom and each atom has its octet, the trichloride molecule has a weak external field and hence has a fairly low boiling point (76 deg.).

For phosphorus pentachloride PCl_5 we place $n=5$; $e=40$; $p=o$. This leaves the phosphorus kernel without an octet, the five chlorine ions being held by electrostatic attraction. The external field is weak and the substance evaporates easily. The tendency of the phosphorus kernel to acquire an octet even if it has to take two electrons from chlorine ions makes this compound dissociate easily into the trichloride and chlorine. If instead of placing $n=5$ we place $n=6$; then $e=40$, and we find $p=4$. The five chlorine atoms cannot share four pairs of electron with the phosphorus octet, but we can imagine that in the solid state of PCl_5 four of the chlorine ions share electrons with the phosphorus octet to form an ion $(PCl_4)^+$, while the other chlorine ion is held in the space lattice by electrostatic forces. It is perhaps probable that the

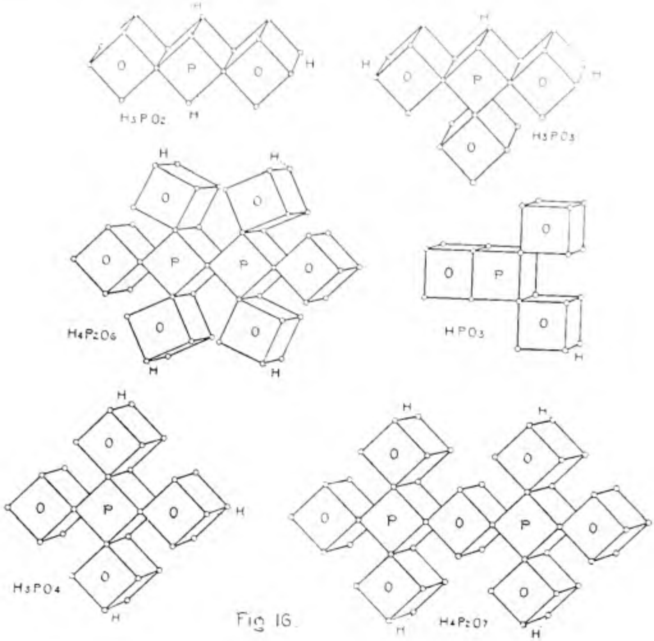
TABLE V

PHOSPHORUS ACIDS

Name	n	e	p	Constitution
Hypophosphorous H_3PO_2	3	20	2	$HO-(PH_2)-O$
Phosphorous H_3PO_3	4	26	3	$HO-(HP-O)-OH$
Pyrophosphorous $H_4P_2O_5$	7	44	6	$HO-\overset{O}{\underset{H}{P}}-O-\overset{O}{\underset{H}{P}}-OH$
Hypophosphoric $H_4P_2O_6$	8	50	7	$(HO)_2(O=)P-P(=O)(OH)_2$
Metaphosphoric HPO_3	4	24	4	$O=\overset{O}{P}-OH$
Orthophosphoric H_3PO_4	5	32	4	$(HO)_3P-O$
Pyrophosphoric $H_4P_2O_7$	9	56	8	$(HO)_2(O=)P-O-P(=O)(OH)_2$

structure of solid PCl_5 is of this kind. If so, the high melting point (148 deg.) of PCl_5 compared with PCl_3 (−112 deg.) is explained by the large electrostatic forces holding the PCl_4^+ and Cl^- ions to each other and by the symmetry of the PCl_4^+ ion. However, liquid PCl_5 is a non-conductor of electricity so that in this state only molecules of the type PCl_5 exist.

In the compound $POCl_3$ we find that all the atoms can complete their octets without



Diagrams of Molecules of Phosphorous Oxy-acids

difficulty. Thus $n=5$, $e=32$, $p=4$ so that each of the four atoms shares one pair of electrons with the octet of the phosphorus atom. This is the reason that phosphorus tends so strongly to form this type of compound with the halogens.

Sulphur $N=16$, $E=6$. Since the shell contains six electrons like that of oxygen, we might expect sulphur to form a molecule S_2. At very high temperatures, sulphur vapor has a density corresponding to this formula, but at temperatures a little above the boiling point the vapor con[illegible] is also the molecule found from cr[illegible] measurements. For this molecule the octet theory gives $n=8$, $e=48$ and $p=8$. By forming a ring compound the eight electrons can be held together by single pairs of electrons, whereas if we arrange the eight atoms in a chain there must be one double bond. The ring structure being much more [illegible] metrical is more probable. The most [illegible] metrical formulas seem to be 1, a continuous ring of eight electrons arranged in space as shown in Fig. 17. This structure allows the secondary as well as primary valence forces to be satisfied. The molecule probably draws itself together rather more compactly than shown in the figure and thus forms a very symmetrical structure resembling regular tetrahedron. 2. The second possible ring formula is

$$S-S-S-S$$

$$S-S-S-S$$

Although this has a superficial resemblance to the structures best representing the P_4 molecule, it seems unlikely that it corresponds to the constitution of S_8. We shall see that the tendency of the sulphur atoms to form chains is a characteristic property of this element.

Fig 17.

Polysulphides. The tendency by which oxygen atoms attach themselves to each other forming compounds like ozone and hydrogen peroxide, is exhibited in still great degree by sulphur atoms. Thus there is a series of sulphides of sodium represented by Na_2S_x where x may have values up to five. Placing $n=5$, $e=32$ we find $p=4$. The most probable structure is

$$Na_2^{+}\left[\begin{array}{ccccc} & & S & & \\ & & | & & \\ S & - & S & - & S \\ & & | & & \\ & & S & & \end{array}\right]^{--}$$

The octet theory thus explains the formation of the sulphides from Na_2S to Na_2S_5 and indicates that more than five sulphur atoms in the anion would require a more complicated structure.

Oxides of Sulphur. For sulphur dioxide we find $n=3$, $e=18$, $p=3$, giving the structure $O=S-O$. For the trioxide SO_3 we have $n=4$, $e=24$, $p=4$, and thus find $O=S\begin{smallmatrix}\nearrow O\\ \searrow O\end{smallmatrix}$ This is the most stable oxide because all four pairs of electrons of the sulphur octet are shared by the oxygen atoms. It is readily seen from the octet theory that the molecules $O=S\begin{smallmatrix}\nearrow O\\ \searrow O\end{smallmatrix}$ should show a tendency to polymerize to form long chains having the structure

$$\begin{array}{cccccccccccc} & O & & O & & O & & & O & & O & \\ O & S & O & S & O & S- & - & -O & S & O & S=O \\ & O & & O & & O & & & O & & & \end{array}$$

The more stable solid modification of SO_3, which consists of long fibrous crystals probably has this structure.

The very unstable sesquioxide S_2O_3 which is formed as a blue liquid or bluish-green solid, when sulphur is dissolved in liquid SO_3, at 12 deg. C., gives by the octet theory $n=5$, $e=30$, $p=5$. It thus probably has the composition $S-O=S\begin{smallmatrix}\nearrow O\\ \searrow O\end{smallmatrix}$ and may thus be regarded as persulfide of SO_3. The blue color, which indicates an unstable arrangement of electrons, is probably quite analogous to that produced by the action of hydrogen peroxide on chromates.

Persulfuric anhydride S_2O_7 is a very volatile liquid which solidifies to a mass of long needles at 0 deg. C., and decomposes readily into oxygen and SO_3 when heated. The octet theory gives $n=9$, $e=54$ and $p=9$. From this value of p and from the fact that the product is formed by an electric discharge under conditions which yield ozone, the constitution probably is

$$\begin{array}{ccccccc} & & O & & & O & \\ & & | & & & & \\ O & - & S & -O- & S & =O-O & \\ & & | & & & & \\ & & O & & & & \end{array}$$

Oxyacids. The constitutions of the ions of these acids as found by the octet theory are given in Table VI. The ions rather than the free acids are tabulated because many of the acids do not exist in the free state. In determining the value of e the charge on the ion must be taken into account.

In the more stable acids all four pairs of electrons in the octets of the central atoms are shared by the adjoining atoms.

Halogen Compounds. The most stable chloride of sulphur is S_2Cl_2 for which $n=4$, $e=26$, $p=3$. The constitution is thus $Cl-S-S-Cl$. The very unstable chloride SCl_2 has the structure $Cl-S-Cl$. The tetrachloride exists as a solid at very low temperatures and has been said to exist as a liquid at 20 deg., but dissociates rapidly with rise of temperature into chlorine and S_2Cl_2. The octet theory gives for SCl_4 $n=5$, $e=34$, $p=3$. This indicates that three chlorine atoms share pairs of electrons with the sulphur atom and form a positive ion $(SCl_3)^+$ while the fourth chlorine atom forms an ion Cl^-. Since the sulphur atom shares only three of its pairs of electrons such a compound should be very unstable. There is, however, very little evidence that it exists, except in the solid state. It is more probable that a very unstable second order compound between Cl_2 and S_2Cl_2 accounts for the experimental data.

Fluorine has so little tendency to share electrons with other atoms that it forms only one compound with sulphur, namely, SF_6. The symmetrical arrangement of the six fluorine ions opposite the six faces of the octet of the sulphur kernel, and the fact that the fluorine atom and the sulphur kernel are of about the same size, gives the compound SF_6 an extraordinary stability. As a matter of fact, this gas, notwithstanding the large proportion of fluorine in its composition, is a tasteless and odorless gas which is exceedingly stable and inert.

Another tasteless and odorless [illegible] ing fluorine is formed when [illegible] and [illegible] are brought into contact with a heated [illegible] num wire. The composition [illegible] O_2F_2. Here $n = 5$, $e = 32$ and $p = 4$. This [illegible] stitution $O - \overset{F}{\underset{F}{S}} - O$ in which each [illegible] atom shares a pair of electrons with the sulphur atom. In this case the tendency of the fluorine to share electrons has been over-

TABLE VI

IONS OF THE SULFUR ACIDS

Name of Acid	Formula	n	e	p	Constitution
Sulfurous	SO_3^{--}	4	26	3	O – S ⟨ O, O
Sulfuric	SO_4^{--}	5	32	4	O ⟍ ⟋ O S O ⟋ ⟍ O
Hyposulfurous	$S_2O_4^{--}$	6	38	5	O ⟍ ⟋ O S – S O ⟋ ⟍ O
Thiosulfuric	$S_2O_3^{--}$	5	32	4	O ⟍ ⟋ S S O ⟋ ⟍ O
Pyrosulfuric	$S_2O_7^{--}$	9	56	8	O O O – S – O – S – O O O
Dithionic	$S_2O_6^{--}$	8	50	7	O O O – S – S – O O O
Trithionic	$S_3O_6^{--}$	9	56	8	O O O – S – S – S – O O O
Tetrathionic	$S_4O_6^{--}$	10	62	9	O O O – S – S – S – S – O O O
Pentathionic	$S_5O_6^{--}$	11	68	10	O O O – S – S – S – S – S – O O O
Persulfuric	$S_2O_5^{--}$	10	62	9	O O O O – S – O – S – O O O

come by the combined tendencies of the sulphur atom to take up an octet and to share all four of its pairs of electrons with its neighbors.

Chlorine $N=17$, $E=7$. The essential differences between chlorine and fluorine seem to be due to the more strongly electronegative character of fluorine and its smaller atomic volume. Chlorine, like fluorine, tends to form negative ions, but it differs from fluorine in that it can share electrons with oxygen, especially if at the same time the molecule takes up electrons from some more strongly electropositive element. It shows a tendency like phosphorus and sulphur to share all four pairs of its electrons if it has to share any.

Oxides of Chlorine. The monoxide Cl_2O according to the octet theory has the structure $Cl-O-Cl$, since $p=2$. For the heptoxide Cl_2O_7 we place $n=9$, $e=56$ and find $p=8$, giving the structure

$$\begin{array}{ccccccccc} & & O & & & & O & & \\ & & | & & & & | & & \\ O & - & Cl & - & O & - & Cl & - & O. \\ & & | & & & & | & & \\ & & O & & & & O & & \end{array}$$

This is the most stable oxide of chlorine since each chlorine shares four pairs of electrons. The peroxide ClO_2, the least stable of the oxides, contains 19 available electrons. It is thus one of the few compounds that have an odd number of electrons. The only other compounds of this kind we have thus far considered, namely, NO and NO_2, had in each case one electron too many to form the normal structure. But ClO_2 has one electron too few to form a normal compound of the type $O-Cl-O$. The determination of its structure will be an interesting but probably difficult problem. It is significant that no oxide of chlorine corresponding to NO is known. This is probably due to the fact that a condensed structure like that of NO, CO, etc., is not possible with atoms having an octet in their kernels.

Oxy-acids. The octet theory explains immediately the chlorine oxy-acids. Thus four oxygen atoms can be successively added to the chlorine atom in hydrochloric acid. This gives the acids

$$HCl,\ HCl-O,\ HO-Cl-O,$$

$$\begin{array}{ccccc} & & O & & \\ & & | & & \\ HO & - & Cl & - & O \end{array} \text{ and } \begin{array}{ccccc} & & O & & \\ & & | & & \\ HO & - & Cl & - & O \\ & & | & & \\ & & O & & \end{array}$$

corresponding exactly to the acids

$$HN=O;\ HO-N=O;\ \begin{array}{ccccc} & & O & & \\ & & | & & \\ HO & - & N & = & O. \end{array}$$

In each case the octet theory shows why higher acids cannot be formed. In nitric acid and in perchloric acid all four pairs of electrons in the octet of the central atom are shared by the adjacent atoms.

First Long Period

Beyond argon we find that the first three elements have properties closely related to those of the second short period, but, as was already pointed out in the discussion of the structure of the atoms, these relationships largely disappear beyond titanium. From this point on we find that the octet theory does not apply at all if in calculating e we take the total number of electrons in the shell. For example, all chromic, manganous, ferric and cobaltous salts contain odd numbers of electrons. This difficulty disappears, however, if in calculating e in Equation 2 we consider only the *available* electrons. We have already discussed why only a certain fraction of the electrons should be available in these elements.

There is nothing arbitrary about this choice of the number of available electrons. In compounds of iron, chromium, manganese, etc., there are fundamental changes in the character of the compounds whenever the number of available electrons changes. Ferrous and ferric salts, for instance, even in the solid state, are as different from one another as though they were salts of different metals. Their colors, magnetic properties, chemical properties, etc., are all unmistakably different. But among the elements which precede argon there are no such differences. Thus we cannot satisfactorily divide nitrogen, phosphorus or chlorine compounds into classes according to the valence of their parent atom.

In the compounds of V, Cr, and Mn in which these elements enter the acid radical, there seems to be a tendency for the central atom to form octets, although the stability of the octet is much less than those formed by P, S and Cl. Thus we repeatedly find compounds, Na_3VO_4, Na_2CrO_4, Na_2MnO_4 and $NaMnO_4$ in which four oxygen atoms surround the central atom. Since the free atoms of these elements have little or no tendency to take up electrons to complete their octets, we must conclude that any kernel with a sufficiently large positive charge (five or more) tends to surround itself with an octet *provided all four of the pairs of electrons in this octet are shared by adjoining atoms.* Thus we may speak of any octet being stabilized by the sharing of its pairs.

Among the elements beyond argon it is common to find that a single element forms several acids corresponding to different numbers of available electrons as illustrated, for example, by Na_2MnO_4 and $NaMnO_4$. In the first compound the manganese atom has six available electrons while in the second it has seven. We must picture to ourselves the manganese kernel in the first case as consisting of a simple kernel like that of argon, having seven positive charges, holding a single electron prisoner within the outer octet that is shared by the four oxygen atoms.

It is evident that this sort of thing greatly complicates the application of the octet theory. The difficulty, however, is one that is forced upon us by the actual properties of the elements beyond titanium. Complications of this kind are observed especially among such elements as *V*, *Cr*, *Mn*, *Cb*, *Mo*, *Ta*, *W* and *U*.

Another factor that complicates the chemistry of the elements of high atomic weight is the general tendency to form secondary valence compounds, especially by the elements of small atomic volume, such as those in the so-called eighth group. All the elements of high atomic weight such as *Sb*, *Bi*, *Se*, *Te*, *I*, and *Cs*, show very marked tendencies to form secondary valence compounds. A general discussion of this field, however, would be out of place here.

Valency, Co-ordination Number and Covalence-valency

According to the octet theory each carbon atom in a molecule of an organic substance has an octet and shares all four pairs of its electrons with adjacent atoms. For organic compounds, therefore, a pair of electrons held in common by two atoms corresponds exactly to the bond in the ordinary valency theory. Among other compounds, however, this relationship does not hold. Thus the octet theory indicates that the nitrogen atom in HNO_3 shares four pairs of electrons with the oxygen atoms, in other words, the valency of nitrogen is four. To distinguish between the valency thus found and that assumed in the ordinary valence theory we shall denote by the term "covalency" the number of pairs of electrons which a given atom shares with its neighbors.

Werner's co-ordination number represents the number of atoms, or molecules, irrespective of their valency, which are arranged in space around a given atom. The *maximum* co-ordination number for carbon is four which is realized in saturated hydrocarbons and halogen compounds. In many organic substances, however, such as CO, CH_2O, the co-ordination number is less than four. From the standpoint of the octet theory, the ordinary conception of valency is not definite, but involves at least three different properties of the atoms. In tracing relationships between the elements it has usually been necessary to disregard all valencies of the elements, except the maximum positive and negative valencies. Now the maximum positive valency is a definite conception: it represents the number of electrons in the shell of the atom. Thus if the element combines with an excess of fluorine or oxygen these elements will usually take all the electrons in the shell. The maximum number of fluorine atoms or twice the maximum number of oxygen atoms thus held is a direct measure of the total number of available electrons in the shell. On the other hand, the maximum negative valency represents the number of electrons which the atom must take up to reach a stable form like that of the inert gases. Both of these conceptions are definite, although quite different. In most compounds, however, the atoms do not take up or give up electrons but rather share them with other atoms.

With carbon it so happens that the number of pairs of electrons shared by other atoms is equal to the maximum positive and the maximum negative valency. For other elements, however, there is no necessary relation between the number of pairs of electrons shared and the number of electrons in the shell of the original atom. It is for this reason that the utmost confusion occurs when the ordinary valencies are applied to inorganic compounds in which atoms share pairs of electrons.

In using the octet theory to determine the structure of inorganic compounds we determine p in Equation 2 from the total number of available electrons and make no assumptions regarding covalency. This simple theory corresponds with the known facts very much better than the ordinary valence theory, but does not yet accomplish all that could be desired in explaining why certain compounds exist, while others do not. For example, since phosphorous and nitrogen atoms contain the same number of electrons in their shells, the simple octet theory represented by Equation 2, indicates that nitrogen compounds corresponding to all known phosphorous compounds could exist and vice versa. Thus we might expect the following compounds $H_3 NO_4$, $Na_4 N_2 O_7$, $P_2 O$. Similarly because sulphur and oxygen have equal numbers of electrons in their shells we might expect compounds like OS_2, $H_2 OS_4$, OF_6 and $O_2 Cl_2$ corresponding to SO_2, $H_2 SO_4$, SF_6 and $S_2 Cl_2$ respectively.

The octet theory may be made much more useful by supplementing it by a study of the values of the *covalency* as observed for the different elements. We have already noticed that with carbon it is practically always four while with fluorine it is one or zero. Table VII gives in the column marked P a list of the values of covalency corresponding to the elements of the two short periods. The symbol $(O+)$ means that the atom does not share any pairs of electrons with other atoms but has given up one or more electrons and therefore has become positively charged as, for example, in the case of the lithium ion. The symbol $(O-)$ indicates that the atom has taken up electrons to complete its shell but does not share electrons with other atoms, as, for example, the chlorine ion Cl^-.

The values of P represent the number of *pairs* of electrons which the atom shares with other atoms. In the column marked S is given the maximum number of pairs of electrons which an atom is capable of sharing with a single other atom. The values of P shown by heavy-faced type represent the covalency which occurs in the largest numbers of compounds. Thus for nitrogen in ammonium salts, in nitrates, in $N_2 O_4$, etc., $P=4$, while in ammonia, nitrous acid, NCl_3, and many organic compounds, etc., $P=3$.

This table brings out clearly how the covalency of the elements from carbon to fluorine decreases steadily as the number of electrons approaches that of neon. With the corresponding elements of the second short period the lower limits of the covalency decrease as in the first period, but the maximum covalency remains constant at 4. Thus chlorine forms $HClO_4$, but there is no corresponding fluorine compound.

The covalence of an atom is closely related to the co-ordination number. According to Werner the co-ordination number is four in the following compounds $NH_4 Cl$, HBF_4, $H_2 SO_4$, $H_3 PO_4$, $HPH_2 O_2$, $H_2 PHO_3$, $HClO_4$, but not in HNO_3, CO_2 or $CH_2 O$. According to the octet theory the covalency of the central atom of all these compounds is four. In HNO_3, CO_2 and $CH_2 O$ one or more of the oxygen atoms is held to the central atom by two pairs of electrons, while in all the others there is never more than one pair of electrons involved in holding together two adjacent atoms. This difference between the octet theory and Werner's theory accounts for many of the cases of unsaturated supplementary valencies.

In a very great number of compounds the co-ordination number and the covalence are identical and the octet theory then corresponds exactly to Werner's theory just as for organic compounds it is equivalent to the ordinary valence theory.

TABLE VII

COVALENCY OF THE FIRST EIGHTEEN ELEMENTS

	E Electrons in Shell	P Covalency						S		E Electrons in Shell	P Covalency						S
H	1	(O+)	1	(O−)	..	..	..	..									
He	0	O	..	....	..	..	..	..	Ne	0	O	..	..	..	..	....	..
Li	1	(O+)	..	....	..	..	..	..	Na	1	(O+)	..	..	..	..	....	..
Be	2	(O+)	4	....	..	..	..	..	Mg	2	(O+)	..	..	..	..	....	..
B	3	(O+)	4	....	..	..	..	..	Al	3	(O+)	4	..	..	..	....	..
C	4	....	4	....	..	..	..	3	Si	4	(O+)	4	..	..	..	....	2
N	5	....	4	3	2	..	..	2	P	5	(O+)	4	3	..	..	....	2
O	6	....	(4)	3	2	1	..	2	S	6	(O+)	4	3	2	1	(O−)	2
F	7	....	..	....	..	1	(O−)	1	Cl	7	....	4	3	2	1	(O−)	1
Ne	0	O	..	....	..	..	..	..	Ar	0	O	..	..	..	..	....	..

A few examples will make this clear. In the compound HBF_4 we have $n=5$, $e=32$, $p=4$. Each fluorine atom thus shares a pair of electrons with the octet of the boron atom. The covalency of boron is thus four in this compound. Similarly for NH_4Cl we place $n=2$, $e=16$, $p=0$. The four hydrogen nuclei thus attach themselves to the four pairs of electrons in the nitrogen octet making the positive ion NH_4^+. Since the chlorine atom has a complete octet it exists as a negative ion. Therefore ammonium chloride is a salt resembling $NaCl$. In this case also the central atom, nitrogen, has a covalency of four. These structures correspond exactly to those given by Werner.

An interesting compound whose constitution is not given by the ordinary valence theory is $B(CH_3)_3NH_3$. Applying the octet theory we have $n=5$, $e=32$, $p=4$. Whence the structure is

$$\begin{matrix} H_3C \searrow & & \swarrow NH_3 \\ & B & \\ H_3C \nearrow & & \nwarrow CH_3 \end{matrix}$$

According to the octet theory this is a typical primary valence compound in no way different from organic compounds. It is interesting to note that in this compound the covalence of both the carbon and nitrogen atoms is four. The structure arrived at is identical with that postulated by Werner except that he assumes that the bond between the boron and the nitrogen corresponds to supplementary valence, while the others are of the primary type. The octet theory indicates that they are all of the same type.

For the compound $B(CH_3)_3$ we place $n=4$, $e=24$ and find $p=4$. But it is not possible to hold three methyl groups by four pairs of electrons. However, if we place $n=3$ we find $p=0$. The structure of this compound therefore must be $B^{+++}(CH_3)_3^-$. Since the volume of the boron atom is small compared with the methyl group and since there are enough methyl groups to surround the boron atom, the electric field will be nearly wholly internal and the substance thus has a low boiling point and is not an electrolyte.

The compound $P(CH_3)_3$ gives $n=4$, $e=26$, $p=3$ so that each methyl group shares a pair of electrons with the phosphorus atom. This compound can add itself to methyl iodide to give a compound $P(CH_3)_4I$, for which we find $n=6$, $e=40$, $p=4$. This leads to the structure $[P(CH_3)_4]^+I^-$ in which each of the four carbon atoms shares one of the pairs of electrons with the phosphorus atom. The covalency of both the carbon and the phosphorus atoms is four. The structure is quite analogous to a typical primary valence compound.

The structures of compounds like [illegible], $KBrCl_4$, $K_2Zn(CN)_4$, $Cu(NH_3)_4Cl_2$, [illegible] etc., can be found by the octet theory in the same way. As a further example let us consider the platinum-ammonia compounds. In these the platinum is divalent, that is, there are two available electrons in the shell of the atom. For the compound $Pt(NH_3)_4Cl_2$ we place $n=7$, $e=48$, $p=4$. The four NH_3 radicals are thus held directly to the platinum each sharing a pair of electrons. This allows the nitrogen and the platinum to have a covalence of four. The chlorine atoms become ions. For the compound $[Pt(NH_3)_3Cl]Cl$ we place $n=6$, $e=40$, $p=4$. The three NH_3 radicals and one of the chlorine atoms are attached to the platinum while the second chlorine forms an ion. The compound $Pt(NH_3)_2Cl_2$ gives $n=5$, $e=32$, $p=4$ so that both chlorine atoms are attached to the platinum. For $K(PtNH_3Cl_3)$ we have $n=5$, $e=32$, $p=4$. All three chlorine atoms and the NH_3 are attached to the platinum, and the potassium forms a positive ion. In K_2PtCl_4 we find $n=5$, $e=32$, $p=4$ so that all four chlorine atoms are held by the platinum while the potassium atoms form positive ions. It will be noted that in each of these compounds the covalence of the nitrogen and platinum is four. According to this theory all these compounds should be looked upon as typical primary valence compounds.

Compounds with Co-ordination Number Six. The elements of the first short period never have a co-ordination number greater than four. This is probably due to the strong tendency to complete the first octet. Among the elements of the second period silicon forms H_2SiF_6 and a few other compounds which show a co-ordination number of six even when these compounds are in solution. Aluminum forms compounds like cryolite, Na_3AlF_6 but this exists only in the solid state. Phosphorus, sulphur, and chlorine form no compounds of this kind with the exception of the compound SF_6.

The elements from titanium to nickel and the corresponding elements in the subsequent periods, have especially strong tendencies to form compounds with a co-ordination number six. With these elements there is little or no tendency to complete an octet unless all four pairs of electrons are shared, so it is not surprising that a larger number of pairs of electrons can also be taken up. We may imagine two ways in which this may occur. It is possible that a shell of twelve electrons consisting of six pairs tends to form around the central atom. We may call such a group a *disextet*. If m is the number of disextets in a molecule then we have by analogy with Equation 2

$$p = \tfrac{1}{2}(12m + 8n - e) \qquad (3)$$

We may use this equation for compounds in which one of the atoms has a co-ordination number six in the same way that Equation 2 was used for compounds with co-ordination number four.

The other way of looking at these compounds is to consider, as we did in the case of H_2SiF_6, that the central atom does not share any pairs of electrons with the surrounding atoms, but holds these by electrostatic forces. It is evident that there is no difficulty in explaining the structure of K_2PtCl_6 on the assumption that the platinum atom has four positive charges and that the six chlorine ions are held around it by electrostatic attraction. On the other hand, it is not at first apparent how groups like NH_3, H_2O, etc., can be held by electrostatic forces in compounds like $[Pt(NH_3)_6]Cl_4$ and $PtCl_4(H_2O)_2$. The groups that can enter into compounds in this way are NH_3, HO_2, HCl, PCl_3, etc., in which the covalence is less than four.

We may look upon each of these groups as consisting of a central octet to which are attached positive radicals. In the cases of NH_3, H_2O and HCl the hydrogen nucleus is the positive element. In PCl_3 the central octet has eight electrons having a kernel with only five positive charges, so that it has a net negative charge of three units. Each chlorine atom contributes to this structure six electrons and a kernel with seven positive charges, a net positive charge equal to one.

If we now assume that the positive parts of these added substances are mobile, then when the molecule is brought near a positive charge the central atom is attracted by this while the others are repelled. Thus a molecule of water normally represented by HOH, when it is brought near a positive charged ion will take the form $\frac{H}{H}O \ldots . Pt^{++++}$. This displacement of the positive charges in the water molecule causes it to be strongly attracted to charged ions, particularly those having large charges.

Because of this effect any highly charged ion, especially if of small volume, can attract molecules of such substances as H_2O, NH_3, etc. The number that can be held depends on geometrical considerations. In view of the more or less cubical form of most atoms and the symmetry with which six groups can place themselves it is not surprising that the co-ordination number of six should be so common.

By either of these theories we can account for the structure of practically all complex compounds having a co-ordination number six. The second of these theories explains also the few cases in which the co-ordination number has values other than four or six.

GENERAL CONCLUSIONS

The theory of atomic structure advanced in the present paper not only explains in a satisfactory manner the general properties and relationships of all the elements, but also gives a theory of the formation and structure of compounds which agrees excellently with the facts. It leads directly to a valence theory for organic compounds which is the exact equivalent of the ordinary theory. When applied to the structure of complex inorganic compounds it leads to a theory practically identical with that of Werner. In cases like those of the oxides of nitrogen, etc., which have not previously been explained by any theory of valence the results are thoroughly satisfactory. The structure of the nitrogen, carbon monoxide, and hydrocyanic acid molecules are accounted for and new relationships are obtained.

Under these conditions the postulates underlying the theory receive strong support. In fact, the results seem to establish the fundamental correctness of most of the postulates. The recent advances in the physics of the electron have been largely along the lines of Bohr's theory. It is generally assumed that the electrons are revolving all in one plane, in orbits about the nucleus. Such a view is wholly inconsistent with that of the present paper. Bohr's theory has had marked success in explaining and even in predicting new facts connected with the spectra of hydrogen, helium and lithium, and must therefore contain important elements of truth.

It will probably be possible to reconcile the two theories. As has already been pointed out, Bohr's stationary states have a close resemblance to the cells postulated in the present theory. The series of numbers 1, 1/4, 1/9, 1/25 occur in much the same way in both theories.

The cellular structure postulated here also seems to be closely related to J. J. Thomson's* theory of atomic structure in which he postulates tubes of force. It seems as though each cell in the present theory is analogous to the inner end of one of Thomson's cylindrical tubes of force. This view suggests that in an atom the electrons are acted on by a repulsive force inversely proportional to the cube of the distance from the nucleus and an attractive force proportional to $1/\tau^2$ where τ is the index number of the shell in which the electron is located. Thus instead of the force varying continuously, as in Coulomb's law, it varies discontinuously in proportion to 1, 1/4, 1/9, 1/25, etc., and only at large distances where τ is very large does the force vary approximately continuously. In some such way we may hope to be led to a modification of Bohr's theory in which the electrons do not rotate about the nucleus.

SUMMARY

The theory presented in this paper is essentially an extension of Lewis' theory of the "cubical atom."† It may be most concisely stated in terms of the following postulates:

1. The electrons in atoms are either stationary or rotate, revolve or oscillate about definite positions in the atom. In the most stable atoms, namely, those of the inert gases, the electrons have positions symmetrical with respect to a plane, called the equatorial plane, passing through the nucleus at the center of the atom. No electrons lie in the equatorial plane. There is an axis of symmetry (polar axis) perpendicular to this plane through which four secondary planes of symmetry pass forming angles of 45 deg. with each other. These atoms thus have the symmetry of a tetragonal crystal.

2. The electrons in any given atom are distributed through a series of concentric (nearly) spherical shells, all of equal thickness. Thus the mean radii of the shells form an arithmetric series 1, 2, 3, 4, and the effective areas are in the ratios $1:2^2:3^2:4^2$.

3. Each shell is divided into cellular spaces or cells occupying equal areas in their respective shells and distributed over the surface of the shells according to the symmetry required by Postulate 1. The first shell thus contains 2 cells, the second 8, the third 18 and the fourth 32.

4. Each of the cells in the first shell can contain only one electron, but each other cell can contain either one or two. All the inner shells must have their full quota of electrons before the outside shell can contain any. No cell in the outside layer can contain two electrons until all the other cells in this layer contain at least one.

5. Two electrons in the same cell do not repel nor attract one another with strong forces. This probably means that there is a magnetic attraction (Parson's Magneton Theory) which nearly counteracts the electrostatic repulsion.

6. When the number of electrons in the outside layer is small, the arrangement of the electrons is determined by the (magnetic) attraction of the underlying electrons. But when the number of electrons increases, especially when the layer is nearly complete, the electrostatic repulsion of the underlying electrons and of those in the outside shell becomes predominant.

7. The properties of the atoms are determined primarily by the number and arrangement of electrons in their outside shell and by the ease with which the atom is able to revert to more stable forms by giving up or taking up electrons.

8. The stable and symmetrical arrangements of electrons corresponding to the inert gases are characterized by strong internal and weak external fields of force. The smaller the atomic number, the weaker the external field.

9. The most stable arrangement of electrons is that of the pair in the helium atom. A stable pair may also be held by: (a) a single hydrogen nucleus; (b) two hydrogen nuclei; (c) a hydrogen nucleus and the kernel of another atom; (d) two atomic kernels (very rare).

10. The next most stable arrangement of electrons is the *octet*, that is, a group of eight electrons like that in the second shell of the neon atom. Any atom with atomic number less than twenty, and which has more than three electrons in its outside layer tends to take up enough electrons to complete its octet.

11. Two octets may hold one, two, or sometimes three pairs of electrons in common. One octet may share one, two, three or four pairs of its electrons with one, two, three or four other octets. One or more pairs of electrons in an octet may be shared by the corresponding number of hydrogen nuclei. No electron can be shared by more than two octets.

This theory explains the periodic properties of all the elements including those of the

* Phil. Mag., 26, 792, 1044 (1913).
† Jour. Amer. Chem. Soc., 38, 762 (1916).

eighth group and the rare earths. It meets with success in explaining the magnetic properties of the elements, and applies as well to the so-called physical properties, such as boiling points, freezing points, electric conductivity, etc., as it does to the "chemical properties." It leads to a simple theory of chemical valence for both polar and non-polar substances. In the case of organic compounds the results are identical with those of the ordinary valence theory, while with oxygen, nitrogen, chlorine, sulphur and phosphorus compounds, the new theory applies as well as to organic compounds, although the ordinary valence theory fails nearly completely.

This theory explains also the structure of compounds which, according to Werner's theory, are second order compounds with a co-ordination number equal to four. According to the present theory, such compounds are to be regarded rather as typical primary valence compounds.

This valence theory is based on the following simple equation:

$$e = 8\,n - 2\,p$$

where e is the total number of available electrons in the shells of all the atoms in a molecule; n is the number of octets forming the outside shells, and p is the number of pairs of electrons held in common by the octets. This equation is a complete mathematical statement of the primary valency requirements, not only in organic, but in inorganic chemistry.

The theory leads to very definite conceptions as to the positions of the electrons in the molecules or space lattices of compounds. The structures of molecules of N_2, CO, HCN, and NO prove to be exceptional in that the kernels of both atoms in the molecule are contained within a single octet. This accounts for the practically identical "physical" properties of nitrogen and carbon monoxide, and for the abnormal inertness of molecular nitrogen.

The results obtained by the use of the postulates are so striking that one may safely reason that the results establish the fundamental correctness of the postulates.

These conclusions, however, are not easily reconciled with Bohr's theory of the atom. Bohr's stationary states have a rather close resemblance to the cellular structure postulated in the present theory. There are also striking points of similarity with J. J. Thomson's theory of the structure of atoms, in which he assumes that the attractive forces are limited to certain tubes of force.

The Flow of Steam Through Pipes

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As the art of steam engineering was developed by the practician rather than [illegible] formulas for calculation are usually of an empirical nature. Of these formulas some [illegible] readily to accurate computation, for instance, those for the flow of steam through pipes. To fulfill [illegible] requirements more satisfactorily in this case a simplified formula with supplementary table has been derived in this article. Its application is exemplified by the solution of four different types of problem.—Editor

Some of the formulas hereinafter given were taken from "Flow of Steam in Pipes," by F. N. Hatch, *Electrical World*, Vol. 68, No. 24, December 9, 1916. Unfortunately, Mr. Hatch put his computed results in the form of a chart that is not easy to use and that is encumbered with a number of factors unnecessary in ordinary work.

Like most of the data used in steam and mechanical engineering, the formulas are approximate, so that refinement means waste of time and effort. What the engineer wants is a quick and ready means of picking out a pipe size to transmit a given weight of steam a given distance in a given time at not too great a loss in pressure. He has pounds per minute, length in feet, and initial pressure given. What size of pipe shall he use?

Babcock's formula for the flow of steam through pipes is

$$W = 87.5\left[\frac{pDd^5}{\left(1+\frac{3.6}{d}\right)L}\right]^{1/2} \qquad (1)$$

where

W = weight of steam in lb. passed per min.
p = pressure drop = $(p_1 - p_2)$ in lb. per sq. in.
D = mean density of steam in lb. per cu. ft., that is, density at $\frac{p_1+p_2}{2}$ lb. pressure per sq. in.
d = inside dia. of pipe in inches.
L = equivalent length of straight pipe.

This formula, (*1*), is derived from Unwin's formula for pressure drop, viz.:

$$p = 0.0001307\left(1+\frac{3.6}{d}\right)\frac{W^2L}{Dd^5} \qquad (2)$$

Actually both (*1*) and (*2*) are approximations from certain formulas for the flow of water through pipes. No one seems to know how nearly correct they are. Since both formulas contain the fifth power of d, a slight error in d may introduce a considerable error in the result.

It is obvious that W can also be found from D, V, the velocity at which steam travels in ft. per sec., and A, the area of the pipe in sq. ft., as follows:

$$W = 60\,VAD \qquad (3)$$

Square (*1*) and (*3*) and equate. The result is

$$(60\,VAD)^2 = (87.5)^2\left[\frac{pDd^5}{\left(1+\frac{3.6}{d}\right)L}\right] \qquad (4)$$

For A put $\frac{\pi d^2}{4\times144}$, obtaining

$$\left(\frac{60}{4\times144}\pi d^2VD\right)^2 = (87.5)^2\left[\frac{pDd^5}{\left(1+\frac{3.6}{d}\right)L}\right] \qquad (5)$$

or

$$\left(\frac{60\pi}{4\times144}\right)^2V^2D = (87.5)^2\left[\frac{pd}{\left(1+\frac{3.6}{d}\right)L}\right] \qquad (6)$$

whence

$$p = \left(\frac{60\pi}{4\times144\times87.5}\right)^2\left[\frac{1+\frac{3.6}{d}}{d}\right]V^2DL \qquad (7)$$

which is merely another form of (*2*), and may be written

$$p = kV^2DL \qquad (8)$$

where k is a constant for any value of d.

It follows from (*8*) that

$$V = c\left(\frac{p}{DL}\right)^{1/2} \qquad (9)$$

where

$$c = \left(\frac{1}{k}\right)^{1/2} = \left[\frac{1}{0.000014}\left(\frac{d}{1+\frac{3.6}{d}}\right)\right]^{1/2} \qquad (10)$$

Putting the value of V from (*9*) in (*3*), the value of W is

$$W = 60\,Ac\left(\frac{pD}{L}\right)^{1/2} = m\left(\frac{pD}{L}\right)^{1/2} \qquad (11)$$

The value of $m = 60\,Ac$ may be computed once for all for each pipe size.

It is evident that, for any given length of any given size of pipe, W varies as $(pD)^{1/2}$. Values of $(pD)^{1/2}$ for various values of p and D can be computed for various initial pressures (Table II) so that the only computation not of plain first order multiplication necessary in any application of (*11*) is finding the value of $L^{1/2}$. In computing L, the usual allowances must be made for fittings, valves, openings, etc.

When W, L, and p are known and the problem is to find the pipe size, solve *(11)* for m thus:

$$m = W\left(\frac{L}{pD}\right)^{1/2} \qquad (12)$$

Then look up the pipe size corresponding to m in the computed values of m in Table I. For the convenient use of *(12)*, values of

$$\left(\frac{1}{pD}\right)^{1/2}$$ are given in Table III.

To decide on initial pressure and pressure loss, one or both, necessary to deliver a given weight of steam through a given length of a given size of pipe—that is where W, L, and m are given, put *(11)* in the form

$$(pD)^{1/2} = \frac{W}{m} L^{1/2} \qquad (13)$$

From the resulting value of $(pD)^{1/2}$ a selection can be made using the computed values of $(pD)^{1/2}$ in Table II.

For initial pressures other than those given in Tables II and III, the values of $(pD)^{1/2}$ can be interpolated.

To find p when W, m, L, and D are given, put *(11)* in the form

$$p = \frac{L}{D}\left(\frac{W}{m}\right)^2 \qquad (14)$$

or

$$p^{1/2} = \left(\frac{L}{D}\right)^{1/2} \frac{W}{m} \qquad (15)$$

TABLE I

Pipe Size Inches	m	Pipe Size Outside Dia. Inches	m
1	46	14	49300
$1\frac{1}{4}$	104	16	71420
$1\frac{1}{2}$	159	18	98190
2	325	20	130160
$2\frac{1}{2}$	561	22	168200
3	977	24	211900
$3\frac{1}{2}$	1463		
4	2063		
$4\frac{1}{2}$	2680		
5	3820		
6	6260		
7	9300		
8	13060		
9	17650		
10	24450		
11	32000		
12	38410		

The last form may be preferable as the value of $D^{1/2}$ can be taken from Table II for $p = 1$.

Values of m are given in Table I. For outside diameter pipe sizes above 12 inches, walls $\frac{3}{8}$ inch thick have been assumed. Pipe sizes 12 inches and below are of ordinary medium pressure weight.

Values of $(pD)^{1/2}$ are given in Table II for initial pressures, p_1, 30 lb. and above, and for pressure loss, p, from 1 to 10 lb. Above 30 lb. initial pressure, the value of D (steam density) can be used at initial pressure without serious error. Below 30 lb. initial pressure, the value of D should be taken at the mean pressure in the pipe, and $(pD)^{1/2}$ computed in each case.

TABLE II

VALUES OF $(pD)^{1/2}$. (D TAKEN FROM PEABODY'S TABLES)

p \ p_1	30	50	75	100	125	150	200
1	0.272	0.345	0.417	0.476	0.530	0.576	0.663
2	0.384	0.488	0.539	0.673	0.755	0.815	0.937
3	0.471	0.598	0.722	0.825	0.917	1.998	0.130
4	0.544	0.690	0.834	0.952	1.060	1.152	1.326
5	0.608	0.772	0.933	1.065	1.186	1.289	1.483
6	0.666	0.845	1.022	1.166	1.299	1.413	1.624
7	0.720	0.913	1.103	1.259	1.402	1.524	1.754
8	0.769	0.976	1.179	1.346	1.499	1.628	1.875
9	0.816	1.035	1.251	1.428	1.590	1.728	1.98
10	0.860	1.091	1.319	1.505	1.676	1.821	2.086

TABLE III

VALUES OF $\left(\frac{1}{pD}\right)^{1/2}$

p \ p_1	30	50	75	100	125	150	200
1	3.60	2.61	2.40	2.10	1.89	1.73	1.51
2	2.60	2.09	1.70	1.49	1.33	1.23	1.07
3	2.12	1.67	1.38	1.20	1.09	1.00	0.88
4	1.84	1.45	1.20	1.05	0.94	0.87	0.75
5	1.64	1.29	1.07	0.94	0.84	0.78	0.67
6	1.50	1.18	0.98	0.86	0.77	0.71	0.61
7	1.38	1.10	0.91	0.78	0.71	0.66	0.57
8	1.31	1.02	0.85	0.74	0.67	0.61	0.53
9	1.23	0.97	0.80	0.69	0.63	0.58	0.50
10	1.16	0.92	0.75	0.66	0.60	0.55	0.48

Example 1

How much steam will a 2-in. pipe 100 ft. long transmit when the initial pressure is 100 lb. and the pressure loss 5 lb.?

The formula to be used is *(11)*.

In Table I is found $m = 325$ for a 2-in. pipe.

In Table II is found $(pD)^{1/2} = 1.065$ when $p_1 = 100$ and $p = 5$.

Since $L = 100$, $L^{1/2} = 10$.

Substituting these values in (11),

$$W = 325 \times \frac{1.065}{10} = 34.6 \text{ lb. per min.}$$

Example 2

What size pipe is required to transmit 1000 lb. of steam per min. 200 ft. at 7 lb. drop, the initial pressure being 125 lb.?

Use formula (12).

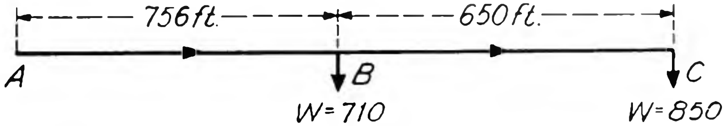

Fig. 1

$W = 1000$, $L^{1/2} = 14.1$, and since $p_1 = 125$, $p = 7$.

From Table III is found $\left(\frac{1}{pD}\right)^{1/2} = 0.71$

then,

$$m = 1000 \times 14.4 \times 0.71 = 10{,}224.$$

Referring to Table I, it is seen that an 8-in. pipe for which $m = 13{,}060$ is the nearest larger size.

Example 3

A 6-in. steam main 150 ft. long is to have the initial pressure adjusted so that the line will transmit 500 lb. of steam per min. What must the initial pressure be if the pressure drop is not to exceed 5 lb.?

Use formula (13).

$$W = 500, \ m = 6260, \ L^{1/2} = 12.25$$

then,

$$(pD)^{1/2} = \frac{500}{6260} \times 12.25 = 0.978$$

Referring to Table II, [illegible] 100 lb. initial pressure and [illegible] 5 lb. pressure loss, the pipe [illegible]. Also, if the initial pressure is [illegible] the pressure loss will be [illegible].

Example 4

Given the conditions of Fig. 1, [illegible] size pipes shall be used? Assume the pressure loss to be approximately proportional [illegible] length, and the pressure loss to C 15 lb.

For section AB, let $p = 7.5$.

Then, by formula (12) and Table III (to get $\left(\frac{1}{pD}\right)^{1/2}$ use $p = 1$[illegible]) $m = 1560 \times 27.5 \times 0.69 = 29{,}600$.

By Table I this value indicates an 11-in. pipe. Assume that a 10-in. pipe, for which $m = 24{,}450$, can be obtained. Then, by formula (13) and Table III,

$$p^{1/2} = 27.5 \times 1.89 \times \frac{1560}{24450} = 3.33$$

whence

$$p = 11.09 \text{ (assume 11.0)}.$$

The pressure at B is therefore $125 - 11 = 114$ lb.

Then for section BC we have $p = 15 - 11 = 4.0$, and $p_1 = 114$, and, by formula (12) and Table III (interpolating),

$$m = 850 \times 25.5 \times 0.97 = 21{,}024.$$

By Table I, this value indicates a 10-in. pipe which will give slightly more than 110-lb. pressure at C.

The pipe will therefore be 10-in. throughout.

A Practical Brake Horse Power Formula for Internal Combustion Engines

By Hermann Lemp

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From the old familiar formula $PLAN \div 33{,}000$ = indicated horse power, the author derives a remarkably simple and practical formula for the brake horse power of internal combustion engines. This formula is particularly convenient in that all its numerical coefficients have been combined into the single round number 1,000,000. An especially useful form of the formula is the one which shows to be constant the ratio of brake horse power to the product of the mean effective pressure and mechanical efficiency.—Editor.

Early in 1905 the writer developed a simple formula specially suited for automobile motors or stationary electric lighting sets, of the multi-cylinder type, which during these many years has proven itself to be practical, as it affords a simple means for comparing the efficiency of motors of different build, whose piston diameter and stroke, speed and brake horse power are given.

This formula reads:

For a single-acting multi-cylinder engine of the four-stroke cycle type:

$$\frac{s \times d^2 \times n \times N \times MP}{1{,}000{,}000} = BHP \qquad (1)$$

For a single-acting multi-cylinder engine of the two-stroke cycle type:

$$\frac{s \times d^2 \times 2 \times n \times N \times MP}{1{,}000{,}000} = BHP \qquad (2)$$

in which s stands for stroke of piston in inches.
d stands for diameter of piston in inches.
n stands for number of revolutions per minute.
N stands for number of pistons (not cylinders*).
MP stands for mean effective pressure (MEP) in lb. per sq. in. of piston area multiplied by mechanical efficiency.

For a double-acting engine, formula (1) and (2) should be multiplied by 2.

The preponderant number of internal combustion engines are single-acting, of multiple cylinder type, and work on the four-stroke cycle. They are mostly used in automobiles, motor boats, airplanes and stationary lighting sets, and are usually of a speed so high that the taking of indicator diagrams is not practical, while on the other hand the brake horse power outputs are easily ascertained by a cradle dynamometer, a Prony brake, or a plain electric generator, whose efficiency curve is known. Furthermore, the stroke of such an engine is usually expressed in inches.

To suit these conditions the special formula described above has been derived from the well-known horse power formula:

$\frac{P\,L\,a\,n}{33000} = IHP$, which gives the indicated horse power of a single cylinder, double-acting engine.

in which P stands for the mean effective pressure in lb. per sq. in. of piston area, usually termed MEP.
L stands for the length of piston stroke expressed in feet.
a stands for the area of piston expressed in square inches.
n stands for the number of strokes ($2\times$ revolution) per minute.
33,000 stands for the ft-lb. per minute contained in one horse power.

To adapt this formula to the brake horse power of a multi-cylinder engine of the four-stroke cycle, single-acting type, the formula becomes:

$$\frac{P\,L\,an \times N \times M}{33{,}000 \times 2} = BHP$$

where M stands for mechanical efficiency.
N stands for number of pistons.
n stands for number of revolutions.

Since in a four-stroke cycle an active stroke occurs only every other revolution, the formula was divided by 2, or further expanded becomes:

$$\frac{P \times \frac{s}{12} \times d^2 \frac{\pi}{4} \times n \times N \times M}{33{,}000 \times 2} = BHP$$

The formula may now be simplified by writing all constant factors together, followed by variables, thus we have:

$$\frac{3.14}{4 \times 12 \times 33{,}000 \times 2} \times s \times d^2 \times n \times N \times MP = BHP$$

* *Number of pistons*, and not number of cylinders, because with the opposed piston type of engines, two pistons may be traveling at the same time in the same cylinder.

The first part of the formula may now be solved and replaced by $\frac{1}{1,008,403}$ or for all practical purposes $\frac{1}{1,000,000}$ and we then have the final formula (1) shown at the head of this article.

$$\frac{s\times d^2\times n\times N\times MP}{1,000,000}=BHP \qquad (1)$$

The fact that the quotient of the constant factors $\frac{1}{1,008,403}$ when replaced by $\frac{1}{1,000,000}$ produces an error of less than nine tenths of one per cent had been discovered accidentally by the writer at the time this formula was developed, and it is this feature which renders the formula particularly useful.

Fig. 1. Illustrating the Application of the Formula to a Concrete Case by Use of the Slide Rule

We may now write the formula in the following form:

$$\frac{s\times d^2\times n\times N}{1,000,000}=\frac{BHP}{MP}$$

showing that the relation between *BHP* and *MP* remains fixed for any set of conditions.

The slide rule is extremely useful for solving for either *BHP* or *MP*, by multiplying $s\times d^2\times n\times N$ and setting 1 on scale *C* over the product, when by means of the rider either *MP* may be read off on scale *C* or *BHP* on scale *D*.

This is best illustrated by a concrete example:

A four-cylinder, four-stroke cycle engine of 5-in. bore, 6-in. stroke delivers at 600 r.p.m., 22.9 b.h.p. What is its *MP*?

$$6\times5\times5\times600\times4\times MP=22.9\ BHP.$$

Multiplying $6\times5\times5\times600\times4$ on the slide rule brings the rider to 36 on scale *D*, opposite which having placed 1 on scale *C* we will find opposite 22.9 on scale *D* an *MP* of 63.6 on scale *C*. See Fig. 1.

This *MP* [illegible] accurately [illegible] based on [illegible] *MEP*, with a mechanical efficiency of [illegible] per cent which with a compression of 60 lb. is reasonable to expect in a normally designed engine.

With slide rule set as above, the respective values of *MP* and *BHP* can be varied at will since their relation remains constant.

The writer wishes to lay particular stress on the value of *MP* as a characteristic value whereby to compare engines. We find this value in recent works and technical papers expressed as *mean effective pressure per b.h.p.* or *brake mean effective pressure.*

The writer has already recommended that *mean pressure* or its symbol *MP* should be adopted for this value and this figure is being used more frequently. A high *MP* is an indication that both the indicated horse power for a given displacement is high and the internal friction is low, hence a large brake horse power is developed.

To illustrate:

Diesel engines have a very high mean effective pressure owing to a high thermal efficiency, but the mechanical efficiency is relatively low as compared with automobile engines of the constant volume type. For this reason the *MP* is only slightly larger than that of an engine of the constant volume type. An *MP* of from 70 to 84 is the average.

On the other hand, we have quite a number of aviation engines of the constant volume type which have an *MP* as high as 100 and 105. This is due to the high thermal efficiency combined with a high mechanical efficiency.

IN MEMORIAM

John Burnham Pevear, for many years District Manager of the Cincinnati Office of the General Electric Company, after several months' illness, died at Braintree, Mass., on Monday, June 30, 1919. He was born on December 20, 1867, at Lynn, Mass., where he received his early education. His first electrical experience was gained in 1890, when he entered the employ of the Thomson-Houston Electric Company as a member of their construction force in charge of the electrical equipment of the West End Railway Company, Boston, Mass. In 1893 he was transferred to the Supply Department of the General Electric Company's Cincinnati Office where he was advanced from time to time until on June 17, 1902, he became District Manager. He held this position until February 28, 1915, when he retired from active business, making his home at Brookline, Mass., until about nine months previous to his death, when he purchased a country residence at Braintree, Mass.

John B. Pevear

Mr. Pevear was a son of the late Henry A. Pevear, a noted philanthropist, and the first president of the Thomson-Houston Electric Company after it was located in Lynn, Mass.

In 1893 Mr. Pevear was married to Miss Marie E. Walker, of Boston, by whom he is survived. There are no children, but two brothers also survive, Frederick and William Pevear, both of Lynn, Mass.

BOOK REVIEW

DYKE'S AUTOMOBILE ENCYCLOPEDIA TENTH EDITION

960 Pages, 6½x10, 3360 Illustrations, $5.00
Publisher, A. L. Dyke, St. Louis, Mo.

To any automobile owner who is in any way interested in the construction, operation, and care of his car we recommend this book. It is better than a manufacturer's instruction book, because it does not cover only a single make of car, but virtually all makes of cars. It is difficult to think of any feature or part of an automobile that is not fully described and illustrated in a manner that can be readily understood by the average car owner. As a single instance, we have in mind the electrical equipment, including the ignition, lighting, and starting systems, which are the most difficult parts of the automobile for the layman to understand. Trouble here will more often "stump" the repair man than any other trouble to which the ordinary automobile is subject, yet a careful reading of the electrical section of Dyke's Encyclopedia should make it an easy matter for the garage man to diagnose and remedy the usual electrical troubles, and give the automobile owner a sufficient knowledge of the principles and construction of the electrical system to enable him to effect minor adjustments and repairs on the road. This section alone comprises 300 pages and more than 1000 illustrations. The illustrations are the outstanding feature of the book; they have been prepared with the greatest care, and all important parts are clearly labeled, with cross references between them and the text.

We are unable in the space available to give a list of the subjects which are described and illustrated in the minutest detail, but briefly the book is divided into the following sections:

- Assembly of a car
- Engines
- Carburetion
- Cooling and lubrication
- Ignition—coil and battery
- Ignition—magneto
- Electric systems
- Storage batteries
- Operation, care, etc.
- License, laws and salesmanship
- Tires
- Troubles
- Repairs and adjustments
- Trucks and tractors
- Ford and Packard supplements
- Airplane supplement