of an electric circuit, and the increased expense to the contractor corresponds to the increased expense to the power company.

Now as to the second of our three points, i.e., what power factor can usually be obtained under ordinary conditions, and what will any variation amount to in dollars and cents?

The following table shows the efficiencies and power factors that may be expected from polyphase motors of first-class design and make; if not first-class, or if single phase, both efficiencies and power factors may be considerably lower:—

Constant Speed Polyphase Induction Motors.

Size	Efficiency %			Power Factor %				Starting Current
	Half Load	¾	Full	Starting	Half Load	¾	Full	in terms of Full Load Current
5 h.p.	79	82	82	60	76	84	88	2¼ to 2¾
10 "	81	83	83	60	80	87	90	"
20 "	83	84	84	60	81	88	91	"
50 "	85	86	86	60	81	88	91	"
75 "	86	87	87	65	83	89	92	"
100 "	88	89	89	65	85	91	92	"
Average	84	85	85		81	88	91	

In designing alternating current transmission systems the generally accepted allowances made for the power factor of the load are as follows:

Lighting load only	95%
Mixed load, chiefly lighting	90%
Mixed load, chiefly motors	85%
Motor load, ordinary	80%
Motor load, if very intermittent and irregular	75%

These naturally allow for the worst conditions ordinarily met with, but even worse conditions do sometimes exist where the load is irregular and the motors over large for the work or of poor design, average power factors as low as 70%, or even 65% being sometimes met with in mining work, steel rolling mills and similar intermittent loads.

A consideration of the above figures will show that where the amount charged for power is to vary in proportion to the "power factor," this power factor becomes a very important matter.

While an individual motor working at full load may have a power factor of 90% or a little more, a number of motors on more or less intermittent and irregular work do not usually give a resultant load factor of more than 80%, and may only give 70%, or even less.

Right here is where the manufacturer or power user not infrequently gets let in for what he does not fully expect or realize. Usually he has no clear idea of what his power factor is likely to be, and thinks he is getting a 10% margin anyway. The power company, on the other hand, know perfectly well that the power factor of a load consisting entirely or mainly of motors will not reach 90%, and that there will consequently be an extra payment required on the score of low power factor.

It is usual, as shown in the sample clauses given above, to name 90% as the normal power factor, but it would appear fairer in the case of contracts for motor loads to name a higher price and a power factor that there is some probability of being able to obtain in practice.

As to the difference in annual cost that may be caused by a power factor lower than the 90% specified in the agreement, suppose the case of a steel rolling mill using 500 h.p., paying $25 per h.p. year for power, and having an average power factor of 75%.

$$500 \text{ h.p. @ } \$25 = \$12{,}500. \quad \$12{,}500 \times \frac{90}{75} = \$15{,}000.$$

or an extra cost per annum of $2,500, i.e., 20%.

Now, as before explained, it is perfectly legitimate and proper that the power company should be paid extra for a load involving a power factor which is lower than that covered by their ordinary rates, but it ought to be clearly understood in such cases what the power factor and consequent extra charge to the customer is likely to be.

As to the third of the three points to be discussed, i.e., if the power factor is not as good as it should be, what can be done to improve it.

Low average power factor in connection with an ordinary polyphase motor load, assuming the motors to be of good make and design, is mainly due to frequent stopping and starting, and to working the motors at less than full load. It is greatly aggravated by using motors too large for their work, so that even when the tool is fully loaded the motor is under loaded.

If the motors are large for the work and the work is intermittent or variable, the average load factor may easily be that due to an average of half load. Referring to the table of power factors, it will be seen that the average power factor of motors from 5 to 100 h.p. is 91% at full load and 81% at half load, a difference of 11%. In practice, when some of the motors are being constantly stopped and started, or varying between small load and full load, the difference may be considerably greater.

Much may therefore be done to improve the power factor by having the motors properly proportioned to their work and, as far as possible, avoiding starting several motors at the same time or allowing them to run light. As good modern polyphase motors have an overload capacity of at least 50% for half an hour, and much greater momentary overload capacities, there is seldom any necessity to put in motors rated above the output of the tool, and in many cases of intermittent load the motors may safely be of less rated h.p. than that of the tool.

If the works give a low load factor that has to be paid for, it is therefore well worth while to take careful measurements of the power required by each tool and to re-arrange the motors and drives accordingly.

If these measures are not sufficient to secure a power factor reasonably close to the 90% specified, this result can always be secured, where there are a number of ordinary induction motors installed, by substituting for one of these a separately excited synchronous motor of slightly larger capacity than required for driving its load and adjusting the excitation until the desired power factor is secured. This will affect the power factor of the entire load or works. It is not usually desirable or economical to endeavor to bring the power factor of a motor load above 90%. This is a matter in which the advice of a competent electrical engineer would have to be taken as to the choice of a motor to suit the conditions in the particular factor under consideration, but it is not an expensive matter, and the saving in the first year would, in many cases, more than repay the entire cost.

In conclusion it may be asked why should all this complication come in at all. The reply is that it is an inherent and unavoidable factor in the alternating current system of power supply, that this system represents the latest and best practice in power distribution, and that there is no definite prospect at the present time of its being superseded, so that power factors must be accepted and reckoned with. They are at least as great a nuisance to the power companies as to the power users, and power companies would usually sooner have a good power factor than the additional payments which they have to charge when the power factor is low.