ENGINEERING PRELIMINARIES

FOR AN

INTERURBAN ELECTRIC RAILWAY

GONZENBACH

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BY

ERNEST GONZENBACH.

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CONTENTS.

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INTRODUCTORY.

In view of the present interest in interurban railway development and engineering the writer submits, as the result of an invitation from the STREET RAILWAY JOURNAL, the plans and recommendations embodied in a report on a proposed railway in the Middle West which serves as a good example of many roads now on paper, and which may soon assume tangible form. This article is in no way to be construed as an attempt to generalize and instruct others in the art of railway construction, but is intended to show the way in which certain conditions were to be met in a certain case, together with the reasons which led up to the recommendations and plans therein submitted.

At the time the writer was invited by the promoters to examine and report on the proposed road and its equipment, there had been submitted by one of the large manufacturing companies a proposition to equip the road for high-speed service with four large motors of 125-hp per car, 80-lb. track rail, and 100-lb. third rail, and correspondingly heavy sub-stations, distributing system and power house. The promoters had, furthermore, taken several trips to examine a lately opened high-speed railway with an equipment similar to the one they proposed to install, and there seemed to be a fairly unanimous opinion that the new road should follow the same general lines. As I shall again refer to this road we may designate it for our purpose as the A, B & C Railway. The writer's recommendations differed in many respects from those proposed by the manufacturing company, mostly, however, in the fact that smaller motors and smaller sub-stations and power house equipments were recommended throughout for the reason that, as will be shown below, as good or better service could be given with these smaller equipments than with the larger ones, by a very simple departure from the accepted form of time-table in use on most railways. As a result the proposed total investment per mile of track is very much lower, and the operating costs per car-mile will at the same time be reduced.

It is far from the writer's intention to insinuate any tendency on the part of the manufacturing companies to recommend and sell heavier equipments than are necessary. Numerous instances are on record where selling companies proposed less expensive equipments than those demanded by the purchaser, and their reputations in this respect are sufficient evidence to the contrary.

The present tendency towards extremely heavy equipments for cross-country roads is an outgrowth of elevated and similar practice, where heavy equipments and high acceleration are not only justified but absolutely necessary. The earnings of elevated roads which warrant these heavy investments are never approached, however, by the strictly interurban road, and there are several of the latter now in operation which stagger under the financial burden of the elevated equipment and country road income.

The preliminary step in any electric railway undertaking, therefore, is first to make an accurate and conservative estimate of the income which can be derived from all possible sources of revenue, including passenger and freight receipts, amusement resorts, mail and express and electric lighting and power. This estimate should not be a mere guess, but can be very accurately arrived at by comparison with what other roads are doing. One must carefully choose roads, however, which physically and financially are nearly parallel cases to the proposed road, operate in much the same class of country, industrially considered, and known to be efficienty equipped and handled. The examples from which to judge need not be numerous if they are carefully chosen. The plans for our example, which we will call the D, E & F Railway, will be developed from the preliminary estimate of income and equipment to the operating details.

Estimated Income.

A map of the proposed railway, Fig. 1, shows that it would serve a number of small towns, and that it parallels a trunk line railway which gives a very fine, though infrequent, service. The surrounding country is one of the rich farming districts of the West, and F is a large industrial town. There is also considerable industrial activity in most of the towns to the west of F as far as E. From E to D is a farming and dairy country, with few or no industries. The first step now is to get an accurate record of the population. For this purpose census figures only should be used. All of the population of towns along the railway may be counted, and all of the country population within three miles of either side of the railway. The result is the population figure which appears on the map and which does not include the population of the terminal city, which cannot be counted because the road will not serve all of its population, and as the percentage served is uncertain, it is advisable to base all comparative figures on a common basis.

Comparing the proposed road carefully with others in operation we find the following roads which operate through nearly the same class of territory. The names of the roads are omitted and initials substituted arbitrarily for obvious reasons:

		Population served.	Miles, track.	Gross receipts per year.	Gross receipts per mile track per year.	Gross receipts per capita per year.	Operating expense.
1	G & H......	150,000	153	$753,000	$4,920	$5.02	56%
2	I & J.......	22,600	30	165,000	4,230	7.30	53%
3	K & L......	49,700	108	464,000	4,285	9.34	54%
4	M & N.....	63,000	58	338,000	5,820	5.37	54%

In view of the fact that these four roads are examples selected because of similarity to the case under discussion, they represent very nearly what earnings may be expected of the D, E & F Railway. The population outside of the terminal city D being 61,600, and assuming the lowest per capita earnings listed $5.02, would give an estimated gross income of 61,600×$5.02=$309,000.

The average per mile gross receipts for the four roads is $4,815. The D, E & F will have a mileage of sixty-four. On this basis the gross receipts should be 64×$4,815=$308,000.

The average per capita income, adding all gross receipts

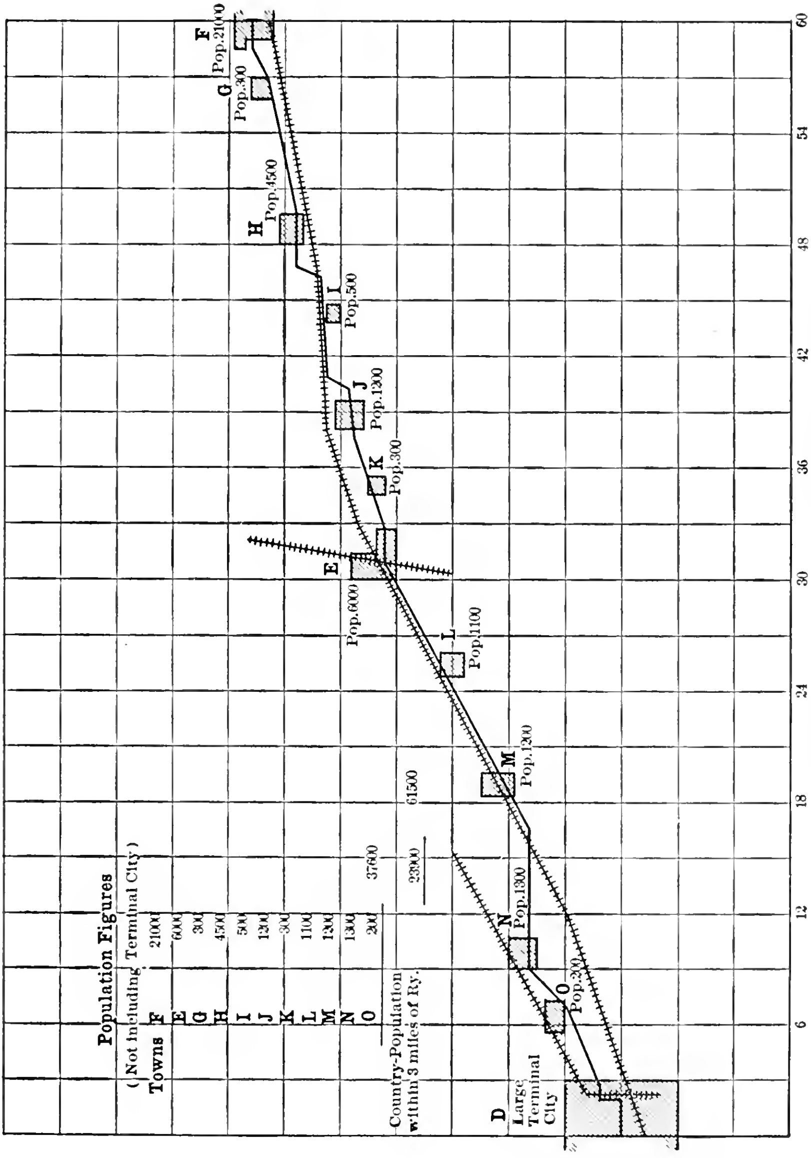

FIG. 1.—MAP OF PROPOSED INTERURBAN RAILWAY.

and dividing by the population of all four roads, is \$6.20. Using this as the per capita figure we have \$6.20×61,600= \$381,000. It will on the whole, however, be safer to use the lowest figure, or about \$310,000 as the estimated gross income.

The operating expenses may safely be assumed as 55 per cent. of the gross receipts, or \$170,000, leaving \$140,000 for interest, sinking fund and dividends.

As a matter of fact there is considerable revenue to be derived from the sale of electric light and power along the line, and the carload freight business should also be attempted. By a vigorous pushing of these items and an exceptionally good passenger service it should not become difficult for a good manager to push the gross income as high as \$400,000 per annum. Having now estimated the income, we may proceed to estimate the investment required to produce it.

General Requirements.

The road has a length of 62.5 miles from end to end, not including side tracks. As the map shows, for most of its distance it parallels a steam road which gives a most excellent service, and has express trains between D and F, making the time in one hour and forty minutes, including a stop at E. The fares on the steam road are about 2½ cents per mile, and there are three express trains and five locals in each direction each day. In order to give as good or better service on the electric line it is necessary to provide comfortable, even luxurious, coaches and make as fast time between terminals as the steam railroad does. It is becoming customary, too much so, to recommend for such service an acceleration of 2 miles per hour per second, a maximum speed of 60 miles to 70 miles per hour, and a schedule speed of from 40 miles to 45 miles per hour, as previously mentioned.

Such a proposition is worth the most careful consideration. It has the advantage that with the schedule speed proposed the fastest time of the steam trains may be equalled and the traffic between local points accommodated at the same time. Each car becomes an express train, and there is really only one tangible objection which can be urged against such an equipment, namely, its high first and operating cost. The high rate of acceleration and frequent stops demand excessive power, which, in turn, demands heavier apparatus all the way back from the car to the boiler room in the power house. Without question there are places where such an equipment will well repay the extra cost of installing it, but the place for it is hardly in the class of roads of which the D, E & F is an example.

In order to reduce the first cost and at the same time enable a service to be given which shall meet the competition of the steam road, the writer arranged a train schedule of which Fig. 2 is a sample. The number of cars required in service to maintain this schedule, with half-hour headway, is ten as against eight, which would be required were the heavier equipment installed and used. Emphasis must be laid on the last condition because of the roads which have been built and equipped to maintain a schedule speed of 35 miles to 40 miles per hour, with stops averaging 3 miles apart; there is to-day not one which actually is making this schedule speed, not because of inability to attain the maximum speed, but due to the numerous stops. One of these is the A, B & C road referred to, which has cars equipped for such speeds, but whose schedule at present is 28 miles per hour, and there is little prospect of its ever exceeding 34 miles per hour unless a limited service is inaugurated, which, however, is not what the equipment was designed for — this on a road having practically no city or street tracks and entirely on its own right of way. It seems, therefore, that while 40 miles per hour schedule speed is perfectly feasible its practical application and economy on a country road remains yet to be demonstrated, and it should not at present be accepted as sufficient reason for additional investment on a road such as is under discussion, and which has a considerable street mileage.

A little study of train movements, as shown in Fig. 2, shows that there are three classes of service provided for while there are only two classes of trains. The "limited" trains consist of two cars, but only one of these is a through car. The other car of the train is "limited" for half the distance, and is then dropped to a local:

1. A "limited" service, making the time between D and F in one hour and fifty minutes, or a schedule speed of 34 miles per hour.

2. A mixed limited service, being a local half the distance and limited the rest of the distance. The time required by one of these cars is two hours and twenty-five minutes.

3. A local service, making the distance, D to F, in three hours, or a schedule speed of 21 miles per hour.

The first or "limited" service will land through passen-

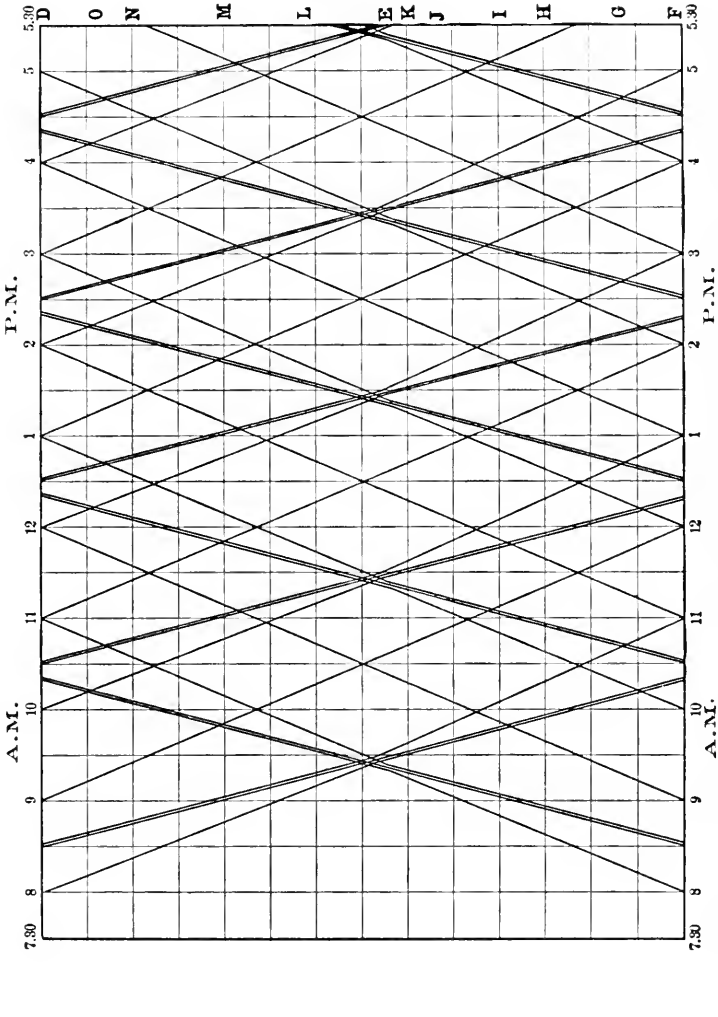

FIG. 2.— TRAIN SCHEDULE FOR TEN CARS EQUIVALENT TO HALF-HOUR HEADWAY.

gers at either terminal as quickly as the steam trains. The second class of service is modelled on the suburban time-tables of many steam roads, which run trains "express" part way and "local" the balance of the run. This class of trains should serve a very numerous class of passengers desiring quick time from country points to city. The local trains proper have a two-hour headway, and would naturally get little through traffic, but they serve a very useful purpose in handling the traffic between country points. Moreover, such trains can also take care of the mail and express business by attaching a regular express car to the local.

It is quite clear that this schedule can only be used when cars are equipped on the multiple-unit system of train control. No railway should be installed in any other way in the present state of the art. The only objections against the system are complicated mechanism and high first cost. The first objection is answered by the fact that cars so equipped are giving less trouble in service than similar ones equipped with hand control. The second objection is formidable, but good things command a high price, and the only remedy is to accept the situation and pay the price demanded, which may be high; yet it is even more expensive to be without it. Better to cut out some of the fancy apparatus in the power house and sub-stations and apply the money saved to purchase of a train-control system. The road, of course, is to be single track, and it will be urged by many practical railway men that the schedule shown in Fig. 2 is complex and makes too many meeting points at irregular intervals, as compared with a schedule providing half-hourly headway, which would give practically the same class of service with all cars having the same schedule time between terminals. This objection is not quite as formidable as it appears. With half-hourly headway and two hours time, the number of meeting points will be seven, the same as that of the "local" cars in schedule, Fig. 2. The "limited" trains will have only six meeting points and the total number of meets will, therefore, be less. It is true that these meets occur at unequal intervals, and a siding which may be a meeting point on one trip may not be on the next trip of the same car. Considering the amount and various classes of traffic handled on single-track steam roads, such as the Erie, it should not be difficult to apply to the case in hand the methods of despatching which have made it possible in steam practice, especially if the electric road has in addition to a thorough despatching system an automatic block signal system. The latter can now be obtained in the market, and no road should be without such a safeguard, for the advertising effect on the public and the moral effect on employees alone make it a paying investment. It should be noted that a half-hourly headway with single cars is assumed to take care of all the business the road is capable of, and Fig. 2 is designed to operate cars to give a service of approximately the same number of car miles as the half-hour service. In case it were found more desirable to give an hourly headway with single cars, Fig. 2 may be modified similarly, giving "local" service at two-hour intervals and a "limited" service at intervals to suit the traffic. A frequent service up to certain limits seems to be more profitable, however, and if the business warrants it should certainly be adopted.

Another point which may be urged in favor of Fig. 2

schedule is that with the multiple-unit control system " extra " cars need not be sent out on the line, but can simply be attached to a regular car without in any way interfering with its schedule, in fact adding to the maximum possible time of the " regular." There is an absence, therefore, of any need for the troublesome " extras," which are the cause of probably 80 per cent. of the wrecks occurring on both steam and electric roads. This same rule, of course, holds in the case of single cars at equal-time intervals, and it is cited here only to show that with the schedule and system recommended the question of " extras " and provision for them cannot be urged against it.

THIRD RAIL VS. TROLLEY.

A further point to be decided before details are determined upon is whether the third rail or overhead trolley should be adopted. Apparent lower first cost very often decides this in favor of trolley. The trolley has been so long standardized and has given such universal satisfaction that the third rail is often looked upon with suspicion; it is reported to be dangerous to life, troublesome in freezing weather, expensive, etc. As a matter of fact, the third rail as a conductor of current has some disadvantages, notably that of becoming troublesome when coated with ice. This objection is gradually being met and removed, and one may confidently predict that in one or two more winters sufficient experience will have been had entirely to overcome these disadvantages. The trolley itself is not entirely above reproach in this respect.

In the matter of first cost there is often unconscious discrimination, due to the fact that the conductivity of the circuit is lost sight of. One often hears it argued that "we can put up a trolley for $1,500 per mile, and the third rail costs $3,500 per mile, and the trolley poles can be used for the high-tension wires." On closer investigation, it usually appears that the speaker has compared a single 000 line or 0000 line or a double 00 trolley having a conductivity equal to about 200,000 circ. mil copper, with a third rail of 70 lbs.

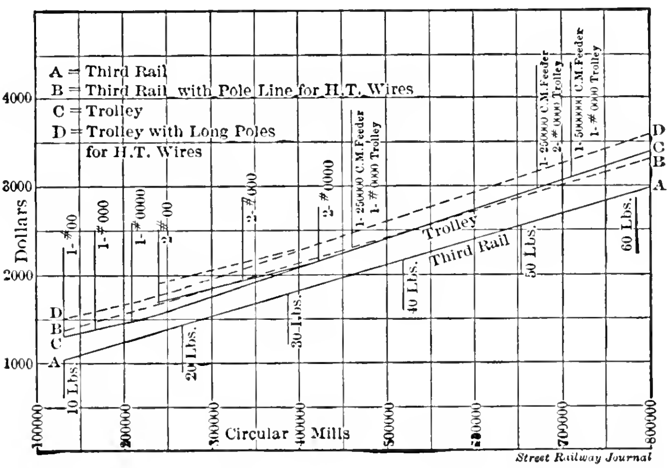

FIG. 3.— DIFFERENCE IN COST BETWEEN TROLLEY AND THIRD RAIL.

to 80 lbs. per yard, which, with low carbon steel, will give a conductivity equal to 1,000,000 circ. mil or over in copper.

The curves shown in Fig. 3 have been prepared to show the difference in first cost between trolley and third rail, and it is interesting to note that the rail is lower in first cost, even down to the smallest sizes. The prices used in making up the costs were those current in October, 1902, plus a 10 per cent. margin, and copper was figured at 14 cents per pound, delivered. Single-track bracket construction only was calculated, as it has become standard for interurban railways of the class we are now considering.

The steel for third rail was assumed to be of a grade giving a conductivity 7.5 to 1 as compared with copper. Its cost was estimated at $38 per ton delivered for the larger sizes, and $40 per ton delivered for the smaller sizes. It is to be hoped that with an increasing demand the rail mills will put this low carbon steel on the market at the same price as the standard mixtures. The cost also includes extra length of ties, bonding, insulators and an allowance for 200 ft. of cable at highway crossings.

The dotted lines compare the costs when a high-tension transmission line is required. The poles must then be considerably higher than when used for trolley purposes only. The high-tension wires should be put out of reach of the trolley pole. For this extra length of poles an increased cost of $3 per pole has been allowed. For the high-tension line forty poles per mile at a cost of $8.50 in place are allowed. The result is shown in dotted curves B and D, Fig. 3. The cost of third rail, plus pole line, is at all points considerably lower than the cost of trolley line carrying high-tension wires.

It so happens that a single No. 00 trolley wire and a 10-lb. per yard soft carbon rail have almost exactly the same conductivity — 133,000 circ. mil copper, making allowance for cables, bonds, etc. If the rail could be bought for $40 per ton, then the cost per mile of third rail would be $1,065. This includes an allowance for extra length of ties, cost of insulators, bonding, joint plates and provision for 200 ft. of cable at highway crossings. The 00 trolley would be $1,308, with copper at 14 cents and material on the same basis, or about 23 per cent. more expensive than third rail. It is not expected that the third rail will be installed in such small sizes, but the comparison serves a useful purpose.

The chief advantage of the third-rail system, however, is its low maintenance cost. It is this feature which warrants its continued increased use, and no doubt will make it advisable for many roads now using trolleys in high-speed service to change to third rail.

Assuming that a service, as shown in Run Sheet, Fig. 2, has been adopted, third rail and train control have been decided upon, and the road is to be built in a manner successfully to compete with the parallel steam line, while at the same time keeping the investment as low as is consistent with permanency, the details of construction are next to be considered.

LOCATION.

An interurban private right of way located along the highway is very often a sign of imperfect emancipation from horse-car practice. It is sometimes urged that it is necessary to adopt such a location in order to serve the country population along the highway. If that population must be served to the extent of sticking to the highway, then it would seem best to avoid the expense of a private right of way and locate tracks in the middle or on one side of the highway. Following the highway usually means numerous stops, which preclude high schedule speed; and, *vice versa,* high schedule speed is impossible along the highway because of teams on the road and in the door yards of houses, numerous crossings at entrances to farm houses and fields, not to mention the objections of the wary native who may dislike to see a car pass by his door at 50 miles to 60 miles per hour without stopping for *his* accommodation.

Furthermore, highways, as a rule, follow township and section lines, almost regardless of gradients. In order to enable cars to be operated on or to one side of them it is sometimes necessary to mount grades of 6 per cent. to 8 per cent., or to assume great expense in filling or cutting to avoid them.

On the other hand, it is not always the best policy to locate the line to obtain the best gradients, nor to locate exactly as a steam road would be located. Curves and grades are much less serious obstacles to electric cars than they are to steam trains, and if a particularly prosperous farming community can be approached by a little detour of the line it is well to consider carefully before deciding either way. As a general rule, however, the writer believes it to be the best policy to locate the private right of way when near country houses so that the house and barn shall be between the railway and the highway. This avoids some of the objectionable features of the highway location and at the same time serves the neighborhood. One must not lose sight of the fact that interurbans are and must continue to be local roads, dependent upon the population reached for their revenue.

Referring to the map, Fig. 1, on a previous page, the D, E & F Railway starts at the center of D. It has its own tracks, and does not anywhere use the local street railway's track or current. After passing the Union Depot and crossing a steam road at grade the line cuts diagonally across city lots and touches the small suburb O, without leaving its private right of way. The same way it passes N, where a route has been found which does not necessitate any street tracks. From N the course is due east, paralleling a highway, but sufficiently far away to permit high speed. At a point about two miles east of M, there is a crossing with the steam railway. This is to be made overhead for reasons which will be shown later.

At M and L the road passes through on its own right of way, and between these towns the right of way is parallel and adjacent to the steam railroad. At E the right of way extends well into the city limits, but the tracks follow the street the whole length of the business section of E. Passing E the right of way is so shaped that cars touch the hamlet K through J and I, all on its own right of way, and pass through a short section of street at H, with another overhead crossing between I and H. From H, through G to F, the right of way is again parallel to the steam railroad, and cars enter the city streets at the entrance to F. There is a total of 5.4 miles of the road on public street, the balance of 57 miles being private right of way.

The width of the right of way should never be less than 40 ft., even for single-track roads. The price paid for land is often fixed arbitrarily and independent of the width of the strip, so that by insisting on sufficient width in the first place the cost is usually no more than a narrower strip of land.

ROADBED AND TRACK.

In the case we are considering there is comparatively little grading to be done, the country being practically level. Cuts and fills do not exceed over 3 ft. in depth at any place, and the whole right of way is so chosen that the grades do not exceed 1.2 per cent. except in one case where there is a grade of 1.8 per cent. for a distance of 800 ft. The flatness of the land is a reason for using extra care to secure good drainage of the roadbed. There are several bridges of 10-ft. to 25-ft. span required. These may preferably be made of steel concrete construction. In a few cases the headroom under the bridge is so low that concrete-arch construction cannot be employed, and steel girders laid on concrete abutments must be used to secure the necessary cross sectional area for the flow of water at its maximum stage. The subgrade is to have a width of 14 ft. for single track and 25 ft. for double track at sidings.

The two railroad crossings that have been referred to are recommended to be built so that the electric railway crosses the steam road above grade, the approaches to consist of earth embankments with a 2 per cent. grade. Such crossings can be built for about $32,000 each, even in a perfectly flat country. The fixed charges on this investment amount to about $1,600 per annum, hardly more than the maintenance of an interlocking plant, and immeasurably cheaper than the latter when the time lost is capitalized and the extra cost of power added to it. A crossing above grade also disposes at once and for all time of the possibility of collisions at such points.

The right of way is to be fenced, not alone on account of using the third rail, but as an insurance against accidents, which would be an advisable measure with any construction.

In the case at hand, gravel has to be purchased and hauled long distances by railroad, as none is available along the right of way. The cost laid down is estimated between 60 cents and 65 cents per yard. There is available, however, a good quality of rock, and while the cost of rock ballast would not be warranted, provided gravel could be put down for a lower figure, it here becomes good engineering to use this rock. Its cost is very largely a matter of good management, and when properly handled this rock ballast may be laid down for but little more than gravel, or at an estimated cost of 80 cents per cubic yard. Its use should be liberal, not less than 2,200 cu. yds. per mile of track. Plenty of ballast properly placed is generally conceded to be the chief ingredient of a good roadbed, and it is poor engineering to attempt to build a good track with heavy rail and only little ballast, because the latter is very much less expensive than steel rails per mile of track, and a better track for less money may be built, using plenty of good ballast and small rails.

The question of cedar ties *versus* hard wood has been pretty thoroughly thrashed out by steam roads, and the use of cedar ties is increasing, which is pretty good evidence that they are satisfactory, at least on tangents. The specifications should, therefore, read for cedar ties, 6 ins. x 8 ins. x 8 ft., spaced 2 ft. between centers on tangents, every fifth tie to be chestnut or oak, 8 ft. 6 ins. to 9 ft. long, depending on the distance of the third rail from the track rail, which will be discussed under its proper heading. On curves all ties should be of chestnut or oak. Whether the ballast should be tamped level with the top of the tie or crowned at the center is outside the sphere of this paper.

Steel rails for the track are the most expensive single item that goes to make up the grand total of the cost of a railway, and one cannot be too careful in choosing correctly to meet the requirements without buying a rail either too large or too small. The first duty of the rail is to provide a smooth pathway over which the wheel may roll with a minimum of friction. This it does regardless of the size of the rail, provided the alignment remains constant. To preserve this alignment it is necessary that the rail have sufficient stiffness so that it will not bend when a weight is imposed midway between two supports From these and allied necessities has been evolved the present form of rail which in steam railway practice is sometimes subjected to a weight of 40 tons and over per axle imposed with the hammer blow of the reciprocating parts of the locomotive. The tendency has been to increase the size and weight of rails in this class of work, and electric railways have followed this practice to a point where the extra cost of these heavy rails often is not warranted by corresponding gains. Taking into consideration the fact that there are no reciprocating parts on an electric car, there is consequently none of the hammer blow to test the strength of the rail as with steam locomotives. It is further to be considered that the heaviest electric cars in use to-day do not exceed 45 tons in weight, and we are not likely to go very much higher. This weight is equally distributed over four axles, and the maximum weight per axle, therefore, is not likely to exceed 12 tons in electric cars for some little time. It is apparent, therefore, that a very much smaller rail may be satisfactory for an electric railway than for a steam railway. Just how much smaller the rail may be made is a fine point to decide.

Another factor enters here which is absent on steam roads, namely, the value of the rail as a return feeder. This depends again on the total amount of current lost in the rail for a given period. It is this factor which warrants the use of extremely heavy rails in city work where cars are numerous and the current transmitted runs into thousands of amperes. For the interurban railway under discussion the difference in current so lost did not warrant any additional investment in rails, and it would appear, from calculations made on this basis and a comparison of service conditions with other roads, that a rail weighing 60 lbs. per yard would be large enough. On account of the comparatively high speed and the possibility of heavier cars or heavier traffic or both in the future a rail weighing 70 lbs. per yard was actually recommended. For speeds of 60 miles per hour and over new conditions have to be met which do not alter the case in hand, and it is to be hoped that no one will cite the failure of the track during the Berlin-Zossen tests as having any bearing in this case.

The length of rails and the cost of joints should be given careful attention. If the saving in rail-joints on steam roads warrants the use of long rails, then their use is doubly warranted on electric roads, due to saving of first cost and maintenance of bonds. Rails 60 ft. long are recommended; joints to be better than the ordinary railroad fish-plates. Either a "Continuous" or "Weber" joint was recommended.

For track bonding two bonds per joint were recommended, because bond troubles mostly occur at the rail connections, and with double bonding the liability of such trouble is reduced. The two bonds together may be about equal to or slightly below the conductivity of the rail, and too much care cannot be exercised in installing them.

ROLLING STOCK.

A general specification of the cars of the D, E & F Railway might be put into the words " The best which can be bought." To the traveling public the car is the representative of the railway company. Handsome, easy-riding cars with luxurious furnishings are an inducement and invitation to ride, and if such cars are supplemented by polite and neatly uniformed car employees, the business once obtained will be held. The inexpensive advertising of thousands of satisfied passengers is many times more valuable than tons of paper leaflets with fancy engravings and printed invitations to ride on the " greatest electric railway of the world, handsomely," etc. When the public, fed with such glowing printed descriptions of the road, finally decides to take a ride and finds the coaches filled with uncomfortable rattan seats, the bodies mounted on trucks which shake the passenger as if he were a bottle of medicine, and the car in charge of a grouchy conductor of the " step lively " pattern, it usually waits for the steam train when it has a long trip to make and uses the electric only for short distances. In the case we are considering the cars were recommended to be between 55 ft. and 60 ft. long and 8 ft. 10 ins. wide over the sheathing;

the body construction to be of the strongest possible design consistent with good appearance; wide platforms to be provided; the seats to be upholstered in plush. Rattan is generally supposed to be more cleanly than plush, but one has only to look at the rattan seats which have been in use for a year or more to disbelieve. All classes of seat coverings seem to get about equally dirty, and the best a railway can do is to clean seats as frequently as possible and adopt a covering regardless of its supposed hygienic qualities. Rattan has the disagreeable trait of not affording a firm seat. It has not been found that plush seats are more subject to mutilation by hoodlums (an objection sometimes urged) than rattan on roads using both types, and cars are never equipped so as to be beyond the possibility of mutilation by hoodlums anyway. If they were they would have to consist of steel cages with bars in place of windows. On most long-distance electric railways there has been a very noticeable demand for toilet rooms on cars, and while a number of interurbans have lately gone into service without these accommodations the demand for them is strong enough to warrant their adoption. That they are a nuisance is not denied, but a railway serves the public and their absence may be the cause of turning over to the steam railway some of the traffic, and the interurban needs all the fares it can collect.

For the case in hand it should not be necessary to mention that open cars are out of the question, and one type of car will have to answer for both summer and winter service. The windows should, therefore, be of a pattern which will give a maximum opening and not interfere with the view in the summer season, while double windows are a profitable investment for the winter season. The small fittings which add so much to the comfort of the passenger, such as parcel racks, water-coolers, match scratchers, cuspidors, etc., should not be neglected and should be of the best quality and appearance. As a matter of fact, appearance in the car and its fittings has a tangible value as nowhere else on a road. There are roads, however, which make the best appearance in power house and sub-stations, where all sorts of polished brass fancies and pressed-brick decorations are indulged in, and which run little dingy, filthy cars that have a habit of choosing their own time of running and meeting at unexpected places. Such concerns give one the impression that they are retailing their current over the brass railings at the power stations instead of selling it in the form of rides to the public.

Trucks for high-speed service are too often a source of weakness on roads well equipped otherwise. The schedule speed of 34 miles per hour proposed for the D, E & F Railway presupposes a maximum speed of between 50 miles and 60 miles per hour. Some trucks which ride well at the lower speeds may absolutely fail at these higher speeds. It cannot be said that there is any one form of truck which has overwhelming advantages over others; the general design of all seems to follow very closely along the M. C. B. Association standard, differing mostly in details. Some of these details, it seems, should never have been adopted, considering the experience in electric and other railroading. Many roads adopt a form of light truck suitable for city service for high-speed interurban cars with disagreeable results both to passengers and trucks. Other trucks are built up of heavy materials and the spring plank connected with the transom through suspension links of the flimsiest sort, or, in other words, the proportions are not kept uniform in transmitting the strains from swing bolster to pedestal boxes. Whatever shortcomings high-speed trucks may have as a class should be charged not to the manufacturers but to the purchasers. We have become so much accustomed to a certain price for trucks in strictly street railway work that few are willing to pay the extra price needed to produce a really first-class high-speed truck, and competition is so keen among manufacturers that the purchaser is really the loser in the end.

Brakes will, of course, have to be of the air type in our case, and it remains to choose between automatic and straight-air systems. Briefly, automatic air has no value except when cars are to be used in trains. In our case there will be part of the service which will consist of two-car trains and the balance of single cars. It is possible that one of the two-car trains might part and cause great damage, but this is less liable to happen when each car is a motor car than if one were a trailer. Automatic air necessitates the triple valve, and triple valves are apt to "stick" at inopportune moments. This is not serious when there are several cars in a train, but when there is only one or at the most two cars and a triple valve should refuse to work, especially in a crowded city street, the consequences might be disastrous to the public and to the railway. The chances that a two-car multiple unit train will break in two at high speed are many times smaller than that a triple valve may stick at a critical moment, and for the case in hand, therefore, straight air is recommended. A device can easily be provided to apply the air in case a train breaks in two even on a straight-air system. For the very high speeds which are now becoming common on interurban railways a more efficient application of the air-brake is very much to be desired. The Westinghouse "high-speed" brake embodies some of the principles which should be modified for use with cars operating at 30 miles per hour and over, and equipped with straight air-brakes. An initial brake-shoe pressure of 125 per cent. of the weight of the car with gradual automatic release, which is a function of the *speed*, and not of the time, would be a great benefit and accident-saver. Straight air-brakes have attained a degree of satisfaction hardly reached by any other part of the car equipment, and there is danger of letting well enough alone to the extent of not keeping abreast of the present exceedingly rapid march of progress. As an example, it is only necessary to mention that 90 per cent. of interurban roads still carry around their air compressors a cumbersome wooden box, patterned somewhat after the bulwarks which used to be built around the old-fashioned street railway motors and discarded fifteen years ago.

ELECTRICAL CAR EQUIPMENT.

In order to determine the details of car equipments it is necessary to again refer to the run sheet, Fig. 2, on a previous page. There are two conditions which must be met by one type of cars and the cars must be used interchangeably. The local cars call for a schedule speed of 21 miles per hour, and the fast or "limited" cars for a schedule speed of 34 miles per hour. The only accurate method of determining the size and nature of the proposed equipment is by a system of "speed-time curves," and from these curves obtain the square root of mean square current per motor and the maximum current. While such a set of curves may be scoffed at as "theoretical" by some "practical" railway men, it may be remarked that a little of this theory applied in the right place might have prevented the investment of thousands of unnecessary dollars in many cases, and in others might point to profitable investments of larger sums in motors.

The status of the D, E & F Railway, however, being as yet somewhat preliminary, a more rough and ready method had to be used to arrive at a preliminary estimate of the equipments to be installed. The route was divided into sections of varying length, and the stops to be made by the limited cars were noted and marked. All points requiring a slowing down of speed were carefully noted, and the result tabulated as follows:

Average speed m. p. h.	Total distance miles	Time required minutes
10	3.6	21.5
13	1.8	8.3
18	2.5	7.0
25	1.9	5.3

As there is a street mileage of but 5.4 miles the schedule is not seriously interfered with. The allowance of 3.6 miles at 10 miles per hour is exceedingly liberal, and in actual service should be bettered. Deducting the mileage and time noted from the totals we have 52.7 miles which must be covered in 67.9 minutes to make the schedule proposed. This gives an average maximum speed of 46.5 miles per hour, which is rather low in the light of recent installations.

As a check on these figures we may deduct the strictly street operation of the cars at 10 miles and 13 miles per hour, and we have a balance of 57.1 miles to be made in 80.2 minutes with six stops or a schedule speed of 42.5 miles per hour with stops 9.5 miles apart. It should also be remembered that there is a ten-minute lay over provided so that cars may make a schedule speed outside of the towns as low as 38 miles per hour and still commence the return trip on time. Limited cars are to make only one stop in each town along the line, and in two towns only do they enter the streets, at all other places they are on their own right of way. The speed proposed is, therefore, easily within reach without excessively heavy equipments.

The tests published by Clarence Renshaw in the Oct. 4, 1902, issue of the STREET RAILWAY JOURNAL are of the greatest value, and the Union Traction Company, of Indiana, and the Westinghouse Company deserve the thanks of all railway engineers for their liberality in publishing the results of their investigations.

Without going into the details of Mr. Renshaw's paper it appears from his figures that for our service on the D, E & F Railway a motor having a square root of the mean square ampere capacity of about 45 amps. should be adopted. There should be four of these motors per car, and they should be geared to a maximum speed of 48 miles to 50 miles per hour, with an average line potential of 500 volts.

The selection of a suitable motor of this rating lands the engineer in the middle of the controversy as to railway motor rating. Unfortunately motors are still made and sold by their rating in "horse-power." The method of testing motors on the stand with covers off serves an admirable purpose in comparing the performance of one motor with another, and that is all. It is difficult to see what relation such a test can have to service conditions. Even the method of reading temperatures is in doubt. A motor may run for one hour at a certain load and a thermometer will then be placed at some point of its surface. Sometimes the thermometer has to be read at a most acute angle to make the results agree with expectations. A temperature reading by the resistance method might reveal some of the *hot* secrets which the thermometer conceals.

It is only necessary to mention as a case in point the well-deserved reputation which the General Electric 57-motor enjoys among railway men. Its popularity is no doubt due in good part to its ability to radiate heat, yet a one-hour stand test gives absolutely no clue of what it has been able to accomplish in service. For our purpose, therefore, we will select a motor having the capacity to carry without excessive heating 45 amps. to 50 amps. for a run of six hours to eight hours and not call it by any particular "horse-power." Commercially its rating may be anything from 50 hp to 75 hp.

A car equipped with four motors of this size will give most excellent satisfaction, but will not permit the acceleration which is being so much exploited of 1.5 miles to 2 miles per hour per second, and there is no particular reason why such an acceleration should be demanded on a road which is not expected to earn over $6,000 per mile of track. In cases like elevated roads, with their gross receipts from $40,000 to $90,000 per mile, any acceleration, positive and negative, which the passengers will stand, is warranted almost regardless of cost. When the headway between trains is thirty minutes to sixty minutes there is a good opportunity for sandwiching a "limited" car between the locals. To do so, however, it is necessary to employ the methods which have enabled steam railroads to accomplish the same thing. Their system is the outcome of years of experience and has cost them millions of dollars. It is free to be adopted by any electric road. Some of them have adopted it, others are paying for not having adopted it.

Local service is to be given by the same type of car exactly as the limited service, and as the cars are not geared very high the numerous stops of such a service may be made economically, as is shown in Mr. Renshaw's figures. In not gearing the cars as high as has become customary we have in mind the fact that all limited trains will consist of two cars each. If we accept the train resistance figures as published by W. J. Davis, Jr., in the STREET RAILWAY JOURNAL of May 3, 1902, as a result of tests on the Buffalo & Lockport road, then it appears that a 35-ton car at 47.5 miles per hour has a train resistance of 35 lbs. per ton, and a multiple-unit train consisting of two such cars should, according to the same figures, be able to make a speed of 62 miles per hour with approximately the same power consumption per car. Mr. Davis' figures, whether unconsciously or not, furnish a pretty good argument for operation of cars in trains.

Having already decided on using the multiple-unit system of motor control, there remains only to choose between automatic and hand acceleration. This can best be decided by referring to a certain well-known road using the multiple-unit, hand control system. Its cars are supposed to take 800 amps. per car when accelerating, yet, in the face of all attempts to check motormen, the accelerating current is much more frequently 1200 amps. than 800. Hand control introduces a factor of human unreliability which can best be met by automatic feed of the controller, independent of the motorman's judgment or lack of judgment.

To sum up we have determined on cars of a length of say 56 ft. over bumpers, width, 8 ft. 10 ins., which, with equipment, will weigh about 32 tons each. The schedule calls for ten cars in service. As we are not now preparing for any heavy excursion business and the schedule adopted is liable to be the maximum service which will be operated for some time, it is not necessary to purchase a heavy excess of cars. Probably twelve cars will be sufficient to purchase at once, but in our estimates we have allowed for fourteen passenger cars, giving a reserve of four cars above schedule requirements.

In addition to the fourteen passenger cars, of which two only need to be combination baggage cars, it will be advisable to purchase one baggage and express car without seats for passengers and with two side doors on each side and wide end doors; this car to be equipped electrically exactly like the passenger cars and geared for the same speed so that it may be attached to a local and used to pick up milk cans and express freight along the road, or it may be attached to a limited train for the transfer of through baggage or the scenery of theatrical troupes and similar services.

There is also a locomotive to be provided, equipped with the same size of motors as passenger cars but geared for a speed not exceeding 25 miles per hour. This is to be used for moving carload freight, as work car, wrecking car, etc. In the winter it can be fitted with a "nose" and used as a snow-plow. As already pointed out there are no cuts of any depth and no additional snow equipment will be needed.

CAR SHOPS.

For the proper maintenance of cars and their equipment proper shop facilities are absolutely necessary. As there is always much machine-shop work to be done during the construction period, a shop properly equipped before construction commences will pay for itself, and is then, when it is most needed, ready and in working order. It is, therefore, recommended that the D, E & F erect and equip its shop ahead of all other work. These shops should be located adjacent to the power station for economical reasons, as will be shown among power station items.

It is not necessary to erect expensive buildings of a capacity large enough to hold all cars. Shop room for four cars will be sufficient in our case. A separate room holding one car each should be provided for paint and carpenter shop, and the machine shop should have room for two cars. On a road of this character the amount of car painting is very little, and the paint shop may be fitted up to serve as a washroom in the winter time. In the summer the washing may be done outdoors.

The machine shop should be provided with hydraulic wheel press, wheel lathe, one or two small engine lathes, drill press, grindstone and emery wheels, universal shaper, power hack saw and overhead traveling crane of two tons capacity. Such a crane will not lift car bodies and it is not intended to do so, as jacks are to be used for this purpose. The carpenter shop is to be fitted with a band saw, small planer and other pieces of the simpler woodworking machinery. The whole shop should be fitted up so that it may serve as a repair shop for the power house apparatus, and, in fact, do all the repairing and small construction required for the entire system.

POWER STATIONS.

For a preliminary computation of the power required for the D, E & F Railway it is again convenient to refer to Mr. Renshaw's paper. His results show that it is cheaper to transport passengers with limited cars than with local cars, and from his results and similar figures obtained on other roads we are perfectly safe in assuming an average consumption of 75 watts per ton mile in limited service and 90 watts per ton mile in local service. As there are six cars of thirty-two tons each on local service and four cars of the same weight in limited service it follows that the average kilowatts per hour may be estimated very closely to be 690 at the cars. The average losses from power station to car, including third-rail losses, should not exceed 15 per cent.; for safety, we assume them as amounting to 20 per cent. This would give an average demand of 828 kw per hour on the power station.

It is quite well known that in power stations supplying interurban roads of few but heavy cars the momentary load factor or the ratio of average load to maximum load is very low. It is often as low as 50 per cent., and rarely over 65 per cent. of the capacity of the apparatus in operation. To supply an average of 828 kw would, therefore, require at least 1200 kw of machines in operation, and would then at times heavily overtax the apparatus. The boiler and engine economy is not as high as it should be in such a case, and in order to increase the station economy it is necessary to smooth out the load fluctuations, which is best accomplished by the use of batteries. In addition to their utility in this capacity batteries have in our case the advantage of practically furnishing a reserve unit at sub-stations, of enabling repairs on the high-tension line to be made without stopping cars, furnishing all-night current for the moving of carload freight by the locomotive before referred to and enabling a satisfactory lighting service to be maintained; also of furnishing power for the all-night lighting service. The chief disadvantage of the battery is its high first cost, but this disappears when it is bought and installed as an integral part of the motive outfit when the road is first being organized. It is not often realized that the cost of a properly proportioned battery or set of batteries is less than the cost of the additional boilers, engines, generators and sub-station apparatus, etc., which are made unnecessary by its use. It is a safe guess that it is this feature of the battery which causes the representatives of most machinery manufacturing concerns to be so radically opposed to its use. On the question of maintenance there is now sufficient data available so that no one need grope in the dark, and its efficiency, when used simply as a regulator of load fluctuations, is very satisfactory.

We may, therefore, proceed to organize our power house with the understanding that batteries shall be used as regulators and the batteries placed at sub-stations. We have already determined the average demand on the power station with the ten-car schedule, shown in Fig. 2, page 13, and in order to have the 828 kw available it will be necessary to operate approximately 1000 kw at the power station. This is in excess of the average demand, but as there will be a demand for lighting and power service at the small stations along the road if this business is properly followed, and there is an occasional extra car, the 1000 kw available will furnish a very convenient unit, and the occasional fluctuations in current, which are present even when a battery is used, will be easily met by the over-load capacity of generators and engines.

How should this demand be met — by one unit of 1000 kw or by smaller units? It is taken for granted that some sort of reserve capacity must be provided, and the problem would be met in many cases by installing two 1000 kw units. The writer believes that three of 500 kw each would be more advisable and so recommended. The flexibility of three units as against two is worth something, and the first cost for the three smaller equipments is less than the first cost for the two larger units, that is, the idle investment is reduced. There are also three to four hours each day when not all of the cars are in service, and one of the 500 kilowatt units can then carry the load at high efficiency.

The location of the power station is determined by the available water supply, and in the D, E & F Railway has to be placed at one extreme end of the line. Theoretically the location would be more convenient near the center of the line in the neighborhood of E, but no suitable water supply was available there.

It was recommended that the car shops should also be located wherever power stations might be built. The object of this is economy in operation. One master mechanic may have charge of station and shops. Steam, compressed air and water supply from the shops become easy and inexpensive, and the exhaust steam from station auxiliaries may be utilized for heating the shops in the winter time. For the same reason it is recommended to build a general office building in a convenient location near the station and shops. Aside from the saving in rent gained by a building of this sort its heating and lighting become inexpensive, as they are accomplished by by-products of the power station and the executive heads of the property are within reach of the "heart" of the road.

In this as in many other cases the station and shops would be located outside of city limits, well in the country, where available houses for occupancy by employees are few and rather undesirable. This is often the cause of dissatisfaction, and more often the most desirable class of employees cannot be obtained at all when accommodations are scarce. Again this condition usually results in employees living some distance away from the station and shops or even in the heart of the city. When emergencies arise, as emergencies will, and an extra force of men is needed, it is usually difficult to get the men together in anything like reasonable time. It would seem a good investment, therefore, for the railway company, as a company, or its stockholders as individuals, to build a suitable number of convenient small houses supplied with steam-heat, electric light and water from the station, and rent these to employees, charging a reasonable rent and allowing only employees to occupy them. Wherever such a plan has been tried it has invariably been found to work to the advantage of the company as well as employees. Its chief advantage, in the writer's opinion, is that it furnishes a trained emergency force on short notice. A secondary advantage is the income derived from the station by-products, which is, of course, included in the rent received.

Planning a station with these objects in view one may with profit adopt steam-driven auxiliaries, and leave out many of the troublesome automatic contraptions which are supposed to add one-half of one per cent. to the station economy, and actually entail an increase of 20 per cent. to 25 per cent. in the repair account. It is not within our province at this time to discuss the details of power station design; there is already too much controversy on that subject. A few engineers seem to lose sight of the fact that the station is a means to an end only and not the chief object of building a railway. As a general rule, and for the station as proposed by the D, E & F Railway, simplicity is recommended. A general specification would include a gravity coal feed from cars to furnaces, automatic stokers, water-tube boilers, forced draft, steam-driven feed and vacuum pumps and electrically-driven rotary circulating pumps.

At the present time one must consider carefully the installation of steam turbine-generator sets in the engine room. No doubt their use is increasing, but as the prices asked at the time this report was written seemed to be out of proportion to the size of the units and their maintenance as yet an undetermined factor, three engines of 750 hp each were recommended. In a road of this character, whose finances promise to require careful nursing in order to make ends meet, and whose power equipment is just large enough to meet the demands, it is best not to take large chances in vital parts of the plan.

The generators are recommended to be wound for 450 volts, three-phase 25-cycles, and the current carried to the switchboard and handled at that voltage. Several very modern plants of recent design have the switchboard on the high-tension side of the transformers, and there seems to be a tendency to follow this practice. Its advantages are many when the current is generated at high voltage in the machines and it is desirable to take current from machines to lines with a minimum of high-tension wiring. When the line voltage is beyond the limits of generator voltage then it seems that the introduction of the switchboard in the high-tension side of step-up transformers incurs a large amount of unnecessary expense and complication of apparatus, and it seems, moreover, that such practice is out of place in a plant such as we are considering. In order to simplify the station wiring it is also advisable to locate the switchboard on the station floor and avoid the annoying and expensive switchboard gallery, which has no "raison d'etre" except in the very largest power stations. In this connection it is well to observe the practice of handling high-tension currents in use in the power transmission plants on the Pacific Coast, where longer experience has been had than elsewhere in that particular class of work. They handle currents almost exclusively from the low-tension side, and give excellent reasons for so doing, and the practice of using complicated and expensive high-tension switching devices has few advocates among those concerns, which have made the business of power transmission what it is.

As in our case the distance of transmission is over 50 miles, it is advisable to step up to the highest voltage which has proven commercially practicable in this climate, approximately 33,000 volts. The electrical station plant then would consist of three 500 kw, 450-volt direct-connected units, switchboard at 450 volts, and three sets of step-up transformers, one set for each generator, connected to a single 33,000-volt outgoing feeder through simple, hand-operated high-tension switches.

Transmission Line.

I have already referred to a single transmission line, and by this is meant that no duplication whatever is provided. Experience has shown that to provide a reserve two absolutely independent pole lines are necessary, and if each follows its own route to the end of the line, so much the better. Such duplication is very expensive, and is not warranted in our case. By providing two separate circuits on the same pole line nothing is gained. Practically, work cannot be done on one line while the other is carrying current, and six wires of small size on a pole are more troublesome than three wires of larger size. In the latter case they can also be spread farther apart. The cost of cross-arms, pins and insulators is reduced, and the whole line may be made more secure against interference. We have provided batteries at stations, and these are able to carry the entire load for, say, one hour.

With cars in operation a lineman can reach any point on the line, and make ordinary repairs in less than that time. Line troubles are becoming less disturbing as the art of line construction is becoming better understood, and for the ordinary interurban road with a straight run and no branches the writer believes that duplication of lines makes against rather than for good service.

We are gradually emerging from the days when we religiously copied the line construction which has served us well in city work, and are adopting standards suited to the open cross-country runs of transmission lines. Poles are being spaced farther apart, and in our example are recommended forty per mile, or 132 ft. apart. They need not be extra tall for such spacing, except where passing houses or crossing highways carrying other pole lines. They are assumed to have a standard height of 35 ft. for the D, E & F Railway, except as noted, where they may go as high as 50 ft. It seems difficult to believe that lines have actually been constructed with poles 80 ft. apart and 40 ft. high in open cross-country work, yet such is the case in at least one recent installation. The tendency of the future will no doubt be towards longer spans and possibly steel towers in place of poles.

It is a good investment to tamp poles well to within 1 ft. of surface, and after all pole work has been finished to fill around the pole with a good grade of concrete. This stiffens the work and insures longer life of the pole. When properly handled the cost of this concrete top dressing need not exceed $1 per pole.

Pins for several years past have been made of wood, often boiled in paraffine and otherwise prepared, on the assumption that they should form part of the insulation. This practice is now gradually being abandoned and pins and cross-arms are not so much designed to be insulators as they were formerly. The insulation is being put where it belongs, in the insulator. The latter are now made of porcelain for most transmission plants and are easy to obtain for voltages as high as 33,000, but they should never be installed without being tested on the ground. The pole line is the main artery of a long-distance road, and since we have no reserve except the battery, which can only carry the load a short time, one cannot be too careful to use the proper material in its construction. Of course, the old controversy as to the relative merits of glass and porcelain still rages, but porcelain seems to be getting the better of the argument if its increasing use counts for anything, but as long as one concern in Utah and another in Montana successfully transmit power at 40,000 volts over glass insulators the controversy cannot be considered closed. The wires may be proportioned so as to give a maximum drop not exceeding 5 per cent. to the farthest sub-station, and should be spaced in an equilateral triangle with wires 60 ins. apart.

DISTRIBUTING SYSTEM.

It has already been mentioned that the proposition made by the manufacturing company proposing to equip this road included sub-stations about 15 miles apart. The writer's recommendation may seem to go to the other extreme by putting them an average of 7 miles apart. The power house would be located at O on the map (Fig. 1), and the sub-stations placed regardless of any uniform distance, but invariably as near the center of towns as the limitation imposed by high-tension line and the expense of real estate will permit. Going east from O the sub-station would be located and spaced as follows: At N, 4 miles; at M, 8 miles; L, 6 miles; E, 6 miles; J, 7 miles; H, 10 miles; G, 8 miles. This gives seven sub-stations plus one in the power house. The object of this distribution of stations is to let them serve as electric light and power stations for the places where they are located, also to allow them to become passenger, express and freight depots.

Any engineer who has ever operated a road equipped with sub-stations has invariably looked upon these adjuncts of power transmission as a necessary evil and a continuous source of trouble and annoyance, and on first glance it seems like multiplying these troubles to propose more stations rather than make a reduction in their number.

It is readily apparent that the primary object of these stations, as here proposed, is to serve as a central point where a representative of the company may always be found, where information may be obtained as to routes, rates, etc., in short the business to be handled in the same way as steam roads handle their traffic at similar points. Quite often one may observe small places of 1,000 to 1,500 inhabitants where steam roads may keep a day and a night station agent and a freight agent and freight handler in addition. Therefore, if the interurban is after the same class of business, why should it not employ at least one man in each town to be a representative, freight and express agent, and in this case a receiver of the electric lighting and power bills? Such a man may be paid a small salary and commission on all business done at his station. On this basis he should automatically commence to hustle for business. The fact that such a plan has not been extensively tried on interurbans seems another birthmark of horse-car days, and is part of the sometimes heedless chase after reduction of operating expenses. One often gets the impression that the chief object in building some road was "to reduce operating expenses" rather than the hustling for net profits.

The duties here enumerated may leave the station attendant but little time to attend to electrical apparatus, and it is

FIG. 4.— FRONT ELEVATION OF A TYPICAL SUB-STATION.

not intended that he should do so. The station and apparatus must be so designed and installed that the attention required by it is as small as possible. The attendant or agent need not be taught much about the apparatus except the simplest rudiments, and a competent man should be employed to visit each station once a day and examine the apparatus. Figs. 4 and 4a show the outlines and plans of a station suitable for the D, E & F Railway, and combines many functions in a very inexpensive structure. The low basement is used as a battery room with ventilators extending to the roof like chimneys. The first floor is office and express and freight room with wagon platform on one side and car track on the other side. The second floor forms the living apartment of the attendant. The rotary converter room proper is an L, and is comparatively small. Room is provided for one rotary converter only, for a battery booster and motor-generator set. Any extension of service is very far in the future, and should it ever come it is believed that a change to a single rotary of larger size would be more desirable than a duplication of the first unit. A single unit gives the simplicity which is necessary for a minimum of attention required of the station. The direct-current switchboard is located so as to be in convenient reach of the office, and the hand-operated alternating-current switch may be manipulated from the direct-current board by levers. In order to insure a reserve unit for any one of the stations it is advisable to have a portable sub-station, to be placed in a car and arranged for convenient cutting in at any one of the stations. This device has been in use for some years, has given excellent satisfaction and is worthy of being copied by railways desiring to keep their investment in apparatus as low as possible. The size of rotary converter units in our case will be 250 kw each, and the battery of 200 ampere-hours in each station. Stations being so close together and the attention required by apparatus

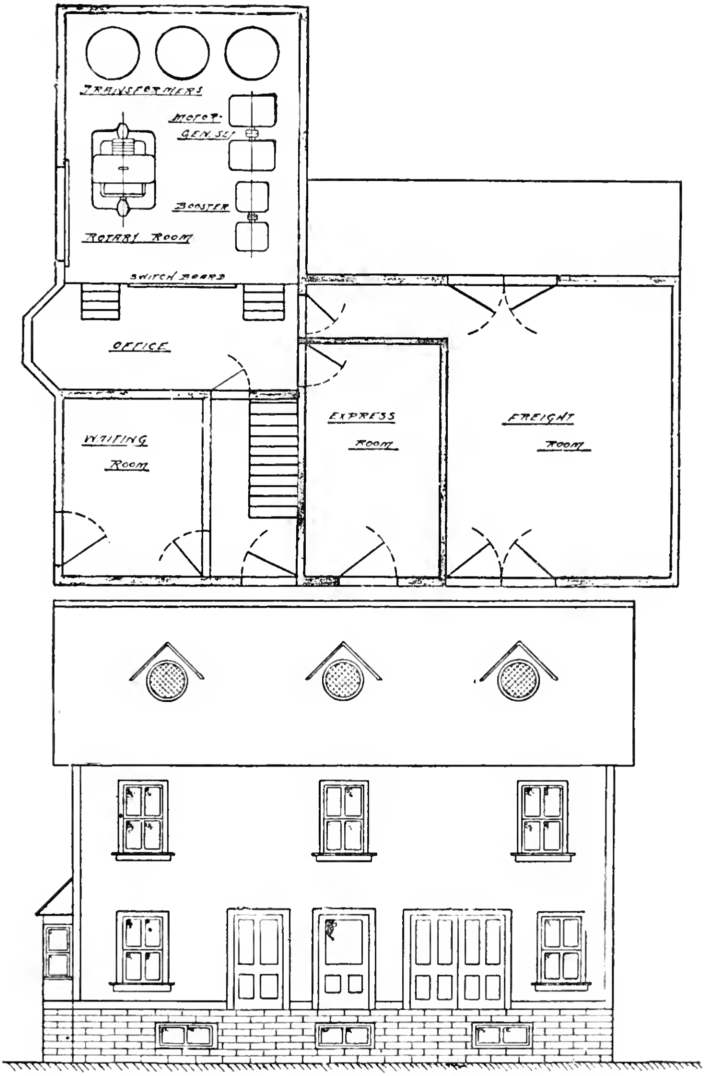

FIG. 4*a*.—PLAN, AND SIDE ELEVATION OF A TYPICAL SUB-STATION, FREIGHT, EXPRESS AND PASSENGER OFFICE, AND DWELLING FOR ATTENDANT.

being a minimum, it is safe to have only one man on duty, especially since he has living apartments in the station. At places like H and P, where the business gives promise of warranting it, two station men may be employed from the very beginning, and possibly a third man, to be a general utility man. At the smaller places one man at the start will be sufficient and efficient, provided he is occasionally relieved for a day.

In order to make sub-station units of comparatively small size properly handle the load imposed by the presence of several cars near one station, it is necessary to have shunt-wound rotaries having a considerable droop in their characteristic curve between full load and 100 per cent. overload. In this very simple way the load will be divided fairly well among two or three stations. At least one of the manufacturing companies continues to furnish compound-wound rotaries year after year in face of the fact that the series winding has been abandoned long ago in the largest roads using alternating currents. Aside from the possibilities of a disastrous mixup in case of a reversal of the direction of the current in the rotary with the presence of a battery, the series winding gives the disadvantage of tending to furnish all the current from one station in case of an extra heavy load near that station. In consequence sub-stations have to be provided with larger units than if the load were divided among two or three stations. On trolley roads one sometimes sees long feeder lines carried out from sub-stations to a point a mile or more from the station before being tapped into the trolley line in order to accomplish practically what the shunt-wound rotary does. With the latter and the fairly steady load which is insured by a battery the power factor of the transmission line may be adjusted by hand adjustment of the rotary converter shunt fields.

Since the sub-stations are also to act as distributing centers for electric lighting and power, the equipment for this purpose must be considered. The power-house current being 25 cycles, a motor generator set is a necessity. This is to consist of a 60-cycle, 2,200-volt two-phase or three-phase generator of a suitable capacity directly connected to a synchronous motor. The latter type of motor will be practically independent of voltage fluctuations, and as the engine speed is constant, due to absence of load fluctuations, it furnishes a very satisfactory driving power. The writer recommends that this motor be a small rotary converter, deriving its power from the same step-down transformers which feed the railway rotary and its direct-current side connected across the storage battery. In case of failure or interruption of the alternating current the converter would act as a direct-current motor and the lighting and power supply need not be interrupted. As the lighting and power business will be a small part of the total station output, this arrangement will not interfere with any of the plans for the supply of the railway proper.

THIRD RAIL.

It remains only to determine the size of rail and some of its details. It is taken for granted that the direct current is supplied at 600 volts. The steel for third rail, as already mentioned, is to have a minimum of carbon and manganese, and its conductivity is to be copper as 7.5 to 1. The size of the rail is now only a question of permissible drop between stations. This "permissible drop" has proved a variable and elusive factor. With sub-stations only 7 miles apart and the class of service proposed, few trolley lines would put up more than two 000 trolley wires, having an area of approximately 335,000 circ. mil. Assuming the two-track rails to have a combined capacity equal to approximately 1,000,000 circ. mil. copper, and a two-car train accelerating between two stations drawing 400 amp. from each station, this would give a drop of 230 volts, or 370 volts at the train. A single car accelerating would cause a drop to 485 volts. As there are frequently two cars between sub-stations, causing the voltage at the car to drop as low as 400 volts or less, more conductivity should be provided, although it is safe to say that in 80 per cent. of interurban roads in operation to-day the drop is as much or more than this. Such excessive drop is exceedingly expensive to the railway company, not only on account of the power lost, but because the motors are not worked efficiently. If the equivalent of two 000 wires is desired in third rail, then a rail weighing 30 lbs. per yard should be installed. Since we desire a higher efficiency of conducting circuit and car equipments in the D, E & F Railway, it is proposed to install a rail weighing 70 lbs. per yard. Such a rail will have a conductivity equivalent to 933,000 circ. mil. copper (which is considerably below its theoretical equivalent, but for commercial work this figure should not be exceeded), and the drop during acceleration, figured on the basis above named, will leave a line voltage of 450 volts for a two-car train and 525 volts for a one-car train. This will insure a very satisfactory average line voltage. Fig. 3 shows comparative cost per mile of overhead trolley and third rail.

It has now become customary to locate the third rail on one side of the track, and the distance chosen for surface work seems to have become quite generally 27 ins. from gauge line to center of third rail. This standard has many advantages, especially where heavy steam locomotives have to be operated over the same tracks, but for cars which have to operate over city streets there is the disadvantage of third-rail shoes protruding beyond maximum width of the car over the sides, thus necessitating lifting mechanism for the shoes in order to avoid the possibility of striking wagons, etc., which the car might pass but for the third-rail shoes. The elevated standard of 20⅛ ins. would seem to be very much better for cars operating through streets in terminal cities. With that standard the shoes will pass anything which the car will pass and need not be lifted nor current turned off from them.

Third-rail insulators continue to be very much below the standard of insulation which we consider necessary for overhead work or for almost any kind of work. Wood has been generally abandoned as worthless even in 110-volt work, and we sometimes go to great expense to secure a good grade of insulation in cases where not half as much is at stake as in the third-rail installation. It is certain that some time in the very near future we shall demand as high a standard of insulation for the third rail as we demand for other classes of work employing the same voltage.

At highway crossings the third rail has to be interrupted and the car drifts across. Experience has shown that this is not at all a drawback; in fact in practice it has many advantages. The chief disadvantage is that the lights in cars go out, and where crossings are numerous this becomes annoying to passengers. Numerous remedies have been proposed to cure this trouble. There is one, however, which has never been tried, to the writer's knowledge. It consists in extending the third rail into the public highway and protecting it by a fence and by automatic cut-out, leaving it dead except when a car passes over it. There is in every public highway a strip of waste land on either side of the traveled roadway, which it would not damage to occupy for third rail, leaving an opening 25 ft. wide in the center of the highway for teams. This can easily be spanned by the shoes, and lights thus remain burning. Such a plan necessitates the co-operation of the township authorities, who are always an uncertain factor. If, in return for this privilege, a light at each highway crossing were offered by the railway there are no doubt cases where such a plan would prove mutually satisfactory. Another way, of course, is to provide battery-operated lights, which commends itself as an advantageous plan which has its own merits.

For the bonding of the third rail only one type of bond has so far come prominently into use, and as its service has proven so universally successful but little is to be said on this subject except to repeat what has already been referred to in track bonding on the use of two bonds for each joint.

Accessories.

Under this head may be grouped all the details, such as telephones, block signal system, etc., which occupy a relatively small place compared to the whole, but whose success or failure may be very largely reflected in the financial returns of the road.

The telephone has come to be accepted almost universally for train despatching and is very superior to the telegraph for this purpose when time-rooted prejudices in the latter's favor have once been overcome. It is of such importance to have communication at all times that some of the best roads have installed duplicate lines and duplicate instruments. For the D, E & F Railway it is important that a reliable telephone service be installed and a reserve provided. A pair of wires must be run the entire length of the road for the despatcher's use and to enable train crews to communicate with headquarters at any point along the line. For this purpose it is recommended to install desk instruments at substations along the line and portable 'phones on cars. No talking is to be done over this line except strictly train despatching. For general business either another line must be run or connections made with local telephone systems. In view of the fact that stations will serve the numerous other purposes before enumerated, it would seem advisable to have connections with the local telephone systems, and it is recommended to install this service in preference to a duplicate private line. To a live road reaching out for business of all classes such connections are a profitable investment. Too much care cannot be taken to secure an absolutely reliable telephone system and to install it in such a way that it shall be useful at all times when it is most needed, during wind and snowstorms. Any reader of this article can no doubt cite a number of roads which are equipped with perfect telephone service during fair weather. When storms disarrange the wires and snow interferes with cars and the schedule is woefully mixed, then these fair-weather despatching systems become worse than useless. It is, therefore, recommended that the telephone wires of the D, E & F Railway consist of a pair of No. 6 Brown & Sharpe gauge galvanized iron wires, or, still better, two twisted pairs having the same tensile strength as the No. 6, the telephone insulators to be provided with deep grooves on top, after the manner of high-tension insulators, to prevent the disturbing dropping of wires due to loose tie-wires and cracked insulators. A high standard of insulation in exterior and interior work is to be maintained.

It is sometimes important to be able to call train crews at points along the line where no regular attendants are stationed, and this would necessitate a call signal device of some sort. It is an open question if such a call signal will warrant its cost in our case, and it is, therefore, recommended that no apparatus be provided for this purpose at the start, but that sufficient cross-arm room be arranged for on the pole line so that it can readily be put in place in case its use seems advisable. With sub-stations an average of 7 miles apart only there will probably be few occasions when the signal would have to be used except during a complete disarrangement of the schedule, and it is, therefore, best to wait, as has been suggested.

As already pointed out, an automatic block signal system is a necessity on a road of this character. One needs only to examine the list of accidents which have occurred on electric railways during the last year or two to be convinced of this. It certainly seems strange that a property which is provided with costly safeguards against low water and high water in boilers, over or under speed of engines, overload and reversal relays on generators, precautions against lightning and "resonance" damages and all the numerous list of such devices, will not usually spend one cent in an effort to avoid the most costly of all accidents — collisions. No doubt this is due in good part to the fact that until recently no satisfactory block signal system at a reasonable price had been on the market, but this argument will no longer hold, as it is now possible to obtain it. It is true that none of these systems have stood the test of time; they are all too new as yet, but as none exists which has stood this test and which is applicable for electric railway service, one must take these chances. One of the essential features of an automatic system which was overlooked in the earlier types of this apparatus was that the signal should return to "danger" in case of any derangement of its working parts or in its current supply. This is now being provided for, and no one needs to hesitate to purchase and install block signals. That no road can afford to be without one is proven by the accident lists which grow larger every year. An ample allowance has, therefore, been made in our estimates to cover the cost of an adequate automatic block signal system.

Closely related to the foregoing is the matter of provision to signal cars at flag stations. At present it is quite customary not to designate flag stops by anything in particular — possibly a small board may be nailed to a convenient fence or telegraph post, and some roads even provide a few luxurious planks in lieu of a platform. A motorman on approaching a flag station rarely can see the passengers, if there are any, until he is quite near, and he must then make a quick stop; too frequently he runs past the stopping point, necessitating backing the car, which consumes time and current. In view of the data which is available proving the value of coasting or drifting of cars with current off, it seems strange that so little provision has been made so far to provide a flag-stop signal which may be seen for a long distance in either direction and thus enable the motorman to shut off power, drift and make the regular satisfactory service stop.

Fig. 5 gives the outline of a station and platform suitable for a flag stop of the D, E & F Railway. A small inexpensive structure, 10 ft. x 12 ft., is provided as a waiting-room, and should be placed at every point wherever a flag stop is located. The receipts of an electric railway are always least during inclement weather, and anything tending to increase the comfort of the traveler during such periods is pretty certain to be reflected in the bad weather receipts. When passengers are expected to wait on an unsheltered platform or at country crossings for from ten minutes to thirty minutes for a car, they are certain to give up traveling until some better day, or, in fact, may not go at all, and it therefore seems shortsightedness not to make some inexpensive provision for their comfort. Outside the small station shown on Fig. 5 is placed a post 18 ft. high, and provided with a semaphore arm 4 ft. to 5ft. long, and worked by a lever from the platform.

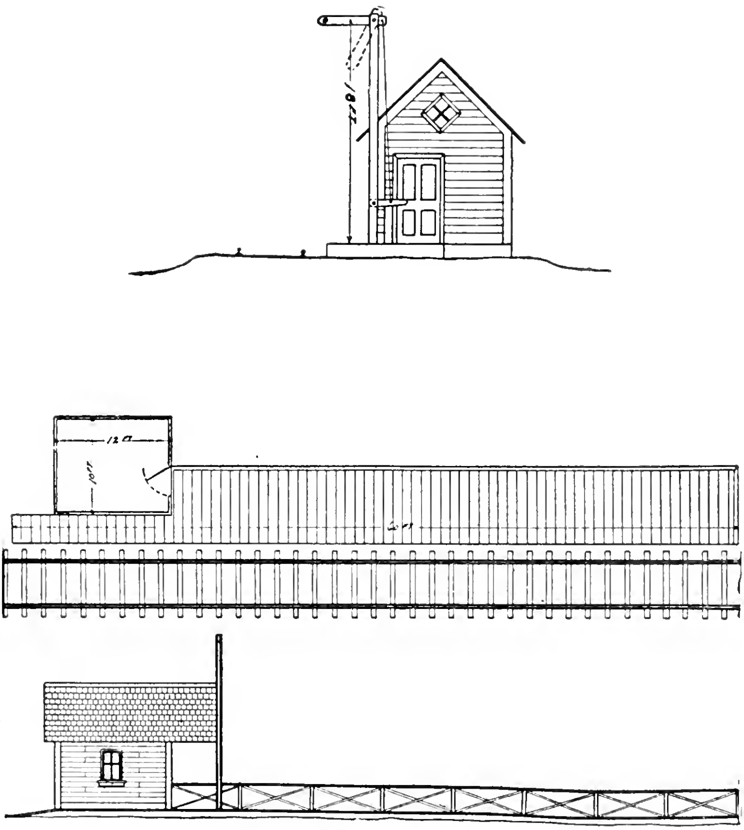

FIG. 5.— PLAN, SIDE AND END ELEVATIONS OF A STATION AND PLATFORM FOR FLAG STOP.

Neither the arm nor the lever can be locked in position, and the passenger must keep his hand on the lever in order to signal a car; as soon as his hand is removed the arm falls back by gravity into the position shown by dotted lines. It can be arranged so that at night the setting of the arm lights a lamp on top of the post. Such a signal may be seen for a long distance and will prove economical for the railway and highly satisfactory to the passenger.

The platform is shown in the engraving as built of wood. A better and cheaper platform may be built by locating as many of the flag stops as possible in advance of the grading of the road. The sub-grade may then be widened at these places and the platform rock-ballasted at the same time similar work is done on the track and roadbed. The cost of this work is usually less than wood construction and it is enduring. The shelter or station can also be built of some less combustible material than wood at little more than the cost of the latter. The extra cost of making these unprotected stations non-combustible is ordinarily well invested, but its advisability must be carefully weighed in each individual case.

The waiting stations, certain highway crossings, switches, etc., must all be provided with lights, and it is wasteful to use a cluster of five lights at each of these points. It is, therefore, recommended to run a single galvanized-iron wire the entire length of the road from which the lights shall be tapped off in series of five lights, but only one light used at each platform, and an electric light to be substituted in place of the oil lamp in switch stands. These circuits would be turned on and off from sub-stations. The liability of lights going out is greater with electric lights than with oil, but the gain in reduced cost of maintenance is sufficient to warrant the risk, which, after all, is not very serious when one considers that most interurban roads run with no switch lights whatever. That such lights are needed even on the most out of the way switches cannot be denied.

Electric railways are at the present time very often the object of crossing-gates agitation, and there are numerous roads which have been called upon to install either gates or a crossing alarm. The latter has usually been resorted to and much difficulty has been experienced in finding something suitable to electric railway conditions. Nothing has been standardized for this purpose at the present time and the application of a crossing alarm must be a matter of special design by the engineer. Their use is to be commended, however, as another very simple way to cut down the size of the accident account.

The distributing systems required to supply electric lighting and power service should also be included under this heading, but it is impossible to go into their details in the present article. In one or two cases it may be advisable to purchase outright an already existing plant and use its distributing system. As a general rule, however, an entirely new layout will have to be provided, and in our case it would consist of an alternating-current series arc lighting system, a four-wire secondary system in the business streets of each of the small towns and groups of houses fed from one transformer in residence lighting. In a number of the very small towns along the railway a very satisfactory revenue might no doubt be derived from such service, the extra investment and operating cost to the railway is very light, and would prove profitable in cases where an independent plant would be out of the question.

The details of construction have all been discussed, and an estimate of the cost of the road built, according to plans outlined, must next be considered. The road from end to end is 62.5 miles long, but counting the mileage of sidings and yard tracks it is necessary to base the estimates on a single-track mileage of 66 miles:

ESTIMATE.

Excavation and embankment	$96,000
Bridges, abutments, and culverts	91,030
Two overhead railroad crossings, at $32,000	64,000
Ties, 2640 per mile, at 55 cents	96,250
Ballast, 2200 cu. yds. per mile, at 80 cents	116,000
Rail, 70 lbs. per yd., at $31 per ton delivered	225,000
Joints, spikes, and bolts for 60-ft. rails	29,500
Labor on track, 56 miles, at $600 per mile	33,600
Labor in street track, 6.5 miles, at $1,800 per mile	11,700
Farm and highway crossings	9,500
Wire fences, 24,000 rods, at 73 cents in place	17,500
Switches, special work, etc	21,000
Bonds, 24,000, at 61 cents in place	14,650
Cross bonds and special bonding at switches, etc	2,000
Third rail, 70 lbs. per yd., 56 miles, at $36 per ton delivered	131,000
Insulators, spikes, and bolts, at 62 cents in place	18,000
Joint plates, bolts, and labor laying rail	9,800
Bonds, 15,000, at 73 cents in place	10,950
Crossings and crossing cables	13,500
Trolley in streets, single-track span construction	24,000
Power station, 1500 kw, at $120 per kilowatt	180,000
Power station building, $11 per kilowatt	16,500
Transmission line, 55 miles at $1,400	77,000
Sub-station, freight, and depot buildings	24,500
Sub-station railway apparatus	65,000
Batteries	80,000

Telephone line	$9,000
Block signal system..	35,000
Stations and platforms..	5,250
Switch and platform lighting circuit..	4,000
General office building..	8,000
Car shops, shop tools, etc..	24,000
Car bodies and locomotive body..	49,000
Trucks and air brakes..	27,500
Electrical car equipment..	76,000
Lighting and power apparatus and supply systems..........	70,000
Accidents, contingencies, and insurance, 5 per cent..........	89,000
Administration, superintendence, office expenses, engineering, etc., 5 per cent..	89,000
	$1,963,750

The estimate does not include any allowance for right of way, franchises and legal expenses, nor for interest during construction. It represents the construction cost purely, which in this case amounts to $29,750 per mile of single track. No doubt opinions will be divided as to the merits of building a road at this cost. Men who have been building interurbans at from $18,000 to $20,000 per mile will be inclined to sneer at the construction proposed, and perhaps charge all the excess cost against "third rail," as is the habit. Others whose roads have cost from $30,000 to $50,000 per mile — some of them trolley roads, others third rail — may be inclined to find the estimate somewhat low for the class of work proposed. Probably both are right, for it is well recognized that the interurbans built at the first figures are often mere horse-car systems grown to maturity, while the term "third-rail road" has become synonymous with roads often extravagantly built and equipped. By choosing the best from each, a road physically and financially somewhat like the example we are discussing will be the result, and will be more valuable than either of the two extremes, on the same principle as a mule is more useful than either of his parents, the jackass and the horse.

Reference has already been made to the A, B & C Railway as an example of extremely liberal equipment and construction. Had the manufacturing company's plan of modelling our road after it been adopted, it is difficult to estimate without going into details what the cost of the D, E & F Railway would have been, but it would no doubt have reached very close to $40,000 per mile. The A, B & C Railway cost nearly $50,000 per mile, and the difference is due to less expensive roadbed and similar physical conditions. Interurban railways seem to be making much the same sort of history as that experienced by the early steam railroads which started with cheap construction, which did not last its allotted time and had to make way for better work. While the present steam railroad standards seem to be somewhat too expensive to be adopted by the ordinary interurbans, it is to be hoped that investors will learn to insist on something better than the exceedingly cheap outfits, ready to fall to pieces after a year or two, which have been built in some places and their securities offered in the market. But in order to secure permanency of construction it is unnecessary to go to such extremes as the A, B & C Railway and similar properties have gone.

The estimated net income has already been shown to be $140,000 per annum. Assuming the D, E & F Railway to be bonded for $2,000,000 at 5 per cent., this will leave $40,000 per annum to apply on dividends, etc. Should the income reach the average of other roads of similar character, which it will, with time and good management, its stock will soon be hovering around par, and the owners will permanently wear a happy smile, which would never have appeared to stay had the extremely lavish or the extremely cheap construction been adopted.

OPERATION.

The operating expenses have been assumed to be 55 per cent. of gross receipts, which seems to be a very fair average result. There are roads operating as low as 45 per cent., and in fact one of the four roads referred to in the estimate of income has operated the last year below 50 per cent. It is also noticeable, in one or two cases where operating expenses are a comparatively small percentage of gross receipts, that apparently no effort has been made to curtail these expenses by employing low-priced and less labor, reducing the frequency of cars, etc., and the very low figure seems to be due to an intelligent increase in gross income rather than a niggardly operating policy. It has been said by a well-known and successful railway man that "the best way to decrease operating expenses is to increase gross receipts." Apparently this has been done in the cases cited. An extra good showing can be made, of course, for a year or two by neglecting track maintenance, equipment, etc., but it is assumed that this will not be the policy of the D, E & F Railway, and with the quality of construction estimated, maintenance and operation should be as low as it is possible to go on any road.

Reference has already been made to location of power house and car shops near to each other, on account of economy in first cost and operation. One master mechanic may have charge of both, and they are always under his eye. The power house force may be organized into two shifts of ten hours each, and one or two men provided for the four hours when the plant is closed down. At the car shops the number of men required is very much affected by the design of the shops. If the latter are well planned for rapidly handling the work, and to facilitate inspection and small repairs, a small force only is required. Many roads find it advantageous to manufacture in their shops small supply parts and sometimes even to take in outside work. If such work does no more than cover its cost it gives at least the advantage of always providing a force of trained mechanics close at hand when something out of the ordinary occurs. This applies more particularly to the smaller roads, which are apt to be very short in shop facilities and whose ordinary repair work would not warrant the employment of even a modest-sized shop force.

Sub-stations in our case have so many functions that only a small share of their attendance should be charged to motive power; say not over one-third. Another third may be charged to train operation and the balance divided between electric lighting and the freight and express business. As already mentioned, only one man is to be stationed at each of the smaller places, an arrangement which has proved feasible in several instances where sub-stations are of larger size and more vital importance. It is only justice, however, to say that such a plan would not be satisfactory where sub-stations are farther apart, have larger units and no living apartments are provided. A general oversight over all the sub-stations may be had by one competent man, as already stated, and all of his time will naturally be charged to motive power. For the maintenance of pole line two patrolmen will be required who are to make an inspection every night and make all repairs during the hours when the plant is shut down.

For maintenance of track it is becoming customary to divide the road into sections, each in charge of a "section gang," the same as is done on steam roads. Each section is provided with a shanty for storage of tools, hand-car, etc., and the men employed live within close call. It is the track work which usually feels the first effect of the economizing policy, and any reader of this article no doubt can name roads which have no track maintenance gangs worth mentioning, or have sections from 15 miles to 20 miles long each, with perhaps two men for such a section. In our case the care and maintenance of the third rail would come under the track gangs and it is surprising how quickly the men will get used to the presence of the live rail, driving and pulling spikes and handling the live rail itself with the utmost unconcern, and no serious consequences on this account have so far been recorded.

The train schedule proposed for D, E & F Railway requires train crews familiar with steam railway operation, and it is a question of importance from what class of employees to recruit them. Of all men street car employees seem to be the least fitted for this work, because the duties of the two classes of service are so divergent. It is not denied that there are many very satisfactory ex-street railway employees on interurban runs, but that fact has no bearing on the present case, because we are assuming trains to be operated exactly as they would be did the motive power consist of steam locomotives. In the latter case would any man, no matter how much experience in street railroading he may have had, be placed in charge of a train without two or three years of apprenticeship in the intricacies of train operation? More often it is five years to ten years before a man has charge of a train. In the meantime the interpretation of whistle, flag, bell and lantern signal and all the "rules of the road" become second nature to him and he does not have to remember them "by the book." He is also very apt to have learned to keep his head in emergencies and not to yell "whoa" when the brakes fail to work. Promotion is none too rapid on steam roads, and it is therefore recommended to recruit train crews for the D, E & F Railway from among young and promising brakemen, station agents, etc., of the steam roads, and teach them the little additional knowledge required to handle electric cars.

As an illustration of the deplorable condition of affairs on some interurban roads and not as a joke (the matter is too serious), a telephone conversation overheard by the writer between a "despatcher" and a "conductor" of a prominent interurban railway is here repeated:

Conductor — "Hello, Bill, that you?"

Despatcher — "Yep, Charlie, that's me."

Conductor — "I'm at ———. Raining like ——— down here."

Despatcher — "So is it up here; barrels full of it."

Conductor — "I am ready to come in. All right?"

Despatcher — "Yes, I guess so. Wait a minute. No. 12 is out somewhere in your neighborhood, and you better kind o' look for her."

The two cars ordered to "kind o' look out" for each other on that dark and stormy night are both capable of over 60 miles per hour, and the schedule regularly calls for nearly that maximum speed. Is it any wonder that accidents are on the increase?

The supply of electric lighting and power requires a distinct organization of its own, and the manner of handling this business, scattered over numerous small towns along the railway, must be "felt" for as the business develops. With the current a by-product of the railway plant it becomes possible to give continuous service, day and night, in even the smallest villages, something always highly appreciated by customers. A systematic canvass for new business and house wiring and other supplies at cost are a great help to get and hold business, in fact, the methods of the most successful electric lighting companies will bear copying.

The manner of securing and holding passenger, freight and express traffic is outside the sphere of this article. It is useless to suppose that the traffic will come without soliciting, and the most successful interurban railways are examples how to handle this part of the business. There are other examples — how not to do it.

GENERAL CONCLUSIONS.

The various factors entering into the problem of selecting methods, materials and equipment for a proposed road have all been discussed, and the reasons pro and con for having made the selections as here outlined have in each case been cited.

There are many whose ideas will differ very radically from those advanced in this article, and it is fortunate that there are differences of opinion — if all men thought alike there could be no real progress of the world.

A summary of the recommendations made and a comparison with some recently-built and heavily-financed properties, shows that it is recommended to invest *less* money in electrical equipments, power house, transmission line, substations, track rails and third rail. It is recommended to invest *more* money in track ballast, car bodies, trucks, block signal system and waiting stations.

It is noticeable that the last items do not have the advantage of being controlled and placed on the market, practically without competition, by large and powerful corporations as do those in the list marked for less investment. One never hears of the electrical or steel manufacturing companies making very strenuous efforts to get their customers to use large quantities of, say, gravel ballast, but they expatiate much and long on the advantages of lots of electrical apparatus, etc. If all the gravel ballast could be handled by one or two of these companies we should soon see deserving men earning large salaries getting railway people to use double the quantities of track ballast now customary — at three times the present price.

Attention is also called to the lighting and power supply business as a means of utilizing the "by-products" of an electric railway power station. Our friends and competitors in the gas business have long since learned the value of these by-products, and electrical concerns of all kinds might, with profit, copy their methods.

In conclusion, it is hoped that there may be fewer interurban roads built which deserve the appellation bestowed on them by a well-known engineer — "monuments of efficient salesmanship" — and if this series of articles will aid in any way towards securing a permanent standard of construction without lavishness or excessive cheapness its purpose will have been served.

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