IS ENGINEERING ON THE DECLINE?

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There is probably no profession which is so little understood by the general public as that of engineering. The question of sound and advanced engineering is one that greatly affects a community whose prosperity depends mainly on the efforts of practical science. Ability and integrity are indispensable qualifications in those who are entrusted with the expenditure of large sums of money in works of public utility. A great work that involves immense original outlay and large yearly expense of maintenance, may be made one per cent. more profitable by the best engineer than by the second best; and out of this one per cent. a liberal amount may well be paid the former for his superior abilities. Therefore, all that the best men have done in the past should be known and compared with our present practice, to prevent us from beginning behind the age and help us to make further progress.

The object of my paper to-night is to call the attention of the public at large to the system in which the construction of our railroads and other incorporated companies are now projected and carried out. It is evident that the first and principal object in most of these works is, that they shall be made productive to those through whose instrumentality the legislative powers are obtained, with but a remote regard to the interests of those who may ultimately become the proprietors of shares, or to the benefit or convenience of the public.

IS ENGINEERING ON THE DECLINE?

The writer is not willing to assert or admit that such is the case, and many grand triumphs of modern engineers might be cited to prove that there has been no decadence in engineering skill.

But the writer does assert that many important public and private enterprises which might be made commercially profitable to investors in them, and of great advantage to the public and to all parties concerned, are handicapped at their outset by reason of the

fact that the engineering departments are entrusted to unskilled and incompetent hands; and the truth of such assertion finds conspicuous illustration in several enterprises of a public and private character that are being conducted, and are in progress in our midst.

This may appear to be a somewhat broad assertion, but it is, nevertheless, one amply justified by the facts which are open to the consideration of all who choose to seek for them.

Let any fair and impartial first-class engineer examine and report upon our public works and those of incorporated companies, and in a majority of cases the verdict in a condensed form will be that they are extravagantly arranged, located and operated.

MECHANICAL ENGINEERING.

What is wanted is economical power; the fact is that but very few manufacturers who use steam power, and especially those controlled by incorporated companies, are aware to what extent the economy of a mill or works, run by any given engine and boilers, is affected by circumstances under which it is located and erected to produce the best results as to wear and tear as well as fuel consumption.

Very many persons—and persons, too, who ought to know better—imagine that a steam engine which is good for one situation is good for all, whereas a greater error than such an assumption can scarcely be imagined. It is true that there are certain makes of engines which may be relied upon to give moderately good results in almost any situation; but not when the *best* results are desired—and the best results always *should* be desired in any manufacturing establishment.

The selection of an engine for the performance of any given work, due regard being of course paid to the nature of the work to be performed, also, how far it is advisable to divide the total power required amongst a number of engines for the purpose of saving shafting and for general convenience, is of itself a most important one, and demands independent consideration.

The next point to be decided is, whether a condensing or a non-condensing engine is to be employed. Except under conditions in which the exhaust steam from a non-condensing engine can be turned to good account for heating purposes, it may safely be

asserted that in all instances where a sufficient supply of condensing water is available at a moderate cost, the extra economy of a well-constructed compound condensing engine will fully warrant the additional cost involved, especially if the power exceeds 100 horse-power.

Boilers are an important factor in the production of economical power. The importance of the use of *high pressure steam* cannot be too constantly urged upon engineers and manufacturers, and that the employment of low pressure steam to run engines is extremely wasteful; yet clear as this is or should be to all intelligent engineers and steam users, they do not recognize its truth. To illustrate! When using steam at forty pounds above atmospheric pressure in a non-condensing engine, one-third of the whole of the power is consumed in overcoming the atmospheric pressure; while if steam were used at 100 pounds to the square inch, one and one-tenth of the power would be so wasted, due to the pressure of the atmosphere (14.7 pounds) being a greater percentage if a low pressure is used than in the case of a high pressure.

It has been proven, both in practice and theory, that the greater the difference between the steam pressure on the piston and the resisting force of the condenser or atmosphere, the higher will be the mechanical efficacy of the steam, hence the necessity of employing high pressure steam in order to obtain the fullest effect of expansion.

It is a well-known fact that the secret of economy in running steam engines lies in the adoption of the highest practicable pressure of steam, thorough jacketing, the earliest cut-off at which the engine will run, and as perfect condensation of steam as possible after the steam has done that work.

No engine can run economically at a high grade of expansion except it be fitted with a condenser; for the greatest economy of expansive working lies in expanding below the pressure of the atmosphere.

Having decided on your motive-power, a location for your works should be in order; in Philadelphia a large river front is presented, and, therefore, in this city there should be no difficulty on this point.

The most important items of expense in any large establishment run by steam power are the *fuel* and *water*, especially in cities where the latter is charged by the cubic foot.

There is an old saying, "That the best is not good enough." It may be assumed as a fact that a steam engine employed for driving a mill or works of any kind cannot be too good, the saving effected by the economical running of the best engines in the great majority of cases enormously outweighing the interest on their extra first cost. So few persons appear to have a clear idea of the vast importance of economy of fuel in large works, that I cannot better illustrate than by showing the saving that can be made in large establishments by the use of the most modern economical make of engines.

COMPARISONS.

(1) We will take the Brush Electric Light Company, Johnson Street, west of Twentieth Street and south of Market Street, this being a modern plant with ample capital behind it.

As regards the location of these works for supplying arc lights, for all intents and purposes they could just as well have been located on the Schuylkill River, where more ground could have been obtained for the amount paid for the present location, besides the advantages of *free water* and cheaper fuel, as the latter could have been set down in their works by boat or rail, thus saving extra handling and cartage.

MOTIVE-POWER.

The present plant consists of ten non-condensing automatic cut-off engines, to wit:

Eight Porter-Allen engines of forty horse-power each, of the following dimensions:

Diameter of cylinder in inches,	8
Length of stroke in inches,	16
Revolutions per minute,	290

Two Corliss engines, connected at right angles to the main-shaft, of the following dimensions:

Diameter of cylinder in inches,	23
Length of stroke in feet,	4
Revolutions per minute,	75
Boiler pressure in pounds per square inch above atmosphere, .	105

These two engines are capable of developing each 250 horse-power with ease, and in case of an emergency 800 horse-power could be realized.

The eight Porter-Allen engines are only run between 5 and 10 P.M., when the demand for light is the greatest.

The average horse-power developed during the twenty-four hours will be about 400, and as the Corliss engines are kept continuously running, we will base their cost for fuel on these data.

The following indicator diagram (*Fig. 1*) from a non condensing Corliss engine, is a fair sample of the distribution of steam in the cylinder.

FIG. 1.

Diameter of cylinder in inches,	22
Length of stroke in inches,	48
Revolutions per minute,	78
Boiler pressure in pounds per square inch,	60
Coal per hour per horse-power in pounds,	3

BOILERS.

The boilers are sixteen in number, consisting of four Babcock & Wilcox Company make, and rated by them at 300 horse-power, based on 11 square feet of heating surface per horse-power and 108 square feet of grate surface.

There are also six horizontal flue boilers, 40 inches in diameter and 17 feet long, containing nineteen flues of 4 inches diameter and 115 square feet of grate surface.

There are also six horizontal flue boilers, 42 inches in diameter and 20 feet long, containing nineteen flues of 4 inches diameter and also 115 square feet of grate surface. The steam pressure carried averages about 105 pounds above the atmosphere and according to calorimetric test averages about three per cent. of water.

FEED WATER.

The charge for feed water for boilers in Philadelphia is based on the maximum horse-power developed, and the rate is \$3 per horse-power per annum; therefore, the water rent for this works will be as follows:

$$400 \times 3 = 1,200 \text{ dollars per year.}$$

COAL CONSUMED.

The consumption of coal can be very nearly arrived at by the type of engine. Corliss non-condensing engines as generally run will average a consumption of coal of *three and one-half pounds per hour per horse-power*.

Taking into consideration the high steam pressure used in this establishment, and the fact that the engines are run to their full capacity only a portion of the twenty-four hours, and that the small engines are not as economical as large ones, and that the eight Porter-Allen engines are used during the demand for the most light, the above-stated consumption per hour per horse-power will be a fair basis to estimate the coal burnt in these works during the twenty-four hours run.

The coal used must be hauled in carts, say one-half mile, and taking into consideration the good quality of coal employed, \$4 will be a fair price per ton delivered. The cost of fuel will be as follows:

Horse-power,	400	$\times$	3.5	=	1,400 pounds per hour.
	1,400	$\times$	24	=	33,600 pounds per day.
	33,600	$\times$	365	=	12,264,000 pounds per year.
	12,264,000	$\div$	2,000	=	6,132 tons per year.
	6,132	$\times$	4	=	24,528 dollars per year.

PROPER LOCATION OF WORKS.

Now, had these works been placed on the river front, as they should have been at the time of their erection, more ground could have been had for the outlay made for their present location, with the advantages of *free boiler feed water*, and coal at a less price per ton delivered direct in the works by rail or boat.

And another, a very important advantage, to wit: in the place of using non-condensing engines, compound condensing engines could have been employed with but a slight advance above the present cost of plant.

A good condenser will increase the economical power of an engine from *twenty to forty per cent.*, or for the same power effect a corresponding saving in the amount of steam used and fuel consumed.

Therefore, in plain terms, if *three pounds* of coal be necessary per hour per horse-power, with a well proportioned and erected non-condensing engine, then *two and one-half pounds* of coal will develop the same power with a first-class condensing engine, as will be shown by the following indicator diagram from a Corliss condensing engine.

FIG. 2.

Diameter of cylinder in inches,	20
Length of stroke in inches,	48
Revolutions per minute,	61
Piston speed in feet,	488
Pressure of steam per square inch in pounds,	89
Vacuum per gauge in inches,	27
Indicated horse-power,	220
Coal per indicated horse-power per hour in pounds,	2'295

ADVANTAGES OF THE COMPOUND STEAM ENGINE.

(1) It furnishes a better working engine, mechanically, for utilizing the benefits of the expansion of high-pressure steam.

(2) Independently of mechanical consideration, it is more economical to use steam expansively in a compound engine than in any form of the ordinary engine.

COMPOUND CONDENSING ENGINES.

The following diagram was taken from a compound condensing Corliss engine. The mill was originally driven by a pair of horizontal slide valve engines, with cut-off of the following dimensions:

Diameter of cylinders in inches,	24
Length of stroke in feet,	4

In order to get good results, it was arranged to erect boilers adapted to carry at least 160 pounds steam per square inch, and to replace one of the twenty-four inch slide valve cylinders by a Corliss cylinder fourteen inches in diameter and four feet stroke, the new cylinder was steam jacketed, and the cranks being at right angles a receiver was placed between the engines.

This alteration has been found to be a very great improvement, and the following diagrams (*Figs. 3 and 4*) taken from the altered engines, speak for themselves.

FIG. 3.

FIG. 4.

It will be seen that running sixty revolutions per minute, and with 165 pounds of steam in the boiler, the non-condensing Corliss cylinder indicates 125.2 horse-power, with a mean pressure of fifty-six pounds, and the condensing cylinder 131.1 horse-power, with a mean pressure of 19.75 pounds, or, collectively, 256.3 horse-power. About one pound of difference of pressure is shown between the two cylinders.

This engine has been frequently run up to 350 horse-power, when all the mill machinery has been on at once. The con-

sumption of water so stated has been measured, and found to be about thirteen pounds per hour, per indicated horse-power, equivalent to a consumption of 1.3 pounds of coal per hour per indicated horse-power, with a boiler evaporation of ten pounds of water per pound of coal. The steam was very dry and the indicator cards account for but 10.33 pounds of water per hour per horse-power developed.

Had the Brush Electric Light Company, therefore, been located at the river and fitted up to run compound condensing in the place of non-condensing engines, the cost per annum would have been :

(1) Water from river free.

(2) Coal at a reduced price owing to there being no cartage, which, including the extra handling, would amount to, say, fifty cents per ton, making the cost delivered \$3.50 in place of \$4 per ton.

Assuming that the steam pressure would be the same as now carried, namely, 105 pounds per square inch above the atmosphere, under any circumstances, the power could be produced for *two pounds of coal per hour per horse-power*.

Then

$$\begin{aligned}
 400 \times 2 &= 800 \text{ pounds per hour.} \\
 800 \times 24 &= 19,200 \text{ pounds per day.} \\
 19,200 \times 365 &= 7,008,000 \text{ pounds per year.} \\
 7,008,000 \div 2,000 &= 3,504 \text{ tons per year.} \\
 3,504 \times 3.50 &= 12,262 \text{ dollars per year.}
 \end{aligned}$$

Thus the saving, if located on river front fitted with compound condensing engines as compared with the present location with non-condensing engines, would be as follows:

Cost at present location for water,	\$1,200 00
Cost at present location for coal,	24,528 00
Total cost,	\$25,728 00
Cost if located at river,	12,262 00
Saving per year,	\$13,466 00

In fact it would pay this company at the present time to excavate on their present premises to the depth of fifteen or twenty feet, place new compound condensing engines in said excavations and make a connection to the river Schuylkill by a line of pipe for their condensation water. This could easily be done as the curb

line on Johnson Street is but thirty three feet above low-water mark. If they excavated twenty feet the water would only have to be lifted about, say, eighteen feet at low water.

I make this statement based on the increasing business of the company. I also understand it is their intention to add 500 additional horse-power in the near future.

The next case of any magnitude is the plant of the Philadelphia Traction Company, located on Market Street below Twentieth Street, as to which, so far as the work to be performed is concerned, location would be immaterial.

MOTIVE POWER.

The steam engines are of the same make and about the same horse-power, namely, two non-condensing Corliss engines, with the exception that they are separate in place of being coupled to one shaft, and the power is transmitted by gearing in place of a belt, as in the case of the Brush Electric Light Company; in all other respects they are substantially the same, and are rated also at 250 horse-power each. The dimensions are as follows:

Diameter of cylinder in inches,	24
Length of stroke in inches,	48
Revolutions per minute,	65
Boiler pressure above atmosphere in pounds,	90

BOILERS.

The boilers are six in number and are commonly called "Two-story" boilers. The lower horizontal shell is 14 feet in length and 4 feet in diameter, the upper horizontal shell is 15½ feet long and 4 feet in diameter, and the two are connected by four necks, 14 inches diameter, about 12 inches long; the lower shell contains forty flues, four inches in diameter.

This style of boiler is not as economical as those of the Brush Electric Light Company, and will consume more coal per hour per horse-power.

The engines in this works, considering the type of boiler and the slow piston speed, will require about four pounds of coal per hour per horse-power.

The average run per day will be about twenty-two hours, and develop in round numbers, say, 400 horse-power. The cost of coal delivered per ton will average about \$3.75.

Then we have cost of fuel and water, as follows :

Water rent at \$3 per horse-power per annum,

$$400 \times 3 = 1,200 \text{ dollars.}$$

Coal at the rate of \$3.75 per ton.

$$\begin{aligned} 400 \times 4 &= 1,600 \text{ pounds per hour.} \\ 1,600 \times 22 &= 35,200 \text{ pounds per day.} \\ 35,200 \times 365 &= 12,848,000 \text{ pounds per year.} \\ 12,848,000 \div 2,000 &= 6,424 \text{ tons per year.} \\ 6,424 \times 3.75 &= 24,090 \text{ dollars per year.} \end{aligned}$$

Had this plant been located at the river front, and been fitted with compound condensing engines, the cost per year would have been as follows :

$$\begin{aligned} 400 \times 2 &= 800 \text{ pounds per hour.} \\ 800 \times 22 &= 17,600 \text{ pounds per day.} \\ 17,600 \times 365 &= 6,424,000 \text{ pounds per year.} \\ 6,424,000 \div 2,000 &= 3,212 \text{ tons per year.} \\ 3,212 \times 3.75 &= 12,045 \text{ dollars per year.} \end{aligned}$$

Water rent free from river.

Then the saving would have been, if located at the river front, and by the use of compound condensing engines, as follows :

Cost per annum at present location :

Water rent per year,	\$1,200 00
Coal per year,	24,090 00
	<hr/>
	\$25,290 00
Cost at river front,	12,045 00
	<hr/>
A saving per year of	\$13,245 00

I will next refer to the proposed Edison electric lighting plant on Sansom Street above Ninth, Philadelphia, as described in *Philadelphia Press* on March 4, 1888, as follows :

"The building will have a front of seventy feet on Sansom Street, and will extend 100 feet back toward Walnut Street. Its cornice will tower 114 feet above the pavement, overshadowing all the lofty roofs in the neighborhood.

"Twenty engines, of 250 horse-power each, will be placed on the first floor. Forty dynamos, with a capacity of 1,500 lights each, or a total capacity of 60,000 lights, will rest on the second floor. On the floor above the dynamos will be the workshops, where wire and conduits are prepared for laying in the streets and

making connections with houses. Clear up on the fourth floor huge boilers, with a capacity of 5,000 horse-power, will be placed. In the fifth floor will be stored over 1,000 tons of coal at a time. The sixth floor, where light and air will abound, as its windows will look twenty feet above the roof of the Continental Hotel, will contain the general offices of the company and space for its clerical force.

FOUNDATIONS ENORMOUS AND SOLID.

"This sounds like an amazing way of erecting a plant, with huge boilers and tons of coal in the air, but this reversal of the ordinary arrangement of machinery is due to the necessity of concentrating enormous power within a limited space. It also necessitates construction of the most massive kind. In the first place, the whole lot will be covered with a deep bed of concrete, four feet in vertical thickness. Resting on this bed will be the foundation walls, five feet thick. The twenty engines on the first floor, which will each hum at the rate of 200 revolutions a minute, are of the high-speed Armington & Sims type. They will each be firmly planted on a concrete monolith fifteen feet square. These twenty monoliths will rest upon a bed of sand one foot thick which in turn rests upon the bed of concrete four feet thick. The dynamos on the floor above the engines will weigh seven tons each and will make 650 revolutions a minute. They will rest on heavy iron beams supported by iron pillars, each pillar being capable of upholding 500 tons. Other pillars and beams support the floors above the boilers, furnaces and coal. The coal is to be driven upon scales, weighed and dropped into a pit. Chutes will be so arranged that the coal can be readily loaded on elevators and carried to the fifth floor. There the coal will be dropped into bins, from which a pipe runs at an inclination to the furnace of each boiler. All this machinery for delivering and feeding the fuel under the boiler will be strongly but simply designed to save time and handling.

FUEL AND BLASTS FOR THE FURNACES.

"On the third floor there will be placed two blast fans, capable of driving 50,000 cubic feet of air per minute into the furnaces. The smoke and other products of combustion will be carried from the furnaces into two chimneys of nine feet internal diameter.

These chimneys or smoke stacks make an original detail of the building, for they will appear as bay windows, starting at the third floor and reaching to the roof. These apparent bay windows will be at the rear of the building; the bay windows shown in the front elevation will contain spiral staircases. There will also be a passenger elevator in the front portion of the structure.

"Pipes will carry the steam from the boilers to the engines on the first floor, and a huge exhaust pipe will rise from the engines to the top of the building. This exhaust pipe will be four feet in diameter at its top, and probably there is no exhaust pipe in use in Philadelphia as large as this.

HOW THE CURRENT IS DISTRIBUTED.

"Every known scientific appliance will be used to regulate the distribution of electricity and to secure perfect uniformity and regularity in the brilliancy of the lamps. Edison's skill in this direction is pre-eminent, and his inventions will be utilized in every possible way. There will be thirty-five great feeding mains running from the station. Each feeding main consists of three bars of copper as thick as a man's thumb. To each of these mains a regulating apparatus is specially attached, so that the pressure is constantly kept at exactly the same point, whether one lamp or 1,000 may be burning on a main. In other words, this regulating apparatus keeps the quantity of current supplied to a main exactly proportioned to the demand.

"When this great station on Sansom Street is completed, it will cost the company about \$1,000,000. It will be one of the sights of the city, and will dwarf the wonders of the electrical exhibition four years ago, which brought thousands of visitors to Philadelphia. But as it will be, this plant is only the beginning of the plan of the company. It will supply only the central portions of the city, and it is expected that other stations nearly, if not quite as large, will be erected in Kensington, Richmond, Spring Garden, Northern Liberties, Germantown, Southwark, West Philadelphia and elsewhere. Already the company has expended \$250,000 in copper conductors, eleven miles of which are laid under Chestnut and Walnut Streets, between Twentieth and Fourth Streets. During the coming summer twenty miles more of conductors are to be laid, extending between the Delaware and

the Schuylkill, under Market Street from the Delaware to the Public Buildings, and on intersecting streets connecting with Spruce, Pine and South Streets."

MOTIVE-POWER.

In regard to the *Armington & Sims* engines, I have no indicator diagrams to refer to, except such as are illustrated in their circulars of date about 1885; their engine was entered for competition at the International Electrical Exhibition of the *FRANKLIN INSTITUTE* in 1884, but was withdrawn before the tests of engine were made.

The following diagram, *Fig. 5*, was taken from one of their engines, 12 x 12 inches, running 350 revolutions per minute,

FIG. 5.

coupled direct to one of Edison's large dynamos; mean effective pressure on piston, 45.28 pounds; indicated horse-power, 106.6.

The following diagram, *Fig. 6*, was taken in September, 1883, by Prof. Thurston, who examined, by request, the design, construction and workmanship, to observe their power of automatic regulation, and to determine what power was demanded in operating electric lights.

The engine was $9\frac{1}{2} \times 12$ inches, running 280 revolutions per minute. Water consumption per hour per horse-power, when fifty lights were on, was, according to the cards, 21.5 pounds. Thomson-Houston dynamos of twenty-five lights each.

This engine, as will be seen from the indicator diagrams, is of

the single valve type, the valve being hollow piston valve, and therefore cannot be as economical as the before described engines.

On page 9 of their circular it is stated: "The engines are adapted to work under the highest pressure, if required. By the

FIG. 6.

use of suitable condensing apparatus, the power of these engines can be increased twenty-five per cent."

The following diagram, *Fig. 7*, is from an *Armington & Sims* condensing engine, built in 1886, of dimensions as below:

FIG. 7 *

Diameter of cylinder in inches,	18.5
Stroke in inches,	30
Revolutions per minute,	129
Boiler pressure per pound,	76
Vacuum in inches,	25.5

* The sizes of the foregoing diagrams have been made to conform to the pages of the JOURNAL.

The construction of boilers to be used is not mentioned, but I understand they are to be of the water-tube type, and to have a forced blast.

The number of lights of this system to the horse-power, average ten of sixteen candle-power per lamp; consequently, to run 50,000 lights as above will require 5,000 horse-power, and no doubt in a short time, as stated in the quoted description, 6,000 horse-power will be required; therefore, we will be safe in basing an estimate on 3,000 horse-power for every twenty-four hours. And with the coal used in banking the fires when some of the engines are standing during the day, a fair basis for the coal consumption will be *four pounds of coal per hour per horse-power*.

Then we have water rent as follows:

$$3,000 \times 3 = 9,000 \text{ dollars.}$$

Amount of coal consumed, as follows:

$$\begin{array}{rcl} 3,000 \times 4 & = & 12,000 \text{ pounds per hour.} \\ 12,000 \times 24 & = & 288,000 \text{ pounds per day.} \\ 288,000 \times 365 & = & 105,120,000 \text{ pounds per year.} \\ 105,120,000 \div 2,000 & = & 52,560 \text{ tons per year.} \\ 52,560 \times 4.50 & = & 236,520 \text{ dollars per year.} \end{array}$$

EDISON'S DIRECT LOW-TENSION SYSTEM.

From the published account, as quoted, it will be seen that this is a very large undertaking, not from the number of lights, 60,000 in number, but under nearly all electric-light systems, especially in those like Mr. Edison's, in which currents of great quantity and low electro-motive force are employed, very large copper conductors have to be employed, by which the great outgoing current of electricity is distributed over a district to be lighted from the station.

The system is termed the "three-wire" direct system, and is of peculiar and of interesting construction.

My object in giving the above description is to show that on account of the low electro-motive force, expensive conductors as above described have to be used, and as a means of saving first outlay the works containing the motive power and dynamos are as a general thing placed as near the centre of the district to be lighted as is convenient.

Now I maintain that by locating the station at the river front the additional cost of increased size or number of conductors will be saved in the first year's run based on 50,000 lights.

Not being in the confidence of the Edison management, I am unable to state the cost per lineal foot of such conductors, including junction boxes and the laying of same, but am satisfied, from a personal examination of the conductors and boxes and the connections as are now in process of being laid on Sansom Street, that in addition to the \$250,000 already invested an additional \$125,000 would place the plant on the Schuylkill River front, say at Sansom Street, and would nearly pay the additional cost of same, in the first year's run.*

The distance from Ninth and Sansom Streets, according to the city plan, to the Schuylkill River is 7,600 feet. The greater portion of this distance is already provided for in the \$250,000.

Now let us see what the cost of power would be provided the location was on the river front. The cost, with additional property over that now proposed, would not exceed the cost of present location.

The cost of first-class compound condensing engines and steam generators would be the same as those contemplated, and the advantages would be as follows:

- (1) Free water from the river.
- (2) Cheap coal price delivered by rail or boat would not exceed at present time \$3.75 per ton.

Then we would have

$$\begin{aligned}
 3,000 \times 2 &= 6,000 \text{ pounds per hour.} \\
 6,000 \times 24 &= 144,000 \text{ pounds per day.} \\
 144,000 \times 365 &= 52,560,000 \text{ pounds per year.} \\
 52,560,000 \div 2,000 &= 26,280 \text{ tons per year.} \\
 26,280 \times 3.75 &= 98,550 \text{ dollars per year.}
 \end{aligned}$$

By changing the location, and using first-class engines and boilers, the saving will be as follows:—

Cost at proposed location, water rent,	\$9,000
“ “ “ coal,	236,520
	<hr/>
	\$245,520
Cost at river front,	98,550
	<hr/>
Saving per year,	\$146,970

* See note at close of paper.

CIVIL ENGINEERING.

In building a railroad there is a peculiar condition relating to its economical running, in which it differs from the economical working of the ordinary manufacturer. A railroad must be as nearly straight as possible when it is first constructed, as improvements made afterwards cost double, as, for instance, the straightening of the New York Division of the Pennsylvania Railroad between this city and Jersey City, now under way.

A manufacturer of cotton or woollen goods, or of an electric light plant, may, at any time, add expensive and more economical machinery or buildings, and thereby produce a better or a cheaper article or light, but in building a railroad, especially if for a city terminus, this cannot be readily done. If the road bed is not originally well laid out and constructed, and capable of being run cheaply and safely, it can only be re-organized at a cost equalling that of a new line.

Let us take as an instance the proposed terminus of the Reading Railroad. This company is engaged at the present time in buying and securing expensive properties along the proposed route at extravagant prices, and when secured, an enormous outlay will be required to erect the superstructure of the proposed road-bed, as shown in the *Philadelphia Times* of March 22, 1888.

This plan will necessitate two reverse curves, which, at the high speed required on the proposed iron structure, will require a gang of boiler riveters constantly at work to make it stable for the service required, as is best illustrated on the elevated iron portion of the Pennsylvania Road at Twenty-second and Twenty-third Streets, where men are constantly employed re-driving rivets in the structure; also on the elevated road in New York.

Every one knows that when the Tabor branch of the Reading Railroad was built, it cut through Mr. Clayton French's property, which was the cause of much litigation; whereas, they could have avoided it at much less cost by going around it, but their Chief Engineer of the road, Mr. Lorenz, said "No! To go around will cause a detention of at least five minutes for each train, and twenty trains a day means 100 minutes," and the road was built straight.

Now, this company can secure an entrance into the heart of the city, without one cent of cost for the right of way, and a straight line at that, by coming in under Broad Street. By so doing, they

remove from public sight the locomotive and cars, and their existence will almost be forgotten.

A tunnel could be built from a point on Broad Street, where it intersects the Richmond branch, a distance of about three miles, at a cost of about \$4,000,000, whereas the present proposed route will cost at least \$10,000,000, exclusive of stations, etc.

This tunnel line would not involve the payment of damages to private property, and it would be entirely free from all grade crossings, or interference with the occupants of private houses, and the noise of passing trains, etc.

The tunnel plan has many advantages and should be preferred upon the grounds of taste and propriety alone, as it will spare us the boiler iron architecture that will cover over many of the principal thoroughfares, such as Arch, Race and other streets.

The following cut, *Fig. 8*, shows a section of tunnel road-bed and proposed station at or near Arch Street. The upper section shows the road-bed at Broad and York Streets, the difference in the height of the two road-beds being the difference in grade between the two points.

Stations can be located at any convenient points along the proposed line, access being had by stairs or elevator as may be desired.

[The estimate for additional cables, given on page 41, is based on statements made in a pamphlet entitled "A Warning from the Edison Electric Light Company," issued by the company within the last three months. On page 57, we read as follows: the "Price of Underground Conductors (complete) per lamp \$8.85," at Denver, Col., for 10,000 lights, and at Minneapolis, Minn., for 21,700 lights, feeders and mains, "\$2.40 per light," estimate made May, 1887. Also, on page 59, "Edison 3-Wire Direct System, \$4.40 per lamp," "September 1, 1887."]

COMMENTS OF PROF. WM. D. MARKS ON MR. LEVAN'S PAPER.

OFFICE OF THE EDISON ELECTRIC LIGHT COMPANY, OF PHILADELPHIA,
435 CHESTNUT STREET,

PHILADELPHIA, June 13, 1888.

Dr. Wm. H. Wahl, Secretary FRANKLIN INSTITUTE.

DEAR SIR:—Mr. W. Barnet LeVan's assumptions with regard to the Edison Electric Light Company's new central station are so