RATON MOUNTAIN ELECTRIFICATION
PROJECT A. T. & S. F. RAILWAY CO.

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ARMOUR INSTITUTE OF TECHNOLOGY
1910
Raton Mountain
Electrification Project
The Atchison, Topeka & Santa Fe Railway Co.

A THESIS
PRESENTED BY
C. C. BAILEY. E. B. SHERWIN

TO THE
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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN
ELECTRICAL ENGINEERING

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PART I

INTRODUCTION AND STATEMENT OF PROBLEM.
Part I.

Introduction and Statement of Problem.

The following thesis is a consideration of the engineering features involved in the substitution of electric for steam locomotives for handling trains over Raton Mountain, in the First District of the New Mexico Division, on the Atchison, Topeka and Santa Fe Railway. The present conditions include a double track from Trinidad, Colo., to Raton, New Mexico, a distance of 23 miles over the Raton range of mountains. As shown in the profile map, Figure (1), the grade averages 2% from Trinidad to Gallinas, a distance of 11.9 miles, the worst condition being met in a 10 degree curve on 1.5% grade. From Gallinas to the State line (4.6 miles), the grade is practically 3.0 and 3.5%, with several 10 degree curves on the 3.0% grade, this being the worst condition encountered. From the State line, the West bound track passes thru the new tunnel, 2789 feet in length on a grade constant at .52%, whereupon the descent begins. East bound traff-
ic, from Raton to the entrance of the old tunnel is on a 3% grade for nearly the entire distance of 6.5 miles, the worst condition being 8 degree curves on 2.8% grade. The descent begins practically at the entrance of the old tunnel, which, is 2037.5 feet in length, with a down grade of 1.9% for east bound traffic.

The present traffic consists of four passenger trains and two freight trains in each direction daily, with the addition of a west bound refrigerator twice a week. This does not include extra freights which average one to three in number, daily, in both directions. The passenger trains vary in weight from 350 to 570 tons.

To handle the traffic Class 1200, Pacific type, single expansion locomotives are used in passenger service. Class 900-1600, Santa Fe type, tandem compound locomotives are used for freight and helper service. The following table is a comparison of the two engines.

<table>
<thead>
<tr>
<th>Class</th>
<th>Class.</th>
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<tr>
<td>900-1600</td>
<td>1200</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>225</td>
</tr>
<tr>
<td>Total weight of locomotive</td>
<td>287240</td>
</tr>
<tr>
<td>Total weight on drivers</td>
<td>284580</td>
</tr>
<tr>
<td>Number of pairs of drivers</td>
<td>5</td>
</tr>
<tr>
<td>Wheel diameter-inches</td>
<td>57</td>
</tr>
<tr>
<td>Tractive effort -lbs.</td>
<td>62800</td>
</tr>
</tbody>
</table>
The practical rating for the 900-1600 class is 450-500 tons for the east and west bound grades. The 1200 class locomotive is rated roughly to haul three passenger coaches up either grade.

The present method for handling passenger trains is to use the regular engine which runs between La Junta and Raton and one or two 900 class engines as helpers, depending on whether the train weight is under or over 500 tons. The helper engines are cut off when the summit of the grade is reached and returned to either Trinidad or Raton. Helper service is expensive to maintain both on account of the cost of maintenance and repairs and the wasteful coal consumption for such short runs. Wages of enginemen in this class of service are also higher than the average paid on regular runs.
PART II.

THE BELEN CUT-OFF.
PART II

The Belen Cut-off.

To overcome, in a measure, some of the difficulties involved in handling the California freight traffic the company built the Belen cut-off from Clovis to Belen, New Mexico, thus completing a route which leaves the main line at Florence, Kansas, passing southwest through Oklahoma, Texas, and across New Mexico to Rio Puerco, where a connection is made with the Coast lines. A comparison of the main line and the cut-off will show the saving in grades by sending the California freight traffic over the latter route. The main line rises 6346 feet from Florence, Kansas to Raton mountain and after dropping down to Las Vegas, rises 1100 feet to the summit of the Glorieta range, 171 miles west of Raton, and drops gradually down to Rio Puerco. Going eastward from Rio Puerco there is a 1200 foot rise to Glorieta and a 2580 foot rise to Raton mountain. The grade westbound is 3.5% on Raton Mountain and 1.5% on Glorieta mountain, while eastbound it is 3.0%
on Glorieta and 3.3 on Raton mountain. The cut-off, however, has but one rise in either direction between Florence and Rio Puerco, 5222 feet west bound and 1456 feet eastbound, with a maximum grade of 1.2% near Belen.

From Florence to Rio Puerco the distance is 779.6 miles over the main line and 769.8 miles over the cut-off. The preceding comparison shows the very considerable saving in grade climbing, which affects the time and money used in handling the heavy refrigerator traffic during the summer season.
PART III.

THE ADVISABILITY OF ELECTRIFICATION.
Part III.

The Advisability of Electrification.

Although it would be impossible to provide a cheaper method of handling the California traffic than by sending it over the cut-off, there are several features of the present system over Raton mountain which might be well improved upon, and it is for this purpose that the following pages are intended.

Electric power has extended the field of profitable railroad operation in two ways.

1st: By providing a cheaper means than steam for carrying on certain transportation work.

2nd: By greatly increasing the earnings that can be secured in favorable locations, as has been done by electric trolley roads paralleling steam roads. As the conditions of the case at hand are only affected by the first method at present, the second need not be considered. There is an abundance of coal and rather a scarcity of boiler feed water near Raton mountain. These two facts, together with the poor efficiency secured from the steam locomotives and
their high cost of maintenance and repair are fundamentally advantages as far as the adoption of electric locomotives is considered.

Taking up the item of coal expense the saving shown by the New York New Haven and Hartford Railroad, is as follows.

Express service 51% saving.
Express local service 54% "
Express freight service 26% "

The New Haven Railroad makes its electric power with a steam turbine power plant, using coal to generate electricity.

In the A.I.E.E. Proceedings, Messrs. Stillwell and Putnam give the estimated saving in fuel by electric operation 49.5% for average railroads in the United States.

Maintenance and repairs of locomotives is another item of steam railroad expense that is largely affected by electrification. The average cost of locomotive maintenance in the United States is about $0.09 to
$0.10 per locomotive-mile. On heavy main line railroads, especially where the quality of boiler feed water is not good, there are important sections where the locomotive repairs average between $0.15 and $0.20 per locomotive-mile for freight locomotives and about two-thirds as much for passenger locomotives. There is not a great deal of data to determine the cost of electric locomotive repairs, but such data as is available, backed by the best judgment of many railroad men, points to a cost for heavy electric locomotives equivalent in power to heavy steam locomotives about $0.03 to $0.08 per electric locomotive mile, under conditions where steam locomotive repairs would probably be about two or three times that amount.
PART IV.

THE THREE POSSIBLE SYSTEMS.
Part IV.

The Three Possible Systems.

There are, in the adoption of electric motive power for the handling of trains over the mountain, three possible systems, which will now be taken up and a comparison will show which seems the most advisable under the existing conditions. The systems available are:

1st: The use of 25 cycle, Three Phase Alternating current at 500 volts; power to be generated at 6600 volts; a 33000 volt transmission line, with transformer substations stepping the voltage down to 6600 volts at the trolley and transformer on the locomotive to further step down the voltage to 500 volts at the motors.

2nd: The use of 15 cycle, Single Phase alternating current at 285 volts; power to be generated at 11000 volts with 3 phase alternators; a 33000 volt transmission line, with transformer substations, stepping the voltage down to 11000 volts at the
trolley and transformer on the locomotives to further reduce the pressure to 285 volts at the motors.

3rd: The use of direct current at 1500 volts, by means of a third rail. This would also require a 6600 volt generating station (alternating current) with the 33000 volt transmission line, and rotary converters at the substations.

The running time and schedule speeds from time table #34, effective January 9, 1910, calculated for each train and averaged, shows the schedule speed of trains to be, in miles per hour:—

<table>
<thead>
<tr>
<th>Route</th>
<th>Pass</th>
<th>Freight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinidad to Summit</td>
<td>17.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Summit to Raton</td>
<td>16.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Raton to Summit</td>
<td>12.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Summit to Trinidad</td>
<td>18.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Average</td>
<td>16.2</td>
<td>9.9</td>
</tr>
</tbody>
</table>

The allowance for resistance of curves, taking the total amount of the various degrees of curves from the profile map, Figure (†), gives the total
degree of curvature in feet as 252550. Taking the length of the line as 23 miles or 120600 feet, the average curvature is 2.1 degrees. Allowing .5 lbs per ton per degree of curve, the curve resistance is 1.05 lbs. per ton, making the train resistance 5 lbs. per ton. Using locomotive units weighing 125 tons, and resistance of passenger train, trailing, tons makes the locomotive resistance at 10 lbs. per ton, 2500 lbs. and the total 525 lbs.

The average grade on the steep section from Trinidad to the summit, 13.1 miles, a rise of 1530 feet, is secured from 1530—6930=2.21%.

For a 3.5% grade the total train resistance-------------5250 lbs.
grade resistance-------------56,000 lbs.
Total tractive effort----------61,250
Tractive effort per mile--------6125 lbs.

The Table of requirements of Motors in Figure 2 shows the various horse power, tractive efforts and speeds for the single phase and three phase motors
for the different train weights.

Taking the above example with two locomotives, at 250,000 lbs. each, the adhesion will be

\[ \frac{61250}{500,000} = 12.2\% \text{ running.} \]

Accelerating a passenger train at .5 miles per hours per second the total tractive effort is 101,250 lbs. and the adhesion 20.2%.

For a 1500 ton train, 3 locomotives at 250,000 lbs. each adhesion running is 19.0 and accelerating, 24%.

The above calculations are for single phase locomotives. The three phase locomotive weighs but 230,000 lbs. So that the coefficient of adhesion will be higher in each case.
PART V.

THE THREE PHASE SYSTEM.
Part V

The Three Phase System.

Considering the locomotive as shown in Figure 14, the principal data are as follows: total weight 230000 lb., all on drivers; two trucks connected by a coupling, each truck has two driving axles, with a three phase motor connected by twin gears to each axle; gear ratio, 4.26; diameter of driving wheels 60 inches; synchronous speed of motor 375 R.P.M., giving a speed of 15.7 miles per hour at no load, dropping to 15 miles per hour for a load corresponding to the one hour rating. The motors are wound for 500 volts and are completely enclosed and air-cooled; clearance between stator and rotor 1/8 inch; trolley pressure 6600 volts; each locomotive has two three-phase transformers reducing the pressure from 6600 to 500 volts arranged so that 625 volts may be used as an emergency point on the controller in case the drop becomes excessive on a heavy grade. The continuous output at 500 volts corresponds to a tractive effort of
11,900 lb. per motor; the locomotive will therefore give 37400 lb tractive effort in continuous duty or 47600 lb tractive effort for one hour. Figure 5 gives the characteristic curves of the motor at 500 volts and figure 3 at 625 volts. The control apparatus is separate for each motor, the various steps being accomplished by the insertion of resistance in the rotor.

THE POWER HOUSE.

Owing to the fact that three different systems of electrification are possible, a power plant has been designed which will most readily meet the requirements of any system.

The power house will be located at Trinidad, just East of the Forbes Wool Co., and 600 feet from the Purgatoire river. The principal dimensions are as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length power house</td>
<td>140</td>
</tr>
<tr>
<td>&quot; width &quot; &quot; &quot;</td>
<td>171</td>
</tr>
<tr>
<td>Height turbine and boiler room</td>
<td></td>
</tr>
<tr>
<td>from floor line to lower chords</td>
<td>41</td>
</tr>
<tr>
<td>Length, boiler room</td>
<td>117</td>
</tr>
<tr>
<td>Width</td>
<td>88</td>
</tr>
</tbody>
</table>
The general design of the entire building and the installation of the machinery is such that the building may be extended to the south and new units added, still maintaining the general scheme of sectionalizing the apparatus. Each turbine is fed by a separate set of four boilers while two turbines and their auxiliaries are arranged as a unit.

The boiler equipment consists of 12 Babcock and Wilcox wrought steel boilers set in batteries of two each. They are rated at 508 horse power, have 5000 sq. Ft. of heating surface and a ft. x 10 ft. chain grate. The equipment is to operate at 175 lbs. pressure with 125° superheat. The smoke connections are made thru the rear of the boiler setting and the gases from the three batteries on either side pass into a self-supporting steel stack 11 ft. 6 in. diameter and 200 ft. high. This stack is of ample size to take care of a fourth battery of boilers, should such extension be desired. Space is also provided for an 18 x 8 ft. steel place fan should the installation of mechanical
draft be deemed advisable.

The coal handling apparatus consists of an 18 in x 24 in. pivoted bucket conveyor running the length of the boiler room and centrally located with reference to the bunkers and ash pits. Coal is received at the north side of the boiler room in a separate compartment and fed into a crusher whence it is carried to the bunkers. Ashes are conveyed from the pits to two ash hoppers over the receiving track hopper. Fine coal is conveyed to a similar hopper by means of a screw-conveyor.

The turbine room contains three horizontal Curtis turbines rated at 3500 K.W. at 1500 R.P.M. The generators connected to the turbines are two pole, 25 cycle, connected and generate current at 6600 volts.

Exciting current at a potential of 125 volts will be furnished by a 150 K.W. horizontal Curtis turbo-generators set and at 150 K.W. motor generator set.

Owing to the fact that cooling water is not available in larger quantities, it is not deemed advisable
to attempt to maintain a vacuum better than within 4 inches of absolute. The condensing apparatus consists of a 10000 sq. ft. surface condenser and 9x22x12 rotative wet vacuum pump. The circulating water is handled by a 15 inch centrifugal pump driven by a 9x12 automatic engine which permits of discharge of the water against the high head of a cooling tower or high suction head of cooling water is taken from the river. In order to cool the water during very hot weather it would be necessary to install six cooling towers, each of which are 26 ft. x 26 ft x 70 ft high, with 18 ft. square flues, the air being circulated by four 9 ft fans at 200 R.P.M. This combination will maintain a vacuum within four inches of absolute, during the hottest weather and will give as high as within 2.5 inches in cooler weather.

As an alternative or reserve for the cooling towers the construction of a pond is recommended. It will serve as a reservoir for water pumped into it when the river is high during the months of July and August. The
area should be 4 acres, with an average depth of 6 feet.

The wet vacuum pumps from each pair of turbines will discharge into a 2500 sq. ft. closed heater of the Wheeler type.

The boiler feed pumps are 16x10x12 duplex outside center packed type for pressures up to 200 lbs. House service is cared for by two vertical 16x10x12 single acting pumps.

CURRENT TRANSFORMING & SWITCHING APPARATUS.

The output of the generators may be fed directly into a bank of transformers or into the feeder and trolley. Each generator has its own bank of 3-1250 K.W. transformers which raise the potential to 33000 volts at which pressure power is transmitted to the substations. All transformers on the system are rated at a 35 degree rise on 50% overload for two hours. All switches except the outgoing line switches, (which are G.E.K-10 solenoid-operated switches) are H3 motor-operated oil switches. The switchboard is shown in figures 23 and 24.
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TRANSMISSION LINE.

The transmission line will be in duplicate, extending the entire length of the line. The line carries two circuits of #1 B.&.S.gauge, stranded hard drawn copper wire. The three cross arms will be placed 42 inches apart and the insulators 30 inches from the center line of the pole on each side. Each circuit is in a vertical plane at one side of the pole, thus permitting the use of short cross arms. The use of a ground wire is recommended in particular for this line. As the country is very dry and good poles are available, wooden poles about 40 ft. long and 10 to 12 in. in diameter are preferred.

SUBSTATIONS.

The substations will be located at Raton, Lynn, and Gallinas. Each will contain 3-1000 K.W.air cooled transformers (35 degree Rise on 50% overload for 2 hours) to step down the 33000 volts to trolley pressure 6600 volts. The feeders will extend in each direction and will consist of two 4/0 stranded hard drawn copper
wire. The oil switches are the G.E.K-10 type, hand operated.

OVERHEAD CONSTRUCTION

IN YARDS.

The standard type of bracket and cross-catenary construction is to be used in the yards. The wires are to be 24 ft. above top of rail and 5 feet apart. For single tracks a bracket type of construction is to be used and for multiple tracks a cross-catenary type, supported by heavy wooden poles located about 8 feet from center line of outer tracks. Wires are to be supported at intervals of 100 feet.

Where wires of opposite phases cross as turnouts, they are to be insulated from each other by section insulators made of wood.

Heavy steel bridges for anchorages for the trolley wires are to be located in the east end of the Trinidad yard and the west end of Raton yard.

Both rails are to be bonded for the double track over the mountain, with but one rail bonded on pass-
ing tracks and in yards. A 4/0 bond is recommended.

OVERHEAD CONSTRUCTION

IN THE TUNNEL.

In the tunnel the wires are to be 19 ft. above the top of the rail and 8 ft. apart. The latter spacing will enable train men to walk on the tops of cars. As the tunnel is lined with concrete and is absolutely dry, no especial care in regard to insulation need be taken. The Great Northern method of using a Detroit Clamp, attached to a stud and a turnbuckle with two swivels, then to a petticoat strain insulator and to the roof, is recommended. These supports are to be spaced 50 ft.
Figure 3.1: Figure text.

Note: This section likely contains a figure or diagram, but the text is not legible due to the quality of the image.
PART VI

THE SINGLE PHASE SYSTEM.
Part VI

The Single Phase System.

Considering the locomotive, the principal data are as follows: total weight 250,000 lbs., all on drivers; two trucks connected by a coupling, the front truck has two driving axles with a single phase motor connected by twin gears to each axle; gear ratio 4.89; diameter of driving wheels 69 inches; the back truck has three driving axles with similar motor equipment; the speed varies from 13.4 miles per hour with 1500 ton train on a 3.5% grade to 29 miles per hour with 360 ton train on a 1.12% grade. The motors are wound for 285 volts and are completely enclosed and air-cooled by forced draft at 1500 cubic feet per minute; trolley pressure 11000 volts; each locomotive has one transformer reducing the pressure from 11000 to 285 volts. Figure 6 shows the characteristic curves for the single phase motor.

POWER PLANT.

The power plant for the single phase system will have three, 11000 volt, 15 cycle, connected three phase
The text is not clearly visible due to the low quality of the image. It appears to be a page from a book or a document, but the content is not legible.
generators, especially built for this service. A Tirrill regulator will be placed across the railroad phase. The induction motors to be used in the power house are to be of the three phase type, leads from all three phases on the generators being brought out for this purpose. As the frequency is so low and the regulation rather poor, the lighting load will have to be carried by the exciters, or a special motor generator set.

The overhead construction is to be of standard single catenary suspension type, the poles to be situated as in the three phase system.

Substations are to be located at Raton and Morley. There is not need of another station for the allowable voltage drop can be greater than the three phase transmission line. Two 1500 K.W. single phase transformers are to be used for each generator stepping the voltage up to 33000 for transmission. Similar equipment is specified for each substation to reduce the voltage to 11000 for the trolley.

The main feature in which this system differs
from the three phase is that here, use can be made of both tunnels; the new one being retained for west bound service and the old one for east bound, as is done at present. The old tunnel has a clearance of 17 feet above the rail top, which will be sufficient for the single trolley. It will probably be necessary to line the tunnel with concrete, as there is considerable dampness present with the old timbering that is now in use. This will increase the number of tracks electrified to include the east bound main line between Lyon and Wootton.
PART VII

THE DIRECT CURRENT SYSTEM.
The Direct Current System.

The third system available is the use of 1500 volt direct current by means of a third rail. Characteristic curves of the motors intended for such service are shown in Figure 7. The company engineers allow 60000 pounds per driving axle for low speeds, but 50000 pounds is a conservative limit where but four driving axles are to support all the weight, making a 200000 lb. locomotive. Another type for consideration is similar to the Mallet compound, using two trucks with three driving axles in each truck, each pair of drivers having a 600 volt 250 Horse-power motor.

The power plant for this system is exactly the same as for the three phase; the two transmission lines are identical, the difference coming in the use of rotary converters at the three substations, changing the 33000 volt, three phase alternating current to 1500 volt, direct current for the third rail.

The principal disadvantages of this system will be
the danger and complication involved in switching in
the yards, and the fact that only the new tunnel can
be used, owing to the necessary clearance of the third
rail at 1500 volts pressure. It is intended that there'
shall be only a very small amount of switching done by
locomotives, but the danger involved in having the
third rail where there are so many employes is a
point not to be overlooked.
PART VIII

GAS-ENGINE POWER PLANT.
Part VIII

Gas Engine Power Plant.

Between Trinidad, CoL., and Dillon, N.Mex. there are a large number of coal mines. The larger part of the output of these mines is converted into coke at Dillon, Morley, and Starkville, and shipped to the Colorado Fuel and Iron Company at Pueblo, Col. All the gas generated in the process is wasted. In addition to this, the present method of coking does not give a sufficient number of B.T.U's to warrant the construction of a gas engine to make use of the gas. Usually, coke oven gas is very good for gas engine purposes and if the present method of coking can be changed to give the calorific value required by gas engine manufacturers, a cheap and very efficient source of power can be obtained. The first cost of the power plant will be higher than that of an equivalent steam plant, but this disadvantage will be more than offset by the saving in fuel and the decreased cost of production of power.
PART IX

TRAIN OPERATION.
Train Operation.

The present train schedule is shown in Figure (11), and from it can be seen the nature of the service over the mountain. Out of the four east-bound passenger trains and two freights, but one passenger train makes a regular stop, while two passengers have four flag stops each. With the west bound traffic but one train makes any stops between Raton and Trinidad. No. 1 has two regular and three flag stops.

Between Trinidad and Raton, trains run with the current of traffic, keeping to the right eastbound trains, Lynn to Starkville, westbound trains, Wootton to Raton, are governed by staff rules. East bound trains, Raton to Lynn, and Starkville to Trinidad, and west bound trains, Trinidad to Wootton are governed by block signals. A 36 lever interlocking plant is located at Lynn and a 40 lever machine is installed at Wootton. Trains are governed through the tunnels.
I saw

(2) "Eye/" as means of communication, the money we
can obtain goes to provide the rest of the 12 costs. If
students can't raise the rest of the money, they must
find it from other sources. Once we have
the money, we can start the planning and
construction of the project. It's important that we
make sure all the necessary steps are taken and
the project is completed on time.

Furthermore, it's important to ensure
safety and health standards. We must
consider all aspects of the project,
including the safety of everyone involved.

The final step is to ensure that the project
meets the expected standards and
criteria. This involves careful
planning, execution, and
monitoring. It's crucial that we
consider all factors to ensure
success.
by staff machines and likewise down grade, Lynn to Raton and Wootton to Starkville.

The regular run for freight and passenger engines is between La Junta, Col. and Raton, N.Mex., a distance of 104.5 miles, the two stations being division points. The company maintains extensive repair shops and round houses, at both places. The round house at Raton has 25 stalls and the one at Trinidad has accommodations for about 10 engines, with plenty of room for enlargement.

With the adoption of electric motive power it is intended that all traffic shall be handled exclusively by electric locomotives, and that the mountain be made a separate division or so-called electric zone. This would reduce the length of the first district by 23 miles and require an increase in the round house facilities at Trinidad to take care of the steam engines as well as the electric locomotives at that end of the run.

LOCOMOTIVES REQUIRED.

The passenger and freight locomotive units are to
be identical. Roughly estimating two units per train for passengers and three units per train for freights, by making three light runs of two units from Trinidad to Raton between 3 and 4 A.M. and one of 3 units from Raton to Trinidad between 1 and 2 P.M. and one of 1 unit from the summit to Trinidad between 12 and 1, mid-day, the actual service will be given by 8 units.

The light running will be 131 miles.

Average mileage per locomotive per day is:

Freight \( 3 \times 5 \times 23 - 7 = \) 338 miles.
Pass. \( 2 \times 8 \times 23 = \) 368 "
Light \( \) 131 "

Total miles per day \( \) 837 "
5% switching \( \) 41

878

Average for each loco. 110.

The service given by the electric locomotives under the single phase system is shown by the provisional schedule, Figure (13), while the schedule for three phase is
that the native and indigenous people's traditional lands and communities are being threatened by the construction of new roads and developments. It is important to ensure that these projects do not displace or harm the indigenous populations, and that their rights and needs are taken into account. It is also crucial to protect the natural environment and biodiversity of the area. We must work together to find solutions that balance development and preservation, and that respect the cultural and environmental values of the indigenous community.
shown in Figure (12). Typical load curves are shown respectively in Figures (10) and (9). The time required to handle the traffic is practically the same for three phase as for steam locomotives, considering passenger trains, while in the case of freight traffic the three phase system cuts the time down considerably. The single phase system is in most cases much more rapid than the steam locomotives, as there is quite a variation in the speed allowed, the passenger running time being reduced 2 to 10 minutes in both directions and the freight traffic 30 minutes eastbound and 40 minutes to 1 hour and 20 minutes westbound.
(2) Then the two variables

\[ \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} = 0 \]

(3) one of them

\[ \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} = f(x, y) \]

(4) the other does not

\[ \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} = \text{constant} \]

(5) is a linear equation, and

\[ \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} = \text{variable} \]

(6) is a nonlinear equation.

Therefore, it is important to understand how these equations relate to each other in the context of the problem at hand.
RATON MOUNTAIN
ELECTRIFICATION PROJECT
The Atchison, Topeka & Santa Fe Railway Co.
C C. BAILEY
E B. SHERWIN
ENGINEERS

Figure No. 1
## REQUIREMENTS OF MOTORS ON VARIOUS GRADES

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<th>Speed in mph</th>
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**RATON MOUNTAIN ELECTRIFICATION PROJECT**

The Atchison, Topeka & Santa Fe Railway Co.

C. C. Bailey, E. B. Sherwin

ENGINES

Figure No. 2
G.E.I-306 RAILWAY MOTOR
25 CYCLES
ALTERNATING CURRENT
CHARACTERISTIC CURVES
CALCULATED FROM TESTS
GEAR RATIO 81/1 : 1.26
DIAM. OF WHEELS 60"
500 VOLS. THREE PHASE
WESTINGHOUSE
363 H.P. RAILWAY MOTOR
750 VOLTS
Gears ratio 11:16-37 wheels
(Aproximate)
## New Mexico Division - First District

### Westward

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<th>First Class</th>
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<th>Water</th>
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### Capacity in Tons

- Fuel: 21
- Water: 385 W.T.
- No. of Stations: 59.4

### Stations

- Trinidad
- Jansen
- Jaramillo
- Gillingham
- Morley
- Wootten
- State Line
- Lynn
- Keath
- Maton

### Average Speed per Hour

- 179.8 mph
- (23.0)

### Present Schedule

With Steam Locomotives

### Ratón Mountain Electrification Project

The Atchison, Topeka & Santa Fe Railway Co.

C. C. Bailey

E. B. Sherwin

Figure No. 11
### NEW MEXICO DIVISION.—FIRST DISTRICT.

#### WESTWARD.

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**RATON MOUNTAIN ELECTRIFICATION PROJECT**

The Atchison, Topeka & Santa Fe Railway Co.

C. C. Bailey

E. B. Sherwin

Engineers

Figure No. 12
# New Mexico Division - First District

## Westward

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<tr>
<th>Time Class</th>
<th>Second Class</th>
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<th>Gain in Feet</th>
<th>Speed Limit</th>
<th>Freight Freight with Caution</th>
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## Eastward

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<th>Freight Freight with Caution</th>
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## Stations

- Transworld
- Jansen
- Starkville
- Gallina
- Stonewall
- Worthing
- State Line
- Lynn
- Neotha
- Mtn.

## Average Speed per Hour

- (R.30)
- (18.4)
- (13.5)
- (12.0)
- (10.5)
- (19.5)
- (15.9)
- (17.9)

## Provisional Schedule

With Single Phase Locomotives

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Raton Mountain Electrification Project

The Atchison, Topeka & Santa Fe Railway Co.

C. C. Bailey

E. B. Sherwin

Engineers

Figure No. 23
RATON MOUNTAIN ELECTRIFICATION PROJECT

The Atchison, Topeka & Santa Fe Railway Co.

C. C. BAILEY  E. B. SHERWIN
ENGINEERS

Figure No. 14
TIME-DISTANCE CURVES FROM TIME TABLE No. 34
(Effective Jan. 9, 1910)
ATCHISON, TOPEKA & SANTA FE RAILROAD.
TRINIDAD TO Raton

MILES FROM TRINIDAD.
RATON MOUNTAIN ELECTRIFICATION PROJECT
The Atchison, Topeka & Santa Fe Railway Co.
C. C. BAILEY E. B. SHERWIN
ENGINEERS

Figure No. 17
RATON MOUNTAIN ELECTRIFICATION PROJECT
The Atchison, Topeka & Santa Fe Railway Co.
C. C. Bailey
E. B. Sherwin
ENGINEERS
Figure No.: 17

THE GREAT NORTHERN 3-PHASE LOCOMOTIVE
PLAN OF TRINIDAD YARDS
RATON MOUNTAIN ELECTRIFICATION
ATONSON, TOLEMA & SANTA FE RAILWAY CO.

SCALE - 100 FEET = 1 INCH

DRAFTED BY C. C. BIBBY
CHECKED BY C. M. BARTON

North View, S.
PLAN OF LYNN YARDS.
RATON MOUNTAIN ELECTRIFICATION
A.T. & S.F.Ry.

TAKEN TO BE ELECTRIFIED

Scales: 100 Feet = 1 Inch
Traced by C.C. 
C. E. Builders

Engineers
RATON MOUNTAIN ELECTRIFICATION PROJECT
The Atchison, Topeka & Santa Fe Railway Co.
C.C. BAILEY E. B. SHERWIN
ENGINEERS
Figure No. 21
PLAN OF WOOTON YARDS

RATON MOUNTAIN ELECTRIFICATION
A.T. & S.F. R'y Co.

TRACK TO BE ELECTRIFIED

Scale: 1" = 100 Feet - Track

Drawn by C.G.B.

C.E. Bailey

E. B. Shorter