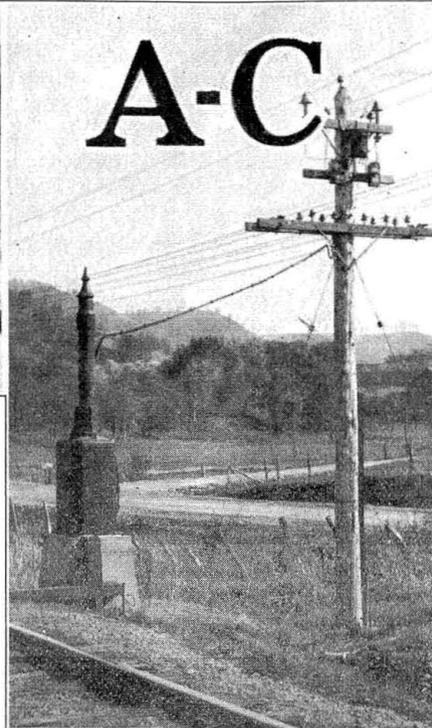
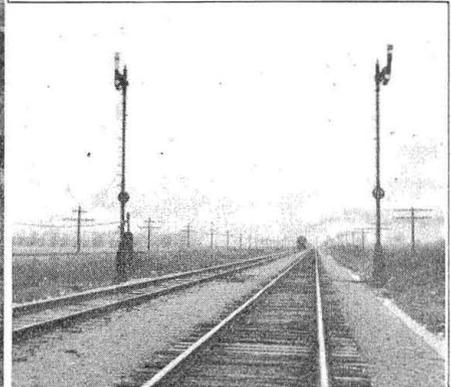


Comparative Maintenance Costs of



Signaling on the C.M.&St.P.



A summary of experience on two divisional installations in service for 14 years, including actual costs

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DURING the years 1913 and 1914, the Chicago, Milwaukee & St. Paul made several extensive alternating current automatic block signal installations affording protection for 450 miles of road on four, double-track divisions between Chicago and the Twin Cities and between Chicago and Savanna, Ill. These installations were followed a little later with direct current block signaling on 425 additional road miles of the double track line between Minneapolis, Minn., and Aberdeen, S. D., and between Savanna, Ill., and Omaha, Nebr. These with other existing installations between the points mentioned made a total of about 1,000 miles of double track signaling.

At the time these installations were first under consideration the alternating current and primary battery systems were in prevalent use as the a-c, floating battery system had not yet been developed and the storage battery system using either a d-c charging line or the portable type battery charged at a central point was not being used to any extent. The a-c system was immune to foreign d-c currents which had been troublesome at a number of the larger cities and the longer track circuits that were possible with this system could be used to good advantage with the two-mile spacing of signals that was contemplated. Although the initial installation cost would be higher than for the primary battery system the subsequent maintenance and operation costs, after making allowance for interest charges on the increased capital investment, should be considerably lower.

It was, therefore, decided to install a substantial mileage of the a-c system and to continue the existing and make additional d-c primary battery installations on the outlying divisions. It is the purpose of this article to analyze the results that have been obtained in actual operation from the two systems; present comparative figures showing the maintenance

and operating expenses; and to suggest ways in which such systems could be modernized, economies produced, and performance improved.

Value of Maintenance Cost Data

At periodic intervals, reports are published showing the fuel performance in the different classes of train service on the various roads engaged in interstate business. Figures are compiled from statistics furnished to the Interstate Commerce Commission showing fuel consumption per thousand gross ton-miles in freight service and per passenger car-mile in the passenger service. Necessarily a wide variation in conditions exist on the different roads that would affect the performance, such as use or non-use of superheaters and boosters, differences in efficiency of locomotives, kind of fuel furnished and heating qualities of same, nature of traffic and volume of business handled, number of main tracks, gradient and curvature of line, necessity for helper service, tonnage, speed, dead time, terminal and other delays, frequency of stops, efficiency of signal system, length of runs and many other factors. Still the figures produced are of considerable value in helping to keep the general officers informed as to what is being accomplished on other roads and to stimulate employees connected with train operation to greater effort in saving fuel and moving trains economically.

If similar comparative data of this kind showing the cost of signal and interlocking maintenance on roads operating in the same territory was available it would be valuable in making comparisons of the different kinds of signal systems and forms of maintenance organizations that are now in general use even though there necessarily would be wide variations in the conditions on the different roads, as in the case of the fuel performance reports.

A rough way of arriving at relative maintenance costs, and one which was used some time ago by a

number of roads centering in Chicago, would be to take the amounts chargeable to the different I. C. C. signal, and interlocking operating expense accounts and divide them by the number of operated units or functions maintained which would give the average cost per unit. Possibly some uniform maintenance cost record system using a formula for determining unit costs that would be equitable for purposes of comparison will be worked out in the future. Information of this kind that has been developed and published from time to time in *Railway Signaling* has been interesting and regular periodic reports based on statistics furnished to the I. C. C. would be conducive to economical methods and would be of benefit in stimulating and encouraging the maintenance and supervisory forces.

The spirit and tendency of the times is toward greater efficiency and improved methods in signal operation and maintenance. It is unfortunate that railroad accounting is not more precise, more elastic and capable of quickly reflecting good results and detecting leaks and sources of loss in inefficient signal systems. The present I. C. C. accounts are too broad and should be further sub-divided, so as to separate the expense for maintenance and operation of interlocking plants, automatic, manual and other block systems, station and switch protection signals. If unit costs could be developed as in other lines of

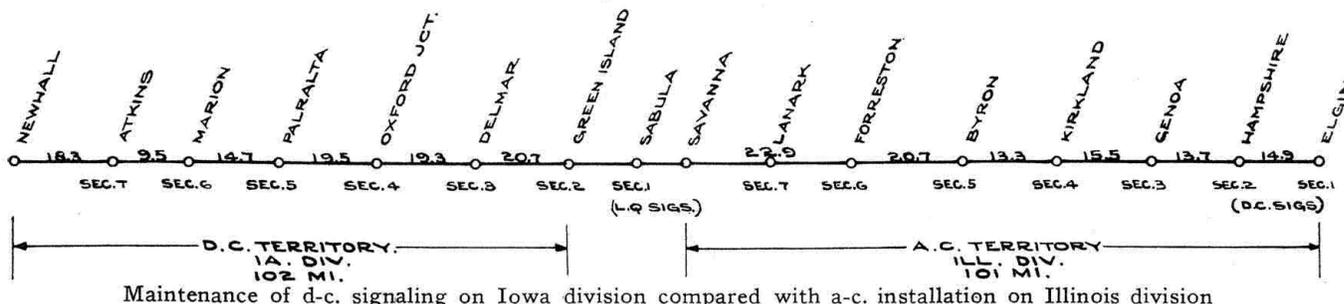
Switch & Signal Company's Style B, three-position, upper-quadrant, and semi-automatic interlocking signals are Type T-2. The d-c signals are equipped with 10-volt mechanisms, operated from 18-cell primary batteries and are controlled by polarized line circuits on which 800-ohm line relays fed from the main batteries are used. Switch indicators also operated from the main batteries are used.

A-C signals are equipped with 110-volt mechanisms and are operated from a 60-cycle, single-phase circuit. The slot magnets of these signals are line circuit controlled and serve as relays, the armatures being equipped with contacts for controlling the local motor operating circuits. Track circuits are of both the center and end-fed neutral type. Oil lighting is used on the d-c signals while the a-c signals are equipped with 2½-watt, 6 and 12-volt electric lamps, which are burned continuously.

The accompanying table and diagram shows the various maintainers sections and the number of signal and interlocking units on each. (The A. R. A. table of values is used with certain minor additions, and the maintenance costs are separated as between the different I. C. C. accounts for the year 1926).

A-C Power Consumption

Power for the a-c automatic signal system is transmitted over a 60-cycle, single-phase, 4,400-volt line.



Maintenance of d-c. signaling on Iowa division compared with a-c. installation on Illinois division

commercial and industrial accounting wide variations that now undoubtedly exist on different divisions of the same railroad and between different maintainer's territories on the same division would be discovered and conditions readjusted, the benefits from the use of modern equipment and appliances would be extended, and faulty methods and defects in design would be corrected.

Comparison of A-C and D-C Signal Systems

A comparison of the maintenance costs and operating efficiency of the a-c signal system on the Illinois division with the d-c system on the Iowa division will be presented. The a-c territory under consideration extends from Elgin to Savanna, 101 miles, and the d-c section from Green Island, Ia., to Newhall, 102 miles. On the former, there are 135 automatic and semi-automatic signals and four interlocking plants taken care of by six maintainers and one helper. On the latter, there are 132 signals and four interlocking plants now taken care of by six maintainers and one helper. Previously each d-c maintainer was furnished a helper, but the territories were rearranged and shortened up some months ago, at which time additional maintainers were put on and the helpers taken off.

The operating conditions are very similar on the two divisions, although the traffic on the Illinois division is the heavier. The blocks average two miles in length. Automatic signals are the Union

Normally two end-fed primary circuits of 30 and 71 miles in length are used and there are two additional substations for center feeding the line in case of emergency. Current is also taken from the signal line for electric lighting at the Savanna rail mill and stock yards, and at a coaling station, pumping plant, several street crossings, a few of the small depots, the interlocking towers, and for indicators in telegraph offices and crossing flagmen's houses.

The power consumption during 1926 for the a-c automatic signal system, after deducting current used by the other departments and that required for automatic street and highway crossing protection, electric locking at interlocking plants and for lighting train order signals amounted to about 180,940 k.w.h. or an average consumption of 15,078 k.w.h. per month. This current was purchased from commercial sources at an average cost of .03c per k.w.h. The average consumption per block per year amounted to 1,340 k.w.h. or \$40.20. These figures include track circuits, switch indicators, and automatic signal lighting.

Primary Battery Consumption

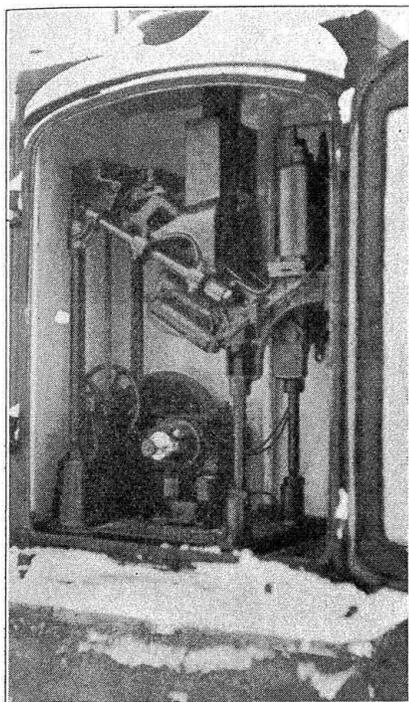
There were approximately 2,697 battery renewals used in the d-c territory during 1926 for automatic block signal operation and for switch indicators, and 3,461 renewals were used on the track circuits or a total of 6,158. The total bill for operating energy after adding the current used for three signals operated by storage battery amounted to \$7,389.00,

or an average of \$55.99 per block per year. Track circuit conditions in both the a-c and d-c territory are generally unfavorable and consequently the energy consumption for track circuit operation is high.

Two different battery saving circuits are used for reducing the hold clear current of the d-c Style B signals. With one scheme the main 18-cell operating battery is split so that only half of the cells are used for the slot circuits when the signal is in the clear position. In the other scheme the circuits are so arranged that the slots are connected in series when the signal is clear. These schemes reduce the hold-

system was due to there being more units of equipment required, it is believed that it would not be proper to include interest and depreciation.

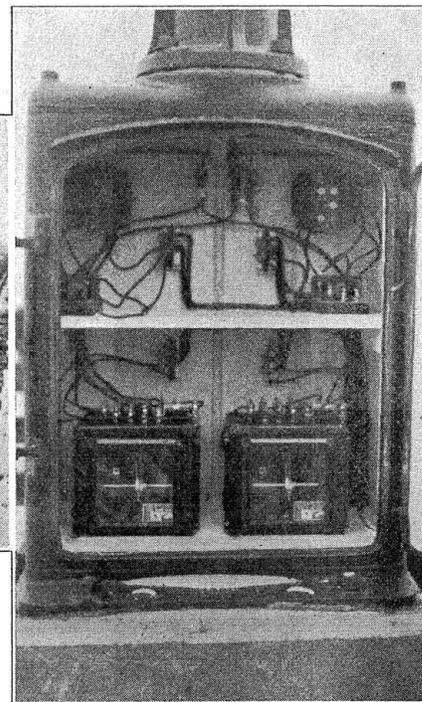
Motor car supplies and repairs have not been included for the reason that these cars are also used in the maintenance of interlocking plants and crossing signals and the cost for this item would in any event be about the same on the two divisions. The repair and renewal of insulated rail joints has also been omitted from the statement for the reason that this work is handled by the track department and no figures covering this expense are available. On account of the longer a-c track circuits, approximately



Union Style-B, three-position, signals are used on both the D-C. and A-C. installations discussed



Above—The bonding is the same type on both A-C. and D-C. sections, using bond wire and channel pins. Right—Interior of relay case at cut section on A-C. territory showing Model-15 vane relays



ing currents from 20 to 25 ma., thereby increasing the life of the battery by about 33 1/2 per cent.

Other Maintenance Costs

The figures in the tabulated statement do not include interest nor depreciation. The a-c installation was estimated to cost about \$775 more per mile than the d-c, or a total difference of \$77,500. This difference was due in part to the fact that there were more

500 fewer joints are required with the a-c than with the d-c system. Figuring the upkeep and frequent complete replacement of these joints, at an average cost of \$2.00 each per year, this item would amount to \$1,000 per year.

It is the intention to replace about 5 per cent of the poles of the high tension a-c line each year so that the line will never have to be entirely rebuilt at any one time. The expense for this work, most of which is handled by a separate line crew amounted to \$2,550 during 1926. It will be necessary, however, to furnish repair crews occasionally to renew the trunking and track wiring on the Iowa division since the helpers have been taken off, although no heavy repairs of this nature were made during the past year. On the whole the expense for repairs by crews will probably be somewhat less in the d-c territory.

Maintenance and Operation Costs Automatic Block Signals Only		
	135 A-C Signals	132 D-C Signals
Supervision	\$ 1,562.00	\$ 1,000.00
Labor Acct. 249 Straight Time.....	9,319.00	7,636.00
Labor Acct. 249 Overtime.....	574.00	355.00
Labor Acct. 404.....	417.00	2,907.00
Material Acct. 249.....	3,226.00	2,596.00
Material Acct. 404.....	30.00	7,511.00
Power Acct. 404.....	5,429.00	10.00
Total	\$20,557.00	\$22,015.00
Average per block per year.....	\$152.27	\$166.78

Economy Producing Improvements

The present 2.5-watt lamps, two of which are now used on each of the a-c signals, are to be replaced with standard 3.5-volt, 1-watt A.R.A. lamps as soon as adapters can be obtained. This will reduce the current consumption about 3,500 k.w.h per year, producing a saving of \$105. Primary battery, approach lighting could be used to good advantage with the d-c signals and some of this will probably be put in.

By installing push buttons so that switch indicators would be normally de-energized, the saving in

switches, crossing signals, automatic signals, and other complications on the Illinois than on the Iowa division. The higher cost of the a-c signal system was due principally, however, to the necessity for a separate pole line and power circuit. As the a-c power line is used for other purposes than signaling and considering that the additional cost of the a-c

energy on the two sections would amount to about \$560 per year. Owing to the possibility of the use of switch indicators being discontinued and the inconvenience of applying the buttons, this is to be deferred.

At several points there is considerable switching resulting in hand thrown switches being left reversed for long periods and as these switches shunt the track circuits, considerable current is wasted. By the installation of an insulated joint at these switches and a rearrangement of the track connections, the circuit can be opened and the relay side only shunted which will result in some saving.

The normal hold clear and lighting current for Style B a-c signals amounts to about 50 watts, and in addition to this there is, of course, the current required for motor operation in clearing the signal. The modern types of light signals require from 10 to 18 watts. Assuming that the present semaphore signals are clear an average of 22 hours per day, and adding the current for motor operation, the total consumption would amount to about 425 k.w.h per signal, per year as compared with a consumption of

upkeep of storage batteries, rectifiers and charging line and interest on the added investment there would still be a substantial saving.

The scheme of using portable storage batteries charged by the maintainer at his headquarters is to be tried out in this territory and two short a-c charging lines have been installed in connection with a remote controlled interlocking at Marion, Ia., and an automatic interlocking for railroad crossings at Delmar. These circuits will ultimately be extended and additional installations of the a-c floating battery system will be made in the future.

Signal Performance

There were no false clear signal failures reported in either the a-c or d-c systems during 1926. The ratio of interruptions (not including creditable and light out) was about three to one in favor of the d-c signals. There are several reasons for this. The a-c signals are more subject to trouble from lightning than the d-c signals. While the protection for the primary power circuit is very efficient and there are very few line transformers burned out or other

Table Showing Units of Automatic Block Signal Systems During 1926

Units	Description	Value	A-C Sections							D-C Sections						
			2	3	4	5	6	7	2	3	4	5	6	7		
3	Position Signals	6	126	96	108	108	126	234	144	114	132	108	90	156		
2	Position Signals	4	20	40	36	52	32	92	184	72	24	40	32	32		
	Fixed Signals	1	....	2	....	1	....	3	3	6	....	1	....	....
	Switch or Derail	4	....	24	....	48	....	60	44	....	....	12	....	....
	Switch Power Oper.	8	....	....	....	....	....	....	....	....	....	....	24	....	
	Derail Oper. with Switch	1	....	....	....	2	....	1	1	....	....	....	....	....
	Facing Point Lock	2	....	....	....	6	....	10	6	....	....	6	....	....
	Addn. Facing Point Lock	1	....	....	....	1	....	4	3	....	....	2	....	....
	Movable Point Frogs	8	....	....	....	....	....	....	....	....	....	8	....	....
	Single Slip Switch	4	....	....	....	....	....	....	....	....	....	8	....	....
	Detector Bars	2	....	4	....	16	....	....	....	....	....	14	....	....
	Track Circuits	2	72	70	76	70	86	136	154	164	160	122	108	138		
	Lock, Indicator, Annunc.	2	2	10	....	12	....	21	13	1	....	11	....	9
	Switch Instrument*	1	41	20	47	14	28	47	36	28	34	22	28	31		
	Switch Indicator*	1	24	13	35	10	19	36	21	22	30	17	3	24		
	Crossing Signals*	6	18	42	18	12	18	36	4	18	6	....	24	....	
	Substations*	8	8	....	....	....	8	8	....	....	....	....	....	....
	*Not included in A.R.A. Table															
	+Helper on This Section								+	+						
	TOTAL		311	321	320	352	317	688	613	425	386	371	309	390		

about 158 k.w.h. for the light signal, or a saving of 267 k.w.h. amounting to \$8 per signal per year, or a total of \$1,080 for the entire section. The saving would be further increased by using approach lighting for the light signals, as the figures given are on the basis of lamps burning continuously. The cost of lamp renewals for the light signals would probably not amount to a great deal more than the repairs and replacements required for the present signal mechanisms. There would be no increase of capital investment in changing to the light signals and as they have certain advantages consideration will undoubtedly be given to the use of this type of signal as replacement of the present equipment becomes necessary.

The battery renewals, oil and lamp supplies, and labor for the operation of the d-c signals during 1926 amounted to about \$10,400. The a-c floating system using storage batteries could readily be installed in the d-c territory, as power is available at several points and a separate pole line would not be required. Figuring the power requirements at 20 watts for each track circuit and 5 watts per signal, the consumption would average 76,912 k.w.h. per year, which at .05c would amount to \$3,845 per year. After adding the necessary labor, electric lamp renewals, expense for

cases of trouble there are a good many fuses blown and windings burnt in the secondary circuits although every effort has been made to protect these circuits by means of different kinds of arresters and a continuous ground wire is provided on the line.

The long a-c track circuits have also given considerable trouble. Due to unfavorable ballast conditions, poor drainage, and the extensive use of zinc treated ties it is necessary to maintain heavy feeds on some of the circuits which require attention and readjustment during different seasons of the year.

The a-c system is also subject to power interruptions and outages. These have been reduced to the minimum by carrying the feeder circuits direct to the commercial power company's bus bars where continuous switching service is available and by providing emergency sources, voltage regulators, and sectionalizing switches.

Still there are occasional cases of line or power house trouble which are unavoidable and for that reason and on account of it being less susceptible to interference from lightning and due to several other reasons, the d-c system using either the a-c floating storage battery scheme or primary battery is considered more reliable and satisfactory than the straight a-c system.