stations was increased until appliances for the transmission and distribution of electric power by direct currents has become so costly that extensive use of direct current electric motive power for heavy railway service is unprofitable. Furthermore, sub-stations for changing high tension alternating current to direct current require a high labor cost for their operation.

Large powers can be more cheaply transmitted and distributed with alternating currents than with direct currents and this early led to a general effort among engineers to substitute alternating currents for direct currents for train propulsion and these efforts were effectively seconded by the practical development of two types of alternating current motors which you all know as single phase and three phase motors. Single phase motors are operated on single phase alternating current which requires two conductors for its transmission. In the case of electric railways, the conductors for distributing current to trains, consist of one overhead trolley wire and the track. Three conductors are required for three phase alternating current so that three phase electric railways require two separately insulated trolley wires in combination with the track.

Complete systems for the transmission and distribution of electric power from the power house to moving trains are much more simple with alternating current than with direct, since where alternating current motors are used on the trains it is not necessary to change from alternating to direct current, and also alternating current is readily transformed on the trains from high potential used on the trolleys to low potential used on the motors. Furthermore, three phase motors can be worked with fairly high potential alternating current so that on many three phase roads the current from the trolley wires is not even transformed to low potential for the motors. To complete the comparison of the direct current and alternating current distribution systems used in railway work, it must be remembered that under the conditions met with in railroading the efficiency of power distribution by direct current systems is very inferior to the efficiency with alternating current systems. In existing direct current installations between 25 and 50% of the power generated is lost in transmission from the power house and distribution to the trains, and with direct current systems 35% is probably about the average loss, while with single phase alternating current transmission and distribution the average loss under similar service conditions would ordinarily be about one-third as great. Three phase transmission and distribution is not so efficient as single phase but would ordinarily be far more so than direct current.

There is some difference in the cost of the locomotives employed in the different electric railway systems and it is generally in favor of direct current and three phase locomotives as compared with single phase locomotives, but for ordinary steam railway train weights and distances and density of traffic this difference in the cost of locomotives is several times offset by the difference in the cost of the electric power transmission and distribution apparatus, especially in the case of direct current distribution, even though at the present time direct current locomotives usually cost between 25 and 35% less than single phase locomotives for the same service. This difference in cost will be somewhat reduced as experience in single phase manufacture increases. Generally the electric power taken from the trolley by single phase locomotives is from 0 to 6% more than the power taken from the trolley or third rail by direct current or three phase locomotives doing the same work, but there are some conditions under which single phase locomotives take less electric power than direct current or three phase locomotives because the control apparatus for single phase motors is more efficient than direct current and three phase motor control. But in any event the superior efficiency of power transmission and distribution by single phase currents several times more than offsets the slightly superior efficiency of direct current motors, especially where power is used in large units for moving heavy trains as on ordinary steam railroads.

Estimates recently prepared for the electrification of about 100 miles of single track railroad with about 25 miles of side tracks and with heavy grades to be climbed and very heavy and frequent trains to be handled, show the total cost of direct current transmission and distribution apparatus including sub-stations, $2,381,000.00 and for single phase alternating current with transformer stations $1,011,000.00. This was figured for 1,500 volts on a third rail for direct current and 11,000 volts on an overhead trolley for single phase current. The difference in cost of the two power distribution systems is $1,370,000.00. However, the single phase locomotives for the same railway would be more costly than direct locomotives by about $374,500, but this amount is only about one-quarter of the difference in the cost of the transmission and distribution appliances. Seven direct current sub-stations were required in the distribution system for the direct current equipment, and the attendance on these stations would cost between $15,000 and $20,000 a year, against which the attendance on the single phase transformer stations would be practically nothing.

All of this detail regarding electric power transmission and distribution for the various electric railway systems may seem unnecessary in view of the general knowledge of the subject, but it has a most important bearing on electric railways because it is in this work, that is, in the transmission and distribution of electric power that the greatest expense and difficulty has been encountered. Cheapening the cost and improving the efficiency of electric equipment for the operation of railways moving heavy trains over long distances is the most important result accomplished by alternating current railway apparatus. It is for moving heavy trains long distances that the superiority of alternating current apparatus is most pronounced and it is in this class of work, which includes the work of the majority of steam railways, that we must anticipate the greatest future advancement in electric railroading due to changed conditions.

As already stated, the last two or three years have not been favorable for heavy railway improvements, so the possibilities of alternating current machinery on railways have not been generally realized by practical application, although the reduction in construction cost, and the improvement and efficiency of electric railway appliances, especially for heavy motive power work fully justifies the expectation that in the future electric power will be applied to much work now being done with steam power, and to the hope that electric and steam railways will eventually be united in doing a common business, and that the advantages of a single railway and single organization for serving any given territory will be realized by extending the application of electric power to steam railways for all kinds of service both freight and passenger whenever electricity is profitable for any class of work.

The foregoing paper was read before the Central Railway Club in Buffalo, N.Y., recently.

The International Railway Fuel Association's second annual meeting was held May 23 to 26, at Chicago, Ill. A number of papers and subjects were read and discussed, those on the methods of supervision, instruction and encouragement in locomotive operation to secure the greatest efficiency in fuel consumption, being in charge of a committee, of which D. Meadows, Assistant Division Master Mechanic M.C.R., St. Thomas, Ont., is chairman.