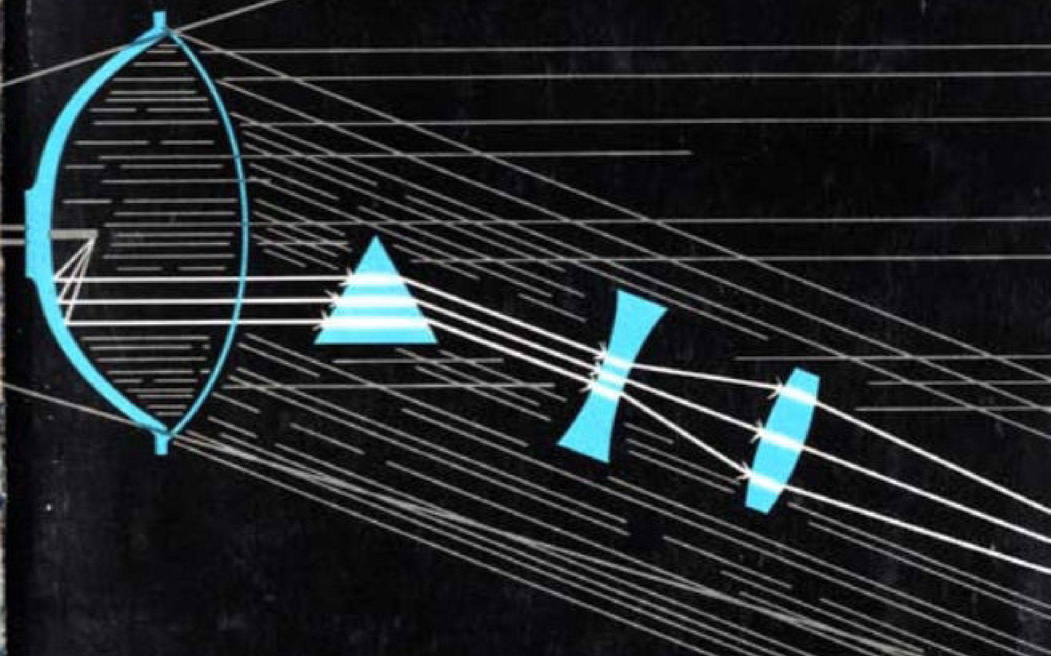
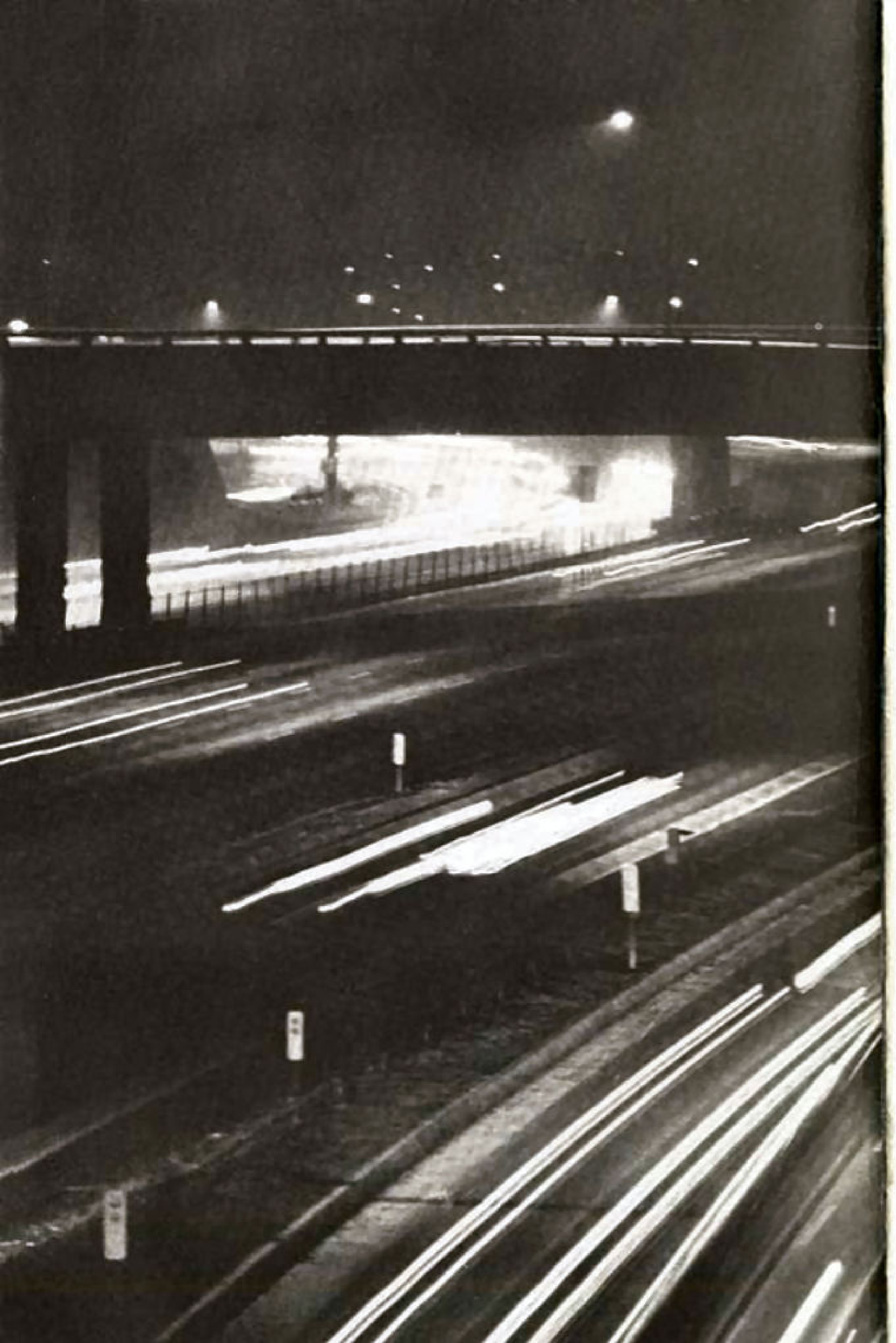
OPTICS and WHEELS





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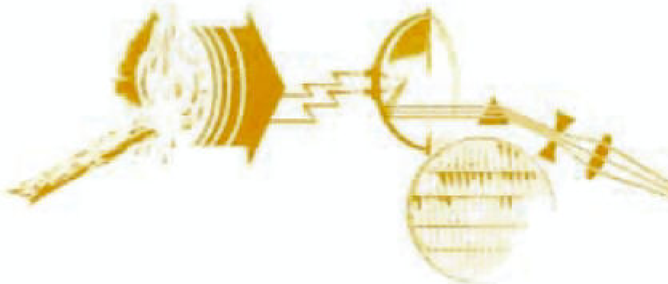

a story of lighting from the primitive torch to the sealed beam headlamp.

Research Laboratories
in collaboration with lighting engineers of
Guide Lamp Division

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foreword

From the beginning of the industry, all branches of science have contributed to the continuous improvement of the automobile, making it more dependable, more economical, safer. The science of optics, dealing with the nature and properties of light, is no exception.

Our knowledge of science is valuable only when it is usefully applied. The following pages show how the scientific facts of optics and light have been applied to help solve the problem of safer night driving through the development of the modern headlight system—a co-operative project undertaken jointly by the automobile industry, lamp manufacturers, highway safety groups and state motor vehicle administrators.

Torches to Tungsten

Prehistoric man contributed many of the fundamentals upon which modern man depends for his present civilization. The discovery of the wheel, the cultivation of plants, the use of tools and the use of fire are all things which we take for granted. All of them represent tremendous advancements. They were the results of sound thinking and venturesome experimentation by unknown prehistoric men.

The caveman, some fifty thousand years ago, began man's winning battle over darkness. Some prehistoric man, more imaginative than the rest, plucked a burning brand from his fire and invented the torch. Light and fire came to symbolize all those things in life that were good and clean, the things men valued. Worship of the sun as the light giver spread to many ancient tribes. Darkness became the grim symbol of the unpleasant and feared and even of death itself. The rites of the fire worshipers, closely akin to sun worship, called for so much fire that whole countries were denuded of forests to supply the fuel. These religions have long since vanished from civilization, but their symbolism remains and man has never ceased to search for means of lighting the darkness.

Until rather recent times the source of all artificial light was fire. The sun was the only important source of light which did not come from fire. The surface of the sun is 10,000 degrees Fahrenheit, and the light comes from this incandescent body. It is the light from the sun which makes life for man, animal and plant possible on our cold world, and it is this light which man has constantly tried to duplicate.

Converting night into day makes man independent of the hour of the day or the season of the year. He can carry out his work and his recreation with less regard for the sun's light.

Since the dawn of history many fuels have been used for lighting: wood, pine-knots, vegetable oils and waxes, animal fats, gas and petroleum. All of these fuels contain carbon and most of them hydrogen. The light given off as they burn is due to incandescent particles of carbon in the flame.

At first, lamps were stone or clay vessels which held oil, many of which were highly decorated. The early effort in developing the lamp was put into making the lamp an object of beauty. Very little effort was put into making the lamp a better light producer.

The next step was the use of solid fuels in the form of a candle.

It is said that the Phoenicians invented the candle long before the Christian Era. These first candles were made with a wick surrounded by beeswax or substances obtained from plants. It was not until about 200 B.C. that the tallow candle made from animal fat was used. About 1750, spermaceti, a wax-like material from the whale, came into general use and created a large industry. Many of the early fuels smoked and had bad odors when they burned. This was a penalty man paid for light.

The first major discovery in lighting in thousands of years was made by accident. A French chemist was heating a bottle over a flame when the bottom cracked and fell out. The glass was hot, so he dropped it over the flame. At once the flame became bright and steady, and the lamp chimney was born. This was in 1783, just seven years after the Declaration of Independence.

From that time on, improvements came more rapidly as a result of research in many fields. Gas was distilled from coal and piped to light streets, homes and stores. An incandescent mantle was soon added by Welsbach, who found that certain earths glowed brilliantly white when heated in the normally blue gas flame. The gas mantle is still used and is most familiar on the gas lanterns used by campers and hunters.

None of the above lights had lent itself for use on the carriages and wagons of the day. Of course a few candle lanterns had been used, but it was not until petroleum became an article of commerce that lights became practical on moving vehicles.

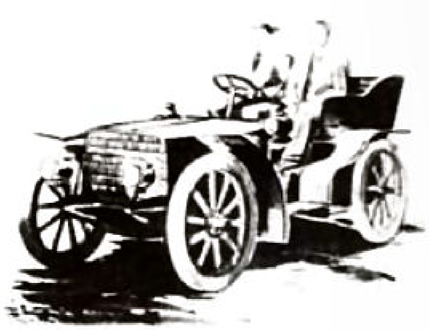
In 1859 Colonel Drake drove the first oil well through 69 feet of Pennsylvania soil. The first attempts to use crude oil produced a black, smoky flame. Before Drake drilled his first well chemists had found that an oil suitable for lamps could be obtained by distilling crude oil. Kerosene, or coal oil, as it was sometimes called, immediately became the preferred fuel for lamps on ships, carriages, in homes and offices. That kerosene lamps could be made portable made them useful on vehicles.

In the days before street lighting, people were often guided home at night by "linkboys" carrying rushlights. This was an early attempt at providing a light to guide travelers at night. Oil and candle lamps were placed on horsedrawn carriages when roads were traveled at night. The stagecoach was often equipped with lights. These first carriage lamps were used, not to light the road ahead, but to serve as a warning to pedestrians and oncoming vehicles, and to provide light to enable passengers to get in and out with safety.

This was the status of lighting when the automobile industry was getting started in the 1890's. The first horseless carriages either had no lights at all or adapted kerosene lamps from horse-drawn carriages. Soon, however, a new light source became available through the work of Major More-

head, a former officer in the Confederate Army, Mr. T. L. Willson and several of his associates. As part of an investigation to obtain aluminum from clay in North Carolina, lime and coal tar were mixed in an electric furnace. The hot residue was thrown into a bucket of water to cool. At once, a gas with a sharp, distinct odor was given off. Thinking it might be hydrogen, the experimenters ignited it with a piece of burning waste. The gas burned with a brilliant flash. Chemical analyses showed the gas to be acetylene, and the material to be calcium carbide. A plant was soon built near Niagara Falls to manufacture calcium carbide for lighting purposes. Acetylene is at present used for welding and as a starting point for several synthetic chemical products, including one form of synthetic rubber.

Acetylene was well adapted for vehicle illumination. It could be easily generated by adding water to calcium carbide, which



was easy to make. It burned with a brilliant, white flame almost twelve times as bright as that obtained from coal gas.

The first acetylene lamps were used on bicycles and incorporated the gas generator in the lamp. When these lamps were placed on the early automobiles, the gas generator was likewise installed on the vehicle. Later it was discovered that acetone absorbs acetylene under pressure just as a sponge absorbs water. Thereafter, acetylene was stored in cylinders. These cylinders were used until empty and then exchanged for full ones.

All of the sources of light discussed up to this point depended upon a flame, the burning of a solid, a liquid or a gas. This had been the sole source of artificial light since the beginning of time. With the discoveries in methods of generating electric power, men began their search for ways of using this source of power for producing light. Electric arcs

were discovered and used for street lighting, but they had no place in portable systems. In 1879, Thomas Edison announced his discovery of the carbon filament incandescent lamp. From then on we were no longer dependent upon fire for illumination. The light of the Edison lamp came from an incandescent carbon filament, but there was no burning of a fuel.

In searching for better light sources to illuminate the road, automobile engineers turned to the electric light. The first filaments used in electric lights were frail and broke easily with handling. They were, therefore, unsuited to the automobile. Now that organized industrial research was working on the problem, developments in lighting were coming rapidly. More progress was made in a single lifetime than had been made in all the thousands of years which had preceded this period.

As a wire is heated, it first gets warm, then turns red, and finally, when it is hot enough, it glows brilliantly. Carbon had been chosen as the filament of the Edison lamp because it could be heated to a high temperature in a vacuum without melting. In attacking the problem by research, other materials with a high melting point were tried.

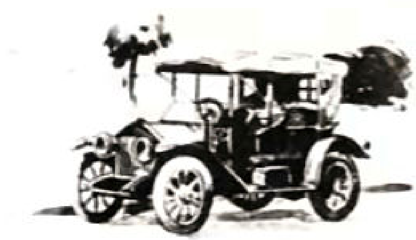
Tungsten is one of the hardest of all the metals and melts at 6,000 degrees Fahrenheit. It is used in tool steels to make a hard material that does not lose its cutting edge. It is also used in one of the newest cutting materials, tungsten carbide, which is almost as hard as a diamond.

Since tungsten is normally very brittle, the first tungsten filament lamps were even more frail than the carbon lamps. About 1910, Dr. W. D. Coolidge discovered a method of making ductile tungsten wire. A coiled filament of this tough, ductile tungsten, combined with a gas-filled lamp developed by Doctor Irving Langmuir, gave a highly efficient and strong incandescent bulb which soon was universally used for electric lighting. It was strong enough to be used in automobile headlights. The present incandescent lighting is one of the most important contributions of industrial research as carried out in the laboratories of progressive business.

There had been frequent at-

tempts to use electric lighting on an automobile from almost the beginning of the industry. The first electric lights in cars were placed in the old oil or acetylene lamps. Since there was no battery or generator on the cars, a dry cell or storage battery had to be used. This made electric lighting expensive and difficult to keep in service. Electric automobiles used carbon filament lamps with the current supplied by the same batteries as were used to propel the vehicle.

Then, in 1911, the Kettering self-starter was installed on the 1912 model Cadillac. The starter required a storage battery and an electric generator. This same electric system could supply the power for the lights. The combination of the battery starting and ignition system with the new ductile tungsten filament light bulbs gave us our present system of electric lighting on automobiles. Very soon all cars were equipped with this system, and



1912 CADILLAC

the acetylene and oil lamps were entirely displaced. The electrical system on the automobile is one of the most important improvements ever put on the horseless carriage.

The illustration shows the 1912 model Cadillac which carried the first electric self-starter as standard equipment. The starter and generator were in a single unit mounted on the engine. The story of the automobile electrical system is told in another booklet in this series, "Electricity and Wheels."

From the first days of the automobile, engineers have given much time to the development of suitable lamps. Improvements in lighting were added to the vehicle to make the automobile a day and night means of transportation. In the first automobiles, lamps were often accessories. In present automobiles, they are an important part of the original equipment. The pages which follow will show some of the problems involved in lighting and how they have been solved.

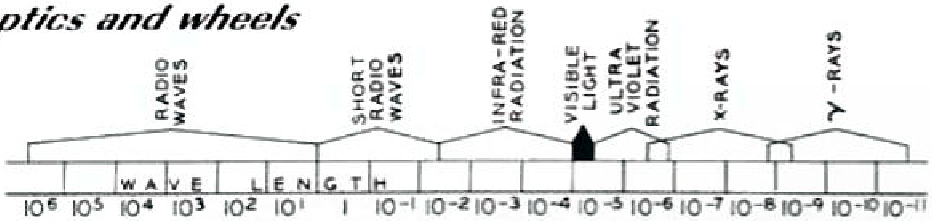
Light

The first section of this booklet gives a few highlights on the methods of producing artificial light. While making the discoveries of light sources, man also learned many facts about light. Research on the fundamentals of light produced a wealth of information which could be used to provide better illumination, make more accurate optical instruments and explain many puzzling events in nature. It is usually true that when pure science research adds to our sum of information, industrial research can use the knowledge to improve our products or invent entirely new ones. The result is that our needs are better satisfied and new jobs in industry are opened up. Discoveries in optics are no exception and they make possible many of our most highly prized benefits of modern industrial civilization. The movies, photography, microscopic studies in medicine, astronomy, television, spectroscopic examination of materials and many other fields depend upon light and optics.

Light seems to be a form of wave motion. It travels at a speed of about 186,000 miles a second. The sun is about 93,000,000 miles away so it takes the light a little over eight minutes to arrive on the earth. A better idea of the vast distance and the tremendous speed of light is obtained when it is realized that it would take an airplane traveling at 600 miles an hour nearly 18 years to cover the distance from the earth to the sun.

Light is usually considered to be transmitted by waves and to be a form of vibration. When the vibration reaches a certain rate, visible light is emitted. X-rays, ultra-violet rays, light, radio waves and heat have many similar characteristics.

The chart on the next page shows the characteristics of electro-magnetic waves of various wave lengths. The long waves



are the ones we use for radio transmission. They may be miles long. Infra-red, or heat, waves are longer than the visible rays. The waves that we call light and can see are only a small part of the scale. The entire scale extends over 60 octaves of which only one is visible to our eyes. The ultra-violet rays are shorter than visible rays and X-rays and gamma rays are still shorter. All of these waves travel at the same speed, 186,000 miles a second.

The method of producing light by a heated filament is to get it hot enough so it will radiate light waves. As the filament is heated, it begins to radiate the long, invisible, infra-red heat waves. As it gets hotter it begins to produce the long light waves—red. As it becomes still hotter the waves become shorter and the light changes to yellow and then to white.

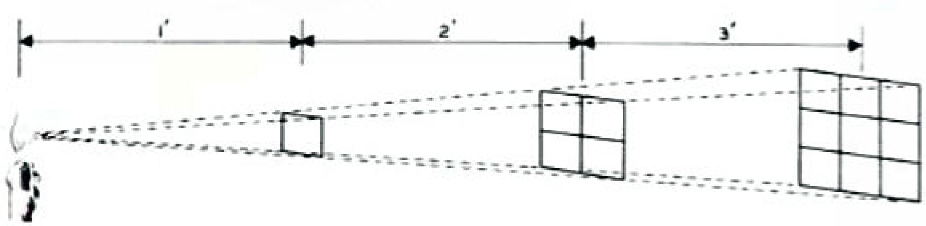
The standard of measurement for light is the candlepower (internationally, this is known as the "candela") one candlepower being the light given off by the burning of a standard size candle. This measurement was first used by William Murdock, who was employed by James Watt, the inventor of the steam engine. Murdock was a highly skilled mechanic and an inventor of note. It was he who showed the world how to use gas lighting. He compared his gas light to the then common light source, the candle, with which everyone was familiar. One candlepower is still the fundamental light unit.

Another interesting property of light is the variation of its intensity with distance. "Light varies inversely as the square of the distance," as the physics books say. This means that at twice the distance the light intensity is cut to one-fourth. This is easily understood when it is realized that the same quantity of light must cover four times the area. At three times the distance the intensity is only one-ninth.

The amount of light on a surface one foot away from a standard candle is one foot candle, a fundamental unit of light intensity on a surface. At two feet from the candle the light intensity is one-fourth of this amount or one-fourth of a foot candle. To illuminate a surface or object at a distance, therefore, requires a very much stronger light source than is needed if the object is near the source. This is an important factor in automobile headlight design. The part of the light beam which is expected to reach far down the road must be much more brilliant than that which is only expected to light the road in front of the car. If the road is to be evenly illuminated, the portions of the beam which reach farther and farther down the road must be brighter and brighter. Every time the distance is doubled, the light intensity must be multiplied by four. Light which reaches the road far ahead of the car must be hundreds of times as bright as that which reaches the road directly ahead if the road is to be illuminated at the same intensity.

The strength of the light source necessary to see an object does not follow the "square law" and experiments show that it is a much higher power. In fact, when the distance is doubled, the light necessary to illuminate an object is increased over twelve times. The exact increase depends upon many factors including the size and color of the object, the condition of the observer's eyes and the percent of light reflected by the object. One reason the "square law" does not directly apply to seeing distances is that the light has to reach the object and then be reflected back to the observer's eyes.

This is the reason it is necessary that automobile headlamps furnish a powerful beam which reaches far down the road. The following pages will explain the shape of the light beam which is desired and the optical devices necessary to produce it.



Manipulating Light

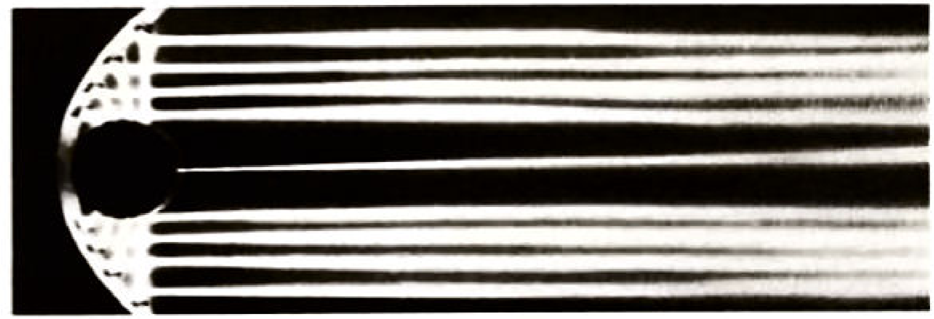
Optics is the science dealing with the nature and properties of light. One of the first laws of light is that it travels in a straight line. However, man early learned that it could be bent and reflected by various optical devices. A number of the fundamental optical principles are used in automobile lighting.

That light can be reflected is perfectly obvious and we find examples everywhere we look. The fact is, we see more reflected light than we do light

from a direct source. In reading this page you are depending upon the reflection of light from the paper.

The law of reflection can be best illustrated by a simple flat mirror. When a ray of light strikes the mirror at an angle, it is reflected from the mirror at the same angle. Light bounces off the mirror just as a billiard ball is bounced off the cushion of a billiard table. The illustration shows the similarity between the action of the ball and that of the beam of light.

There are both diffusing and specular (mirror-like) reflectors. Diffusing reflectors scatter the reflected light in all directions. White blotting paper, which reflects 60 percent of the light, is a diffusing reflector. Others are snow with a 70 to 80 percent reflection factor, and grass and green crops with a 5 to 10 percent factor. The high reflection factor for snow is the reason snow-blindness often affects people traveling over wide areas of sunlit snow. Green leaves of growing plants absorb the sun's energy and store it in a chemical



form for man to use. That is probably the reason 90 to 95 per cent is absorbed and only a small portion reflected.

A bright specular metal surface is an extremely good reflector. Aluminum, vacuum-deposited upon glass, is the most used surface. The best metal surface may have a reflection factor of as high as 96 percent.

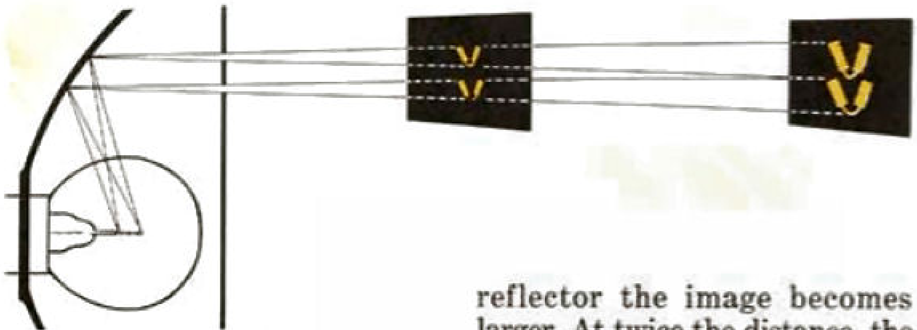
To concentrate the light from a single source, such as the filament of an electric bulb, a curved reflector with a mirror surface can be used. Let us take a series of small reflectors and place them around an electric light bulb. If the reflectors are turned so that the reflected light comes from them in parallel beams, the light in the beam will be greatly intensified. We will have the direct rays from the light bulb plus the light from all the small reflectors.

We could substitute a curved surface for the small reflectors and reflect an unbroken beam. The shape of this surface would be a paraboloid, and the point where the light filament was would be the focus. The fact that a parabolic reflector will send out parallel rays when the light source is at the focus was known in ancient times. It is said that the Greek philosopher, Archimedes, used huge curved mirrors to concentrate the sun's rays on the Roman fleet and thus set it afire. This happened in 212 B.C. when the Romans attacked Syracuse.

The automobile headlamp uses a parabolic reflector to obtain a concentrated light beam. Modern reflectors are usually made of glass with an aluminized reflecting surface, and can multiply the light from a low candlepower filament to as much as six thousand times the candlepower of the light source.

Reflectors from older lamps became tarnished and dirty so that much of the light was absorbed or wasted, thus reducing the light intensity to such an extent that night driving was dangerous. Fortunately, reflectors could be polished or replaced if found defective, thereby considerably improving the efficiency of headlighting on these older cars.

This problem has been conquered, through science and research. The reflector interior has

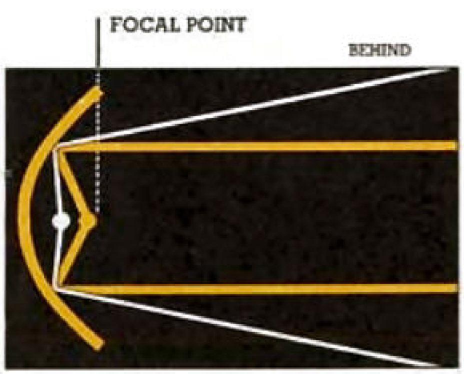


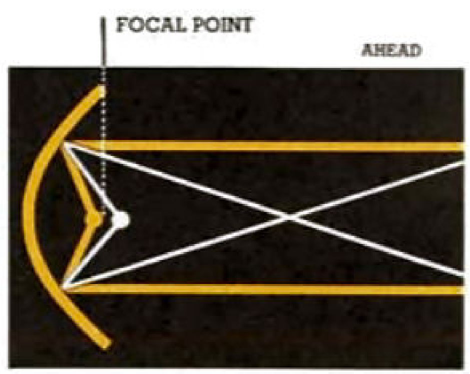
been effectively sealed from dust and moisture, thereby preserving permanently the reflecting surface. This development, known as "Sealed Beam Lighting," was introduced in automobile headlamps on 1940 models.

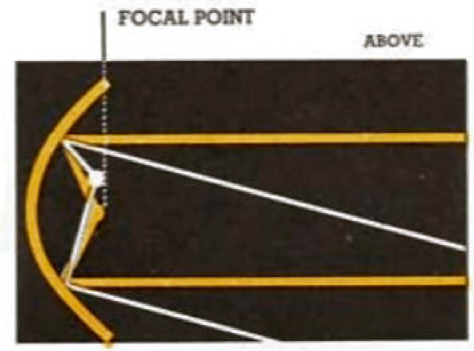
We can demonstrate what happens to the light from any spot on a parabolic reflector by a simple experiment. If a mask with a small hole in it is placed in front of a parabolic reflector and a light bulb, the light from only one small portion of the reflector can be studied. If a screen is placed in front of the reflector, an image of the filament will be projected on the screen. As the screen is moved away from the reflector the image becomes larger. At twice the distance, the area of the image is four times as large. This demonstrates the operation of the "square law." At twice the distance, the same amount of light must illuminate four times the area, so that the intensity will be cut to one-fourth.

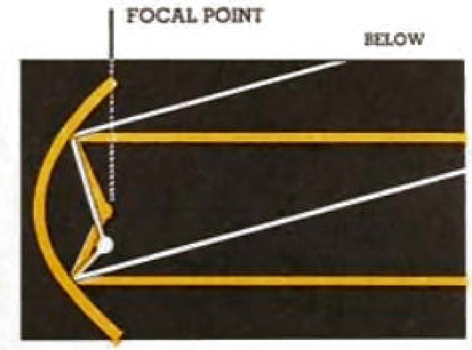
If additional holes are cut in the mask, exposing small areas from the top, bottom and sides of the reflector, the images of the filament will overlap. As more and more of the reflector is exposed, the images blend together. When the mask is completely removed a round spot of light is formed by the images from all parts of the reflector.

The parabolic reflector will reflect parallel beams of light only









when the filament is at the focus. When it is at any other point the beam is entirely changed. If the filament is behind the focal point, the reflected rays are diverging. If the filament is ahead, the light is narrowed to a point where the beams cross and separate. This fact made it necessary in early headlamps to provide a means of focusing the bulb. After 1929, bulbs and sockets were made accurately enough so that focusing mechanisms were not required.

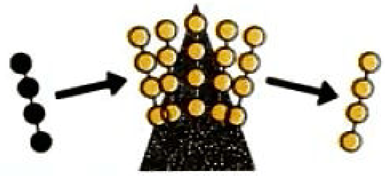
If the light filament is above the focus, the major portion of the beam is tilted down. If it is below the focus, the major portion of the beam is tilted up. We use deliberately offset filaments to control the beam to make it move up and down in the two-beam headlighting system. The shape of the reflector, the type of lens, and the position and shape of the filament can be chosen, therefore, to give the exact beam which is needed to light the road.

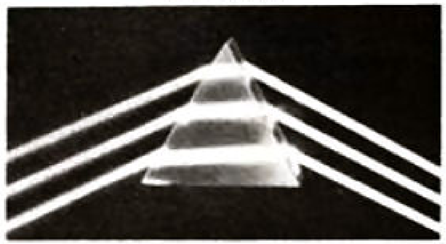
Bending Light Rays

It is fortunate for us that light can be bent, or in technical language, refracted. In traveling from one transparent medium to another, such as from air to water, a light beam is bent. If this were not so, our eyes could not focus light coming to them and we would not be able to see an image.

Refraction, or bending, takes place when light passes from one substance to another because light travels at different speeds in different mediums. The speed is highest in a vacuum and almost as fast in air, or about 186,000 miles a second. It is only about three-fourths of this speed in water and two-thirds in glass.

A mechanical explanation of refraction can be made by using the billiard table. Suppose we mount a row of balls solidly on a shaft to represent a light beam. The balls will roll freely straight down the table if given a push.





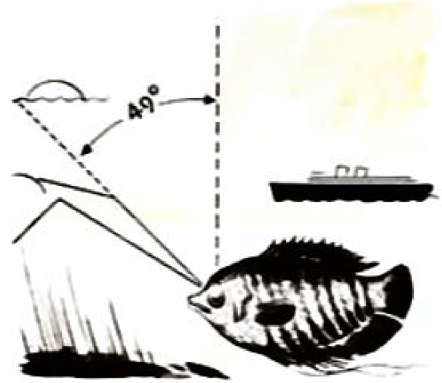
If we put a retarding force, such as a large triangle of coarse sandpaper, in the path of the balls, the direction of their rolling will be changed. The speed of the balls over the sandpaper will be slower than that on the felt of the table. The ball which rolls over the longest piece of sandpaper will be retarded most. When the string of balls leaves the sandpaper triangle, the motion will be changed in the direction of the wide side of the triangle.

A prism is a triangular-shaped wedge of glass. If we send a bundle of light rays through a glass prism, the same action will take place and the emerging rays will change direction.

This is refraction. Many peculiar optical effects can be explained by refraction. The air itself is of varying density from the ground up. The light which reaches us from the sun is, therefore, bent in coming through the envelope of air which surrounds the earth. For this reason, we actually see the sun after it has set. About eight and one-half minutes after the sun has really gone below the horizon we can still see it. Likewise, we can see the sun for the same time before it rises in the morning.

Mirages, as seen by a thirst-maddened desert traveler, are also caused by refraction. Next to the hot, parched sand the air is considerably hotter than it is above it. The hot air is less dense than cooler air and is less refracting. The light passing through the hotter layers is, therefore, bent less than that passing through the cooler layers. The light from a distant object is bent less and less as it passes from the cooler to the hotter air

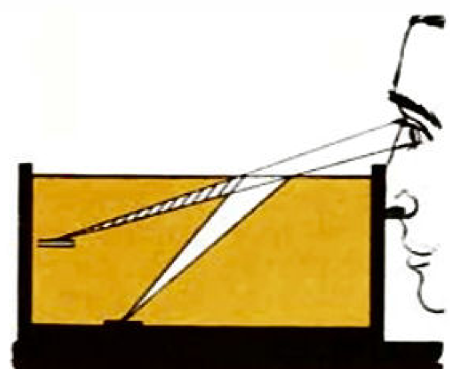
until it reaches a critical angle marked by X on the illustration. At this point, the image is reflected just as it would be by a mirror-like surface such as a lake. This reflected beam is further bent in passing from the hotter to the cooler layers of air until it reaches the tortured eye of the traveler. The beam reaches the eye from a direction which makes it appear to come from a point

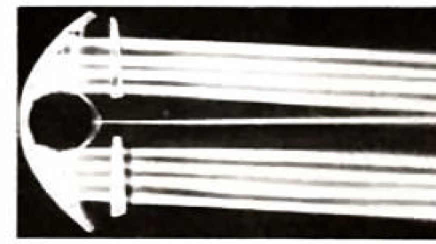


below the ground. The image is inverted and seems to be a reflection at the point X from the surface of a lake. This same effect is responsible for what looks like pools of water on a hot road.

A fish obtains a narrow view of the world above because of refraction. It sees the horizons in a cone with an angle to the vertical of 98 degrees instead of 180 degrees, as we see them. A beam of light is bent 49 degrees in passing from air into water. When the sun is setting on a smooth sea it looks to the fish as if it were setting at a point high in the sky. At greater angles the surface of the sea reflects light and it looks like a brilliant mirror.

On the other hand, when we look into clear water, it appears much shallower than it really is. That is a good fact to remember when swimming in strange lakes. A pan of water with a coin at the bottom will be sufficient to prove this to yourself. The light from the coin is bent and makes it appear to be at the position shown by the cross hatched lines.

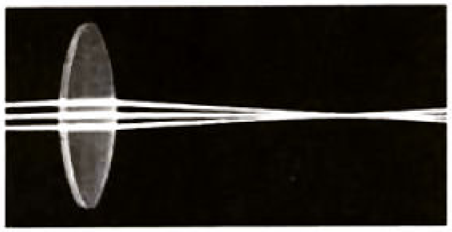


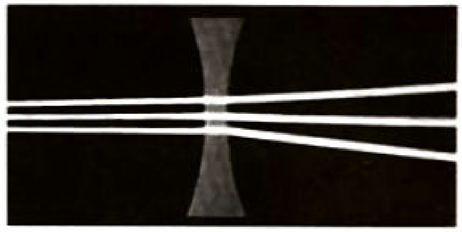


ACTUAL PHOTOGRAPH OF BENDING LIGHT RAYS

The ability of the glass prism to bend a beam of light is very useful in many optical instruments. In our automobile headlamps it is used to change the direction of the light beam which is reflected by the parabolic reflector. The beam may be redirected by prisms to give the right illumination on the road.

Refraction also takes place in lenses. A simple double convex lens is really a series of prism elements. The light from each element is bent according to the angle of the prism. A lens is made so all of the rays concentrate at one point, which is called the focus. This ability of a lens to focus the





rays of light from the sun is used in a burning glass and has been known for thousands of years.

If a lens is made with concave surfaces, the light rays are bent outward and the beam is spread. This is true whether both surfaces or only one are concave. Concave or fluted surfaces are used in headlamp lenses to spread the light beam to cover the road. A broad flat beam instead of a bright round spot is necessary for proper road illumination.

There are many other types of lenses and prisms used for many purposes. Cameras, field glasses, range finders, microscopes, and hundreds of other optical instruments depend upon our knowledge of lenses. Each of these has been developed to a high degree of perfection by optical research work.

The Eye is a Sealed Receiving System

In all of the preceding pages we have described the light sources and the methods of controlling them. But the most important element in the system and the receiving device, the human eye, is also an optical device. It is a sealed system with all the important elements protected from exposure.

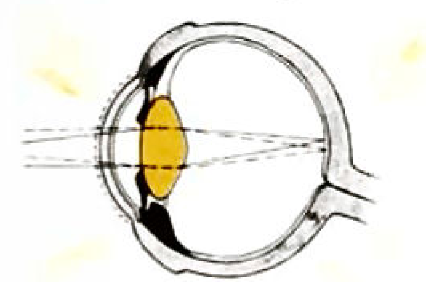
A diagram of the human eye will show how it receives an image. The eye is made up of a number of optical parts with which we are already familiar. A crystalline lens focuses images on the retina just as a photographic lens focuses an image on the film. The retina is made up of light-sensitive cells and is an extension of the optic nerve. The center of the eye is filled with the vitreous humor, a transparent gelatine-like mass. In front of the lens is the iris which expands and contracts to regulate the amount of light which reaches the retina. Muscles control the movement of the eye, the focus of the lens, and the size of the iris.

In describing the effects of automobile lighting, a normal eye with good vision is always

assumed. If the driver's eyesight is poor and he needs glasses, the best lighting will be inadequate. Glasses are lenses which correct the optical defects of the eye. Those who use glasses to correct deficiencies of vision that affect seeing on the road, should always wear them while driving.

In referring to lighting, we should always remember that what we are discussing, and the most important factor, is the effect on our eyes. Glare is an example. When light reaches a high enough intensity we say it is glaring. But glare is not a constant quantity. The intensity of light which will cause discomfort from an oncoming headlight on a dark road would be a low intensity light in the daytime. The light from a match is not very bright, but a match close to the eyes in a dark room will be very glaring. Light from the upper beam of a headlamp will cause glare to an oncoming driver while the same beam directed down will not. Many factors affect glare and even one's physical condition has a bearing on the subject.

Things are not always what they seem and the eye can often be fooled. There are many visual illusions to demonstrate this fact. Many of these are caused by peculiarities of our eyes. The illustration shows an illusion. All of the cars are the same height although the most distant car appears twice as large as the nearest one. This is because we are used to allowing for a change in size with distance. The car which is farthest away should be smaller. Since it is not and our eyes still make the accommodation, the car looks larger. This is the type of experience we use in driving to estimate distances for passing and stopping, and it demonstrates how this may be in error.



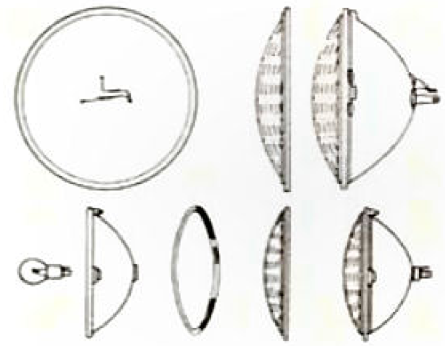
Sealed Beam Headlamps

Up to this point we have traced the progress in the development of light sources up to the tungsten filament electric light bulb. We have seen how the use of a parabolic reflector multiplies the light in the reflected beam to thousands of times that of the filament. That this light could be spread and bent has been demonstrated. The lighting engineer has used this information to produce better night illumination for the motor car driver.

Progress has been steady since the automobile industry first adopted the electric starting, ignition and lighting system in 1911. Each year new and better lights have been given to the motorist. Year after year engineers have worked in the dark rooms of industrial research laboratories and on night road tests to develop new and improved systems. Two-filament light bulbs were developed to give a driving and a passing beam. In 1929, these two-filament bulbs were made accurately enough so focusing was unnecessary. Accuracy was soon further improved so that filaments were located to a limit of a few thousandths of an inch. Optical principles were applied to produce good beam patterns. Each step gave the driver more control over night driving conditions and each was an advancement over the past.

During 1937 a new development program was started to eliminate some of the difficulties experienced with headlights. One of these difficulties was the fact that there were about three dozen different types of headlights in the field, requiring many different techniques for aiming and maintenance. So a lighting committee was formed representing the entire automobile industry, and working in conjunction with the state motor vehicle administrators, safety organizations, headlight manufacturers and lamp manufacturers. The objective was a standard lighting system which could be used on all motor vehicles, and after several years of work and experiment, the Sealed Beam Headlight system was developed and introduced on the 1940 models.

The first Sealed Beam units were of two types. One used an assembly made up of a light bulb, a bright metal reflector, a



gasket and a glass lens, all sealed together to keep out dust and moisture. The other used a glass reflector upon which bright aluminum had been deposited. The glass lens was fused to the glass reflector and the inside filled with an inert gas, just as is done with the lamp bulbs used in your home. The filaments were located in the reflector without the use of a separate bulb since the entire unit was a sealed glass bulb. This all-glass type is now used exclusively.

These two types of units were interchangeable in all respects—optically, mechanically and electrically. Each had two bar filaments, one located above and slightly to the side of the other. The lower filament produced the upper beam, and the upper filament produced a beam which tilted down and to the right for passing. This is just what we would expect from our previous explanation of the location of the light source in respect to the focus of a parabolic reflector.

Advantages

The Sealed Beam system achieved several important objectives:

1. The two-beam arrangement furnished satisfactory highway lighting and provided relief from glare when meeting other cars and in cities.
2. It was easy for the driver to use the right beam at the right time. A left foot switch changed from one beam to the other, and an indicator on the instrument panel showed when the upper beam was in use.
3. Lighting efficiency was maintained as the car grew older, due to the sealed reflector unit.
4. Adjustment was easy. Since everything was combined in one unit, the only adjustment necessary was aiming, which could be done with no other tools than a screwdriver.
5. Parts distribution was simplified. There was just one unit, which fitted all makes of cars and made it easy for the owner to get immediate replacement service.
6. It simplified the work of officials responsible for laws and traffic regulations, because there was one standard unit which did not deteriorate and was simple to adjust.

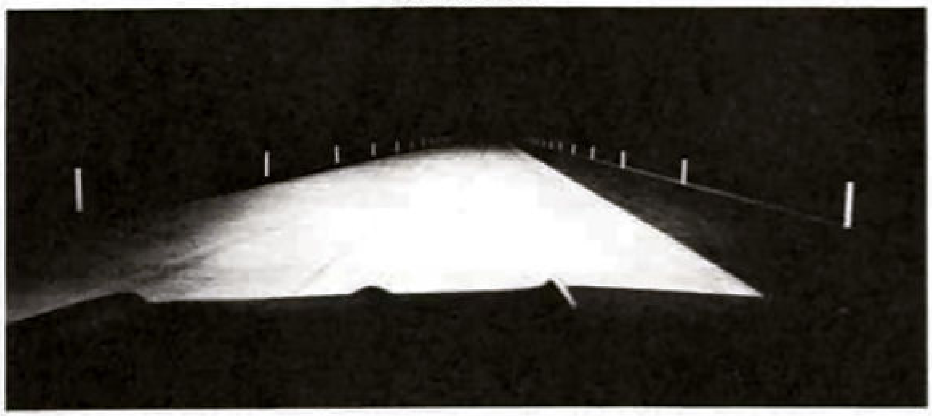
Upper and Lower Beams

As we have mentioned, the Sealed Beam headlamp provided an upper beam for driving in open country and a lower beam for passing or driving in traffic. This was accomplished largely by the position of the filaments in relation to the reflector, but the lens also had a great deal to do with the distribution of light in front of the car. The flutes and patterns you see in headlight lenses are not just decoration; they are accurate optical elements. They are prisms which change the direction of the light beams and distribute the light in the manner decided on by the lighting engineers.

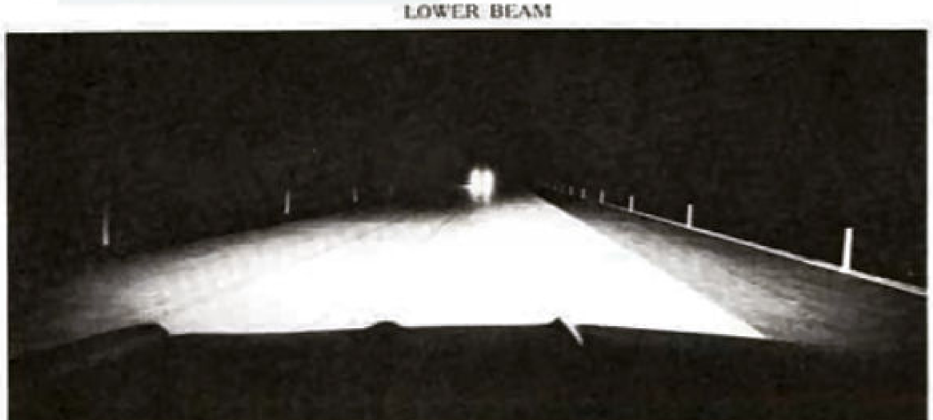
Let us look at the beam patterns provided by the original Sealed Beam system.

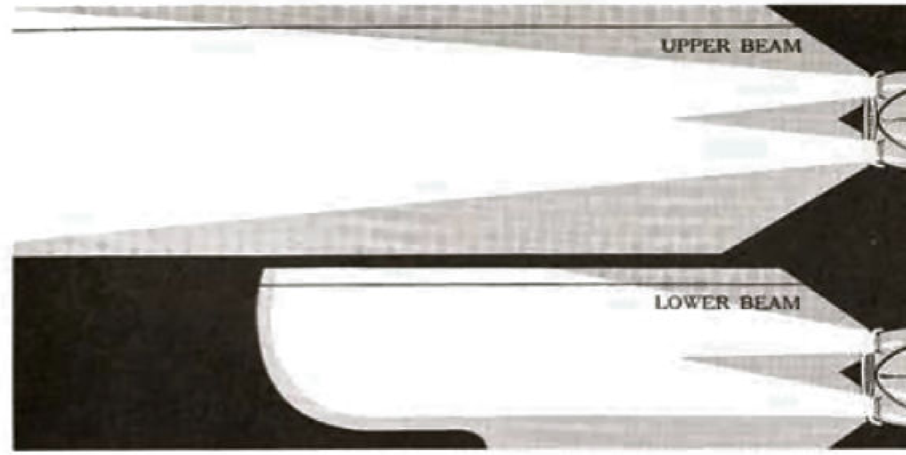
The upper beam was designed to give good road illumination when other cars were not approaching. The brightest part of the beam was aimed far down the road with sufficient illumi-

UPPER BEAM



LOWER BEAM





nation to distinguish dark objects —a pedestrian in dark clothes, a parked car or a road obstruction. Some light was spread to the side to illuminate the shoulders of the road, signs, curves, side roads and objects just off the roadbed. A small amount of light was also distributed upward to illuminate highly placed signs, overhanging projections, bridges and other high objects.

This upper beam was designed with no consideration for other cars on the road. The lower beam was designed for illumination in traffic so that an oncoming driver would not receive glare from your lights. It had most of the same characteristics as the upper beam except that it was aimed lower and somewhat to the right to keep the direct rays of light out of the eyes of the oncoming driver. The glare of these direct rays of the upper beam can be momentarily blinding, and that is why it is so important to use the lower beam when other cars are on the road.

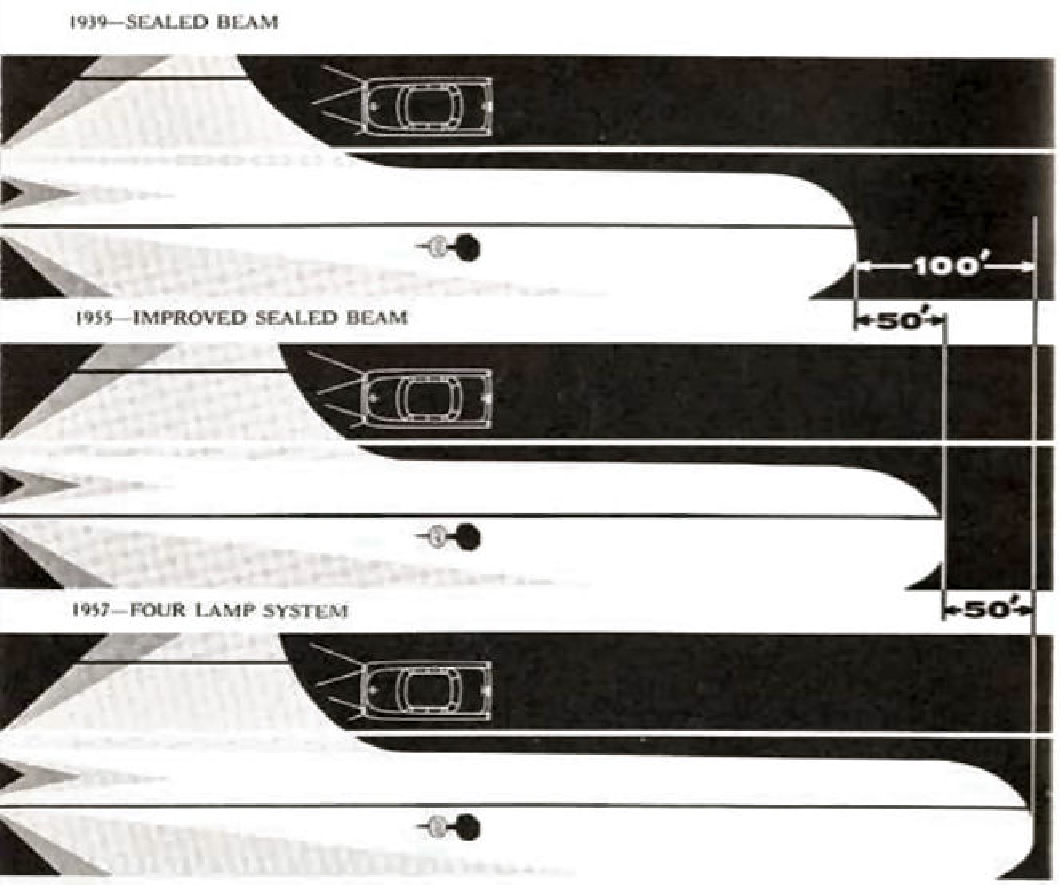
Four-Lamp System

The original Sealed Beam system was a major step forward in automobile lighting, but the lighting engineers did not stop working. Cooperative efforts of the automobile and lamp manufacturers, working with state officials and others, continued. The increasing number of vehicles on the highways increased the importance of the lower beam, and in 1955 an improved Sealed Beam system was approved and brought into use. The principal advantage of the new system was increased light on the right hand side of the road. This made pedestrians and other objects visible at an increased distance of as much as 80 feet with no appreciable increase in glare.

In 1957 a greater change took place. For many years the advantages of a four-lamp system had been recognized. As long as the same reflector and lens must be used for both upper and lower beams, as in the old system, it was necessary to compromise. With four lamps, the upper and lower beams could be provided with specific optical systems best suited for each. There were practical difficulties in adopting such a system, however, and it was not until 1957 that these were overcome and four headlights became an accepted thing throughout the industry.

This system has four Sealed Beam units essentially the same as previous units but smaller in diameter. Two of these have a single filament, and are designed and aimed to furnish the upper beam for driving on an open road.

The other two units furnish the lower beam, and being designed specifically for this purpose, they are able to provide better visibility without objectionable glare. These units also contain a second filament which provides part of the upper beam, but this is definitely secondary and no compromise is made in the lower beam.



When we are driving in town or on a highway with other cars, one pair of headlamps provides the lower beam. When we are on the open highway we switch to the other filament of these lamps and add the other two lamps which furnish the major part of the upper beam. Thus one pair of lamps is always illuminated and is used to mark the outer limits of the car. When all four headlights are on, it indicates that the upper beam is being used.

Visibility is improved over the old system in both upper and lower beam positions. This means seeing danger at a greater distance, thus giving that added margin of safety which can be so important.

Beam Control

Shifting from one beam to the other at the proper time is important, and it has been made so easy in present-day cars that there is no reason for failing to do so. A switch operated by the left foot shifts from whichever beam is in use to the other beam, and a red indicator light on the instrument panel is lighted when the upper beam is on to tell the driver which beam he is using.

An electronic development makes proper beam selection even easier—the Guide-Matic automatic headlight control. This device uses a photo-electric cell to pick up the light from an oncoming car. When light strikes the cell, an electrical impulse is produced. This impulse is transmitted to an electric switch which automatically shifts the headlamp to the lower beam.

This device sees what the driver sees and acts instantly and automatically. When it sees a light approaching, it shifts the headlights to the lower beam and

returns them to the upper beam when the car has passed. On brightly lighted streets, the lights are automatically held to the lower beam. On darkened streets and highways, the lights are immediately returned to the upper beam.

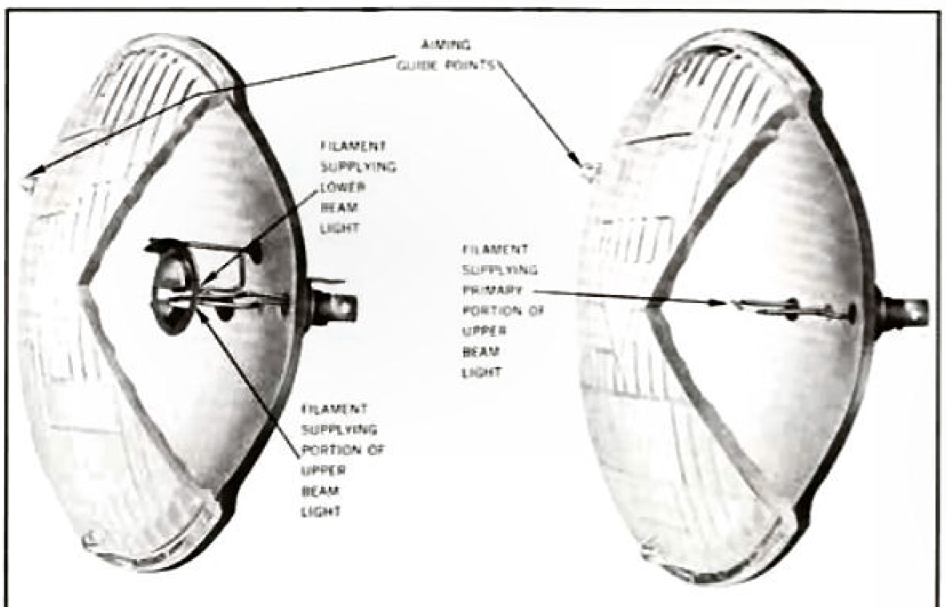
Present-day headlights, even more than earlier types, are definitely designed as a dual system—that is, an upper beam for use when no cars are in range and a lower beam for use all the rest of the time. For that reason it is more important today than ever before that the rules of dimming be observed carefully. When meeting a car or when driving behind another car going in the same direction, the lower beam should be used. It is not just a matter of courtesy; it is a question of safety for you as well as the other driver. No matter how much headlights may be improved, they must still be used in the proper manner by the driver.

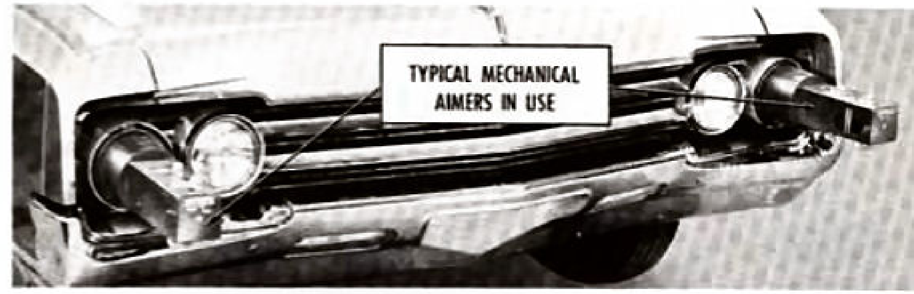
Headlamp Aiming

Modern Sealed Beam headlamps have been designed to make it very easy for you to maintain your lights in good condition for safe driving. The sealed unit protects the reflector against tarnishing. The filaments are designed to give long service life on the vehicle. Proper focus between the filaments, reflector and lens is a built-in feature and your unit remains in focus throughout its life.

There is one highly important thing, however, which the owner must take care of to keep his lights at their maximum efficiency. He must see that his headlamps are properly aimed.

The manufacturer can see that they are aimed correctly when the car leaves the factory, but there is no way of building in permanent correct aiming. Bumps, impacts and normal settling of springs can throw them off. It has been estimated that more than 50 percent of all the cars on the road have headlights that need aiming, and the only cure for this is for the owner to have them checked periodically.





It is much easier to aim headlamps today than it was a few years ago. Modern headlamps have three little projections or aiming pads molded into the lens. These are precision-made and calibrated so that a plane laid across them would form a surface at right angles to the car axis when the light beams are properly aimed. With a simple mechanical aiming device and a screwdriver, headlamps can now be aimed correctly in a few minutes in broad daylight and in a space only as large as the car. The development of this quick and easy aiming method was one of the important factors in making the four-lamp system practical.

Your safety depends largely on how much you can see on the road ahead of you. Keeping your windshield and headlight lenses clean is helpful, but this is generally recognized by the driver whereas incorrectly aimed headlamps may go unnoticed for months. And it takes only a very small misalignment to result in a very large difference in seeing. Suppose the headlamp is aimed one degree too high. Down the road 300 feet the beam will be five feet higher than it should be, which means the lower beam is glaring in the eyes of the oncoming driver. This is dangerous for both of you.

On the other hand, if the beam is aimed too low, the driver does not get proper road illumination. When the headlamp is aimed one degree too low, the illumination 300 feet down the right side of the road is reduced to about one fifth the normal amount. As a consequence the driver may miss seeing objects until it is too late to avoid an accident.

Night driving at its best is more difficult than day driving. Three times as many fatal accidents, on a mileage basis, happen after dark. The automobile industry has conducted research for years to provide the best possible road illumination, but this helps very little if your headlamps are not aimed correctly. It cannot be stressed too much that for safety and comfort in night driving, have your headlights checked at least twice a year.

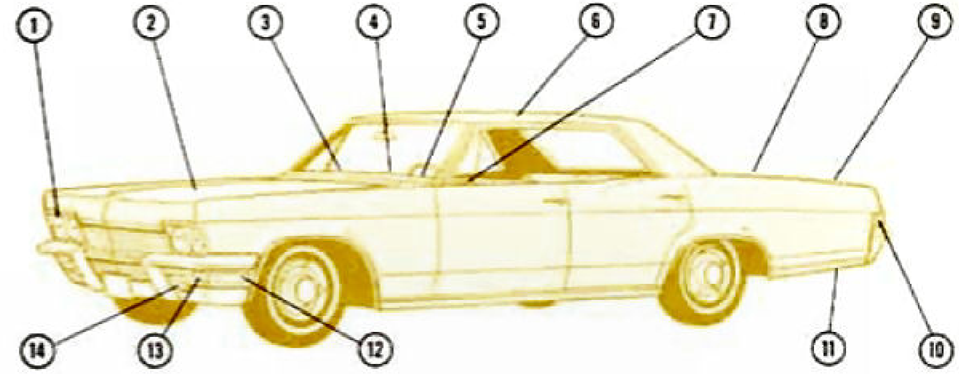
Other Lights and Signals

Many people do not realize the large number of lights, in addition to headlights, with which modern cars are equipped. The diagram points out most of the major units, to which must be added all those small lamps used as indicators on the instrument panel—turn signal, generator, oil pressure, headlight beam, etc.

Probably the most important of these many lighting units are the tail lights, stop lights and turn signals, and these are planned and engineered just as carefully and scientifically as the headlights. Being seen is almost as necessary for highway safety as seeing, and your tail lights are designed to perform this function most efficiently. Light from a low candlepower bulb is concentrated and projected through a red lens in a beam which can be seen for a long distance. The outside shape of the lens may be complicated for styling reasons, but the illuminating engineer has designed prisms into it so that the light is directed to the rear and to the side. In addition, the lens may have a reflex reflector section which will reflect light from the headlamps of an overtaking car and thus provide a measure of protection even if the tail light bulb is not burning.

The stop lights which go on when the brakes are applied may use the same bulbs and lenses as the tail lights or may be separate units. When they use the same bulbs, however, a different filament of higher candlepower is brought into play, so a much stronger beam results. This beam, which gives many times as much light, is necessary so that it can be seen in the daylight and also to distinguish the stop signal from the tail light at night.

Turn signals are operated by the driver to let traffic know when he is about to make a left turn or right turn, or when he is going to move from one lane to another. The driver turns on the signal manually and in most cases it turns off automatically on completion of the turn. Small lights on the instrument panel or on



1 HEADLAMPS
2 UNDERHOOD LAMP
3 GLOVE COMPARTMENT LAMP
4 MAP LAMP
5 INSTRUMENT LAMPS
6 DOME OR INTERIOR LAMPS
7 COURTESY LAMPS
8 TRUNK LAMP
9 LICENSE LAMPS
10 TAIL STOP TURN SIGNAL LAMPS
11 BACK-UP LAMPS
12 CORNERING LAMPS
13 TURN SIGNAL AND PARKING LAMPS
14 FOG LAMPS

the front fenders indicate when it is in operation. The signal lamps are located so they can be seen from either the front or rear of the car—white or amber in front, red or amber in the rear. Turn signals are flashing to attract attention and to distinguish them from other lights on the car.

These lights for signalling intentions to other drivers, and for making the car visible in the dark, are extremely important from the standpoint of safety. They deserve the same attention from the car-owner as the headlights. They do not have to be carefully aimed as the headlights do, but on the other hand, it is not so obvious to the driver when they are not operating properly. Some well-intentioned, conscientious people drive around for weeks with no stop lights simply because they do not realize there is anything wrong. It pays to check all of these lights often to make sure they are working, that the lenses are clean and the beam is bright enough for its purpose.

Most of the other lights are primarily for convenience, although some of them, such as back-up lights and cornering lights, also make a definite contribution to safety. They are all useful, as we soon discover when any of them are not functioning properly. The lighting system of a car today rivals that of a small house of a few years back, and is a far cry from the old acetylene lamps or even the first electric lamps which were such a revolutionary advance in automobile equipment. Industrial research and the lighting engineers have made a great and valuable contribution to the safety and pleasure of motoring.

Research and Vision

To the engineers responsible for good vision in an automobile, night lighting is only one part of the problem, even though it is a very important part. Only a part of the night lighting problem can be solved by the lights on the car. Heavily traveled streets and highways must be illuminated and engineers must design lamps and fixtures which will supply safe lighting. Road signs are an important part of the problem. On many stretches of road, reflex reflectors assist the driver in following the twists and turns, the ups and downs of the road. Reflex reflectors likewise show up obstructions and important road signs.

To study the problems of vision in night and day driving requires constant research on new methods and materials. For the development of headlamps, a long, dark lighting laboratory is required. A test fixture holds filament, reflector and lens so that the effect of each individual part can be tested and studied. In addition to the laboratory, headlamp cars are used for road tests and demonstrations. These cars are made so that a number of different headlamp units can be mounted on the front and controlled from the driver's seat. Beam patterns are developed on the road at night to determine what is required for seeing. Lamps are then designed in the laboratory to produce this result. In this manner

road testing and laboratory development are correlated.

It is also important to study the problem of vision through the windshield and windows. In an automobile we are always looking through glass. Even clean glass in windshield and windows will reduce the light one tenth. Dirty windshields may seriously reduce vision. It is important to keep your windshield and windows clean as a simple safety precaution.

Car design greatly affects vision. Width of pillars, size of windows, design of windshield and rear window—all such things can help or hinder our ability to see out of the car. They affect our vision to the front, sides and rear, and—something not always realized—our ability to see through the car ahead and so anticipate hazards or problems further ahead. A large amount of engineering effort is devoted to this subject of body design as it affects vision, and the results are apparent in today's cars.

Careful study is likewise given to vision through the rear view mirror.

In these and many other ways, automotive engineers study the problems involved in better vision in driving. As new things are developed and new information discovered, they are applied to the automobile. This never-ending work assures you of a constant advancement in the vital problem of vision from your motor car.

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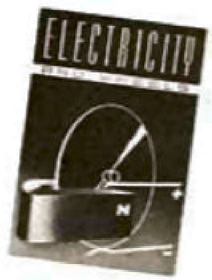

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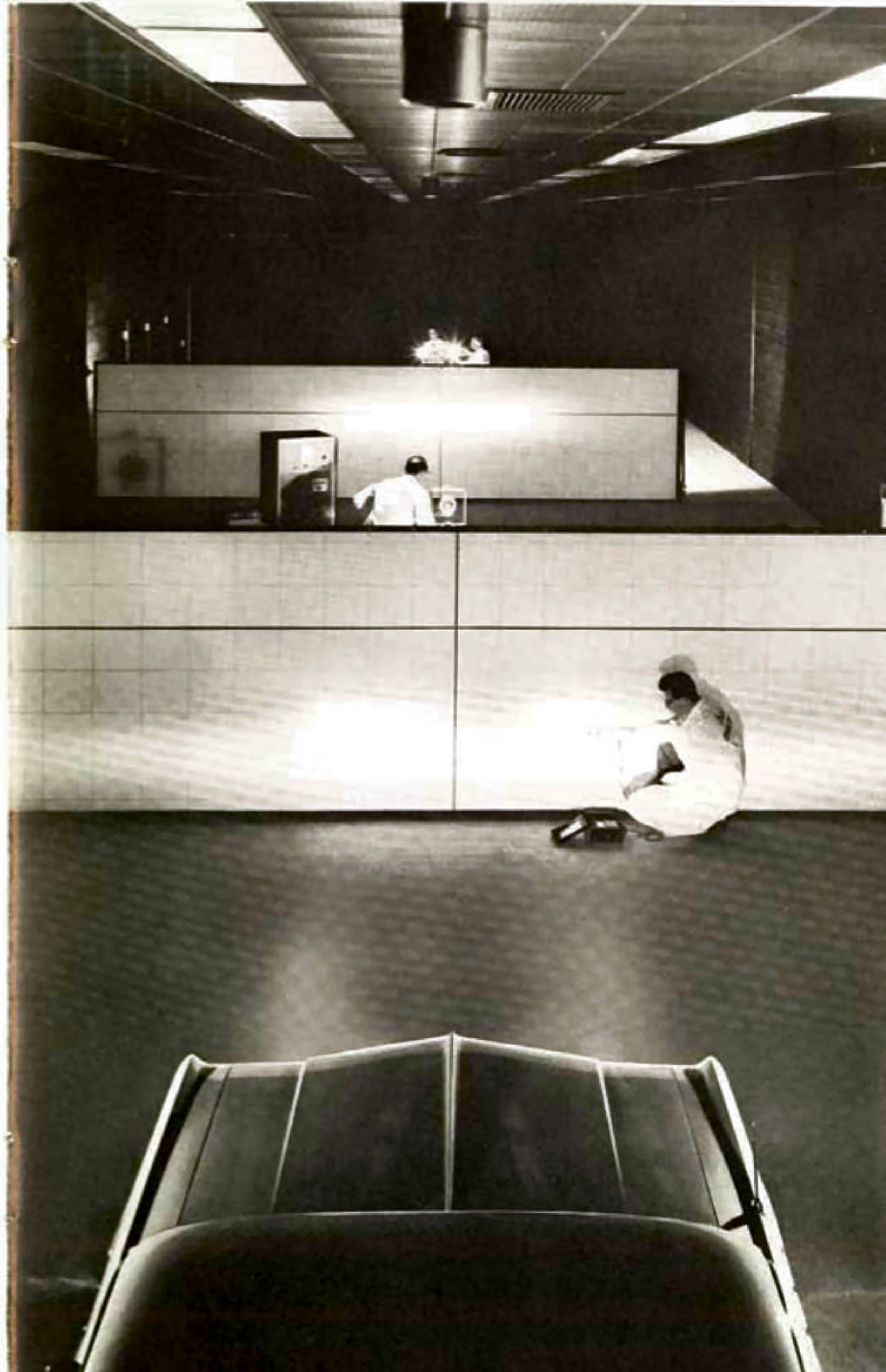

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