



Fig. 10.

If we increase the number of panels, and consequently the number of nodal points, we will not change the principle that I have already demonstrated.

The suspension curve is the natural form for the construction of *any* bridge. It is that form, when placed mechanically exact, gives to us the very *purity* of theoretic bridge-building. It eliminates horizontal values if the cables be hitched on shore. The principle eliminates, furthermore, all lateral bracing.

Out of the three forces that we are to provide material against—the vertical, the horizontal and the diagonal—the suspension principle eliminates most easily the horizontal value, by means of the anchorage at each shore end of the work. The vertical value represented by the little threads that hang the roadway to the cable.

In truth, the suspension principle leaves us the necessity for only the diagonal value for the sustainment of bodies over space, and that is the cable itself.

In a future paper I propose to discuss the mathematics of the forms which I have described.

## SOMETHING NEW CONCERNING THE PHYSICAL PROPERTIES OF STEAM.

By JOHN LOWE, First Assistant Engineer U. S. N.

The volume, temperature, pressure, etc., of steam mutually depend the one upon the other, and vary simultaneously with each other. For example: the volume of one temperature and pressure cannot have the temperature and pressure of another volume; but these relations are strictly defined and are unchangeable.

These relations are well known, and may be found tabulated in Isherwood's works with critical exactness.

They are also expressed in the formula  $\frac{V_p}{V'p'} = \frac{1+(t-39).0025}{1+(t'-39).0025}$  equation (1). In which V= volume of steam, (t) its temperature, (p) its pressure.

In the following table, column D contains the volume of steam as found in Isherwood's works, with the corresponding temperatures, pressures, etc., in the other columns, while column E contains the volumes as calculated by equation (1). By comparing the columns D and E, it will be seen that the formula is only approximate, but for our present purposes it is sufficient, although it is to be hoped that the co-efficients will be corrected at some future time.

| Absolute pressures per square inch. | Temperature, Fahr. | Thermal units in one lb by weight of steam. | Relative volume of steam, water at 32° being unity. Isherwood. | Relative volume of steam calculated from equation (1) | Internal plus the external work of one lb weight of steam calculated from equation (2). | External work calculated from the equation No. (2). | Differences between temperatures 101.36 and t°. | Newly discovered constant derived from columns G and H. |
|-------------------------------------|--------------------|---------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------|---------------------------------------------------------|
| A                                   | B                  | C                                           | D                                                              | E                                                     | F                                                                                       | G                                                   | H                                               | I                                                       |
| 1                                   | 101.36             | 1112.85                                     | 17983.2                                                        |                                                       |                                                                                         |                                                     |                                                 |                                                         |
| 10                                  | 193.20             | 1140.86                                     | 2373.                                                          | 2178.8                                                | 21624                                                                                   | 795.55                                              | 91.84                                           | 8.662                                                   |
| 20                                  | 227.50             | 1151.46                                     | 1219.7                                                         | 1157.2                                                | 29700                                                                                   | 1099.0                                              | 126.14                                          | 8.712                                                   |
| 30                                  | 250.26             | 1158.26                                     | 826.327                                                        | 801.36                                                | 35036                                                                                   | 1296.3                                              | 148.90                                          | 8.706                                                   |
| 40                                  | 267.17             | 1163.42                                     | 627.903                                                        | 617.49                                                | 39031                                                                                   | 1444.6                                              | 165.81                                          | 8.706                                                   |
| 50                                  | 280.89             | 1167.61                                     | 508.292                                                        | 504.93                                                | 42265                                                                                   | 1565.0                                              | 179.53                                          | 8.711                                                   |
| 60                                  | 292.58             | 1171.17                                     | 428.318                                                        | 428.42                                                | 45024                                                                                   | 1668.2                                              | 191.22                                          | 8.723                                                   |
| 70                                  | 302.77             | 1174.28                                     | 371.076                                                        | 372.94                                                | 47424                                                                                   | 1758.5                                              | 201.41                                          | 8.730                                                   |
| 80                                  | 311.86             | 1177.05                                     | 328.086                                                        | 330.79                                                | 49564                                                                                   | 1838.1                                              | 210.50                                          | 8.732                                                   |
| 90                                  | 320.10             | 1179.57                                     | 294.610                                                        | 297.64                                                | 51505                                                                                   | 1906.3                                              | 218.74                                          | 8.715                                                   |
| 100                                 | 327.63             | 1181.86                                     | 267.806                                                        | 270.83                                                | 53277                                                                                   | 1977.4                                              | 226.27                                          | 8.739                                                   |

Let us put H as the total heat in steam. Now, if we compress steam from the pressure  $p = 1$  to the pressures  $p' = 10 = 20$ , etc., as in the table, it has heretofore been supposed that a total work of  $(H' - H)$  772 foot lbs must be performed.  $(H' - H)$  772 is equation (2). See column F. This work is divided into internal and external.

We will not now attempt to define internal work; but external work may be defined as that which is exerted, for example, upon the piston of a steam-engine. The formula commonly used by the engineering profession to calculate external work is  $E = V p \log \left( \frac{p'}{p} \right)$ , equation (3). In which  $\log \left( \frac{p'}{p} \right)$  signifies the Naperian Logarithm of  $\left( \frac{p'}{p} \right)$  and  $E =$  the work restored by steam during expansion or stored in

compression. This formula possesses the merit of simplicity, and for ordinary purposes perhaps is all sufficient. But since the amount of work stored in compression equals the amount restored in expansion, if we accept this formula as correct we must say  $E = V p \log \left( \frac{p'}{p} \right) = V' p' \log \left( \frac{p'}{p} \right)$ , which is absurd by simple inspection. It will be observed that in this formula there is no consideration of temperature. The introduction of this element makes the formula correct, and

$$E = \left[ V p \frac{1 + (t' - 39^\circ).0025}{1 + (t - 39^\circ).0025} \right] \log \left( \frac{p'}{p} \right) =$$

$$V' p' \left[ \frac{1 + (t - 39).0025}{1 + (t' - 39).0025} \right] \log \left( \frac{p'}{p} \right) \text{ Equation (4).}$$

By this formula column (G) was calculated, and it is believed an important fact discovered, viz: *That the external work given out by steam in expanding from the temperature (t') to the temperature (t), bears a constant ratio to that difference, that is, to (t'—t).*

Column (H) contains these differences between  $t = 101.36$  and  $t' = 193 = 227$ , etc.

Column (I) contains the constant ratio  $\frac{E}{t' - t} = 8.7$ , etc. This constant it is believed is now for the first time announced.

This constant is, it will be observed, almost a perfect one, the small differences arising from the imperfections of Equation (1). Because at 60 lbs. pressure the observed and calculated volumes coincide, this constant will eventually be put as 8.723.

We have then discovered a new formula for finding the external work, viz:  $E = \gamma (t' - t) 8.723$ . Equation (5). In which  $\gamma$  = the weight in pounds of steam.

This formula is a rigid one, since as before said, the pressure, volume and other properties of steam vary simultaneously. It expresses all the work that can possibly be obtained from steam by the steam engine.

The difference therefore between this formula and the work actually obtained will be the losses from condensation, etc. These losses will be found to be smaller than generally supposed. As before said, it has heretofore been supposed that the work that should be realized from the steam was  $W = (H' - H) 772$  foot lbs. But the reasoning of this article if sound proves that only

$$\frac{\gamma (H'-H) 772}{\gamma (t'-t) 8.723} = \frac{\gamma .305 (t'-t) 772}{\gamma (t'-t) 8.723} = 26.9, \text{ or that}$$

only  $\frac{1}{27}$ th part of the total heat can possibly be realized theoretically.

This article is only preliminary; but the opinion of the writer at present is that the latent heat performs the internal work, while the sensible heat only is available for external work. If this is correct, then that vapor whose latent heat is the smallest, other things equal, would be the best agent for converting heat into work.

## THE ICE-GORGE IN THE SCHUYLKILL ABOVE FAIRMOUNT.

BY JOHN W. MURPHY.

A paper read before the Franklin Institute.

The ice-gorge in the Schuylkill, at Turtle Rock, extending backwards up the stream some seven miles in distance, has attracted a good deal of attention.

The fear of the effect of the sudden disgorge of this enormous mass of ice has given grave apprehension to the citizens of Philadelphia.

The Fairmount Dam is in danger. If it gives way, damage and destruction follows. Market street, Chestnut street and the partially completed South street bridges will be swept out of existence.

There is nothing, therefore, that engineering skill can or has devised that can withstand this terrific gorge if once in motion.

Think for a moment of a field of ice some miles long, seven hundred feet wide and twenty feet deep, moved by a freshet such as would send it crashing its way against every obstruction that impeded its progress!

Now the purpose of this paper is to show that this gorge of ice is in fact the protection to all structures below it.

Ice is gorged under two conditions of the stream; the first condition is when the stream is rising, the other is when the water falls. Persons who are accustomed to look upon the breaking up of ice in the river, and seeing masses of ice moved by a freshet, rarely comprehend the difference between an ice-gorge that may last for a moment, for an hour or for two hours, and then break away by force of a continually rising current, and a gorge of ice that has been stranded upon the bottom of a river, where the freshet runs away from it, and leaves it high and dry.