not always the case. If the trolley wire runs back to the power house or if there is another feeder nearby that can be used as a pressure wire, the drops in the feeder and track may be measured separately and an accurate idea gained as to just how the drop is distributed. For example, if the upper voltmeter terminal is connected to the end *a* of the trolley wire instead of to *c*, the reading obtained will be the drop through the track alone, because the voltmeter takes such a small current that there will be practically no drop through *T x*. If one terminal of the voltmeter is connected to *c* and the other to *a*, the reading obtained will be the drop in the feeder *F F*. This method is the one to be preferred, because it at once gives an accurate comparison between the loss in the overhead work and the loss in the track and shows what part of the system requires attention in order to bring about better working conditions.

AUXILIARY EQUIPMENT.

35. We have already considered that part of an electric railway system that pertains directly to the supply of current for the cars. The rolling stock and car equipment remain to be considered, but before going on to this part of the subject, it may be well to pay some attention to what might be called the auxiliary departments of a road. Under this head may be included car houses or car barns, repair shops, etc. These, while not, perhaps, directly connected with the running of the cars, are at the same time an essential part of the road. Their equipment varies greatly on different roads, so that the descriptions can only be very general in character.

THE CAR HOUSE.

36. The **car house** or **car barn** is a building used for storing cars that are not in use; that is to say, either for storing the regular schedule cars during the hours when they are not in use or for storing closed cars in hot weather

or open cars in cold weather. The ideal arrangement would be to have the repair shops, the car house, the power station, and the general offices all centralized, as it would effect a great saving in time and labor; but, unfortunately, in most cases this cannot be done, especially on large systems. The nature and extent of the traffic dictates the location of the power stations, and the cost of land that of the repair shop and car houses. Of course, in many cases, a large system is the result of the consolidation of several smaller ones, and this always introduces objectionable conditions that cannot be overcome. On the small roads, it is not so difficult to centralize the buildings. On the large roads, it is the custom to have one large, well-appointed repair shop as centrally located as possible in regard to the several depots from which the cars are sent out on their runs. These depots generally constitute a sort of combination car house and auxiliary repair shop, where light repairs are done to avoid sending the cars to the main shop. Such a combination depot should, from the storage point of view, be as nearly fireproof as possible and should have all the facilities for extinguishing a fire.

Where practicable, the tracks should be far enough apart to admit of easy passage between the cars, and the more uniformly the daylight is diffused throughout the building, the better. In some car houses the storage room is all on one floor; this may be the first or second floor, according as the cars to be stored are out of season or are just temporarily out of use. In other storage houses, two or more floors are used, in which case an elevator must be used for handling the cars on the upper floors.

Where the cars must be transmitted to and from an upper story by means of an elevator, it is almost always the case that the stripped or out-of-season cars are stored there. As there is no possible chance of saving the cars in time of fire, there is no objection to setting them on horses or barrels; but where the storage tracks are on a level with a street track, the cars should be set upon temporary trucks, so that at an alarm of fire they can be run out. For ordinary

over-night storage of cars, the practice of having all cars depend on the use of a transfer table to take them to a track that leads to the street is a bad one, on account of the great fire risk. Where practicable, every storage track should lead to the street at one end or the other of the car house. In some houses it is the practice to grade the rails down to the street, so that in case of fire it is only necessary to let off the brakes and the cars will run out. That part of the car house that is to be devoted to light repair work should have every facility for inspection and repair. There should also be a stretch of about 40 feet of double track, where the cars come into the house, provided with a cement or other water-proof floor, draining to the sewer or to a cesspool. This is to be used for washing the cars as fast as they come in for the night.

37. For inspection of trucks and motors there should be **pits** about 4 feet 8 inches deep directly under the tracks, no pit to be shorter than any car that may be placed over it. As to the total amount of pit room required per car, it is a very hard matter to fix between narrow limits, as it depends a great deal on how much trouble the equipments give. A safe value, however, based on long experience with almost all conditions of working with several types of motors and trucks, is 1 linear foot of pit room for each car that runs into the depot; that is to say, a depot handling 100 cars could get along with 100 feet of pit room without a great deal of shifting. The arrangement of this pit room will depend considerably on the arrangement of the tracks in the house. An ideal arrangement would be to have four pits 25 feet long each, or three pits 33 feet long each, according to the length of the cars to be handled. The pits should have cement bottoms and be properly drained. The space between the tracks on the floor level should be boarded, but the underneath space between the pits should be left open.

A couple of shelves and a row of small bins to hold a few of the most commonly used sizes of bolts, nuts, and washers save time and should be placed in each pit. Each pit must

have a *pit jack*, which is a common pump jack with its rack made longer and terminating at the top in a kind of cradle to hold an armature without bruising it. The jack is provided with a pivoted base mounted on a four-wheel truck. The class of work that it is profitable to do at the outside depots is the changing of motor armatures, field coils, brush holders, bearing wheels, and controllers, and the supplying of missing bolts, nuts, washers, and other small parts, together with the general repair and adjustment of brake rigging. A hand forge and a blacksmith that can make himself useful in other lines of work are usually necessary in any depot running out more than 30 cars. A small drill press and lathe for boring bearings and for drawfiling or turning down armature bearings to standard size, or putting on heads or bands, will soon pay for themselves in a depot shop if operated by a man that can make himself otherwise useful.

38. Wiring of Car House. — The wiring of the car house is a simple matter, but its plan depends on the track layout of the house. Every track should have a trolley wire over it. The house trolley wiring, as a whole, should be separated from the main line outside by means of a line circuit-breaker; it must then be connected to the street wires by means of a jumper that passes through a switch placed outside of the building, so that in case of fire the whole house wiring can be disconnected. The wires in the house are supported on barn hangers made for this class of work (see Fig. 17). The hanger is fastened to the house beam by means of lugs *b*, *b*, the trolley wire being fastened to ear *c*. In iron barns, the hanger must be screwed to wooden blocks supported from the iron girders. In some

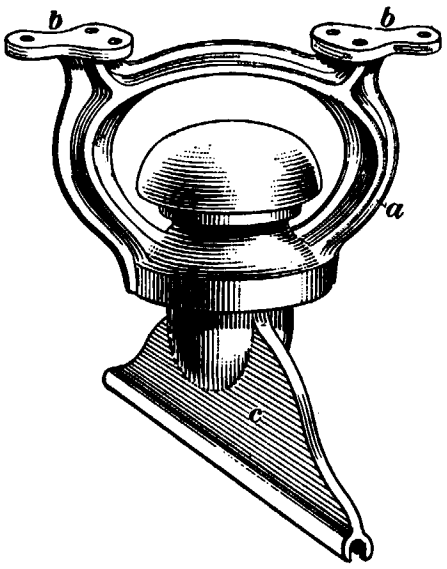

FIG. 17.

barns, the trolley wire is run in an inverted wooden trough placed over it, and the hangers are screwed to the bottom of this trough. In such a case, the trough generally catches the wheel if for any reason it leaves the wire; it also serves as an insulated support for the wheel at night and obviates the necessity of tying down the pole where such a rule is in force. In a metal barn, it makes it impossible for the trolley pole to come in contact with the metal structure and the live wire at the same time if the pole should fly off the wire. Sometimes at short curves under very low structures it is the practice to do away with the trolley wire altogether and replace it with an inverted brass or copper trough, in which the trolley wheel rolls along on its flanges.

39. When the car house is situated near the street line, the several tracks running into it should not start from the main line, but a siding *s*, Fig. 18, should be laid out so that through cars need not go over so many switches. Those from the left pass over the switch *a* only, those from the right over *b* only, saving some amount of wear and tear on car wheels and greatly prolonging the life of the switches.

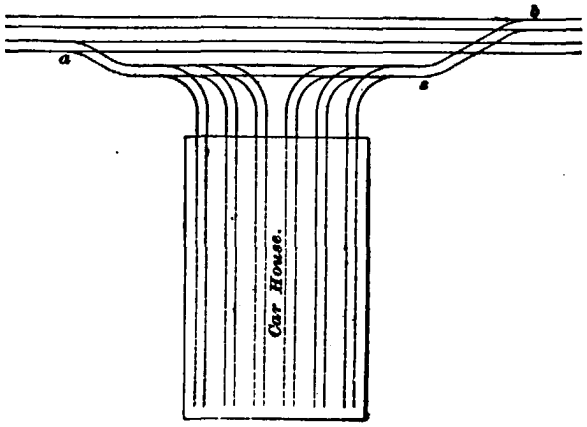

FIG. 18.

THE REPAIR SHOP.

40. The repair shop is the place where all heavy repairs and alterations are made. A well-appointed repair shop should include a *pit room*, *machine shop*, *carpenter shop*, *mill*, *blacksmith shop*, *paint shop*, *winding room*, *commutator room*, *controller room*, and a *wheel-grinding annex*. In the pit room, all truck and motor repairs are made. In the machine shop, all general machine work is done, such as fitting bearings, turning down commutators on the shaft, recutting

bolts, etc. In the winding room, fields, armatures, armature coils, etc. are wound, insulated, and baked. In the commutator room, the parts of the commutator are assembled and the finished article tested. In the controller room, controllers, switches, resistances, etc. are repaired. In the mill, the repair parts for car bodies are made. The best place for the machine shop is in the rear end of the pit room, and the worst place for the forges is next to the paint shop. The armature room should not be exposed to the dust from an emery wheel, and it is equally important that the commutator room be well protected. The shop building should be a substantial fireproof structure and every effort should be made to have good light throughout.

41. The Pit Room and Machine Shop.—The number and length of the pits depend on the nature of the work to be done and the number of cars to be handled. If no armature, field, wheel changing, etc. is done at outside depots and must be done at the main shop, 1 linear foot of pit room per car is about right. The pit rails should be laid on stringers supported by brick piers, and the space underneath between pits should be left open, so that a man can go from one pit to another without going up on the floor. There should be means provided for raising the car bodies off the trucks quickly and with as little labor as possible. A cheap way to do this is to hang over each pit three rails, along which chain falls are free to move from one end of the pit to the other. The center overhead rail is over the center of the pit, and its hoist is used in the truck and motor work after the car body is up. On each of the two outside rails are two chain hoists, and the hoist rails are just far enough outside of the track rails to have the hoists clear the car under all conditions. The system is made more efficient if the hoist rails of neighboring pits are connected at the ends, so that a set of falls can be run over from one pit to another. Only one set of falls is required in each pit, for if more are needed, the car bodies can be set on barrels or horses to free the falls. To avoid the use of extra long hoist chains, the

falls are suspended from the carriages by long double eyebars. In conjunction with the hoists are used two wooden beams with an eyebolt in both ends to take the **S** hook that engages the hook on the chain fall; 2,000-pound hoists are heavy enough for single-truck cars, but in case any extra heavy lifting may arise, it is well to provide one pit with 4,000-pound hoists. With such an outfit, two men can raise a single-truck car in about 5 minutes after the body bolts are out and the motors and brake rods are disconnected. The chain falls should be oiled once a month. It is becoming common practice to provide car shops with an air compressor and reservoir, the air to be used in blowing the dust out of motors, controllers, etc.; in such a case, the compressor, or air pump, is driven by a motor. The air pump stores the air in a main reservoir that is piped to auxiliary reservoirs situated at the points where the air is to be used. Air has proved to be the best thing for cleaning purposes, and in the several instances where it has been used as a means of operating lifts to raise cars and to handle heavy work around the lathe and boring machines, it has scored an equal success.

42. The Machine Shop.—In laying out a machine shop, two important points must be kept in mind: the machines must be so disposed as to admit of having a good light thrown on the work and at the same time must take up as little floor space as possible. The number and kind of machines to be installed depend on the class of work to be done. There should be enough machines so that the work may not be held back for want of them, but at the same time there should be no more of the same or similar kinds than can be kept busy. The repair shop must frequently work overtime, and on this account it is advisable to have it run from a small independent motor, so that in case one or two machines have to be used on overtime, it will not be necessary to run the whole repair shop.

The machines necessary to equip a machine shop are about as follows: One lathe to take an axle with the wheels on it; one smaller one to take armatures and bearings; one

speed lathe; one metal saw; one large and one small drill press; one planer and shaper; one bolt-cutting machine, with right- and left-hand dies; one milling machine; one wheel press; one axle straightener; emery wheels; one grindstone; one power hack saw; one ratchet drill; one punch press; and one power hammer, usually in the blacksmith shop. On a large road, the regular shop work, together with that of power houses, line, and track, will keep the above equipment busy most of the time. On a small road, some of the above might be omitted. The machine-shop practice should be managed so as to do the best and safest work with the tools and stock in hand. The idea of interchangeability of parts should be pushed as far as it will go, even if some other things must be sacrificed.

43. The Winding Room.—As good a place as any for a winding room is in a gallery built around the wall above the machine shop, but a great many object to this plan on the ground that all cores to be wound and wires for winding must be elevated to the gallery. This is true; and where there is plenty of room on the ground floor, it is best to do the winding there; but where space is limited, the above location is a good one, for in case the winding-room motor gives out, there is the shafting below to fall back on. If ground space is available, it can be put next to the machine shop, being separated from it by a fireproof, self-closing door. The machine-shop shafting is extended through and made ready to couple on in case of a breakdown. The size of the armature room required for a given number of cars depends, of course, on many local conditions, among which can be mentioned the type and age of the equipment in use; the condition of the track and line work, and therefore, to a degree, the constancy and value of the normal voltage maintained on the line; the number of different kinds of motors in use and their adaptability to the class of work they are called on to do; the competency of the motormen who handle the cars; and a number of other causes.

For a road operating 100 cars or over, from 6 to 8 square

feet of floor space per car should be sufficient for the winding room. For a small road, the space required per car would be much larger. Every winding room that does all its own work, i. e., carries out all the processes of winding and does not buy its armature coils ready-made, should be equipped with about the following: One machine for putting bands on armatures; one field-winding machine; one armature-coil winding machine with a coil former for each type of armature; one gasoline stove, brick-enclosed, with the tank well removed and enclosed (gas is better and safer when it can be had), for heating soldering irons; a device for pulling off commutators (the pinions should be removed before the armatures are sent in); racks for holding rolls of insulation; stands for holding armatures in course of winding; one machine for cutting insulation; one machine for pressing coil papers; one coil press for each kind of coil; ample facilities for dipping the coils in varnish or some other compound; racks for holding completed armatures; an oven or its equivalent for baking armatures (it can be either steam heated or heated with street-car heaters). If the armature coils are dipped in an air-drying compound, no oven is needed, because the armatures themselves and the fields and other coils can be baked by sending a current through them; but if the armature coils are to be dipped in varnish—a much better practice—an oven must be provided, and it might just as well be large enough to bake everything.

The winding room should be provided with substantial patterns of every standard piece of insulation used in the place; one set of these should be hung in a convenient place; a duplicate set should be kept under lock and key, preferably in a fireproof place.

44. The Commutator Room.—The commutator room should be in charge of a good mechanic, and should have in it a lathe, a drill press, a milling machine, and a gas or gasoline oven for baking the commutators. It should be provided with a full line of gauges for the several kinds of mica bodies used and taper plug gauges for the shaft hole bored in the

shell. In modern practice, commutators all fit on a tapered seat on the armature shaft, and it is essential that the commutator should go on just so far and no farther. There should be provided a device for tightening up the nuts without twisting the commutator bars out of line. There must be an adequate supply of assembling rings and the proper wrenches for adjusting them; and no emery wheel should be allowed in the commutator room. The most natural and convenient location for the room is next the winding room. The commutator room should be enclosed, but should have the best possible light and ventilation.

45. The Controller Room.—There is no particular condition to be fulfilled in selecting a site for the controller room. A location just off the machine shop, where it will be convenient to the machines, is as good a place as any.

46. The Mill and Carpenter Shop.—The mill is the room in which the wood-working machines are placed. The carpenter shop is the room where the cars are run in for general body repairs. There is no reason why they should not both be within the same enclosure—the mill at one end and the carpenter shop at the other. The best place for them is between the machine shop, pit room, and paint shop, a line of single or double track running through, so that a car can come in at one end of the building and go out at the other. In the mill there should be a planer, a boring machine, a lathe, a band saw, a circular saw, and a grindstone. The mill should be run from its own motor or from the one in the blacksmith shop. In either case, the motor should be caged off to save it from the dust and should be cared for more than the others.

47. The Paint Shop.—The paint shop should be at the extreme rear of the main shop and should have free access to the street; it should be provided with as many doors on the street side as there are tracks, so that in case of fire the cars can be run out without any shifting or transferring. The paint shop should receive only cars that have been repaired and are ready to run on the road except for the

painting. This being the case, each track in the shop should have a trolley wire over it, the whole system of trolley wires being kept cut out by means of a switch except when they are to be used. Of course, in cases where open cars are painted in the winter and closed cars in the summer, and there is but a single set of trucks for the two sets of car bodies, it will be necessary to run the bodies in on temporary trucks. Under no circumstances should the car bodies be set on horses or barrels in the paint shop. The risk of fire is too great; they should always be on temporary trucks, and where possible, at the head of each line of cars should be a car fully equipped, so that in case of fire they can be all coupled together and towed out of danger. Another good plan is to have the tracks down grade out of the house, so that when the brakes are released or the chocks removed from the wheels, the cars will run out by gravity. On account of the great fire risk incidental to the storage of so many inflammable materials, oils, varnishes, etc., there should be an absolutely fireproof wall between the paint room and the rest of the shop, communication between the two shops being only through self-closing fireproof doors. As a prime precaution against fire, the building should be of brick, with an iron roof and a cement floor. The floor should be graded to gratings that lead to the sewer or to a cesspool and the roof should be designed to give the best possible light and ventilation. All inflammable materials should be kept in a small, absolutely fireproof room that will admit barrels, etc. without trucking them the entire length of the paint shop. The question of fire risk in a paint shop is a serious one, for the reason that the shop is generally full of cars that will burn quickly if once started.

48. The Blacksmith Shop.—The blacksmith shop must be located where the coal dust and gases from the forges cannot reach the paint shop. If there is a cellar with a good light and a dirt floor, it makes a good place for this shop. In the blacksmith shop should be at least two forges, anvils,

and a blower. One forge should be provided with an ordinary bellows all ready to be connected on, in case anything should happen to the blower or to the motor from which it is run. Besides the usual complement of forge tools, there should be a machine hammer, shears, and a drill press.

49. The Grinding Room.—If the brakes on a trolley car are applied too hard or if for any other reason the car skids along the track, flat spots, or **flats,** as they are called, are found on the tread of the wheel. These make the wheels pound on the rails, and unless they are removed by grinding or a new wheel put on, the trouble is liable to go from bad to worse. Practically all car wheels are of chilled cast iron. In the molding the tread of the wheel is chilled so that the iron is very hard for a depth of $\frac{3}{8}$ or $\frac{1}{2}$ inch. If the wheel is ground down so that the chilled portion is ground through, there is no use in doing anything further with it, as the iron under the chilled part is too soft to last any length of time. Flats are removed by means of a grinder, which is a device for holding a revolving emery wheel against the tread of the wheel to be ground. The wheels may be ground either in place on the car or separate from the car. The car-wheel grinder can, as a rule, be used to greater advantage out at one of the depots, if the wheels are to be ground on the car; this is undoubtedly the best practice, but it is not always followed. Where the wheels are taken out to be ground, there must be extra means provided for driving the axle, whereas, if ground on the car, one of the car motors can do the work. In either case, the car wheels should make from 20 to 40 revolutions per minute, and the speed of the rim of the emery wheels should be about 5,000 feet per minute. There are several types of car-wheel grinders on the market, and they are all good enough to soon pay for themselves. In general, a grinder must have two hardened centers supported in a substantial frame on both sides of the track; these centers must be movable up and down, so as to meet the requirements of different sized wheels. If the wheel is so small

that the emery will not reach it when the axle is swung on the straight centers, drop centers can be used, but this is seldom necessary. The emery wheels must admit of being fed to and from the wheel and also across the wheel. The bearings must be protected from the flying dust or they will soon be cut up.

If a car is brought in when the flat begins to sound, it can be ground in from 20 to 50 minutes. Even if it takes 2 hours to grind a pair of wheels, it is profitable to do so provided the result of the grinding is not to bring the tread down below the chill. This condition can be ascertained in the course of grinding by knocking the tread of the wheel with a hammer; if the chill is gone, the hammer will easily make a dent. This should also be tried before the axle has been centered. As a rule, one wheel on an axle will be found to be a good deal flatter than its mate; this is due to the fact that on most roads sand is applied to the rail by means of a sand box on each car, and it is always the wheel on the sand-box side that has the deepest flat, because in most cases the flat is due to locking the wheels before applying the sand and then sliding the locked wheels into the sand. Experience has proved that trouble from flat wheels can be to a great extent eliminated by sanding either one or both rails from a sand car; this applies the sand continuously and lessens the chances of the car wheels beginning to slide. Notwithstanding that one wheel may need more grinding than the other, they must both be ground down to within $\frac{1}{16}$ inch of the same diameter. When one wheel is larger than its mate, there will be more or less slipping, and this develops more flats. To grind the small wheels on double-truck cars, a device must be rigged up to turn them, as they have no motor of their own to do it. There has been a great deal of discussion as to whether it pays to grind car wheels or not, and it is safe to say that it pays to grind some wheels, while others it does not. On the whole, a car-wheel grinder will soon pay for itself in many ways if the wheels are brought to it when they should be.