LOCOMOTIVE HEADLIGHTS

Serial 1959 Edition 1

ELECTRIC-HEADLIGHT EQUIPMENT

PRINCIPLES OF CONSTRUCTION

GENERAL FEATURES

1. The electric headlight is the result of a growing demand for a type of headlight that is superior to the old-style oil lamp that has been in use for so many years. The general adoption of the electric type for all classes of locomotive service makes it necessary for those responsible for the care and operation of locomotives to become familiar with the principles of construction and management of that type, so that they may be able to handle it properly and prevent its failure on the road.

2. Main Parts of Equipment.—As a matter of convenience, the equipment composing an electric-headlight outfit may be considered as consisting of four principal parts, namely, the headlight, the electric circuit, the generator, and the steam turbine. The headlight itself consists of an electric lamp, by which the light is produced, located inside a reflector that focuses the light and throws it forwards along the track. The electric circuit consists of the wiring, connections, and switches through which the electric current is supplied to the lamp. The generator is the electrical device or machine by which the current for the lamp is produced, or generated, and is connected with the lamp by the wiring. The generator is driven by being directly connected to the shaft of a small steam turbine that in turn is run by steam drawn from the locomotive boiler. Briefly, then, the steam runs the turbine that turns the generator and so produces the necessary electricity, which is conducted by wires to the lamp, where it produces light.

3. So far as understanding the action of the moving parts of the electric headlight is concerned, the apparatus may be divided into two sections—the steam end and the electrical end. The steam end includes the steam piping and the steam turbine that produces the power to drive the generator; and the electrical end includes the generator and its connections. To understand how the pressure of the steam produces rotary motion of the steam turbine, it will be necessary to study something about the principles of construction and action of the turbine. Similarly, to understand how the generator produces an electric current and how the electricity is transmitted to the lamp, it will be necessary to take up a brief study of the elements of electricity. The moving parts of the turbine and the generator are fastened to the same shaft, so that they rotate together at the same speed, and are carried in a framework that forms one continuous piece. The turbine and generator combined in one unit in this way form what is commonly called a **turbo-generator.**

STEAM END

4. Principles of Steam Turbine.—A steam turbine is a form of engine by which the energy of steam is converted into work and produces rotary motion of a shaft. In the ordinary steam engine this is done by means of a piston that moves back and forth in a cylinder, together with a piston rod, a connecting-rod, a crank, and a frame. The steam turbine has no pistons or rods, and none of its parts reciprocate, or move to and fro. Instead, the moving part consists of a wheel, along the edge of which are fastened a large number of small buckets or curved blades. The steam is allowed to flow from the end of a pipe or nozzle placed in such a way that the jet of steam strikes the buckets. This gives a turning movement to the wheel and rotates it continuously in one direction.

5. A diagram showing the principle of one style of steam turbine is given in Fig. 1. The wheel *a* is fastened on a shaft *b* held in bearings so that it can rotate easily. Around the edge of the wheel are a number of curved buckets *c*, and opposite the lower part of the wheel is a nozzle *d* from which steam under pressure is allowed to flow. The steam escapes from the nozzle at a very high speed, strikes the buckets with considerable force, and causes the wheel to rotate rapidly in the direction of the arrow.

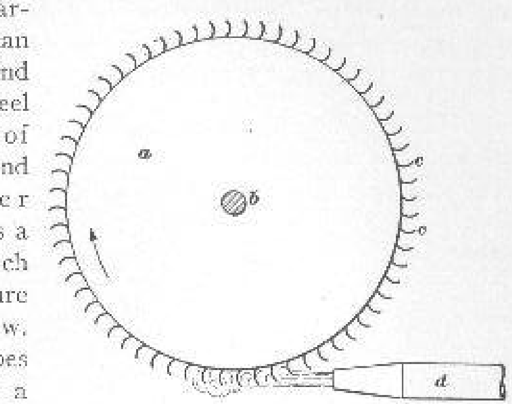


FIG. 1

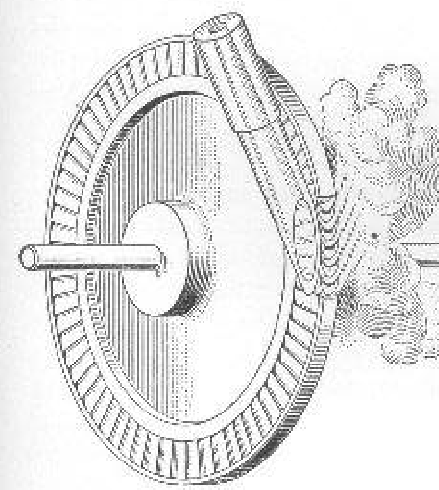


FIG. 2

6. Blade Arrangement.—The diagram in Fig. 1 is intended merely to show the principle of the steam turbine. As a usual thing, the steam nozzle is not placed directly in line with the edge of the wheel. Instead, the buckets are curved crosswise of the wheel, as indicated in Fig. 2, and the steam nozzle is set at one side, so as to discharge the steam against one edge of the buckets, at an angle. The steam then strikes down into the hollow of the bucket, forces the wheel to turn, and escapes at the opposite side.

Another way of arranging the buckets is shown in Fig. 3. In this case the buckets are set along one side of the wheel and the steam jet from the nozzle strikes them directly in line with their centers, as shown. The steam escapes from the buckets at their inner edges.

7. Details of Construction.—The wheel of the turbine is enclosed in a cast-iron casing, so that it turns inside a closed chamber. The casing is commonly made in two parts that are bolted together, but that may readily be taken apart to allow the wheel and the buckets to be inspected. The buckets in the smaller turbines, such as are used for headlight turbo-generator sets, may be made of steel or of some alloy like bronze. When made of steel, they are usually given a special treatment that prevents rusting and reduces wear. The jet of steam escaping from the nozzle into the buckets has a very high speed, and as the steam very probably carries water with it, the cutting effect of the particles of moisture sweeping across the faces of the buckets is severe, resulting in wear, or erosion, as it is commonly called. The shaft also is made of steel, and may be given an anti-rusting treatment. The speed at which the turbine wheel turns is kept practically uniform by means of a governor. The governing device may have a variety of forms, some of which will be described later.

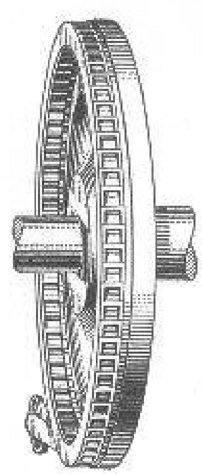


Fig. 3

8. Advantages of Steam Turbines.—The steam turbine has a number of distinct advantages over the reciprocating steam engine for furnishing power. First of all, the turbine wheel turns always in one direction, and is nicely balanced, so that there is no shock or vibration connected with its operation, provided that it is kept properly adjusted. It has no internal rubbing surfaces, and so it requires no lubrication except for the bearings of the shaft on which the wheel is mounted. It can produce much higher speeds of rotation than the reciprocating engine, and it occupies considerably less space than a piston engine of the same power.

ELECTRICAL END

9. Purpose of Electrical Instruction.—It is not necessary for the locomotive engineer to be familiar with all the theory relating to the generation, transmission, and use of electricity, but he ought to be familiar with some of the elementary principles. Such knowledge will help him to understand better the causes of the troubles that arise in connection with electric-headlight apparatus and so make it easier for him to detect and locate faults and apply the necessary remedies. For these reasons, an explanation will be given as to how electricity is produced, how it is conducted from one place to another, and how light is produced from it.

10. Magnets and Magnetism.—A common and interesting toy is the horseshoe magnet, illustrated in Fig. 4. It consists of a bar of flat steel bent into the shape of a horseshoe and possesses the strange property of being able to attract and hold small pieces of iron or steel that are laid against the ends. For example, if the iron strip *a* is laid across the ends of the magnet, it will be held fast and a considerable pull will have to be exerted in order to remove it. The power of a magnet to hold a piece of iron in this way is due to the magnetism it possesses.

Fig. 4

11. Electromagnets.—A magnet like that shown in Fig. 4 is called a permanent magnet, because, after it is once magnetized, its retains its magnetism, or power to attract iron and steel. If a piece of soft iron bar is bent into the shape of a **U**, as shown at *a*, Fig. 5, and each arm is wound with a coil *b* of insulated wire in the manner indicated, then, when electricity is caused to flow through the wire that forms the coils, the soft iron bar becomes magnetized and is able to attract iron and steel just as the horseshoe magnet in Fig. 4 can do. A magnet of the type shown in Fig. 5 is called an electromagnet. So long as an electric current is maintained in the wire coils, the **U**-shaped bar will have magnetism; but if the circuit is broken, so that no electricity flows through the coils, then the iron bar ceases to be a magnet.

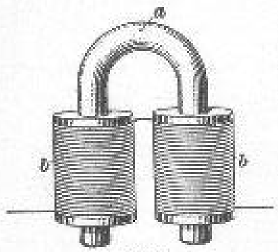


FIG. 5

12. Poles of a Magnet.—The ends of the iron or steel bar that forms a magnet are called the **poles** of the magnet, one end being called the *north pole* and the other the *south pole*. These poles are usually indicated by the letters *N* and *S*, respectively, as in Fig. 4. If two magnets are brought close together, with the north pole of each opposite the south pole of the other, as in Fig. 6 (*a*), they will attract each other, or be drawn toward each other, as indicated by the arrows; but if the north and south poles of one are brought opposite the north and south poles of the other, as in (*b*), then they will repel each other, or tend to force each other away, in the directions indicated by the arrows.

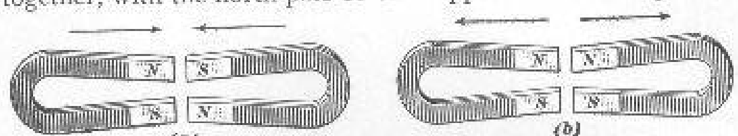


FIG. 6

13. Lines of Force.—The attraction of unlike poles and the repulsion of like poles of magnets are due to the magnetic forces produced by the magnets. These forces act through all the space around the magnet, and the positions in which they act may be found by a simple experiment. If a sheet of glass is laid over a straight bar magnet, as shown in Fig. 7, and fine iron filings are sprinkled on the surface of the glass, they

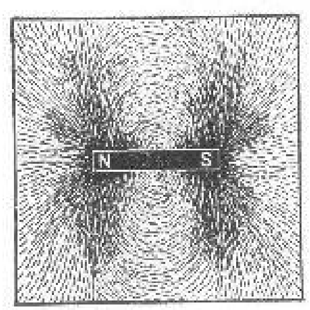


FIG. 7

will arrange themselves in a pattern of curved lines, as shown. These lines run from the north pole to the south pole of the magnet and represent the paths of the magnetic forces that act in the position occupied by the surface of the glass. These curved lines in which the magnetic forces act are called **lines of force.**

14. Generating Electricity.—The source of electricity for use in headlights is an electric generator. This is a machine that consists of a stationary frame inside which is a rotating part driven by a steam turbine. The stationary part contains magnets and the movable part carries wires that are caused to move past the poles of the magnets and close to them. This rotation of the wires past the ends of the magnets sets up

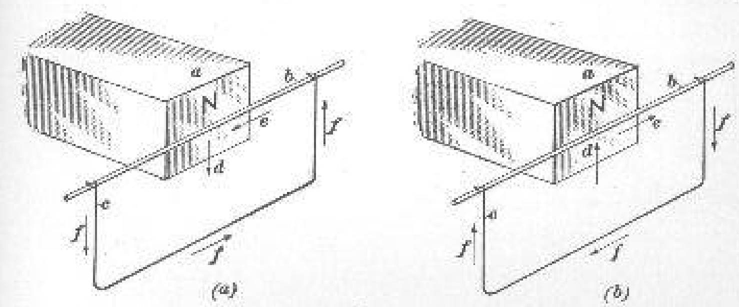


FIG. 8

currents of electricity in the wires, and the wires are so connected that the electricity generated in each can be conducted to the point where the current is to be used.

15. The principle of the electric generator may easily be shown in connection with Fig. 8 (*a*), in which *a* is the north pole of a magnet and *b* is a straight piece of wire to which a loop *c* of finer wire has been connected, as shown. If the wire *b* is moved down past the end of the pole *N* of the magnet, as indicated by the vertical arrow *d*, it will cut directly across the lines of magnetic force that radiate outwar.'s in all directions from the end of the pole, and this cutting across the lines of force will set up an electric current in the wire *b*. The current in the wire will have the direction shown by the arrow *e* and a flow of electricity will occur through the loop of fine wire, as indicated by the arrows *f*. If the movement of the wire *b* is stopped, the current in the wire ceases immediately. If the direction of movement of the wire *b* is reversed, as in (*b*), so that it moves upwards past the pole *N*, then the electricity will flow in the opposite direction, as shown by the arrows. Briefly, then, an electric current may be produced by moving a wire through the lines of force near the pole of a magnet. It makes no difference whether the magnet is a permanent magnet or an electromagnet; the effect is the same. In the generator used for headlights, however, electromagnets are employed.

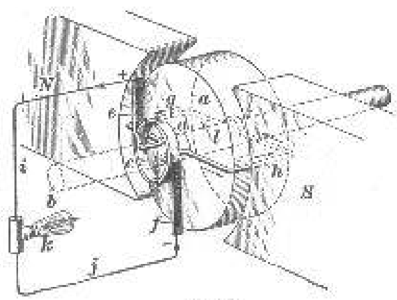


FIG. 9

16. Simple Form of Generator.—The device shown in Fig. 8 for producing electricity is not a practical form, because it cannot furnish a continuous current. In order that the flow of electricity may be unbroken, it is necessary to provide certain essential parts, as indicated in Fig. 9. These essential parts are the poles *N* and *S*, the armature *a* on the shaft *b*, the commutator bars *c* and *d*, and the brushes *e* and *f*. The poles are the north and south poles of a magnet, and between them is the armature *a*, which is fixed on the shaft *b* by which it is rotated. The semicircular bars *c* and *d* also turn with the armature, but they are insulated from it. A wire loop is carried around the armature and its ends are fastened to the commutator bars, forming two straight parts *g* and *h* across the circumference of the armature. When the armature turns, these parts *g* and *h* swing in a circle and are moved directly across the ends of the pole pieces *N* and *S*, with the result that an electric current is set up, as explained in the preceding article. The brushes are stationary and rest lightly against the commutator bars. Two wires *i* and *j* are connected to the brushes and lead to a lamp *k*, as shown.

17. The device illustrated in Fig. 9 is a simple form of electrical generator. Suppose that the parts have the positions shown and that the armature is rotating in the direction of the curved arrow *l*. The part *g* of the wire loop is thus caused to swing directly across the end of the pole *N*, which, as explained in Art. **15**, results in a flow of electricity in the direction indicated by the arrow on that part of the wire. At the same time the part *h* of the loop of wire moves up across the end of the pole *S* and a current is generated in it, in the direction of the arrow. The result is that a flow of electricity is set up, following the direction of the arrows along the loop. This electricity flows from the loop into the bar *c*, then into the brush *e*, and so by way of the wire *i* to the lamp *k*, from which it flows back to the generator by way of the wire *j*, the brush *f*, and the commutator bar *d*. As the armature continues to turn, current continues to be generated by the movement of the wires *g* and *h* past the ends of the poles, and the flow of electricity to and from the lamp is continuous.

18. Conductors and Insulators.—In order that there may be a flow of electricity, there must be an unbroken path in which it can flow. Usually, copper wire is used to form the path for an electric current, although water, earth, iron, and many other substances will allow electricity to pass through them. Any substance that will allow electricity to flow through it readily is called a **conductor.** Those substances through which electricity can pass only with the greatest difficulty are called **non-conductors** or **insulators.** The most common substances used for insulators are porcelain, glass, mica, cotton, silk, and rubber. Electric wires are covered with cotton, silk, and rubber so that the electricity may not escape, and when such wires are strung up, they are fastened to porcelain insulators to prevent leakage of current.

19. Closed and Open Circuits.—The path in which electricity flows is commonly called a **circuit.** If the path is complete, or continuous, so that the current is not interrupted, it is said to form a **closed circuit;** but if the path is broken, so that it is not continuous, it is said to form an **open circuit.**

A circuit may be changed from a closed circuit to an open circuit by breaking a wire, unfastening a wire, or opening a switch, but the most common way is by using a switch. By means of a switch, a circuit may be opened or closed at pleasure, with little effort or loss of time. A current of electricity may pass through a closed circuit, but it cannot pass through an open circuit.

20. Fuses.—A wire of a certain size can transmit a certain current of electricity with safety. If the current is increased, its passage may heat the wire to such an extent as to cause melting; or it may damage some electrical device connected in the circuit. To prevent trouble due to too heavy a current, it is customary to use a fuse in the circuit. A **fuse** is

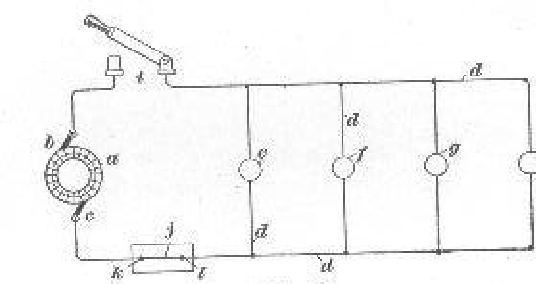


Fig. 10

simply a short piece of soft wire or a bar of soft metal held between two parts of the circuit. The current must pass through the fuse, the soft wire or metal of which has a low melting point. Consequently, if the current is increased to a point where it may endanger the apparatus in the circuit, the heat produced by it in passing through the fuse causes the latter to melt, thus breaking or opening the circuit, preventing any further flow of electricity and so obviating any harmful effects to the apparatus. Fuses are made in such forms as to be easily and quickly replaced when they melt, or *blow out*, as it is commonly termed.

21. Wiring Diagrams.—To show the various parts of an electric circuit and the apparatus connected therewith, it is

customary to use what is called a wiring diagram. For example, suppose that it is desired to show a wiring diagram for a generator that furnishes current to four lamps, all on the same circuit, but in different localities. Such a diagram is shown in Fig. 10. The barred circle *a* and the black dashes *b* and *c* taken together form the symbol that represents the electric generator. The circle may be understood as indicating the commutator, and the black dashes the brushes. The wires that conduct the current are indicated by the thin lines *d*, and the four lamps are represented by small circles *e*, *f*, *g*, and *h*. A switch *i* is inserted in the circuit, so that the lamps may be turned off or on in an instant by opening or closing the circuit. When the switch is in the position shown, the circuit is open, and when the switch is pushed down the circuit is closed. A fuse *j* is

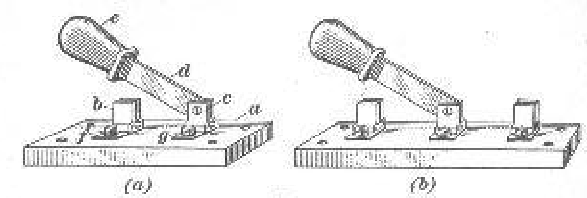


Fig. 11

inserted in the circuit, between the posts *k* and *l*, to prevent the passage of a dangerously heavy current.

22. Single-Throw and Double-Throw Switches.—A view of a single-throw switch is given in Fig. 11 (*a*). It consists of a base *a*, made of some insulating material, to which are attached two metal posts *b* and *c*, the blade *d* of the switch being hinged to the post *c* so that it can be swung up or down by means of the handle *e* of insulating material. The post *b* is made of two thin jaws, so that, when the blade *d* is forced down to close the switch, it fits snugly between them. The wires in the circuit of which the switch forms a part are fastened to the posts *b* and *c* by the binding posts *f* and *g*. When the blade is forced down, and the switch closed, current passes from the wire attached at *f* to the post *b*, thence through the blade *d* to the post *c*, and through the connection *g* to the wire attached at that point; or, if the connections are reversed, the current will pass from g to f in the opposite direction. This form is called a single-throw switch because the blade is thrown in but one direction to close the switch. A double-throw switch is shown in (b). In this form the blade may be thrown to one side or the other to close the switch. Such a switch may be used on two circuits that do not need to be closed at one time.

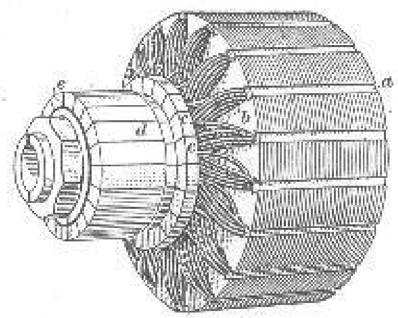


FIG. 12

23. Armature and Commutator.—The armature of an electric generator is the rotating part that carries the coils of wire that cut across the lines of force passing between the pole pieces. One form of armature is shown in Fig. 12. The body of the armature is built up of a large number of thin, notched plates, which, when put together side by side, with the notches matched, form a core containing slots a in which the coils b are placed. The ends of each coil are connected by wires, as at c, to the bars of the commutator d, there being as many commutator bars as there are coils. The bars are made of copper and are insulated from one another as well as from the other metal parts of the armature. The insulation consists of thin strips e of mica, or isinglass. The armature and the commutator are combined in one assembled piece that fits on the shaft of the generator and rotates with it.

Another style of armature, mounted on its shaft, is shown in Fig. 13. The slotted armature is shown at a and the shaft at b.

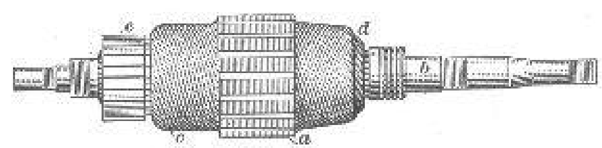


FIG. 13

The slots in the armature may readily be seen, and the ends of the coils that lie in these slots are smoothly wrapped with a covering, as at c and d. The ends of the wire forming each coil are attached to opposite bars of the commutator e.

24. Volts.—Just as it requires pressure to cause steam to flow through a pipe, so does it require pressure to cause electricity to flow through a conductor. But, whereas the pressure of steam is expressed in pounds per square inch, the pressure or force that causes electricity to flow is measured in **volts,** and the instrument by which the pressure is measured is called a *voltmeter*. Commonly, the pressure is called the *voltage* of the circuit, which means the number of volts indicated by a voltmeter connected to the circuit.

25. Amperes.—The **ampere** (which is pronounced *am-poir*) is the unit used for measuring the rate of flow of electricity, or the quantity flowing in a given time. The instrument used to find the number of amperes is called an ammeter. An electric current heats a wire through which it passes, and if the current is heavy—that is, if the quantity flowing is large—the heating may become so great as to melt the wire. The ammeter enables the rate of flow to be measured and thus it is possible to proportion the circuit to the current it is to transmit, and so prevent damage to the conductor.

26. Ohm.—Electricity meets with resistance in flowing through every body. If the body is of metal, such as copper or silver, there is very little resistance, and the body is called a conductor of electricity. But such substances as mica, glass, silk, and porcelain offer so much resistance that hardly any current can pass through them, and they are therefore called non-conductors, or insulators. The resistance of an electric circuit of any kind can be measured, and the unit for measuring it is the **ohm,** which is the resistance offered by 362 feet of round copper wire $\frac{1}{16}$ inch in diameter. The smaller the size of a wire, the harder it is for a current to pass, and the greater is the resistance. If a conductor having a very low resistance is placed across a circuit, the current will pass through it in preference to the part having the higher resistance. The flow of electricity through such a path is commonly called a *short circuit*.

27. Watt and Watt-Hour.—If the number of volts and the number of amperes in a circuit are multiplied together, the product is *watts*. The **watt** is the unit used to measure the rate of doing work in a circuit. The amount of work done, or the amount of electrical energy used, is measured by the unit called the **watt-hour,** which is the work done in 1 hour at the rate of 1 watt; that is, the number of watt-hours of work done in a circuit is found by multiplying the number of watts by the time in hours.

SUNBEAM HEADLIGHT OUTFIT

28. General Arrangement.—An outside view of the Type RE-3 Sunbeam turbo-generator is given in Fig. 14. The end *a* of the casing encloses the armature, field coils, commu-

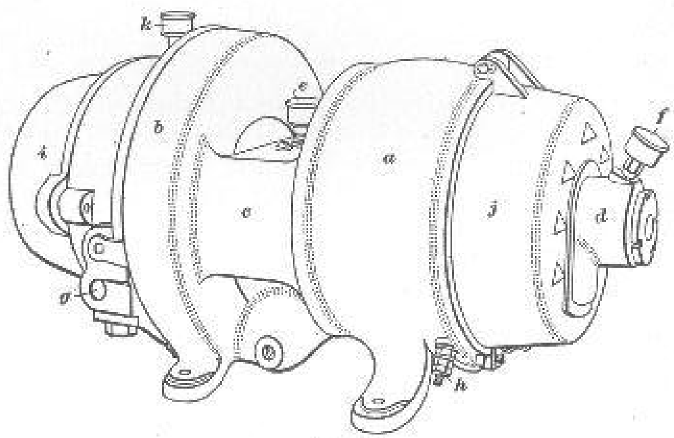


FIG. 14

tator, brushes, and other parts of the generator. The other end *b* forms the shell inside which are the turbine wheel, nozzle, and governor. These two ends are joined by the yoke *c*. The shaft to which the turbine wheel and the armature are fastened is carried by two roller bearings, one inside the yoke casting *c* and the other inside the housing *d*. These bearings are lubricated by the oil cups *e* and *f*. Steam enters the turbine through the opening *g* and is exhausted through an opening at the bottom of the casing. The electrical connections to the generator are made by binding posts, one of which is shown at *h*. The covers *i* and *j* are removable and so enable inspection of the governor and the commutator to be made without difficulty. The oil cup *k* furnishes lubrication for the governor.

29. Turbine.—A vertical section of the Sunbeam turbo-generator, taken lengthwise, is shown in Fig. 15. The main shaft *a* rotates in the ball bearings *b* and *c* and carries the armature *d*, the turbine wheel *e*, and the governor *f*. The speed of the turbine is kept fairly constant by throttling, or partly closing the opening through which steam flows into the turbine nozzle. If the speed rises, the governor shuts off the steam a little more, and so the speed is reduced; or, if the speed falls, the governor admits more steam and brings the speed back to what it should be. The valve by which the steam flow is regulated is shown at *g*, attached to a long stem *h* that is connected to the lever *i*, which is pivoted at its upper end and is under the control of the governor *f*.

30. The turbine wheel *e*, Fig. 15, is a steel disk that fits on a tapered part of the shaft and is held in place by the sleeve nut *j*. The rim of the wheel is made with a flange *k* that is turned inwards and over which the vanes or buckets *l* are hooked. A ring *m* is then screwed fast to the disk, flush against the backs of the hooks by which the vanes are held, thus keeping them all in place, yet enabling them to be removed or replaced with ease. The nozzle through which steam is discharged against the buckets is inside the casing at *n*, and the steam, after being discharged from the wheel, escapes through the exhaust opening *o* to the exhaust pipe. The chamber *p* in which the wheel rotates is filled with steam at exhaust pressure. To prevent this steam from leaking out in either direction along the shaft, packing rings *q* are set into the casing at each side, around the shaft. These rings are made of graphited woven asbestos and copper and require no adjustment; but they should be renewed after long periods of operation.

31. Generator.—The generator, Fig. 15, is a two-pole machine, the poles being formed in the main casting *r*, on oppo-

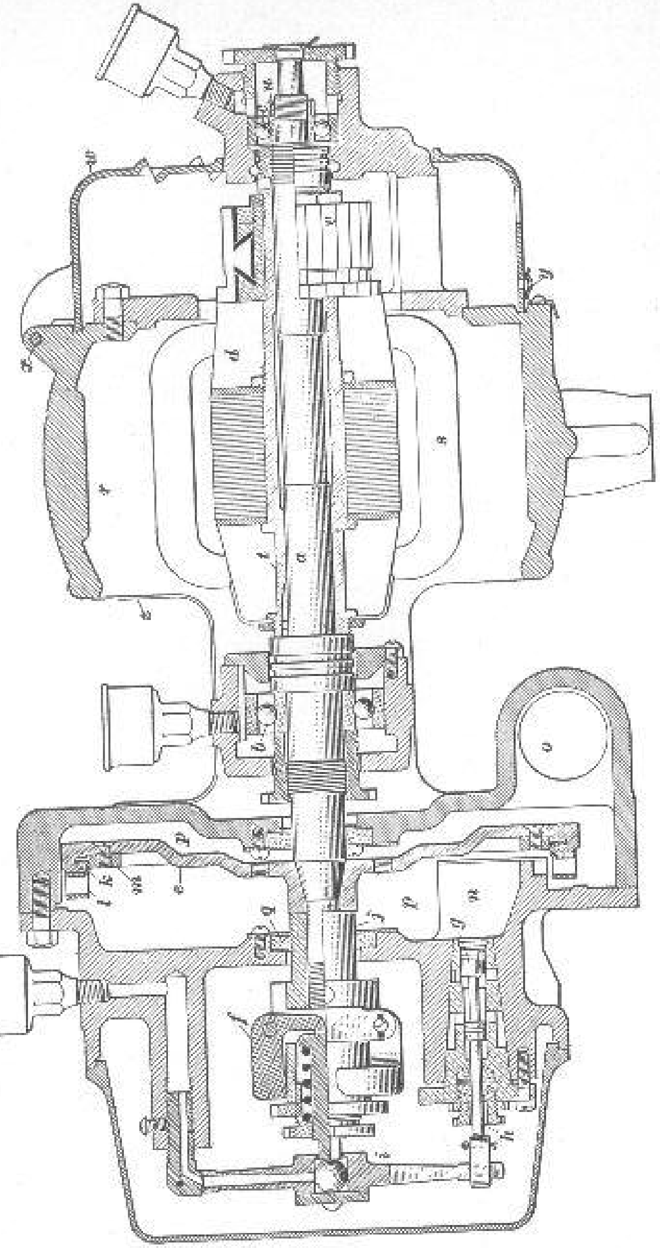


Fig. 15

site sides of the armature *d*. Each pole is approximately square in section and its inner face is curved so as to fit closely around the armature. A field coil, also made in square form, is slipped over each pole and is held in place by a steel retainer that in turn is held by two pins that pass through the pole pieces. The outline of one of the field coils is shown at *s*. The armature is constructed on a bronze sleeve *t* that can be slipped off the shaft *a* after the locknut *u* has been removed. Thus, in case the armature must be removed, as when it is damaged, it may easily be slipped off and replaced by a new one, enabling the generator to be put back in service without loss of time.

32. The sectional view, Fig. 15, does not show the graphite brushes that collect the current from the commutator *v*.

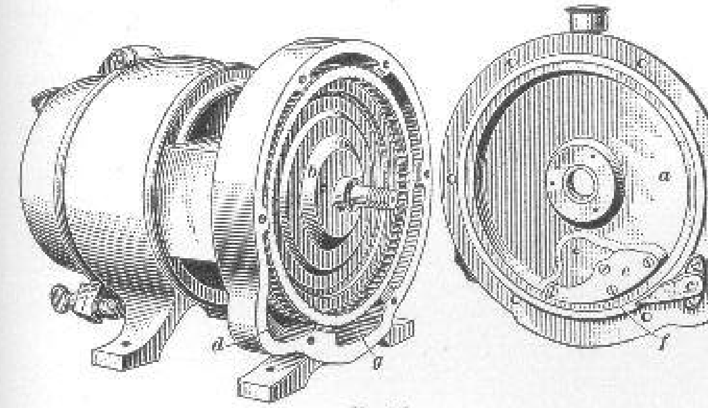


Fig. 16

These brushes, one on each side of the commutator, are pressed against the surface of the commutator by flat coiled springs, the pressure of which can be adjusted. A steel cover *w* encloses the commutator and brushes and protects them from dust, dirt, and steam. This cover is hinged on a pin *x* and is held in place by a spring clip *y* at the bottom, so that it may quickly be raised to allow inspection of the commutator and brushes. The armature *d* has eighteen slots, in which are the armature coils. These coils are securely bound in place by steel wires, and a heavy protector of metal is fitted over the coils at the end of the armature farthest from the commutator. A sheet-steel cover *z* prevents dust and moisture from entering the generator at the inner end of the armature.

33. Steam Flow in Turbine.—The action of steam in the turbine may be understood by reference to Figs. 16 and 17. In Fig. 16 the head *a* of the turbine is shown removed, exposing the turbine wheel *b* and the chamber in which it turns. The nozzle *c* from which the steam first flows is carried on the head *a* and fits into the space *d* when the head is bolted in place, being then directly opposite the faces of the buckets on the wheel. The head also carries the device shown at *e*, by which the steam that has once passed through the turbine

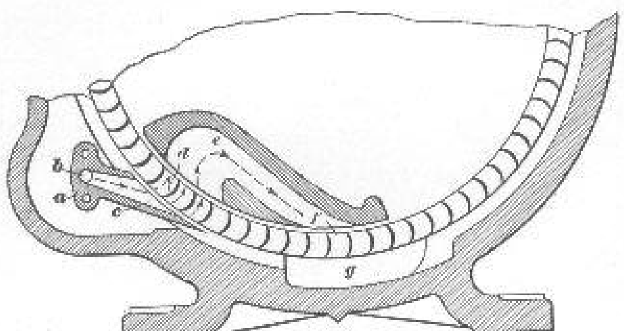


Fig. 17

buckets is caught, reversed in direction, and caused to pass through a second time, thus giving additional impulse to the wheel. The blades on the wheel run in the narrow slot or passage *f*; thus, they receive steam on the outside from the nozzle *c* and on the inside from a nozzle beneath the plate *e*. The steam then escapes through the passage *g* to the exhaust pipe.

34. A diagrammatic view of the course of the steam through the turbine buckets is shown by the section in Fig. 17. The steam enters the first nozzle *a* through the opening *b* and flows through the tapered passage *c*, increasing in speed as it expands in the enlarging passage. On leaving the nozzle *a* it strikes the buckets *d* and causes the wheel to turn. As the

buckets curve backwards, the steam escapes from their inner edges in a direction nearly opposite to that which it had on leaving the nozzle *a*, and collects in the chamber *e*. This chamber is curved, so as to direct the steam once more against the buckets, as at *f*. The steam discharged from this second stage of the work enters the passage *g* and goes to the exhaust. As the inner edges of the buckets do not revolve in so large a circle as the outer edges, they have a speed about 350 feet per minute slower than the outer edges. Thus, the steam flowing from the nozzle at *f* has an additional effect in giving motion to the turbine wheel. Using the steam twice is equivalent to compounding, and is economical of steam.

35. Steam Strainer.—Steam is conveyed from the boiler to the turbine through a $\frac{1}{2}$-inch pipe that has a valve

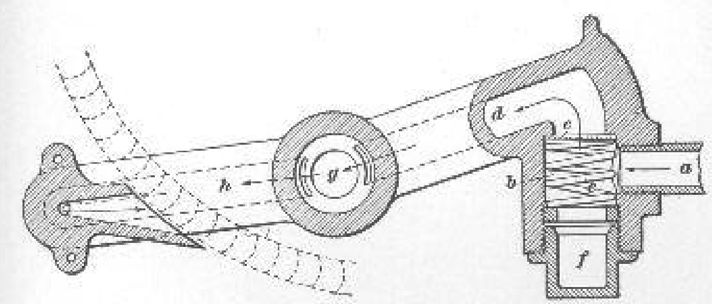


Fig. 18

within convenient reach of the engineer in the cab. To prevent scale or dirt flowing along with the steam from entering the turbine, a strainer is used. The arrangement may be understood by reference to Fig. 18, which shows a part of the head of the turbine. The $\frac{1}{2}$-inch steam pipe is connected at *a* and the steam is discharged from it into the chamber *b*, from which it flows up through the wire-gauze strainer *c* into the passage *d*. The gauze strainer is held in place by a spring *e*, but both spring and strainer can be removed by unscrewing the cap *f*, thus enabling cleaning to be done rapidly. The steam, freed of all solid matter, flows along the passage *d* to the center of the turbine head, at *g*, where the governor valve is located.

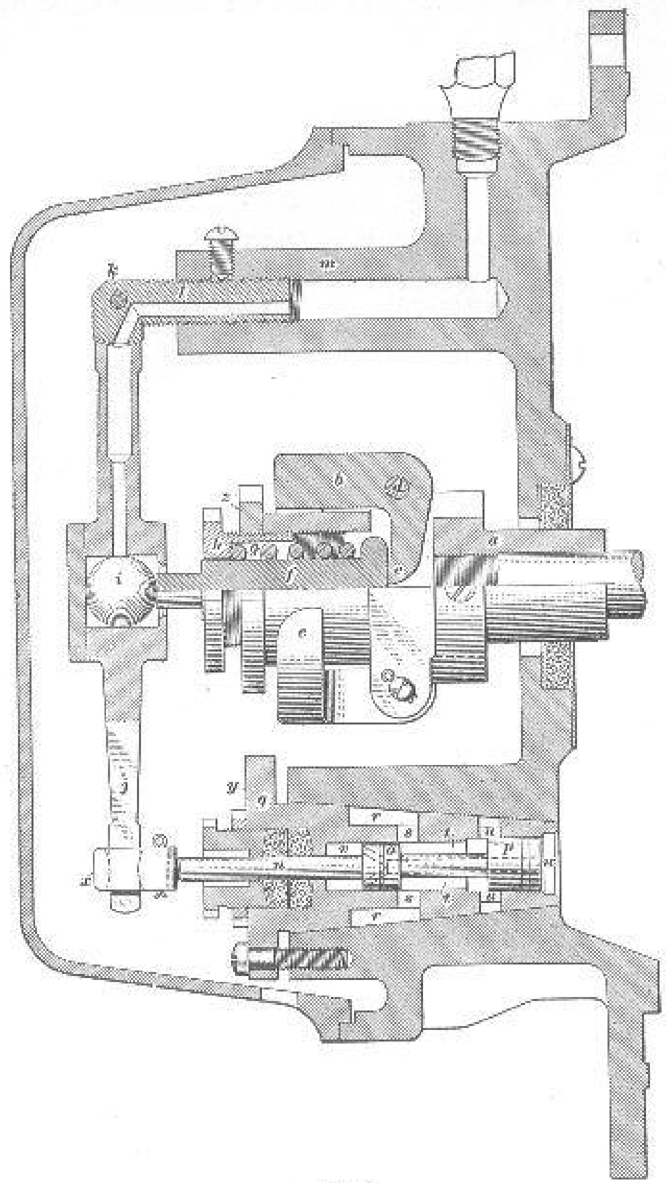


Fig. 19

After passing the governor valve, the steam continues along the passage *h* to the first steam nozzle, and thence to the turbine wheel, as already explained in connection with Fig. 17.

36. Governor.—The entire governing device of the Sunbeam turbo-generator is shown in section in Fig. 19. The governor itself is carried on the turbine end of the main shaft. It consists of a body *a* that is screwed on the shaft and that carries two heavy weights *b* and *c*, the former being shown in section. Each weight is made in the shape of an **L** and is pivoted on a pin *d* in the body *a* of the governor. The inner arms *e* of these weights bear against the flat head of a steel pin *f* that fits inside a recess in the body of the governor. A coil spring *g* presses against the under side of the head of this pin and tends to push it to the right. It is held in place by the nut *h*, and the farther this nut is screwed in, the harder will the spring press the pin *f* toward the right.

37. When the turbine is running, the governor weights spin around with the shaft and centrifugal force is set up; that is, the heavy ends or weights *b* and *c*, Fig. 19, are thrown outwards, away from the shaft. Thus they swing on the pivot pins *d* and the short arms *e* move to the left, against the resistance of the spring *g*. By properly adjusting the spring pressure by means of the nut *h*, a certain speed of the turbine will be required before the centrifugal force of the weights will be great enough to move the pin *f*. This is the regular running speed to which the turbine is adjusted. If the speed falls below this regular running rate, the spring *g* overcomes the force exerted by the weights and pushes the pin *f* to the right. In other words, if the speed gets too high, the weights push the pin *f* to the left; and if it gets too low, the spring pushes the pin to the right. These movements are used to control the amount of steam admitted to the turbine and so govern the speed, as will now be explained.

38. Governor Lever. The end of the pin *f*, Fig. 19, bears against a steel ball *i*, held in the center of a lever *j*. This lever is pivoted on a pin *k* at the upper end, the pin being held in a threaded stud *l* that may be screwed into or out of the bracket *m*. If the governor moves the pin *f* to the left under an increase of speed, the lever *j* is moved to the left; and as its upper end cannot move, the lower end moves farther to the left. This lower end fits in a slot or yoke on the end of the stem *n* of the governor valve. The upper half of the lever *j* is hollow, as is also the stud *l*, so that lubricant from the cup may reach the steel ball *i*, which is subjected to the pressure and wear of the pin *f* that turns rapidly with the turbine shaft.

39. Governor Valve.—The governor valve, Fig. 19, consists of two pistons *o* and *p* on the same stem *n*, the piston *p* being somewhat larger in diameter than the piston *o*. These fit snugly in the bronze valve cage *q*. Steam at boiler pressure, coming to the valve from the strainer, as described in connection with Fig. 18, enters the space *r*, Fig. 19, whence it flows through the ports *s* in the valve cage to the chamber *t* between the two pistons. It then passes out through the ports *u* on its way to the turbine nozzle. As the steam in the chamber *t* is at high pressure, it tends to push the piston *o* to the left and the piston *p* to the right; but, as the two are on the same stem, and as the piston *p* has the larger area, the net result is that the valve always tends to move to the right. However, as the end of the valve stem is connected to the lever *j*, which bears against the governor pin *f*, it can move to the right only when the speed of the turbine falls and the governor spring pushes the pin *f* to the right. The valve moves to the left whenever the speed rises and the governor pin presses to the left against the ball *i* in the lever *j* and swings that lever to the left.

40. To illustrate the action of the governor valve, suppose that the speed of the turbine increases above the normal. The governor weights fly out, move the pin *f*, Fig. 19, to the left, and push the lever *j* and the valve stem to the left. When this happens, the piston *p* is moved to the left, so that it partly closes the ports *u* through which the steam must pass to the turbine nozzle. The result is that the steam is throttled and its pressure reduced, so that when it reaches the turbine buckets it has less effect on them, and the speed of the wheel decreases. If the speed falls below the regular, normal rate, the spring *g*

forces the pin *f* to the right, and so relieves the pressure against the ball *i* in the lever *j*. As the steam pressure in the chamber *t* always tends to push the piston *p* to the right, it is now free to do this, because there is no lever pull on the valve stem. This movement to the right increases the opening of the ports *u* and so the steam admitted to the nozzle has a higher pressure and speed, thus bringing the turbine back to its normal rate.

41. Under normal conditions the ports *s*, Fig. 19, are always open, the regulation of the speed being governed by the movement of the piston *p* over the ports *u*. If the governor should fail, from any cause whatever, the steam pressure would force the valve over to the right as far as it would go. In that position the piston *o* would close the ports *s* and no steam could enter the chamber *t* or reach the turbine. Excessive speed that might damage the turbine, the generator, or the lamps would thus be prevented.

A hole is drilled through the center of the valve stem so as to connect the chamber *v* with the space *w* at the right of the piston *p*. Thus, exhaust-steam pressure only is exerted on the outer faces of the two pistons. A stuffingbox around the stem *n* prevents steam from leaking out into the space beneath the cover at the turbine end.

42. Valve Adjustment.—The governing valve operates at all steam pressures without the need of adjustment. It it so set at the factory as to have a travel of ¼ inch, and when so set, the distance from the end *x*, Fig. 19, of the yoke to the face *y* of the valve cage is 1⅜ inches. Resetting of the valve is seldom necessary, as there is extremely little wear of the governing mechanism if the ball *i* is kept properly lubricated. However, if adjustment should become necessary, the required ¼ inch of travel may be obtained by means of the stud *l*. It should never be obtained by changing the position of the nut *h*, as that is to be used solely for the purpose of adjusting the speed.

43. Capacity and Speed.—The Type RE-3 turbo-generator is intended for incandescent headlights on both switching and road locomotives. It has a capacity of 500 watts at 32 volts. The speed of the main shaft must be 2,400 revolutions per minute to maintain the desired voltage; but the voltage may be increased or decreased by raising or lowering the speed of the turbine. To change the speed, it is necessary to alter the pressure of the spring in the governor. The locknut *s*, Fig. 19, is first loosened, so that the adjusting nut *h* can be turned. If the speed is to be increased, the nut *h* is screwed in; if the speed is to be lowered, it is screwed out. After the adjustment is made, the locknut is tightened again. The effect of screwing the adjusting nut in is to increase the pressure of the spring *g* against the head of the pin *f*; therefore, to overcome this increased pressure and move the pin and the lever *j* to the left, the turbine will have to run faster, so as to produce greater centrifugal force in the governor weights.

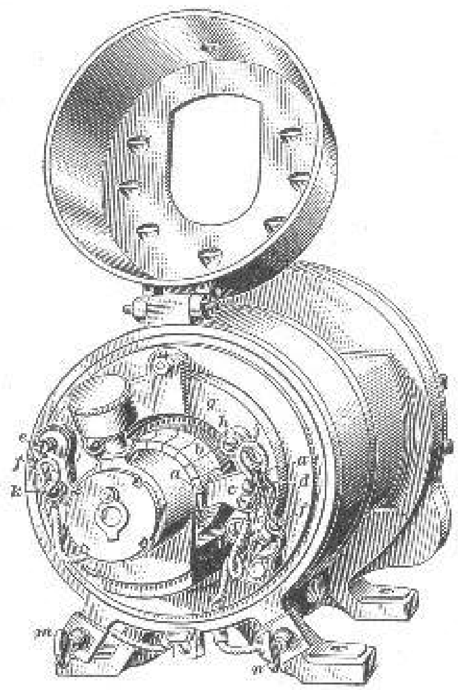


FIG. 20

44. Brushes and Brush Holders.—A view of the generator end of the Sunbeam turbo-generator, with the cover raised to expose the commutator and brushes, is shown in Fig. 20, and a detail sketch of the brush holders and connections is given in Fig. 21, corresponding parts being indicated by the same letters in both illustrations. The brushes *a* are graphite blocks curved at one end to fit the commutator *b* and flat at the opposite end. Each brush fits in a slot in the holder *c* and is pressed against the commutator by a flat spring *d*,

one end of which is coiled around the pin *e*. The head of this pin is hexagonal and it can be turned so as to wind up the spring and so increase the pressure on the brush. After being adjusted, it is locked in position by the setscrew *f*, which bears against one of its flat faces. The brush holder *c* is held firmly to the frame *g* by the two screws *h* and *i*, which are fitted with insulating bushings. These prevent the electric current from passing into the frame *g* and so forming a short circuit. Wires *j* carry the current between the brushes and the posts *k*, and connections are made from the posts *k* to the binding posts

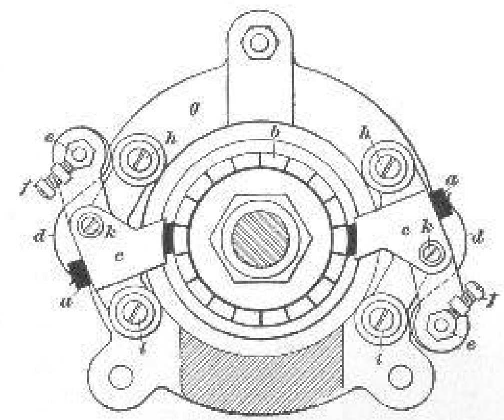
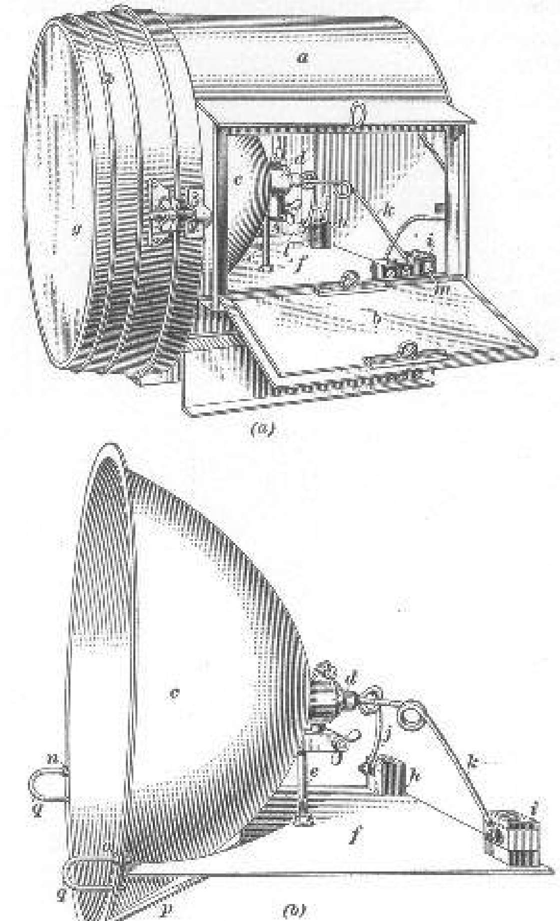


FIG. 21

m and *n* on the outside. The wires leading to the headlight are connected at *m* and *n*, these connections being commonly called the *terminals* of the generator.

45. Sunbeam Headlight.—The arrangement of the various parts of a Pattern 1018 Sunbeam headlight is shown in Fig. 22 (*a*). The case *a* that encloses the lamp, reflector, and fixtures is made almost wholly of steel, the various sections being welded together to form one piece. This construction results in both stiffness and strength. The interior of the case is readily accessible when the side-number doors *b* are opened. The reflector *c* and the device *d* by which the lamp is held are supported by the post *e*, which is carried by the slide *f*. The slide is a flat metal plate that fits in grooves on opposite sides of the case. When the front door *g* is opened the slide *f* may easily be pulled out, bringing with it the lamp, the reflector, and



(*a*)

(*b*)

FIG. 22

the lamp support. At the rear corners of the slide are fixed two blocks *h* and *i* that carry insulated metal strips to which are connected the wires *j* and *k* that lead to the lamp. In the side-number chambers are fixed two blocks, to which are

screwed the spring contact strips *l* and *m*. When the slide *f* is in place, these spring contacts rest against the metal strips on the blocks *h* and *i*. The wires from the generator are attached to the blocks that carry the contact springs *l* and *m*, and the current passes to the lamp by way of the blocks *h* and *i* and the wires *j* and *k*. The construction may be seen more clearly in (*b*), which shows the slide and its attached parts removed from the case.

46. Reflector and Lamp Adjustments.—The purpose of the reflector is to catch the light from the lamp and throw all the light rays forwards in parallel lines. In order to obtain this result, the lamp must be placed in a certain position near the back of the reflector. If the lamp is not thus placed, the adjustment will be faulty and the light will be scattered, or else it will be concentrated in a point, instead of being thrown in a beam. The adjustment of the positions of the lamp and the reflector is known as focusing, and it is facilitated by the construction of the lamp support, as shown in Fig. 23. The reflector *a* is firmly fastened to the clamp *b*, which is screwed on the top of the post *c*. This clamp is split, and between the halves is fitted the post *d*, to which is fastened the split clamp *e* that surrounds the neck of the lamp *f*. Locknuts *g* and *h* enable the clamps to be tightened readily.

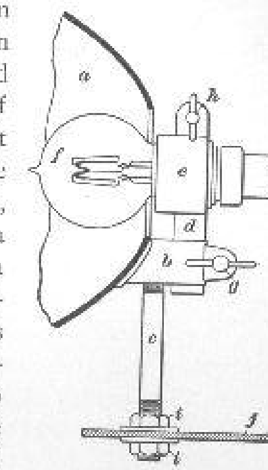


FIG. 23

47. The lamp may be moved up or down and swung to the right or to the left by loosening the locknut *g*, Fig. 23, while adjustment forwards or backwards may be made after loosening the locknut *h*. The nuts *i* by which the post *c* is held to the slide *j* are used to lengthen or shorten the post and thereby tilt the reflector downwards or upwards, so as to throw the light far ahead or close in front of the locomotive.

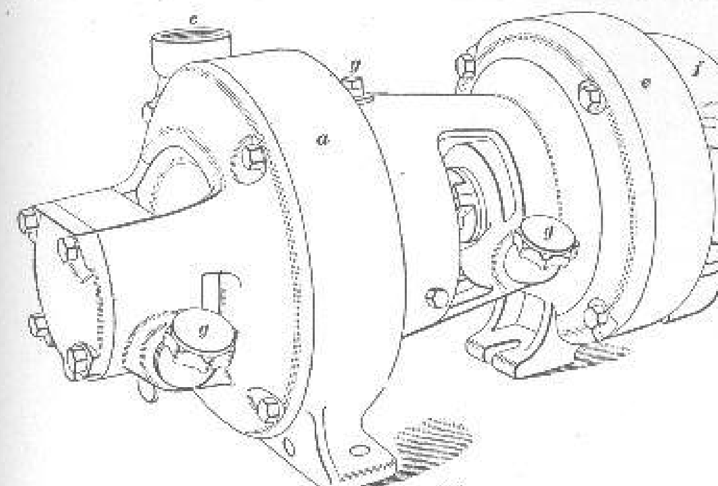
For, as shown in Fig. 22 (*b*), the reflector is supported at the front by being bolted to the slide at the points *n* and *o*, the rod *p* acting as a brace. Thus, raising the rear end of the reflector by lengthening the post *e* tilts it downwards. The hooks *q* form grips by which the slide may easily be pulled out of the headlight case without strain on the reflector. The rear end of the brace *p* fits over the end of the post *e* beneath the slide and is slotted so as to allow for the adjustment of the reflector.

PYLE-NATIONAL HEADLIGHT OUTFIT

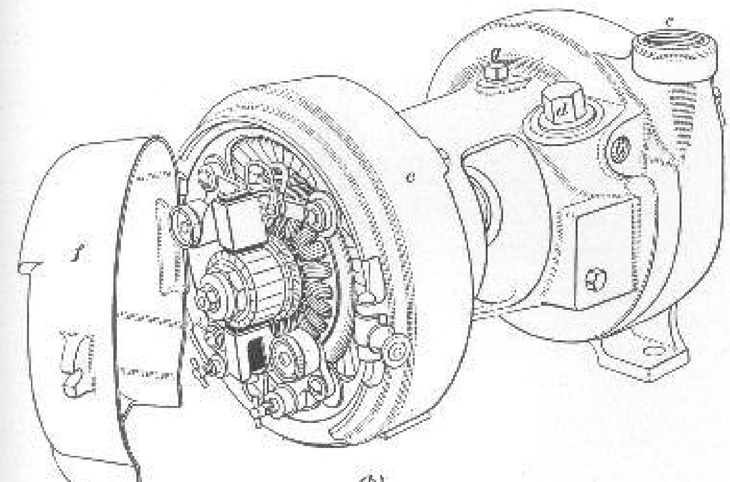
48. General Arrangement.—Views of the Pyle-National K-2 turbo-generator for headlight service are given in Fig. 24 (*a*) and (*b*), the former showing the turbine end and the latter the generator end with the cover swung back. The turbine wheel rotates inside the casing *a*, the steam entering at the inlet *b* and escaping through an exhaust pipe connected at *c*. The governor valve, by which the flow of steam to the turbine is controlled, is contained in a chamber beneath the screw cap *d*. The housing *e* carries the field poles between which the armature rotates, and the movable cover *f* enables the brushes and the commutator to be inspected easily and quickly. The caps *g* close oil cups through which lubricant is supplied to the bearings of the shaft.

49. Turbine.—A lengthwise section showing the internal construction of the K-2 Pyle-National turbo-generator is given in Fig. 25. The main shaft *a* is supported by the ball bearings *b* and *c*, and the end of the shaft overhangs the latter bearing and carries the armature *d*. The turbine end of the shaft is held by the bearing *b*, which is mounted in the casting *e* that forms the turbine cover. The chamber *f* surrounding the bearing catches the lubricant that runs out of the bearing. The cap *g* is removable, to permit the bearing to be inspected. An air space *h* is formed between the turbine cover and the bearing, to prevent heat from passing from the wheel chamber to the bearing. Packing *i* prevents the escape of oil along the sleeve of the ball bearing.

50. Turbine Wheel and Nozzle.—A view of the turbine wheel and the attached governor parts as they appear



(*a*)



(*b*)

Fig. 24

when removed from the casing is shown in Fig. 26 (*a*). There are two rows *a* and *b* of buckets side by side along the rim of the wheel. The inlet nozzle and the reversing buckets are in

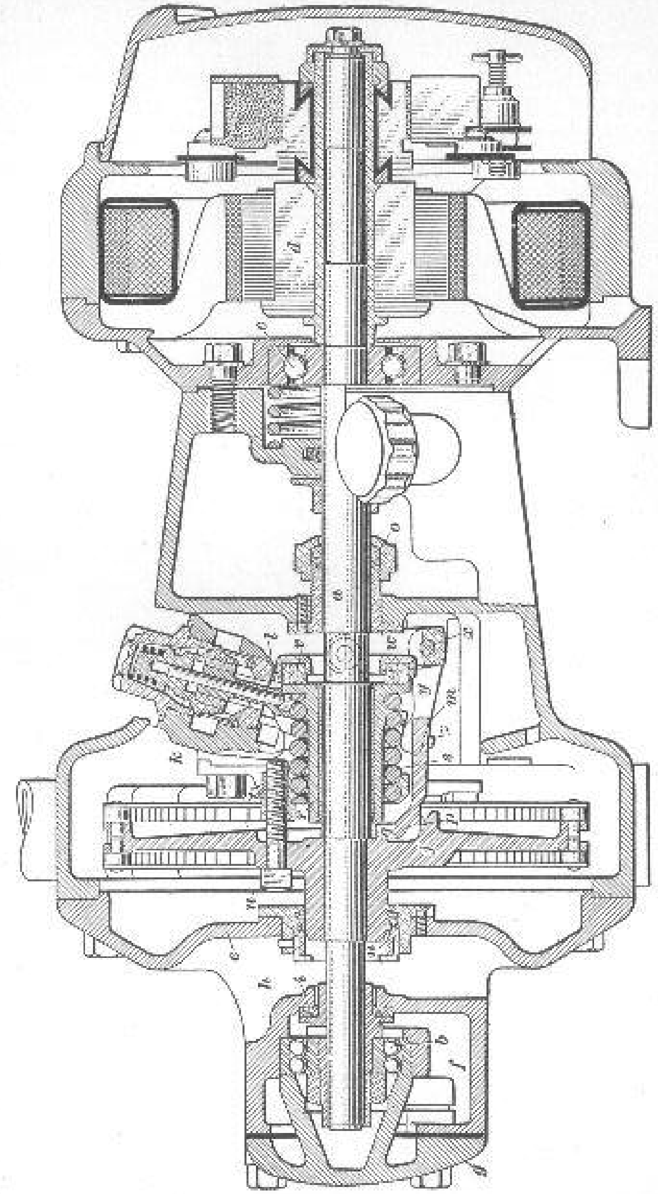


Fig. 25

one piece, shown in (*b*). This piece, when in place, occupies the position shown in (*a*). The steam escaping from the nozzle *c* strikes the inside edges of the row of buckets *a*, which are curved. It escapes from these buckets at the outer face of the wheel and is caught in the pockets *d* of the reversing buckets. These pockets are **U**-shaped and simply reverse the direction of flow of the steam and turn it back so that it is discharged into the second row of buckets at their outer edges. On leaving these buckets at the inner edges, the steam passes

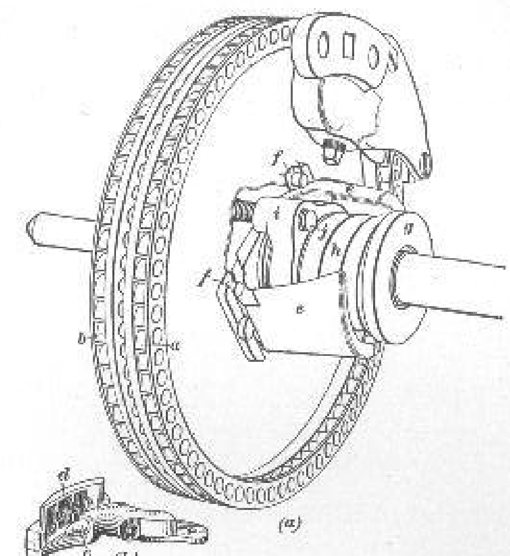


Fig. 26

to the exhaust. But by the use of the reversing buckets and two rows of buckets on the wheel, the steam is made to do double duty. The governor parts are clearly shown. The semi-cylindrical weights *e* are on opposite sides of the shaft and are fulcrumed at *f*. The collar *g* is enclosed by the spring *h*, which is held firmly in the nut *i*. One of the two screws by which this nut is held to the wheel is shown at *j*.

51. The turbine wheel *j*, Fig. 25, rotates inside the chamber *k*, which also contains the governing mechanism. It is keyed to the shaft *a* and at its outer edge carries a double row of buckets against which the steam strikes. The steam that reaches the nozzle of the turbine must pass governor valve *l*, the amount of opening of which is under control of the governor. The governor, shown at *m*, is of the centrifugal type and rotates with the shaft. Its method of operation and its action on the valve *l* will be explained later. Leakage of steam from the chamber *k* outwards in either direction along the shaft is prevented by packing at *n* and *o*.

52. Governor.—The governor of the turbine consists of two weights that are like the halves of a hollow cylinder or sleeve and that partly surround the shaft. One of these is shown in section at *m*, Fig. 25. It is made with a knife edge *p* that acts as a pivot and that is carried in a suitable notch in a bracket that is solid with the turbine wheel. The end *q* of this weight bears against a sleeve *r* that is loose on the shaft and that is formed with a collar at the opposite end, against which bears a spring *s*. This spring is held at the opposite end inside a nut *t* that in turn is fastened to the wheel hub by two adjusting bolts, one of which is shown at *u*. The collar on the sleeve *r* rests against a ring *v* of antifriction metal that is held in a frame attached to the arm *w* of a bell-crank lever pivoted at *x*. The other arm *y* of this bell-crank is forked and fits over the stem *z* of the governor valve *l*.

53. Governor Action.—When the turbine is running, the governor weights *m*, Fig. 25, the spring *s*, the collar *r*, and the nut *t* all turn with the wheel *j* and at the same speed. The spring *s* presses the collar *r* against the ring *v* and so tends to push the arm *w* to the right and raise the arm *y*, which would have the effect of pushing the stem *z* up and so forcing the valve *l* shut, thus cutting off the entrance of steam to the nozzle. But a spring on the lower end of the stem counteracts this pressure, and so long as the turbine runs at the proper speed the valve *l* remains open. If the speed gets too high, however, the weights are thrown outwards by centrifugal force and their short arms *q* press against the sleeve *r* and assist the spring *s*. The sleeve *r* is therefore moved to

the right, causing the bell-crank to turn on its pivot *x* and partly closing the valve *l* against the pressure of its spring. The partial closing of this valve restricts the flow of steam to the turbine nozzle and so cuts down the speed. As soon as the speed falls, the centrifugal force becomes less, and the influence of the weights is removed, so that the spring on the stem *z* opens the valve *l* again and pushes the sleeve *r* back into its normal position.

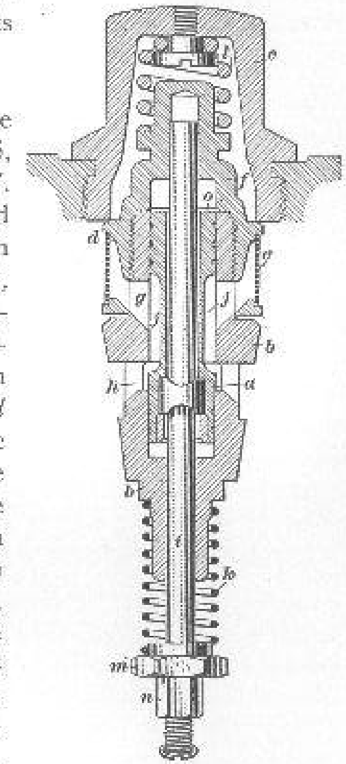
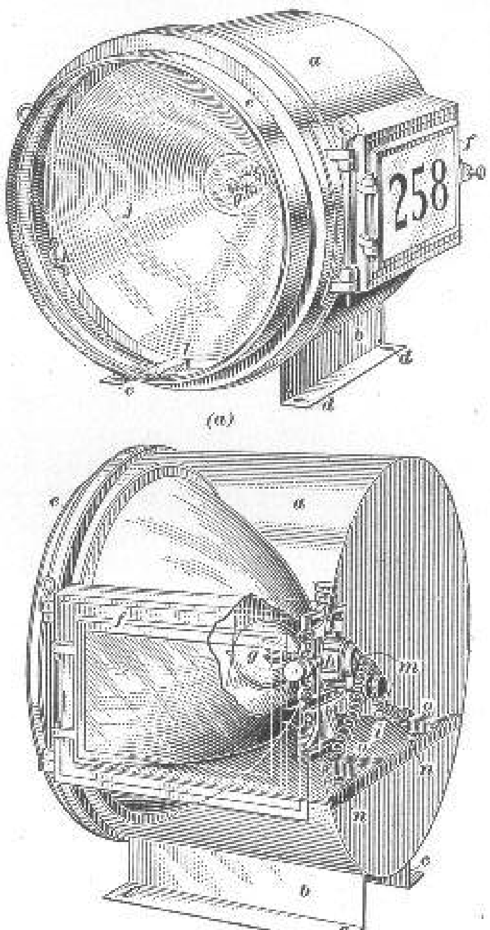


Fig. 27

54. Governor Valve.—The governor valve shown at *l*, Fig. 25, is shown enlarged in Fig. 27. The valve itself is a double-ended piston *a* that slides up and down inside the bronze valve cage *b*, which is made tapering on the outside and is held in place in the turbine by the cap *c*. Steam from the supply pipe enters the space *d* surrounding the upper end of the valve and passes through the strainer *e*, which is carried by the screw cap *f*. It then collects in the chamber *g* and flows down around the valve into the space *h*, which communicates with the passage through which it flows to the nozzle. If the governor acts to decrease the speed, it pushes up on the stem *i* and so forces the valve *a* upwards. The lower piston thus is brought nearer the outlets of the passages *j*, and the steam flowing through is throttled, or reduced in pressure, which in turn causes the speed of the turbine to decrease. The spring *k* forces the stem down when the pressure due to the governor is relieved, and the steam pressure then pushes the piston valve *a* down.

55. Speed Regulation.—The speed at which the turbo-generator runs depends on the governor adjustment, but the normal running speed is 3,600 revolutions per minute. At this speed the generator will deliver its rated capacity of 500 watts at a pressure of 32 volts. If it is found that the speed is incorrect, the governor valve needs adjustment. Usually, the speed of the turbo-generator will increase by reason of the wear of the governor parts. To adjust the valve, it is first necessary to remove the valve cap *c*, Fig. 27, the spring *l*, and the cap *f* that holds the strainer, thus exposing the top of the valve and valve cage. These must be flush with each other when the valve is correctly adjusted. If they are not even, the nuts *m* and *n* must be adjusted until the top of the valve *a* comes flush with the top of the valve cage *b*, as indicated at *o*. Then the nut *m* should be locked in position by the nut *n*. Successive adjustments of the governor valve will result in moving the nuts *m* and *n* higher on the stem, until finally they will reach the limit and can be moved no farther. It then becomes necessary to renew the antifriction ring *v*, Fig. 25.



(*a*)

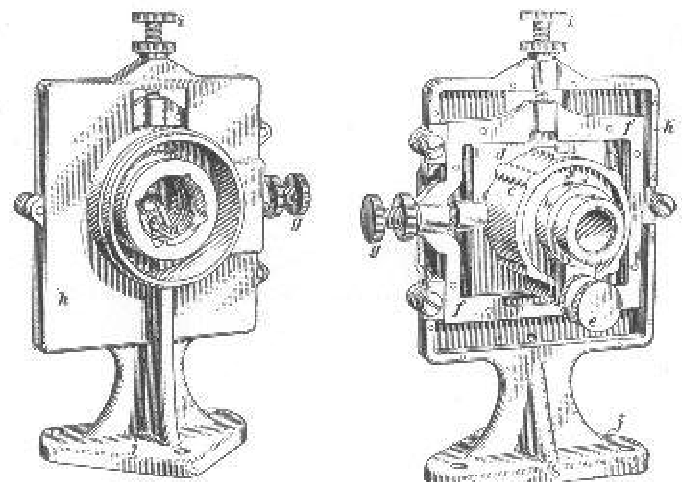
(*b*)

FIG. 28

56. Pyle-National Headlight.—An outside view of the Pyle-National standard incandescent headlight is given in Fig. 28 (*a*) and a part sectional view in (*b*). The case *a* is made of rolled steel reinforced by heavy bands, and the attachments are of malleable iron. All seams and joints by which the various parts are connected are welded by electricity, so that there is no chance of their loosening under the effect of vibration. The case is supported on two brackets *b* and *c* that have slotted holes *d* to allow the headlight to be adjusted somewhat, after being placed on the locomotive. The front is closed by a door *e* containing a lens, and there is a number-plate door *f* on each side, through which access to the interior of the case may be gained.

57. The incandescent lamp *g*, Fig. 28, is held by a standard *h* that is fastened to a slide *i*. The slide is a flat plate to which the reflector *j* is attached at the front. When the door *e* is opened, the slide may be pulled out of the case by means of two handles, one of which is shown at *k*. When in place in the case, it is held back in its correct position by the pressure of the clip *l* fastened to the inside of the lens door. The wires *m* lead from the lamp to insulated posts *n* at the back end of the slide, and when the slide is in place in the case, these posts *n* are wedged between the jaws of two insulated contact blocks *o* that are attached to the case. The wires that convey current from the generator to the headlight are connected to the contact blocks *o*, and thus the circuit is completed through the lamp

58. Micrometer Adjustable Lamp Stand.—Front and back views of a micrometer adjustable lamp stand are shown in Fig. 29 (*a*) and (*b*). The lamp socket *a* is carried by a sleeve *b* that fits snugly inside a sleeve *c* cast in one piece with the block *d*. By means of the screw *e*, the sleeve *b* may be moved back and forth inside the sleeve *c*, thus enabling the lamp to be moved backwards or forwards inside the reflector.



(*a*) (*b*)

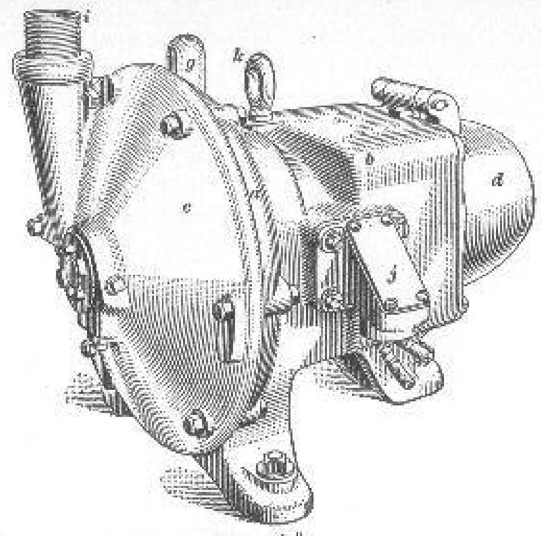
Fig. 29

The square block *d* fits in guides in the hollow frame *f* and may be moved sidewise by means of the screw *g*, thus allowing for sidewise adjustment of the lamp. The hollow frame *f* is held in vertical guides in the stand *h* and may be moved up and down by the screw *i*, thus making possible the vertical adjustment of the lamp. The base *j* of the stand is firmly bolted to the slide in the headlight case and the adjustments in three directions insure that the lamp will be properly located. Each adjusting screw is fitted with a locknut by which it may be held in place after the necessary adjustment has been made.

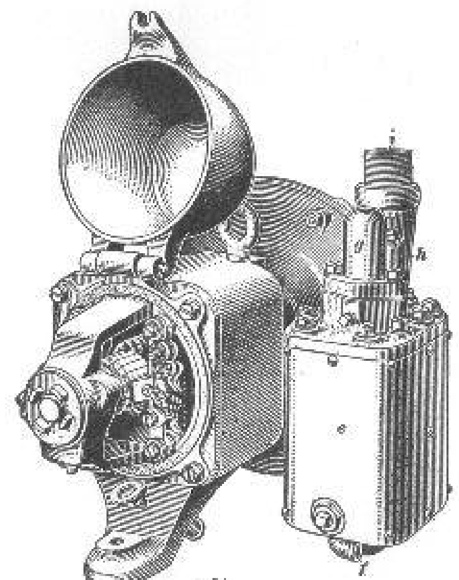
GENERAL ELECTRIC COMPANY HEADLIGHT OUTFIT

59. General Arrangement.—Views of opposite sides of the General Electric Company turbo-generator for electric headlight service are shown in Fig. 30 (*a*) and (*b*). The turbine wheel is contained in the casing *a*, which is part of the casting *b* that encloses the field coils, poles, armature, and governor. The circular cover *c* may be removed to allow inspection of the turbine wheel. A hinged cover *d* at the opposite end protects the commutator, brushes, and bearing of the main shaft. The steam enters the bottom of the steam chest *e*, which contains a separator for removing excessive moisture from the steam, as well as a screen for catching all solid matter. This moisture is led off through the drain *f*, the steam flowing to the turbine nozzle after passing through a reducing valve beneath the cap *g*. A pop-valve *h* above the chamber leading to the nozzle prevents any overpressure of steam. The exhaust escapes through a pipe attached to the outlet *i*. The fitting *j* is a conduit connection box containing the terminals of the generator, to which the wires are connected. The eyebolt *k* affords a simple means of lifting the entire turbo-generator.

60. Details of Construction.—A sectional view of the turbo-generator as it would appear if cut lengthwise in a horizontal direction and then viewed from above, is given in Fig. 31. The shaft *a* on which the turbine wheel *b* and the armature *c* are fixed is carried by the ball bearings *d* and *e*. The wheel is held in place by a key in the shaft and by the nut *f*. It is built up of two disks or plates laid face to face and riveted together over a circular hub. The buckets *g* are made with T-shaped tongues that are gripped by the outer edges of the wheel disks and are thus held to the wheel. The buckets also have short lugs at their outer ends, which fit into holes in a strip of metal *h* that encircles the tips of the buckets. These lugs are riveted over on the outside of the metal strip, called the *shrouding*, and the buckets are thus held firmly together.



(a)



(b)

Fig. 30

61. The generator, Fig. 31, has two poles *i* on which are wound the field coils *j*. The brushes *k* are supported by brush

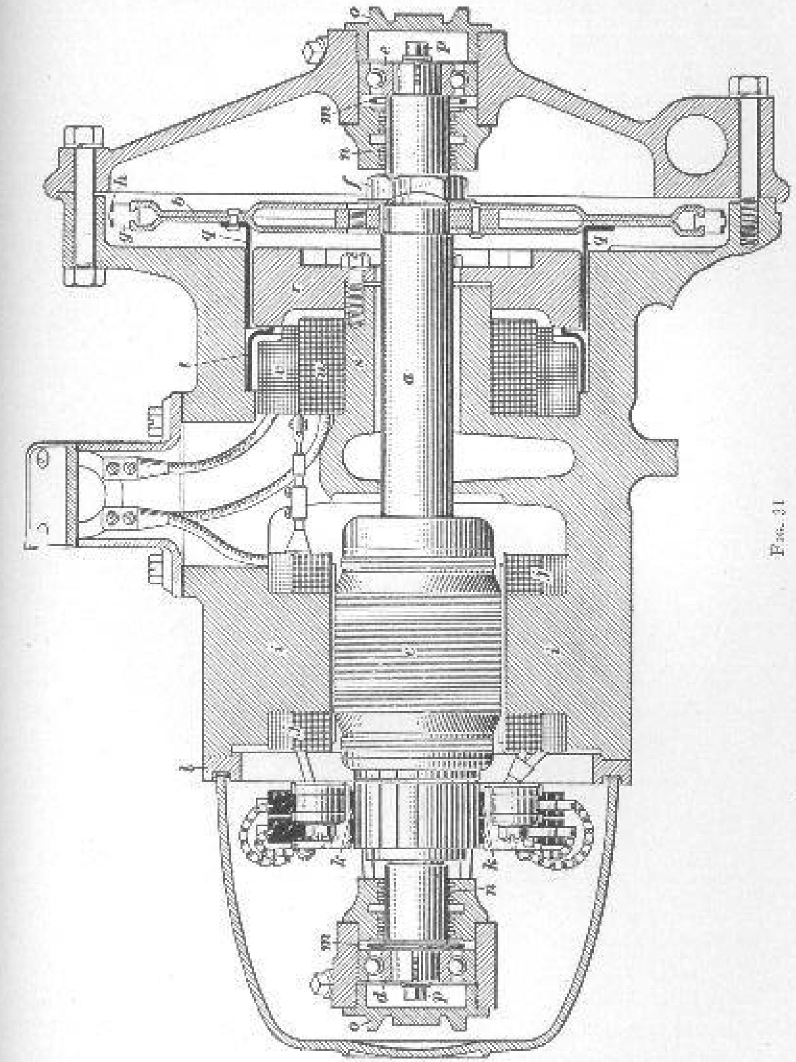


Fig. 31

holders attached to the ring *l*. The ball bearings are lubricated by oil rings *m* that hang down from the shaft and dip into oil wells below, the turning movement carrying the oil rings around and raising the oil from the wells to the bearings. To prevent the escape of oil along the shaft, labyrinth packing is used, as shown at *n*, while the caps *o* prevent the escape of oil at the ends. The bearings are held tightly in place on the shaft by the tapered plugs *p*, which, screwed into the ends of the shaft, expand it sufficiently to cause it to grip the inner rings of the bearings tightly.

62. In order to make allowance for a varying lamp load, and so prevent the turbine from overspeeding, a magnetic brake

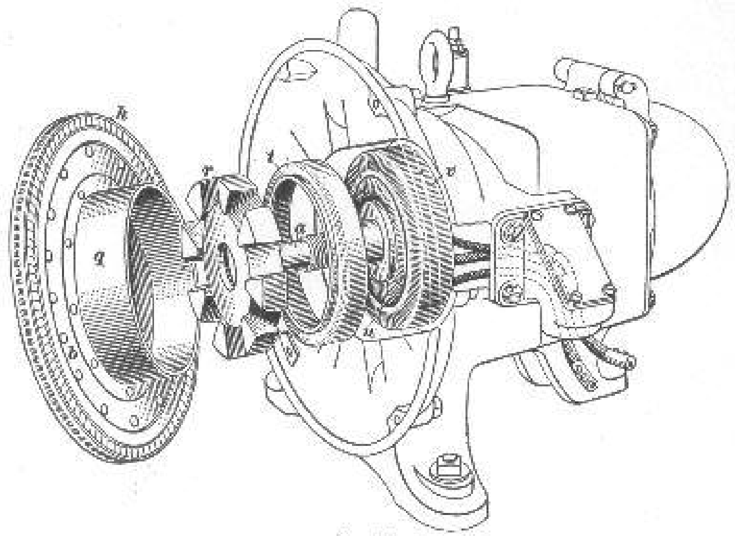


Fig. 32

is provided. The parts that comprise the brake may be seen in Fig. 31, but Fig. 32 shows a perspective view of the details, from which the construction may be more easily understood. Corresponding parts are given the same reference letters in both illustrations. A copper cylinder *q* is riveted to the turbine wheel and turns with the wheel. It fits in the narrow space between the frame of the machine and the circular iron disk *r*, which is bolted to the central hub *s* of the turbo-generator and carries a casing *t* inside which are two coils or windings

u and *v*. A current sent through either of these windings makes an electromagnet of the disk *r*; but the windings are so arranged that they oppose each other in magnetizing effect. The coil *u* is connected directly across the terminals of the generator and the other coil *v* forms part of the load circuit.

63. When the disk *r*, Figs. 31 and 32, is magnetized and the copper cylinder is rotating around it, currents known as *eddy currents* are set up in the copper cylinder, and the result is to cause a drag or braking effect on the cylinder and thus retard its motion and that of the turbine wheel. The greater the degree to which the disk *r* is magnetized, the stronger is this braking effect. There is no contact of the cylinder *q* and the disk *r*. The whole effect is purely magnetic. If there is no lamp load, the coil *v* receives no current and the magnetizing effect of the current in the coil *u* is very strong, resulting in a heavy braking effect on the cylinder, and so preventing the turbine from overspeeding; but when the lamp load is on in full, the magnetizing effect of the coil *v* is great enough to offset that of the coil *u*, with the result that there is no retarding effect produced. Between these two extremes the braking effect increases as the lamp load decreases and so the speed of the generator remains uniform.

64. Steam Separator.—The sectional view, Fig. 33, is a vertical section through the steam chest on the center lines of the reducing valve and pop valve. The steam enters the lower end of the steam chest through the pipe *a*, and thence rises through the vertical pipe *b*, from the upper end of which it is discharged into the umbrella-shaped cap *c*. This cap deflects it downwards into the chamber *d*, from which it again rises and passes through the screen *e*. The double change of direction of flow of the steam in getting past the cap *c* tends to throw out all the moisture carried by the current and the screen *e* prevents any solid matter from being carried along. The moisture collects in the bottom of the chamber *d*, from which it is allowed to escape past the valve *f* to the drain *g*. The body of the steam chest is surrounded with non-conducting material *h* to prevent loss of heat from the steam.

65. Reducing Valve.—The cover of the steam chest, Fig. 33, carries the reducing valve *i*, which consists of a steel stem that fits snugly inside the valve cage *j*. A central hole *k* is drilled into the lower end of the stem, as shown by the dotted lines, and the hole *l* communicates with this central passage.

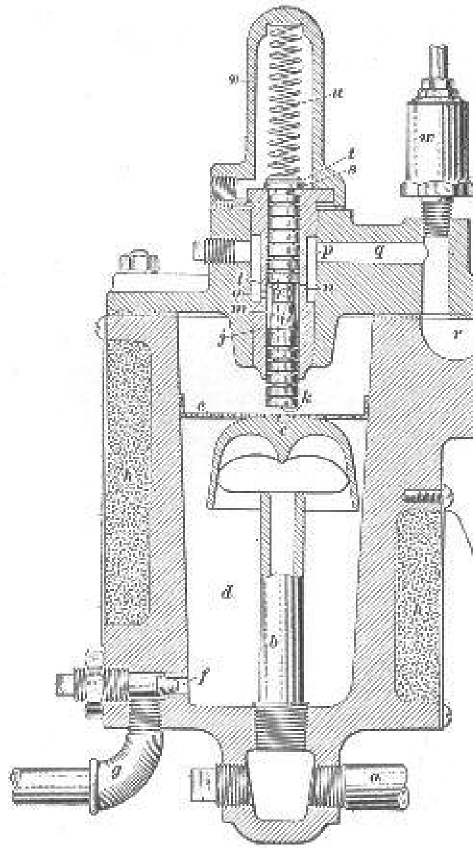


FIG. 33

Dry steam, after passing the screen *e*, flows up the hollow stem and escapes through the hole *l* into the space *m* around the stem. Two holes *n* and *o* in the valve cage permit the steam to escape from the chamber *m* into the space *p*, from which it flows along the channel *q* to the passage *r* that leads to the tur-

bine nozzle. A collar *s* is formed on the upper end of the stem and on it are placed a number of very thin washers *t*. The spring *u* inside the cap *v* exerts pressure on the stem and tends to force it downwards.

66. The object of the reducing valve *i*, Fig. 33, is to maintain a practically uniform pressure of 100 pounds per square inch in the passage *r*. When steam is turned on, the pressure in the steam chest acts upwards on the stem *i*, against the downward pressure of the spring. At the same time, steam flows up the central passage *k*, out into the space *m*, and thence into the passage *q*. So long as the rate of flow is such as to maintain the desired pressure in the passage *r*, the valve stem *i* does not move. But if the pressure tends to rise, the stem is forced upwards somewhat, so that its lower end partly covers the port *o* and throttles the steam, thus reducing the pressure. In this way, by moving up and down, and so throttling the escaping steam more or less, a uniform pressure at the nozzle is maintained. If, through some accident, the valve stem *i* should stick, the pop valve *w* will relieve excess of pressure, as it is set to open at 120 pounds per square inch.

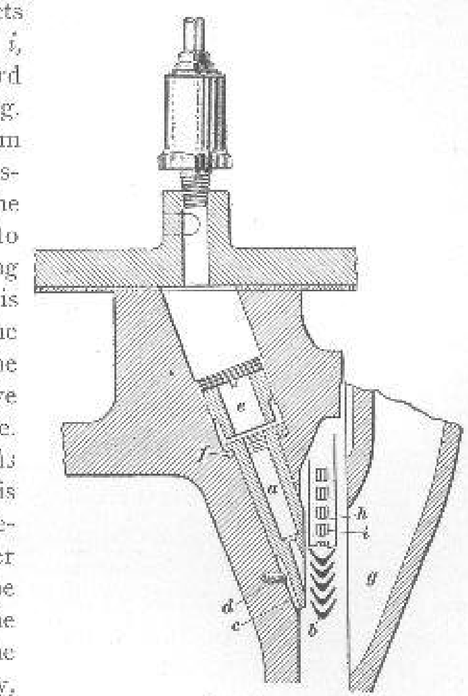


FIG. 34

67. Adjusting Voltage.—The speed of the turbine depends on the pressure of the steam admitted to the nozzle, and the voltage of the current depends directly on the speed. Therefore, to vary the voltage it is only necessary to change the running speed, which may be done by changing the number of washers on top of the valve stem *i*, Fig. 33. For example, if the voltage is to be reduced, remove one or more of the washers *t*. These washers should be about one hundredth of an inch thick, in which case the removal of one will decrease the voltage about 2 volts. Adding washers will increase the voltage.

68. Turbine Nozzle.—The arrangement of the turbine nozzle with respect to the buckets may be seen from Fig. 34, which is a section through the nozzle and surrounding parts. The nozzle *a* fits snugly into a hole drilled at an angle to the wheel and the side of the nozzle tip is cut away, so that the clearance between it and the buckets *b* will be very small. A slot *c* is cut in the side of the nozzle and a pin *d* is fixed in the wall so that the nozzle will always be inserted in the correct position. The locknut *e*, when screwed down, holds the nozzle in place, a tight joint being made at *f* by means of a gasket. The steam enters the buckets at one side and escapes into the exhaust passage *g* at the other side. A part of the shrouding *h* is shown, with the tongues *i* on the ends of the buckets riveted over on the outside of the shrouding.

INSTALLATION AND OPERATION

69. Locating the Turbo-Generator.—The turbo-generator should be located on top of the boiler, in front of the whistle dome, or just in front of the cab, or just behind the stack, as may be found most convenient or practicable; but if it is placed back of the whistle, pops, or sand dome, it should be fitted with a protector plate to shield it from escaping steam, soot, sand, cinders, etc. Care should be taken to see that no part of the turbo-generator extends beyond the clearance lines of the locomotive, and that the inspection doors or covers may be opened without fouling any rods or pipes. The generating outfit should be easily accessible, so as to insure frequent

inspection and save time in case repairs are to be made. A steel bedplate or bracket, of the form shown in Fig. 35, should be fastened by studs to the top of the boiler, and drilled, as at *a*, to match the bolt holes in the frame of the turbo-generator. There should be enough space between the flat top *b* and the boiler shell *c* to allow the nuts of the holding-down bolts to be inserted easily. The holes *a* should be slightly larger than those in the frame of the turbo-generator, so that any slight errors in matching the holes will cause no trouble. The turbo-generator should be set crosswise of the boiler and should be level on the bedplate when the engine is standing on a level track.

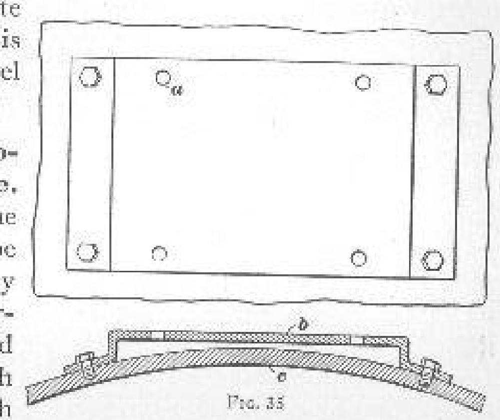


FIG. 35

70. Steam Piping of Turbine. The steam for the turbine should be taken from the dry pipe or from the turret in the cab and led to the turbine through a $\frac{3}{8}$-inch or $\frac{1}{2}$-inch pipe. A metal-disk globe valve should be inserted in this pipe, within easy reach of the engineer, to serve as a means of admitting steam to the turbine in starting and of shutting it off in stopping. If it is found desirable, a tee may be inserted in the pipe near the turbine, so that oil may be introduced into the entering steam to prevent the accumulation of foreign matter on the internal parts of the turbine. Long steam lines are to be avoided, if possible, as they are hard to keep tight under the vibration of the locomotive. To prevent excessive condensation of steam, the pipe may be run underneath the jacket of the boiler.

71. Exhaust Piping and Drains.—An exhaust pipe $1\frac{1}{4}$ inches in diameter should be connected to the exhaust opening of the turbine. If the turbo-generator is located near the stack, the exhaust pipe may be run up along the stack to the top. If the turbo-generator is near the cab, the exhaust pipe should be run upwards and then bent backwards so as to allow the steam to trail over the top of the cab. To produce the best results in turbine operation, the exhaust pipe should be as short as possible and free from sharp bends. If the discharge end of this pipe is reamed out, the whistling noise of the exhaust will be greatly reduced. A $\frac{3}{8}$-inch drain pipe should be run downwards from the turbine to a point below the running board. It should contain no valve, but should always be open and free to discharge condensation.

72. Headlight Wiring Diagrams.—The wiring of the lighting outfit will vary somewhat according to the service in which the locomotive is engaged. As a simple illustration, take the case of a locomotive used for switching service. It will be

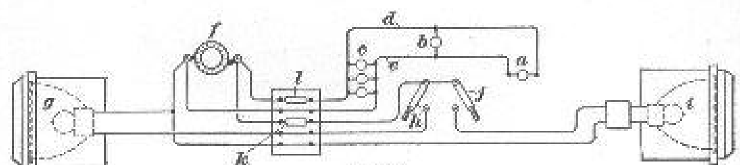


FIG. 36

fitted with front and rear headlights, a deck light, three cab lights for the water glass, pressure gauges, and lubricator, and an engineer's lamp. These will be arranged on three circuits, as shown in Fig. 36, which is the wiring diagram for this type of engine. The deck light *a*, engineer's lamp *b*, and cab lights *c* are on one circuit, indicated by the wires *d* and *e*, which lead directly to the generator *f*. The front headlight *g* is on a circuit that may be closed by closing the switch *h*, and the rear headlight *i* is on another circuit that is controlled by the switch *j*. Fuses *k* and *l* are inserted in the circuits to prevent damage from excessive current.

73. If the locomotive is employed in through service, it carries a front headlight, the usual deck and cab lights, a pair of classification lights, and a number light, or number-plate light, in the top of the headlight casing. It may also have a

headlight dimmer, which is simply a coil of wire having a high resistance, that is placed in the headlight lamp circuit. The resistance thus introduced reduces the current to the lamp and so makes the lamp burn dim. The wiring diagram is shown in Fig. 37. The headlight lamp *a* is on one circuit that has switches at *b* and *c*. The former, when opened, completely cuts off current to the lamp. The switch *c*, when opened, compels the current to pass through the resistance coil indicated by the zigzag line *d* and so makes the lamp burn dim. If the switch *c* is closed, the current passes through its blade and the headlight burns with full brilliance. All the other small lights, including the number-plate lamp *e* in the headlight case, are on a separate circuit. A fuse board or panel *f* carries fuses that protect both circuits.

74. Electric Wiring.—It is necessary to protect all wires leading to the headlight and to the various other lamps so that

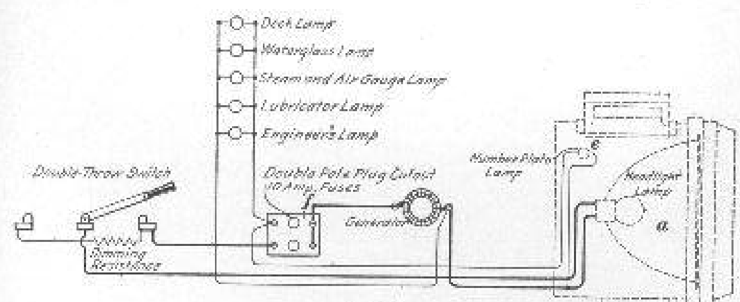


FIG. 37

they may not be accidentally broken or become detached. Metal conduits should be used. The wires are held inside these and are thus protected from damage. The conduits themselves may be fastened to the roof of the cab and to the supports of the hand rail.

75. Starting the Turbine.—No particular care need be observed in starting the turbine. The valve on the steam line is simply opened, and if the turbo-generator is in proper running condition, the turbine should start at once. It is well, however, to blow high-pressure steam through the steam-supply pipe of a newly installed outfit before that pipe is connected to the turbine, in order that all scale and dirt inside the pipe may be torn loose and blown out. If this precaution is not taken, the dirt that may accumulate on the strainer may clog it and prevent the proper operation of the turbine. The valve on the supply pipe should be wide open when the turbo-generator is in service and the cab lights should burn brightly when the turbine has come up to normal speed of running.

76. Adjustment of Ball Bearings.—If the turbo-generator is to run properly, the ball bearings must be kept lubricated, free from dirt, and correctly adjusted. It is advisable to have the outer race, or ring, of the ball bearing fit loosely enough in the housing to allow it to work around slowly in the direction in which the shaft rotates. This creeping of the outer race will result in uniform wear of the bearing; whereas, if the fit is too tight, so that the outer race cannot turn, the wear will come mainly on the lower part. On the other hand, if the outer race fits too loosely in the housing, it will vibrate under the rapid rotation of the shaft and the vibration will quickly pound out the seat of the bearing. Ball bearings may be cleaned by removing them at intervals of two or three months and washing them thoroughly in kerosene. The housings should be cleaned at the same time.

77. Vibration of Rotor.—If the rotor, or rotating part of the turbo-generator, vibrates when running, the chances are that the bearings are worn or loose, and these should be examined first of all. However, there are other faults that may produce excessive vibration. For example, the armature shaft may be sprung, so that the rotor does not run true; or the armature itself may be out of balance. The shaft should not be allowed to have endwise play, particularly in those types of machines in which such movement will affect the action of the governor.

78. Testing Governor Action.—The governor should work freely and promptly at all times, so as to prevent excessive speed. To test the working of the governor on any turbo-

generator used with an incandescent headlight, all that is necessary is to run the turbo-generator under load and then unloaded and note whether the governor controls the speed when the load is removed. To prevent burning out the lamps, the wires leading to them should be disconnected and a resistance coil should be attached to the terminals of the generator. One form of such coil is shown in Fig. 38. It consists of an oak spool *a*, about $1\frac{1}{2}$ inches in diameter, around which is glued a sheet of asbestos $\frac{1}{32}$ inch thick. On the outer surface is wound a spiral *b* consisting of 6 feet of No. 12 nichrome wire. The ends of this wire coil are firmly held between copper washers under the heads of the screws *c* and *d*, which pass through the spool and are fitted with brass nuts at *e* and *f*. The wires *g* and *h* that connect the resistance coil with the generator are attached at *e* and *f*. The throttle valve should be fully open during the test and the load due to the resistance coil should be thrown on and off several times by connecting the coil to the generator and disconnecting it in turn.

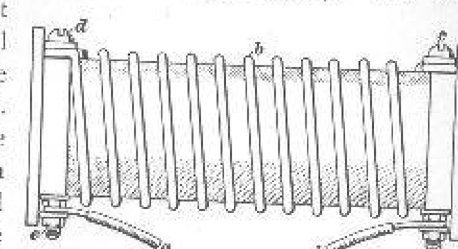


FIG. 38

79. Shaft Packing.—The purpose of the packing around the rotor shaft is to prevent the escape of steam from the turbine. If the steam is allowed to blow along the shaft, it may reach the oil chamber surrounding the ball bearings. The condensation of this steam will cause water to accumulate in the oil chamber, drive out the oil, and so leave the bearings without lubricant, in which condition they will soon become pitted and rusted. Therefore, the shaft packing should be kept in good condition and set up tightly enough to prevent leakage of steam.

80. Lubrication of Turbo-Generator.—The bearings of the turbo-generator require continuous lubrication, and the necessary cups for oil or grease are supplied with the machine.

The method of lubrication and the kind of lubricant to be used will depend on the make of machine, and so no fixed rule can be laid down. But, in any case, the recommendations of the maker as to the quantity and grade of oil or grease to be used should be followed.

81. Changing the Lubricant.—In some makes of turbo-generators that are so constructed as to use oil for lubrication, grease may be substituted without making any changes in the equipment. The first thing to do is to remove the bearings and wash out the oil chambers thoroughly with kerosene. If compressed air is available, a jet from a nozzle should be directed into all crevices and corners so as to drive out all dirt and oil that may remain there, and it would be well to subject the ball bearings to the same treatment. The bearings should then be put back in place, and the oil chambers should be filled with grease. The grease used must not contain dirt, grit, or acid. It is an excellent plan to consult the makers of the equipment as to the brands of lubricant that they recommend.

82. Care of Commutator and Brushes.—The surface of the commutator should be kept smooth, round, and true, so that excessive wear and sparking of the brushes may be avoided. If the surface should become rough, it may be smoothed with sandpaper. The valve on the steam-supply pipe should be opened very slowly until the turbo-generator is running at a low speed. Then a strip of No. 0 sandpaper nearly as wide as the commutator should be inserted under the upper brush, drawn down on both sides, and kept taut by holding with the fingers. While the generator is running, the strip of sandpaper should be shifted to and fro in an axial direction, until the surface of the commutator is smooth. The correct position of the sandpaper is indicated in Fig. 39. Emery cloth or emery paper should never be used for this work.

83. If the face of the carbon brush, where it bears against the commutator, becomes rough or scored, it may easily be trued. The strip of sandpaper, Fig. 39, is reversed, so that the sanded face is against the brush. Then, with the ends pulled down as before, it is drawn under the brush in the

direction in which the commutator turns, by pulling on one end. The operation should be repeated until the brush is ground smooth and is of the same curvature as the commutator. The brush should bear uniformly against the commutator at all points along the face of the brush. Its bearing may be inspected by removing it from the holder, which is easily accomplished after the spring is lifted.

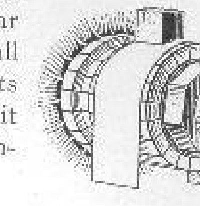


Fig. 39

84. The commutator bars are insulated from one another by strips of mica inserted between them. These insulating strips should not be even with the surface of the commutator bars, but should be slightly below it. They may easily be cut down by making use of a piece of hacksaw blade having a width equal to that of the mica strip. A handle should be fastened to the blade and the tool should then be used as in Fig. 40. All the mica should be cut away to a depth of about $\frac{1}{64}$ inch below the surface of the bars.

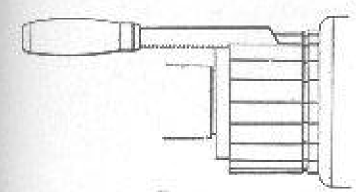


Fig. 40

The correct appearance of the finished work is shown in Fig. 41 (*a*); but if the work is done carelessly and incorrectly, it will appear as shown in (*b*).

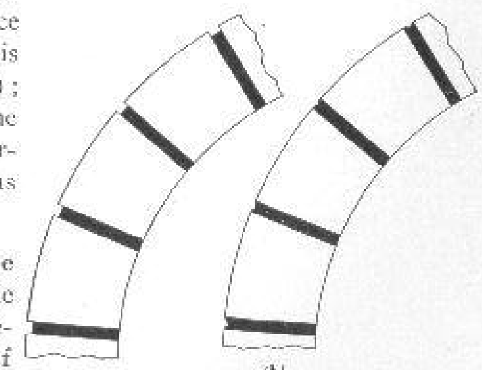


Fig. 41

85. Truing the Commutator.—If the commutator should become badly out of round, so that smoothing with sandpaper will not remedy matters, it should be trued in a lathe. To perform this operation, the entire armature should be removed from the generator and slipped on a mandrel, which may be an extra shaft. The lathe tool used for turning down the face of the commutator should have a short point and the feed should be fine, so that very light cuts will be taken. The surface should be finished by polishing it with sandpaper in the manner already described. It should *not* be filed. After the truing operation has been finished, it will probably be necessary to cut down the mica between the bars, as previously explained.

86. Sparking at the Brushes.—When the generator is in operation, trouble may be experienced through excessive sparking at the points where the brushes rest against the commutator. Such sparking may be due to one or more of a number of causes, among which may be mentioned the following:

1. The brushes may rest too lightly against the commutator, in which case the spring pressure should be increased.
2. The brushes may be worn so short that they cannot be made to bear properly against the commutator, in which case they should be renewed.
3. The brushes may be composed of poor material. If this is the cause, they should be replaced.
4. The brushes may be rough and uneven where they touch the commutator. If so, they should be smoothed by sandpapering, as already explained.
5. The surface of the commutator may be rough, in which case it should be sandpapered or dressed up by turning in a lathe.
6. The commutator may not run true.
7. The strips of mica between the commutator bars may project above the surface of the commutator. These should be cut down, as previously described.
8. There may be a short circuit.

87. Routine of Inspection.—To insure the greatest freedom from operating troubles and breakdowns, the headlight apparatus should be given regular and complete inspection. In making an examination of the different parts, a definite plan should be followed, so that nothing may be overlooked or neglected. Merely as a suggestion, the following order

of inspection is outlined: (*a*) Preliminary inspection; (*b*) inspection of turbine; (*c*) inspection of generator; (*d*) inspection of headlight. The details of these four steps will now be considered.

88. Preliminary Inspection.—The steam should be turned on and the turbine brought up to speed, after which the switch should be closed so as to throw on the lights. These should burn steadily and brightly. If a voltmeter is available, it may be connected across the terminals of the generator and the voltage may thus be determined. It should be from 32 to 33 volts.

89. Inspection of Turbine.—The cover at the turbine end should be removed, and the turbine buckets examined to see whether they are damaged or worn. If the governor parts are visible, they should be examined to see whether they are properly adjusted and in working order. The strainer in the steam inlet should be cleaned, if necessary.

90. Inspection of Generator.—The cover at the generator end should be removed and the condition of brushes and commutator observed, to see that no undue sparking is taking place. The screws and nuts holding the wires in position and fastening the brush holders to the frame should be tight, and the wires leading from the brushes to the generator terminals should not touch the cover when it is closed. Cinders or dirt inside the cover should be cleaned out.

91. Inspection of Headlight.—Because of the vibration to which the headlight case is subjected, it should be inspected carefully and all nuts and screws should be tightened, particularly those that control the adjustment of the lamp for focusing purposes. The lamp itself should be screwed home in its socket. The slide should be held firmly in position and the reflector should be clean and brilliant.

92. Care of Headlight.—As the reflector, lamp standard, and contact blocks are carried by the slide, it is not necessary to disconnect any wires when the reflector is to be removed. All that is required is to open the front door and pull out the slide, using the pulling rings or loops for this purpose. Under no circumstances should the reflector be grasped with the fingers to remove the slide, as by so doing there is danger of bending the reflector and tarnishing its interior surface. The reflector is commonly made of copper, which is then silver plated and burnished on the inside, so as to produce a brilliant reflecting surface. The glass globe of the lamp should be clean and the lens should be free from smudges and finger prints. In some instances, glass reflectors are used.

93. It is absolutely necessary to keep the reflector bright and clean. If it is allowed to become dull and tarnished, the effectiveness of the light may be reduced very greatly. In case the reflector does become dirty, a good way to polish it is to apply a suitable abrasive, using a fine grade of cotton flannel as a polishing cloth. The makers of the various types of headlights will suggest the grades and kinds of abrasives to be used. So-called metal polishes should always be avoided. In polishing the reflector, the rubbing should be straight inwards from the rim to the center and out again, and not in circles.

94. Focusing the Headlight.—The headlight should be properly focused. This may be done by throwing the beam of light against a wall situated from 60 to 70 feet from the lamp. First adjust the lamp position, by moving it sidewise and up or down, until the light thrown against the wall appears as a series of rings, one inside another and all having the same center. Then tighten the adjusting screws on the sidewise and vertical adjustments, as the lamp is then on the center line of the reflector. Next, the adjusting screws that control the forward and backward movement should be loosened and the lamp moved until the circle of light against the wall is as small as can be obtained. Then the lamp is properly adjusted and the remaining adjusting screws should be tightened and locked, so as to hold the lamp in position. If the light is too high or too low to strike the track properly, the reflector and lamp together should be tilted downwards or upwards, as may be necessary.

95. Shape of Reflector.—The reflector of the locomotive headlight is bowl-shaped and the inside surface is a paraboloid; that is, if the reflector were cut in two along its center line, the curved outline of the inside would be a true parabola. Fig. 42 shows the outline *a* of a parabolic reflector. The parabola is a curve that has a certain peculiar property. Inside the curve, on its center line, is a point *b* called the focus. If a light is placed at this point, or focus, its rays will strike the curve *a* at various angles, as at *c*, *d*, *e*, and *f*.

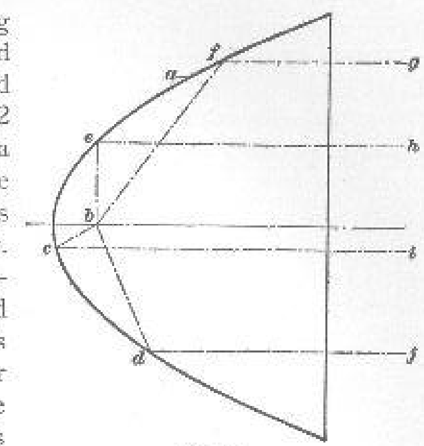


FIG. 42

But in each case the ray of light will be reflected in one direction, which is a straight line parallel to the center line of the parabola. In other words, the light rays are thrown out at the large end in parallel lines, as indicated at *g*, *h*, *i*, and *j*. Consequently, when a headlight reflector is parabolic in shape and the lamp is placed exactly at the focus, the reflected light will form a beam in which all the rays will be parallel and will therefore carry to the greatest distance, with the best effect.

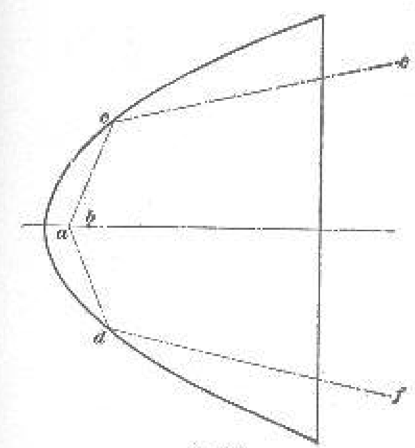


FIG. 43

96. Importance of Correct Focusing.—It is important to have the lamp located precisely at the focus of the parabola, if the light is to be thrown to the greatest distance with the best effect. If the lamp is set at *a*, Fig. 43, behind the focus *b*, the light rays, striking at *c* and *d*, will be reflected outwards in diverging rays *e* and *f*; in other words, the reflected light will be scattered and will illuminate the road only a short distance in front of the locomotive. If the lamp is set ahead of the focus, as at *a*, Fig. 44, the light rays that strike the reflector, as at *c* and *d*, will be thrown forwards in converging rays *e* and *f* that will meet and cross at some point ahead of the locomotive. Up to the point at which they meet, the light beam will gradually grow smaller, but will be brilliant. Beyond the crossing point the rays will diverge and the light will be scattered.

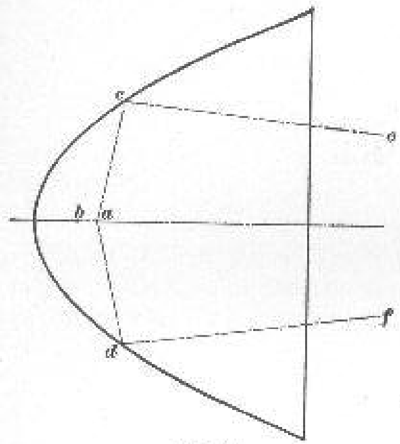


Fig. 44

97. The lamp may be properly focused with respect to the reflector and yet may not be correctly set with respect to the track. Consequently, after the lamp has been adjusted so as to throw a beam consisting of parallel rays, the headlight case must be set to throw the beam down the center of the track, so as to illuminate objects at a distance of from 800 to 1,000 feet ahead of the locomotive. If the beam does not shine down the center of the track when the lamp has been properly focused in the reflector, the case must be shifted to the right or to the left until the desired position is obtained. If the beam has the proper direction, but strikes the track too close in front of the locomotive the front end of the case should be raised by placing shims under it. Under no circumstances should the lamp be put out of focus in the reflector to throw the beam central on the track.

98. Switcher Lens.—The goggle glass, or lens, in the front door of the headlight case is clear and smooth in head-

lights that are intended for road service, so that the beam of light will not be obstructed or scattered, but will be thrown forwards to the greatest possible distance. In the case of an engine used in switching service, however, a single powerful beam of light from the headlight is not desirable. It is too brilliant and produces a blinding glare that may prove dangerous to switchmen, yardmen, and enginemen. For a switcher headlight a softer light is desired. Such a light may be obtained by using a goggle glass that scatters or diffuses the rays of light reflected from the parabolic reflector. One form of switcher lens that accomplishes this purpose is shown in Fig. 45. The outer face is smooth, but the inner face, toward the lamp, is formed into a large number of small ridges. The result is that the light rays do not pass through in straight lines, but are bent at different angles, thus producing a soft, diffused light

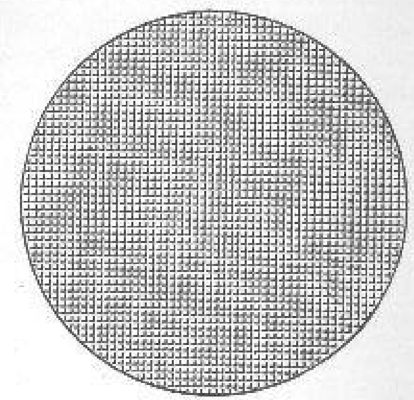


Fig. 45

99. Control of Lamps.—If the equipment is in proper condition, the lights in the cab and the number-plate lamp in the headlight case should burn brightly as soon as the turbo-generator reaches its normal running speed. With the usual form of wiring, there is a double-throw switch in the circuit leading to the main lamp of the headlight. In one closed position of the switch, the full current passes to the lamp and gives it its greatest brilliancy. In the other closed position, the dimming resistance is put in the circuit, the current is reduced, and the light is cut down to about half its former intensity. When the switch is in the open position, no current is furnished to the headlight except that for the number-plate lamp. The other lamps have switches in their sockets, so that they may be shut off easily.

100. Speed and Voltage.—The speed of rotation affects the current produced, because the voltage is proportional to the rate at which the armature coils cut across the lines of force between the poles. The faster the armature turns, the greater the voltage. If the speed gets too high, therefore, the voltage will be excessive and the headlight lamp and the cab lights will all become unusually bright. If the voltage continues to increase, the lamps will be burnt out. On the other hand, if the turbine speed decreases, the lights will grow dimmer as the speed falls. If the lights fluctuate, or grow bright and dim alternately, the speed of the turbine is not being kept uniform and the governing device is at fault. If the cab lamps burn properly when the headlight is on, but get very bright when the headlight switch is opened, the indications are that the governor is unable to control the speed properly, and the remedy is to clean and readjust the governor.

101. Turbine Failures.—The turbine should start just as soon as the steam is turned on. If it fails to do so, steam is not being admitted to the turbine, or else it cannot escape from the turbine. Sometimes a second valve is used on the steam-supply pipe, and in that case it is well to determine whether this valve is open. On the other hand, the failure of steam to enter the turbine may be due to a clogged strainer. The strainer can be examined readily. Again, the trouble may be due to freezing up of the turbine, which may occur in cold weather. If freezing is found to be the cause, the drain pipe should be disconnected and placed in the firebox to thaw out. Meanwhile, steam should be turned on to the turbine. If the buckets are frozen up, the steam will eventually blow through and loosen them. When all is clear, the drain pipe should be reconnected. Freezing may be prevented by keeping the steam-supply valve open just enough to keep the turbine turning slowly, without generating enough current to cause the lamps to glow. If the turbine starts, but soon slows down or stops completely, the fault probably is a clogged strainer. This is particularly likely to occur in the case of a newly installed outfit or when a new steam pipe has been fitted.

102. Failure of Lights to Burn.—If the turbo-generator is running at the proper speed and yet the lamps fail to burn, the trouble may be due to one or more of a number of things. A wire may have jarred loose from its connection, or may have broken off, thus preventing the flow of electricity. The brushes may not be bearing against the commutator, in which case no current will pass. The commutator may be dirty, or the brushes in bad condition, so that the proper current does not pass. If fuses are used on the lighting circuits, a fuse may be loose or burned out, and should be tightened or replaced. And finally, there may be a short circuit somewhere, which means that the current, instead of following the circuit through the lamp, finds another path of less resistance through some metal part of the locomotive or through contact of bare wires.

103. Lights Too Bright or Too Dim.—Lamps that burn too brilliantly indicate excessive speed of the turbine, and this can be due only to faulty governor action. If the governor is of the type that controls the steam admitted to the turbine, it should be cleaned and adjusted. Temporarily, however, the speed of the turbine may be decreased by partly closing the valve on the steam-supply pipe and thus throttling the steam. The correct speed is reached when the lamps show their normal brightness. If the lights are too dim, the steam valve is not fully open, the boiler pressure is too low, the governor is improperly adjusted, the strainer at the steam inlet is clogged, there is a short circuit, or the brushes are sparking.

104. Emergency Throttling.—When the speed of the turbine is found to be too high—which can be detected by noisy running and the brilliance of the cab lights—the steam supply should be throttled by partly closing the globe valve on the steam pipe. This valve is located in the cab, and by it the engineer may control the turbine speed. On arrival at the terminal he should report that the governor fails to control the speed, so that proper repairs may be made before the locomotive is sent out again. When the engineer finds it necessary to throttle the steam in this way, he should try to bring the speed as nearly as possible to that at which the turbine should run, so as not to burn out the headlight by excessive current.

105. Short Circuits.—If two wires that form the two sides of a circuit come in contact by reason of the wearing off of insulation, the current passes from one wire directly to the other at the point of contact, instead of going through the lamp or lamps as it should. Or, the two wires may come in contact with some metal part of the locomotive, and a short circuit will result, the current taking a path through the metal from one wire to the other. When a short circuit occurs, the lamps go out, the turbo-generator runs slowly, a large volume of steam comes out of the exhaust pipe, and the brushes spark badly. The machine should not be allowed to continue to run with a short circuit, as the armature and field coils will be burnt out.

106. Locating Short Circuits.—If the failure of the lamps is caused by a short circuit, the generator will run slower and more noisely than usual. To locate the trouble, disconnect both terminal wires on the generator. Then, if the machine at once increases in speed to the maximum, the fault is not in the generator. Next, reconnect the main wires at the terminals and remove the fuse from the cab circuit. If the short circuit is in the cab wiring, the headlight will continue to burn. If the short circuit is in the headlight wiring, it may be detected by putting the cab-circuit fuse in place and removing the headlight-circuit fuse, when the cab lamps will continue to burn. If the fault is located in the cab wiring, leave out the cab-circuit fuse and reconnect the main wires of the headlight circuit. In this way it will be possible to continue to use the headlight.

107. Open Circuit.—If the generator runs very rapidly, but seems to run lightly, as though without load, the circuit is probably open. To locate the trouble, start at the generator and place a piece of metal from one terminal to the other and remove it. If a flash is seen, the open circuit is not in the generator. If no flash is seen, the trouble is in the generator and cannot well be repaired on the road, unless the fault is

caused by a loose field connection. In that case, tightening the loose screw will put it in order. If the generator is found to be in good condition, make the test in like manner on the binding posts at the lamp. If no flash is seen, one of the wires between the generator and the lamp is probably broken. If a flash results, the trouble is in the lamp, and one of the wires will probably be found to be disconnected.