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RELATIVE VALUE OF PRIVATE AND PURCHASED ELECTRIC POWER FOR TEXTILE MILLS

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Members of the Society

The rivalry between the isolated plant and the central station has called forth many valuable and interesting papers, usually prepared by those most vitally interested either in the isolated plant or the central station. The not infrequent result is that the two debaters approach the same facts from opposite points of view and draw opposite conclusions from them.

2 The central station advocate demonstrates that one kilowatt in the central station will do the work of several kilowatts in scattered small plants on account of the diversity in load; that the central station, besides requiring much less capacity, is also much cheaper per kilowatt than a number of small stations; and that its operating efficiency is higher, all of which is intended to prove that the small plant cannot compete with the central station in cost of power.

3 On the other hand, some mill engineers, manufacturers and other defenders of isolated plants show that the economic advantage of concentrating power in a large station is largely offset by the cost of distribution and high overhead expenses. Also, every mill must have a steam plant for heating and to supply steam for manufacturing needs. Many specific cases and figures are cited to prove that when these factors are properly considered, manufactured power is cheaper than purchased power.

4 Both sides are presented with equal sincerity and plausibility, and the inquiring mill manager is left without solid foundation of fact upon which to base a decision. It is perhaps safe to state that

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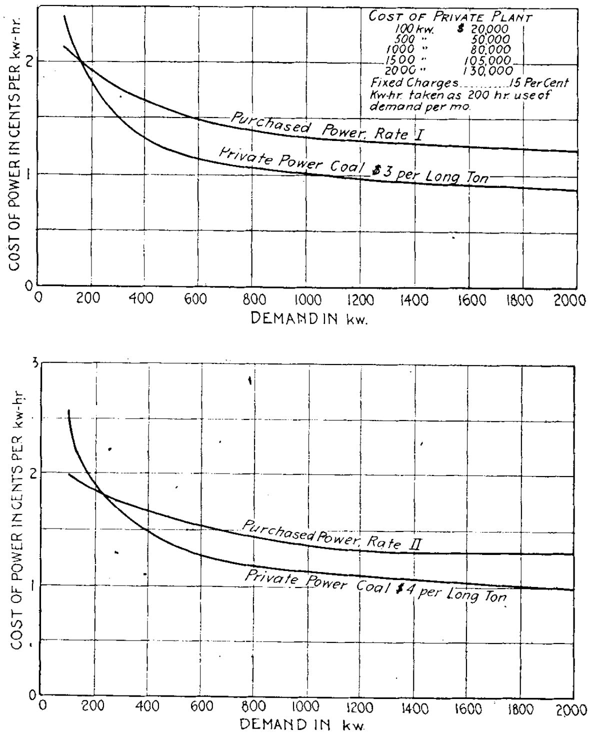
it is difficult to prove the general proposition entirely in favor of one side or the other. Each case is a problem to be decided on its own merits, and the correct solution can be assured only by a correct evaluation of all the various technical and financial factors involved. This paper purports to give an unbiased statement of the factors which affect the relative merits of private and purchased power for the textile industry.

RELATIVE COST OF PRIVATE AND PURCHASED POWER

5 Rather than enter upon a theoretical discussion to determine what purchased power ought to cost, it will give a truer understanding of the matter to consider only what it actually does cost. Figs. 1 and 2 give the cost of purchased power for ordinary textile mill conditions for any load up to 2000 kw. These curves are plotted from the published schedules of public service corporations, one in New England and one in the Middle West. While rates as good as these cannot be obtained in all localities, still these are actual and representative rates. For comparison, the cost of private power has been plotted, using in each case the price of coal obtainable in the district served. The cost is for power delivered at the point of distribution at 550 volts in all cases. No provision is made for use of steam other than for power, and where such use is considerable, the relative cost of private power may be much lower than given. This factor is important and will be treated separately. While the cost of purchased power given is actual, the cost of private power is theoretical, and is not intended to give more than an approximate and general comparison, but is based on known actual conditions.

6 In an actual private plant the power cost very often exceeds that given. The investment as stated is too low to cover any reserve or relay capacity, and therefore the reliability must be considered somewhat inferior to that of those central stations which were used for this comparison. Also, the investment will not take care of any disadvantageous conditions, such as expensive foundations or difficulty in obtaining condensing water; and no cost items are included for land or for coal in storage. All of these items are too indefinite to be included in a general cost estimate, but are always encountered to some extent. The operating costs assumed, while no better than should be obtained, are really somewhat lower than the average. Nothing has been included for supervision other than the actual power plant labor, but this supervision is usually a legitimate item of expense.

7 To show the effect of some of these items on the cost of power, an actual case will be cited. An industrial plant (not a textile mill) in Canada had purchased power for four years, and before the termination of the contract considered carefully the feasibility of generating its own power. The maximum demand was 1500 kw. The proposed plant was to contain two 1000-kw. turbines. Reliability was of great importance, and the concentration of all generating capacity in one unit was not considered satisfactory. Purchased power, being supplied underground by duplicate feeders from a substation fed by several steam and hydroelectric stations, had proven very reliable. There were few interruptions in four years' use, the longest being of three hours' duration. A large amount of high pressure steam was needed in manufacture and there was enough capacity in the fairly new boiler house so that only one additional 350-h.p. boiler would have been required for power generation. On the other hand, foundations were rather expensive, and the condenser supply would have cost



FIGS. 1 AND 2 RELATIVE COST OF POWER FOR LOADS UP TO 2000 KW.

about $12,000, or $8 per kw. Most of the equipment would be subject to import duty and war tax of 35 per cent total. It was found that the plant would cost $80 per kw. of installed capacity, or about $107 per kw. of demand, and power cost would be $0.0123 per kw-hr. with coal at $3.50. As power was being purchased for $0.0104 per kw-hr., it was decided not to generate.

8 If we eliminate duty and tax from this, plant cost would be $93 per kw. of demand, as against $70 assumed in our curves, and power with coal at $4.00 would cost $0.0119. This has to be compared with purchased power at $0.0130 per kw-hr. The saving of private over purchased power would then amount to $4000 per year or about 3 per cent of the cost of the plant.

9 The average yearly saving of the private plant, 500 kw. in size and over, from the above curves, is about 9 per cent of the cost of the plant. The highest value is 12 per cent for the 2000-kw. demand. Therefore, the private plant under ideal conditions can compete favorably with the power rates given, but the margin is not large and must cover several indeterminate cost items not included.

10 The central station rates quoted apply to any industrial plant. A textile mill load is properly considered somewhat more favorable than the average industrial load on account of its very steady demand for power, not only throughout the working period of each day, but also throughout the year and over a period of years. For this reason, special power rates can be obtained by textile mills in some localities, notably in the South, and to some extent in New England. Under these special rates, power usually costs about 1⅛ cents per kw-hr. for demands from 1000 to 2000 kw. and about 1 cent above 2000 kw. Such rates leave little financial inducement for the mill to build its own power plant.

EFFECT OF SIZE OF PLANT ON RELATIVE COST

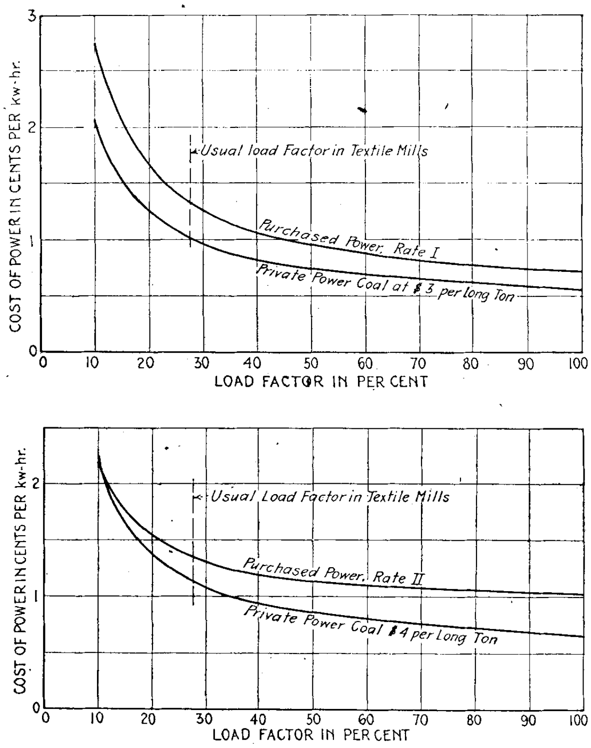
11 It will be seen that the curves for purchased and private power, Figs. 1 and 2, are very nearly parallel. This means that the size of the demand has little effect on the relative cost. The larger plants show a slightly larger proportional saving than the smaller ones, and the very small plants—under 200 kw.—cannot compete with the purchased power rates given.

EFFECT OF LOAD FACTOR ON RELATIVE COST

12 Figs. 3 and 4 have been prepared from the same data as Figs. 1 and 2, to show the effect of load factor on the cost of power in the

case of a 1000-kw. demand. It will be seen that the curves for private and purchased power costs follow the same general direction. It appears, then, that load factor also has little effect on the relative cost of power.

13 There is a striking similarity between the curves shown for private and purchased power, both when the variable is the size of the demand and when it is the load factor. The inference is that these power rates were devised to compete with isolated plants rather than from actual costs, or desired rates, of the central station power. This is entirely logical, being simply an application of the law of supply and demand. If it be true that the cost of central station power is determined by the cost of generating in isolated plants, then it will be unnecessary to discuss further the relative cost. It is improbable that the central station will sell cheaper than the average



FIGS. 3 AND 4 RELATIVE COST OF POWER FOR LOAD FACTORS 10 TO 100 PER CENT

isolated plant cost, and if its rates are very much higher, it cannot sell much power.

14 The above, of course, applies only in the case of new plants, where power can be purchased without any sacrifice of existing investment, and where steam is needed only for power. Also, it must be remembered that the individual plant may depart widely from the average.

EFFECT OF FIXED CHARGES ON RELATIVE COST

15 All that has preceded is a comparison of purchased and private power where the private plant is not yet built. But, in the case of a going plant, the purchase of power would save operating expense only, and would not wipe out fixed charges on investment already made. Fig. 5 shows the cost of private and purchased power, as in Fig. 1, but without including fixed charges. This, then, is a comparison between purchased power and a going plant under good working conditions. The difference in cost is so great that it appears improbable that central stations can cause existing plants to shut down unless in the case of important changes or additions, or the necessary renewal of considerable apparatus, or because of extremely poor operating economy.

EFFECT OF USE OF STEAM ON COST OF POWER

16 Every textile mill uses some steam for heating and manufacturing. This factor is of great importance, and should always be weighed accurately in considering purchased power.

17 In general, textile mills may be divided into two classes in this respect. The first contains those mills using only a relatively small amount of steam in manufacturing, and includes most silk and knitting mills and cotton and woolen mills not engaged in scouring, bleaching or finishing. Dye houses, finishing mills, print works, and textile mills which finish their product are included in the second class, and have a large but variable demand for steam in the process.

18 Slashing may be taken as typical of a small demand for manufacturing steam. Very often exhaust steam is used in this process. The pressure desired varies from 5 to 12 lb., which is a suitable pressure to bleed from an engine receiver or bleeder turbine. Only in rare cases would it be economical to run non-condensing apparatus to supply slashers on account of the high back pressure required and the relatively small demand. In the case of a bleeder turbine, the saving in live steam amounts to about 30 to 40 per cent of the steam

bled. This saving is reduced by additional fixed charges on extra cost of turbine and exhaust piping, for a relatively small service, and, in a large plant with a long run of pipe, may be negative. For a rough figure, applicable to average conditions, the gross saving will be about $200 per year for each 1000 lb. per hour bled, with coal at $4.00 per ton. This figured out about $0.0001 per kw-hr. in the case of a large cotton mill, or about 1/50 of 1 per cent of the cost of production. While there is no doubt that exhaust steam can be and is successfully used in slashers and similar machines, still live steam at reduced pressure has a tendency to reduce operating difficulties and increase production. When exhaust is used, there are apt to be occasional periods when results are not satisfactory, due to a temporary drop in pressure or excessive condensation or to adverse atmospheric conditions. If live steam is used, it is fed to the slasher in a dry or even superheated condition and this, together with the perfect flexibility in control of pressure, obviates most of these difficulties. Where a saving is relatively so minute, the wisdom of obtaining it at the cost of even a small operating handicap is fairly questionable.

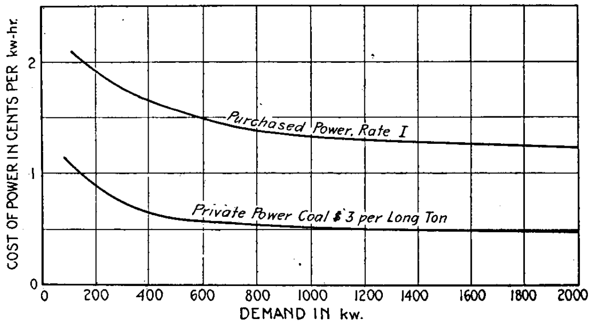


Fig. 5 Relative Cost of Power, without Including Fixed Charges

19 As regards steam for heating, there are two factors, often ignored, which militate against the use of exhaust in textile mills, especially in cotton and woolen mills. One of these factors is the large amount of heat liberated from the machinery during working hours and the second is the diversity in time between the use of power and the use of steam for heating.

20 Table 1 shows the amount of heat required to warm each room in a large cotton mill in zero weather and also in 35-deg. weather, which may be taken as an average during the heating season, and also

the heat liberated from machinery in each room. It is assumed that all the power used in cotton machinery is dissipated as heat.

21 The mill chosen for this example is in northern Massachusetts and has a very large window area and a saw-tooth weave shed. The heating requirements are certainly much more severe than the average. Yet, even in this case, the machinery provides more than half of all the heat required in zero weather, and for much of the heating season no extra heat whatever is needed during working hours, except in the storehouse and basements. In a mill of this kind, the heat is usually turned on at 4 or 5 A. M. to get the mill warmed up before starting time, and is turned off sometimes as early as 9 A. M., and sometimes not at all, depending on the weather. In a weaving mill in northern Massachusetts, where the power used per cubic foot of space is much less than in a balanced mill, the heating system was actually in operation only 25 hours per week average during working hours during the heating season, or about 1/4 of the entire yearly operating time of the mill. Of course, all heat used outside of working hours—nights and week ends—must be live steam. If exhaust is to be used the rest of the time, as a general rule, it is proper to count on a demand

TABLE 1 COTTON MILL HEATING

Building	Contents	H.P.	Heat Radiated from Building, (Calculated) B.t.u. per Hour		Heat Supplied by Power, B.t.u. per Hour*	Heat to be Supplied by Steam in Mill Hours. Zero Weather
			0 Deg.	35 Deg.		
Weave shed......	Looms	1628	8,550,000	4,275,000	4,140,000	4,410,000
Weave shed basement..........	Storage	....	980,000	490,000	....	980,000
Mill, basement...	Storage	....	1,550,000	775,000	....	1,550,000
Mill, 1st floor....	Picking Carding Roving	660	1,900,000	950,000	1,680,000	220,000
Mill 2nd floor....	Picking Carding Roving	647	1,900,000	950,000	1,650,000	250,000
Mill 3rd floor.....	Filling Spinning	691	1,900,000	950,000	1,760,000	140,000
Mill 4th floor.....	Warp Spinning Spooling Warping	1378	2,900,000	1,450,000	3,500,000	....
Storehouse.......	Storage	....	1,800,000	900,000	....	1,800,000
Total............			21,480,000	10,740,000	12,730,000*	9,350,000

*Assuming all power transformed to heat.

only about one-half of the maximum, since the machinery provides the remainder, and this quantity probably will not be used more than 700 hours per year. The only way to meet a demand for exhaust of this character with economy is by bleeding from an engine or turbine. In a cotton mill cited above, bleeding steam for heating would effect a saving amounting to $0.00005 per kw-hr., a little less than in the case of slashers. In knitting and silk mills, the saving will be relatively greater but in warmer climates much less.

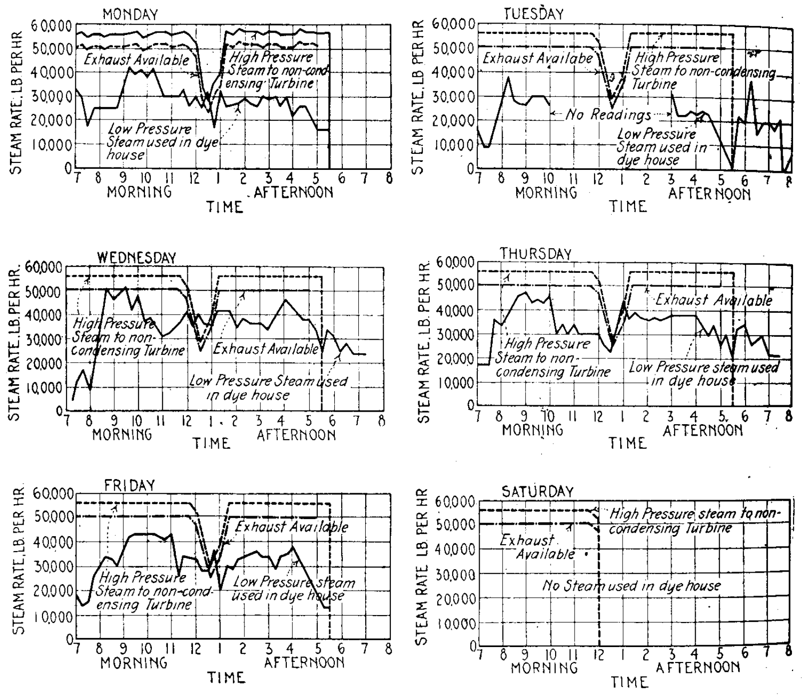
22 It appears, then, that the coal saving effected by using exhaust steam for heating and slashing is very small—smaller, in fact, than the unavoidable errors in estimating the total cost of power. There is, however, some further saving due to economy in investment. It is apparent from the foregoing that if steam for these demands is bled, the extra boiler capacity necessary to meet them is reduced approximately one-half. Also, it is cheaper to get this extra boiler capacity as part of a larger plant built for power generation than to provide it in a separate plant by itself as would be necessary if power were purchased. This matter was investigated in the case of a fairly large cotton mill. It was found that the complete power plant would cost $65.00 per kw., but if the cost of an independent steam plant for heating and slashing were deducted, the cost would have come out about $58 per kw., this latter being the figure used in comparison with purchased power.

23 While it is entirely unsafe to apply average figures to individual cases, it is desirable to form a clear conception of the relative importance of the various factors, and we may say that, in general, the entire fuel and investment saving due to the bleeding of steam for heating and slashing will range from $0.0005 to $0.0010 per kw-hr. A saving of this size cannot have a very important influence on a decision for or against purchased power. Nevertheless, the matter should always be considered.

24 A very different result is obtained in those mills having a large demand for steam for boiling water and drying cloth. In such cases, a large proportion of the prime mover exhaust may be utilized. In some cases, all power is produced in non-condensing apparatus, and all exhaust utilized, and manufactured power becomes then so cheap that no central station can compete. It is seldom, however, that a textile plant can utilize all of its exhaust all the time. This is because of diversity in time and amount between the use of steam and

use of power. The importance of this can best be shown by citing an actual case.

25 Figs. 6 to 11 give curves showing the demand for steam in a worsted mill dye house for one week's operations. These curves are plotted from actual flow meter readings in exhaust main, which were taken every fifteen minutes. In this case the exhaust was provided by a non-condensing turbine. For comparison, the steam fed to the turbine was measured on one day and plotted. For the other days,



FIGS. 6 TO 11 ONE WEEK'S STEAM DEMAND IN WORSTED MILL DYE HOUSE

the steam to turbine was averaged from the kilowatt-hour readings. The curves show how the demand for steam varies from hour to hour and day to day, and also lags behind the power load. The demand for steam in a dye house is light early in the forenoon, but persists for two hours or more after the mill is shut down. The dye house does not run at all on Saturday mornings, which is a custom not uncommon. The result is a very large surplus of exhaust which must be wasted, and in spite of this, considerable live steam make-up is required, as shown by the curves. It is obvious that such conditions result in great inefficiency. Actually less coal would have been burned if a standard condensing turbine had been installed and live steam exclusively used in the dye house. The expected result of this installation was that power would be furnished as a by-product at a purely nominal cost. The actual result was that the power cost was considerably higher than in a plant having no use for steam in the process. This case is especially worthy of study because it is a typical balanced worsted mill of fairly large size doing its own dyeing; there were no special or unusual features involved; the installation was actually made, and the results as given were determined by careful tests.

26 The reasons and calculations leading to the installation of this non-condensing turbine are not known to the authors, but there is no reason to doubt that the installation promised to be very profitable. The total steam used in the dye house was considerably in excess of that to be supplied by the turbine, and it was apparently safe to assume that all exhaust would be utilized. With the turbine, there would be no trouble from oil, and the exhaust pressure was taken at 10 lb. to give good service.

27 The factors which made this attempt a failure were

1 The diversity in time and variable demand for steam
2 The deterioration of turbine which gradually increased its steam consumption
3 It was found by experience that a few of the processes in which the use of exhaust steam was tried suffered either in quality or speed of production. For this reason the actual demand for exhaust probably was not as great as that estimated, although this difference was not very large.

It is evident that all of these factors may be encountered in any similar installation and must be allowed for in the estimates.

28 It is interesting to inquire if it would have been possible to make this installation efficient and still use exhaust steam. The demand is so variable that it is hardly probable that a non-condensing turbine could be satisfactory. It would be impossible to avoid surplus exhaust at times and live steam make up at others. A bleeder turbine appears to meet the situation better, but is not without its difficulties. The required output of the turbine is about 1200 kw. The maximum amount that can be bled at that load from a 1200-kw. machine is about 12,000 lb. per hr., but the greatest demand for exhaust steam in the dye house is 50,000 lb. per hr. If the turbine has different

characteristics, involving practically a 2400-kw. steam end, all the exhaust needed could be bled, but the turbine would run at half load economy. It would be better to use an intermediate size and bleed what steam is possible, supplying the dye house peaks with live steam make-up.

29 Table 2 gives the total steam used per week during the operating time of the mill for turbine and dye house for the operation as actually observed; as it would have been if guaranteed steam rate of turbine had been maintained; if a condensing turbine had been installed; and with a 1600-kw. bleeder turbine.

TABLE 2 STEAM USED FOR POWER AND MANUFACTURING

	High Pressure Steam to Turbine Lb. per Wk.*	High Pressure Steam Make-up in Dye Ho. Lb. per Wk.	Total High Pressure Steam Lb. per Wk.
Present operation, 1200 kw. non-cond. turbine	3,110,000	....	3,110,000
Same with guaranteed steam rate of turbine maintained	2,466,000	47,000	2,513,000
With 1200 kw. cond. turbine	1,120,000	1,580,000	2,700,000
With 1600 kw. bleeder turbine	2,294,000	273,000	2,567,000

*Includes turbine auxiliaries. Condenser driven by motor.

30 These figures show that the condensing turbine is cheaper to operate than the scheme installed, and is not much more expensive than any of the schemes. It is safe to state that the condensing turbine would have been the lowest of all in first cost and the most satisfactory from the standpoint of dye house operation.

31 In this particular case, then, a large demand for steam in the process has little influence on the relative cost of private and purchased power. If power generation in a condensing turbine with live steam used in the process is as economical as the use of exhaust steam, the comparison previously made between purchased and private power where there is no demand for steam is approximately true in this case. There would be some investment saving in providing steam capacity for manufacturing as a part of a larger plant.

32 A careful study of this case is recommended to anyone desiring to supply a large and variable demand for exhaust from a prime mover having a constant power output.

33 Another interesting case is that of a large print works where the demand for hot water and steam was very large in proportion to the power. In this case, condensing turbines were installed and for

the greater part of the time all the condensing water is utilized in the process. This is a closed heat cycle and therefore as economical as to use exhaust, but has the advantage of economical turbine operation irrespective of the demand for waste heat. This example has little practical value in a general discussion because it is so seldom that the demand for hot water is sufficient to absorb all the condenser discharge.

34 It is hardly possible to give general figures of any value to show the effect of these large steam demands on the cost of power. In many cases, the factor is of less importance than has commonly been supposed. Nevertheless, it seems entirely improbable that purchased power can compete successfully in very many cases of this kind. The success of the private installation, however, depends very largely on the skill and thoroughness of the preliminary study of conditions, with special attention paid to the diversity factor and variations in demand.

WATER POWER

35 The proportion of textile mill power supplied by water is constantly becoming smaller. This does not necessarily mean that existing water powers are being abandoned, but very few new mills are now built at water power sites. Where a mill has water privileges of any considerable value, purchased power can hardly displace water power. Even in such plants, however, power is sometimes purchased to relay the water wheels, or for demands in excess of the water power capacity.

RELATIVE RELIABILITY OF PRIVATE AND PURCHASED POWER

36 In textile work, the reliability of power is usually of greater importance than its cost. This is because the cost of power is a very small item in the cost of manufacturing, whereas reliability affects the earning power of the whole mill at its foundation. It is rather difficult to collect satisfying statistics on power reliability by each method of supply. One cotton mill buying power reports interruptions totaling 45 min. in five years. In this case the transmission line was less than half a mile long. Reports from several central stations give total interruptions on the individual lines ranging from 12 min. to 4 hr. per year.

37 A hydroelectric company in the South, which sells to many mills, reports that interruptions of service to textile mills from all causes have averaged less than 2/5 of 1 per cent for the last nine

years. Such records are doubtless better than the average. A large number of managers of representative mills in the South purchasing hydroelectric power state that they consider this more reliable than private steam power.

38 In most cases, purchased power is transmitted electrically by pole lines. Where these lines are short, well constructed and in duplicate, the reliability is very good. On the other hand, a single line many miles in length and fed at a long distance from the consumer is subject to interruptions and regulation troubles. This has been repeatedly proved. It is fair to state, however, that great improvements have been made in the reliability of transmission.

39 The reliability of generation is usually better in a large central station than in an isolated plant, and this is especially true when a number of stations are tied to the same system.

40 An interruption of purchased power is more annoying than a shut down in a private plant, because the management does not immediately know the cause or how long the power will be off. For this reason, purchased power is sometimes condemned as unreliable when the total interrupted time per year is small. An isolated plant with considerable relay capacity must, as a rule, be considered more reliable than purchased power. If the plant is small, however, the investment charges on this relay capacity add materially to the power cost, and few isolated plants carry spare apparatus.

41 In considering the purchase of power, reliability should be treated as a very important factor, and carefully investigated. If there is any serious question on this point, the private plant would be the wise decision in most cases.

GENERAL DESIRABILITY OF PURCHASED POWER

42 Assuming that reliable power can be purchased at a cost approximating that of private power, it is not apparent that there are any attending disadvantages. There are, rather, many points in its favor.

43 The saving of investment for a power plant often is considered important, especially when that money can be invested to better advantage in the manufacturing plant. An example will make this point clear.

44 A cotton mill of 100,000 spindles represents an investment of about $2,000,000, and will earn from $2.00 to $4.00 per spindle per year. If it earns $3.00 per spindle, or $300,000 per year, this is

15 per cent on the investment. Power needed would be about 4000 kw. The power plant might cost about $300,000, and power $0.0085 per kw-hr. Purchased power would ordinarily cost about $0.01 per kw-hr. Under these conditions, private power would save in money $14,400 per year. Total earnings are then $314,400 on an investment of $2,300,000, or 13.7 per cent. This is a poorer showing than with purchased power, in spite of considerable saving in power cost.

45 Specialization in manufacture of product only is worth something. A considerable part of the effort of the engineering department of a mill is devoted to keeping the power plant running efficiently. Where cost of power is only 2 or 3 per cent of the cost of manufacturing, the services of the engineering department would probably be of greater value to the mill if devoted solely to keeping the producing machines running efficiently.

46 In the case of a new development subject to future growth, the central station offers a perfectly flexible source of power.

47 When a radical change in existing conditions is introduced it is inevitable that there will be some wrong applications. Whenever the purchase of power proves undesirable, or too expensive, it is easy to give it up. The fact that so very few plants have gone back to private power after once purchasing is pretty good evidence that purchased power really is desirable.

POWER CONTRACTS

48 Where schedules for purchased power are published and intended to cover all conditions of use in industrial plants, they are necessarily complicated, and some are unnecessarily complicated. Cases have been known where a manager has refused to buy power for the sole reason that to do so required him to sign a contract he could not understand. Conditions governing the use of power in textile mills are such that power companies often offer them special rates at a flat rate per horsepower-year or per kilowatt-hour, with a guaranteed minimum. Such a contract would be received more favorably by the average mill man than one based on demand and monthly use of demand with various discounts, even though the final results were identical.

49 Contracts for purchased power should be carefully studied in all details before signing, as there are many technical features which are sometimes made to react to the disadvantage of the consumer. In general, power companies show a tendency to get the consumer's

point of view and to make their contracts more simple and more liberal.

AMOUNT OF POWER PURCHASED IN THE TEXTILE INDUSTRY

50 The figures in Table 3 from the 1910 United States Census show the total and relative amounts of power purchased in the various textile industries, and also the total figures for all industries, for the year 1909.

TABLE 3 POWER PURCHASED FOR TEXTILE MILLS
From U. S. Census Report for 1910

Industry	Total h.p. Used	Total h.p. Purchased	Per Cent Purchased
Cotton goods, including small cotton wares	1,296,517	108,512	8.4
Hosiery and knit goods	103,709	13,286	12.8
Silk and silk goods including throwsters	97,947	10,354	10.6
Woolen, worsted and felt goods and wool hats	362,209	13,783	3.8
Total	1,860,382	145,935	7.8 Average
All industries	18,675,376	1,749,031	9.4

51 It will be seen that the hosiery and silk industries purchase relatively more power than the average textile mill, and this might be attributed to the comparatively small demand for power in these mills. The small use in woolen mills is probably due to the generally large use of steam in this industry. Since these figures were compiled, the capacity of central stations has more than doubled. It will be interesting to observe from later census reports if the use of purchased power in the textile industry has increased proportionately.

DISCUSSION

Fred N. Bushnell (written). One notable feature of the paper stands out prominently, and that is the absence of any attempt to show the relative value between mechanical and electrical drives, which indicates that material progress has been made in the trend of thought and state of mind with which engineers, closely in touch with textile problems, now view the application of the electric motor to this class of work.

One of the greatest difficulties encountered in any attempt to show comparative costs, and one that nearly always places purchased power at a disadvantage, is the incomplete knowledge of all the facts entering into the cost of private plant manufacture, and the necessity of assuming economies which may or may not be realized in practice.

The authors frankly point out that in an actual private plant the power cost very often exceeds that given; that the investment as stated is too low to cover any reserve or relay capacity; that the investment will not take care of any disadvantageous conditions, such as expensive foundations or difficulty in obtaining condensing water, also that no cost items are included for land or for coal in storage, all of which must be taken into consideration in studying the curves.

On the other hand a price named for purchased power is a definite, unequivocal and positively known quantity about which there is and can be no question, and this fact should also be borne in mind in any attempt at comparison.

We have now reached a period of highly developed specialized knowledge in matters immediately affecting our principal activities, and a tendency has very naturally developed to eliminate all problems of minor importance, not directly connected with our principal article of manufacture.

The shoe manufacturer is seldom a tanner of the leather or a weaver of the cloth he uses, the toolmaker does not mine or produce the steel he needs, nor the miller the wheat he grinds, and the day is approaching when the textile mill will find no more reason for manufacturing its own power than it will for the study of the intricacies and uncertainties of agriculture in order to supply its raw cotton.

The authors are to be congratulated upon the evident fairness with which they discuss the subject.

JOHN A. STEVENS (written). Although this paper purports to be an unbiased comparison of isolated and central station electric power, it conveys the impression that the latter is preferable.

As the authors state, each case is a problem to be decided on its own merits, and the correct solution can be assured only by a correct evaluation of all the various technical and financial factors involved. Each is, in other words, strictly a technical and financial problem which requires careful study indicating economies brought about by a certain investment, of which the savings affected by the increased economies represent a certain earning. Sometimes the balance is in favor of isolated power and sometimes of central station power.

A proper comparison of the two systems of power must include the following items, which are very often slighted, misrepresented or omitted: To the price of purchased power must be added the fixed costs of all transforming equipment, including housing, transformation losses and cost of attendance; and if an existing plant is superseded, its fixed charges must also be included at full value.

The cost of isolated power should include every item associated with the power plant, that is light, heat and power and all thereto connected, due reduction being made for use of steam for heating and manufacturing purposes. The fixed charges on the investment, 12 per cent of its initial value being sufficient, should include heavy foundation waterways and coal handling apparatus along with the other plant equipment.

It should be brought out here that careful design of the private industrial plant is of prime importance if central station power is to be competed with. In numerous cases of industrial plants having been pronounced failures, more attention was paid toward making the plant attractive than economical.

The question of reliability has often been brought up. A prime mover is as reliable in an isolated plant as it is in a central station, and if the isolated plant possesses more than one unit, reliability is not a factor. The prime movers in a well run plant are the most reliable parts of the plant. The weakest part of a central station system is its distribution, and from this source the prospective purchaser of power will experience the most inconvenience.

The authors' examples of power costs clearly represent special cases in which, with study from different aspects, the favor might be swung back to isolated service. In the case of the dye house, for example, numerous factors are not considered. Low pressure steam requires piping much larger than does high pressure. A combination of a condensing and exhaust steam turbine will greatly help out the diversity of steam and power demand, and at the same time eliminate some of the losses in bleeder turbines.

One of the most important features not mentioned is an absolutely controllable supply of low pressure or stage exhaust steam at some predetermined pressure. That is to say, whether or not a low pressure system can be installed in a plant depends on the amount of low pressure steam to be used, the amount of power to be used and the cost of installation of the low pressure system, including the additional rates imposed on the steam plant by the low pressure system. A suggested method of approach is a complete analysis of light, heat and power in its every minute detail, including the land occupied by the equipment as against the purchased power, where practically no space would be absorbed by an isolated plant. Further, it is to be specifically recommended that in every case power be purchased in the form of energy, that is, on the basis of kilowatt-hours used.

R. J. S. Pigott. The authors conclude that for small power plants there is very little chance for the isolated plant to make good. In the small plant, the duties for the men operating it are small and cannot occupy their whole time. A low grade man is very frequently employed, and only works part of his time in the power plant, causing the reliability to suffer.

For a fair comparison between the isolated plant and the central station another point which must be known is whether or not proper reserve is carried in the former. The authors state that in few industrial plants is a proper reserve carried, and this has been my own experience. Enough engine or turbine power is put in to run the plant when all the machines are operating, but no spare units are carried. Such a plant is not in a position to be compared fairly with purchased power, because it is not as reliable as a central power station. If the central station carries a 20 or 25 per cent reserve, the isolated plant ought to carry that much, if the reliability is to be the same.

In the cotton industry there is stated to be very little chance for the use of exhaust steam, which seems extraordinary. It is possible that the temperature demand is such that live steam direct to the machines must be used, but it would appear well for mill owners to remodel their processes so as to use low pressure steam wherever possible in place of high pressure steam.

In the works where I am now engaged, nearly half the steam put through the turbines is employed either in the processes or for heating. The power plant has a capacity of 13,000 kw. In this particular plant, low pressure steam, 15 lb. gage, drawn from bleeder turbines, is supplied. Whatever steam is not required for processes or heating in the main plant is passed on to the condensers, with the consequent benefit of comparatively high economy. The steam consumption would be very nearly doubled if we were to use high pressure steam drawn from the boilers, and condense all the steam sent through the turbines.

We have remodelled a number of our processes in order to make use of low pressure steam; the effect upon kw-hr. cost is very pronounced, as the power from bleeder turbines is produced at 75 to 90 per cent thermal efficiency. The case is analogous to that of steam auxiliaries exhausting into a feed water heater.

From an inspection of most of the industrial plants which make use of steam in processes, it would appear that not sufficient attention is given to the ability of the bleeder turbine to furnish steam at a very low cost; and for those who are interested in the question of private or purchased power for industrial works, it would be very advisable to give serious consideration to the remodelling of their processes and heating conditions, to make as much use as possible of bleeder turbines. The growth of sales of the bleeder type of turbine in the last two or three years indicates that the advantages of low pressure steam for industrial purposes are now beginning to be realized.

F. J. BRYANT. This problem of exhaust steam came up when we enlarged the power plant of our cotton finishing works, where a large portion of the steam generated is used for drying. We considered the bleeder turbine very carefully and decided that it did not meet our needs.

We have at present a number of 5 to 10 h. p. "Twin-angle steam engines," which drive drying machines and serve a double purpose of speed regulator and reducing valve. The part of the machine which these engines control consists of a set of drying cylinders over which the cloth passes after it has been partly dried over steam coils. The steam in these cylinders, and the amount of steam in them, depends upon the weight of the goods which they are drying and the amount of moisture in them. As the engines discharge their exhaust into a header which supplies the cylinders of several machines, very good economy is secured. If the pressure falls too low more is admitted by a reducing valve, and if it gets too high a safety valve lets it off. A turn of the throttle valve speeds up the work and lets more steam into the system. All drips and condensations are trapped to a hot well and then returned back to the boiler.

As we now have a surplus of low pressure steam, we are considering the substitution of an alternate current motor and variable speed transmission for one of the engines, and thus cut down the exhaust.

Arthur L. Williston. In this paper the author has assumed that there are three objections to the isolated plant: first, the lack of opportunity to use the exhaust steam; second, lack of margin in the plant; and third, lack of reliability. These are serious shortcomings for any plant to have, but I think it is important that we should not associate them with any particular type of plant. I am sure that we all know central stations that have at least one of these defects; and in some instances all three may be present. It is also true that isolated plants may be so designed and operated as to have none of them. The point that seems to me to need special emphasis is the fact that the same high quality of skill and judgment that is usually bestowed upon the design of the central station is, as a rule, equally important for the isolated plant.

For example, there is not the slightest reason why the isolated plant should not have as large a margin as is needed. It surely is not necessary to go to a central station in order to get a wide margin. It may be obtained in any plant.

Likewise, it is not necessary to go to the central station to get reliability. In the isolated plants with which I have had experience for the past twenty-three years (which happen to have been plants in educational institutions) we have had as great a degree of reliability as we could reasonably expect to have from central stations. In the last plant, since it was started five years ago, we have had practically perfect reliability. A central station does not always give an absolute 100 per cent of reliability.

During the previous discussion it has been pointed out that in an isolated plant processes may often be remodeled so as to use exhaust steam in place of high pressure steam, and that when this is done there is distinct economy in favor of the isolated plant as compared with the price of power furnished from a central station. In educational plants there is little opportunity to use steam for special processes, but they do use large quantities of exhaust steam for heating.

Our shop and laboratory buildings at Wentworth Institute contain equipment not very different from that found in a great many manufacturing plants, and are, for illustration, in almost every way quite typical of the small plants in a great many industries. It is our experience that the exhaust steam used for heating alone consumes all, or very nearly all, the exhaust of our power plant, for six months in the year. There is during the other six months a certain amount of waste, but for one-half of the year the only cost of light and power is a small depreciation charge for the engine dynamo and the renewal of the lamps. A very distinct economy will usually be found in favor of the isolated plant wherever conditions approaching these can be found.

In a great many instances wrong conclusions have, I think, been drawn when making comparisons between isolated plants and central stations because persons have relied on data drawn from improperly designed isolated plants rather than from the results that would be obtained from well-designed isolated plants with thoroughly up-to-date equipment and with all opportunities for economy taken advantage of.

CHARLES H. BIGELOW said that in connection with the problem of isolated plants, he had had some experience in using exhaust steam at a textile plant where there was a large demand for low pressure steam. A 500-kw. non-condensing turbine was first installed, and the exhaust steam used from that at about 8 lb. pressure. The demands for the exhaust steam were very variable, as well as the loads on the turbine; part of the time steam would be escaping through the exhaust pipe into the atmosphere, and at others the required amount would have to be made up through a reducing valve from the high pressure line.

They have since put in a 1000-kw. bleeding turbine, the load having increased, and installed a recording steam flow meter on the supply pipe to the factory. The load on the turbine was the factory load with a four or five-car traction load superimposed, the latter varying from nothing to 300 kw. almost instantaneously.

It was found from the charts that the demands for power as well as low pressure steam were very variable, but the bleeding turbine holds the pressure steady, at 10 lb., varying one pound each side of it as shown on the recording chart. The broad line is as straight as it can be drawn, showing that the regulating mechanism for holding the pressure steady in the first stage of the turbine is doing its part of the work, although it takes about two pounds variation in pressure to make it work.

Incidentally there is an indicating steam flow meter on the supply pipe to the turbine, and this swings from perhaps 15,000 to 30,000 lb. per hour, back and forth, depending on the load and the demands for steam. The bleeding turbine seems in this case to be solving the problem of supplying a variable amount of low pressure steam, without loss to the atmosphere as was formerly the case. The balance of the steam passes to the surface condenser through which the circulating water flows by gravity from a pond owned by the company and under winter conditions operates at over 29 in. vacuum. The condensate flows over a V-notch which incidentally gives a check on the two other measurements of input and the balance of output.

In regard to processes for using low pressure steam, there is a good deal of tradition in the pressure required for manufacturing processes. What is generally really required is temperature, and he wondered whether anything has ever been done to superheat low pressure steam when used in manufacturing processes.

Walter N. Polakov. In this very interesting paper, the figures and curves are based on averages of actual performance, but the question is whether what has been done in the past is of any value to judge as to what should have been done.

It has been pointed out in the discussion that in mill plants the power plant employes are usually of not very high grade. The owners try to hire the cheapest kind of help they can get, and in my experience I have found that on an average between 30 and 40 per cent of the cost of power generation can usually be saved merely by a proper method of operation, as it is not very uncommon to see firemen in a mill wasting tons of coal each day.

Comparing cost curves of private and purchased power, and assuming that large public utility power plants are also not as efficient as they might be, the rate for purchased power will probably be reduced in the future by 20 per cent on the average; whereas, private power cost will also probably go down some 50 per cent. In other words, the difference between the cost of private and purchased power, as shown in Figs. 1 and 2, will be even more pronounced in the future than the authors pointed out from actual experience of the past.

Dan Adams. This paper was intended to be a discussion of the relative value of private and purchased power, as applied to the textile industry only, and the conclusions are not applicable to any other industry, such as machine shops. Mr. Pigott has shown the great savings which can be made from bleeder turbines in this latter industry, which is very different from the textile industry.

The chief difference in regard to the heating has been brought out very clearly in Mr. Duncan's paper. Simply there is no demand, or I will say only a small demand, for heating, coincident with the demand for power; and that is due to the large amount of heat liberated from textile mill machinery, which I think is peculiar to that industry.

Prof. Williston mentioned the saving by heating from exhaust in an institution, but the same thing holds true there. Of course there is a very large saving from the use of exhaust steam for heating in any plant where the demands for power or light and heating coincide, such as office buildings or educational institutions.

It was pointed out by Mr. Bryant and Mr. Bigelow that there are difficulties in controlling the use of exhaust steam in a textile plant, in order to obtain economical results. Usually these problems can be solved, and it is a fact that most textile mills of this character use exhaust steam very generally. It was not intended in this paper to discount the savings which can be made from using exhaust steam when conditions are suitable, but it was intended to point out some of the difficulties; and we feel that some expensive mistakes have been made when it has been attempted to apply exhaust steam to these processes, without an absolutely clear and detailed analysis of all the conditions.

Mr. Bigelow also cites the case of the bleeder turbine, which is running very successfully, and there are many such cases. The bleeding of steam through a turbine is undoubtedly very economical when conditions are suitable.

In the case cited in the paper we could not seem to produce very economical results by using a bleeder turbine, and this was owing to the relation between the demand for exhaust steam and the demand for power. It was found that at times the demand for exhaust steam was more than could be bled from a standard bleeder turbine of the right capacity. For instance, the power output was 1200 kw. and the total demand for steam at times reached 50,000 lb. per hour. All that can be bled from a 1200-kw. turbine is about 12,000 lb. per hour, which was inadequate.

Now, if you use a large bleeder turbine for the sake of being able to supply exhaust steam, you will necessarily reduce the economy of the turbine, when it is not bleeding, because you are then running it at part load economy.

In this particular case, there was no use for exhaust steam whatever for something over 10 per cent of the time. The dye house was shut down on Saturday morning, which is quite common in worsted mill dye houses. The combination of all these factors resulted in a very small saving in this case, but it does not necessarily follow that it would be so in all cases.

Mr. Williston mentioned the fact that isolated plants can produce power as reliably as central stations, and this point was also brought out in the paper, that isolated power is absolutely reliable if the isolated plant has sufficient relay capacity. It should be remembered, however, that if small plants are provided with relay capacity, the investment charges run up very fast and the cost of power then approximates or exceeds the cost of purchased power.

Mr. Polakov brings out the point that the private power cost given in the paper is subject to material reductions. While it is true, as he states, that industrial power plants can on the average be improved very materially, this is less true of the textile industry than of most industries. In other words, I believe that the textile mills have devoted more attention to the economical generation of power, and this is perhaps due to the fact that they are very large consumers of power.