The Steam Loop.

BY WALTER C. KERR.

The steam loop is generally called an ingenious device, and if so, the ingenuity certainly appears at once in the name—"steam loop"—a name which, though almost meaningless, seems very consistent with its simplicity. The name has the further merit of not portraying any of its functions or peculiarities, and hence cannot be an embarrassing restraint, as is so frequently the case with names attached to mechanical apparatus.

That so simple an application of nature's laws as is involved in the steam loop should not have been turned to useful effect earlier is, at first thought, strange, but as one looks deeper into the subject, the reasons become more apparent. While no engineer is unfamiliar with the phenomena on which it depends, it has been interesting to note that even those best informed in practical steam engineering or theoretical research in thermo-dynamic science, seldom understand its action on first acquaintance, though they soon recognize in it a new combination of functions.

Its mission is the simple and useful one of returning water of condensation to steam boilers. Its chief characteristics are that its action is continuous, rapid and positive, and that it is a closed system operating under widely varying conditions, without valves or adjustments. Its construction is simply that of ordinary piping.

The principles on which its action depends are as follows: Difference of pressure may be balanced by a water column. Vapors or liquids tend to flow to the point of lowest pressure. Rate of flow depends on difference of pressure and mass. Decrease of static pressure in a steam pipe or chamber is proportional to rate of condensation. In a steam current water will be carried or swept along rapidly by friction.

To these simple statements there will probably be no dissent. We all have used them in many ways, and some of them have disagreeably used us in a manner quite unwelcome. But it remained for the steam loop to collect a few of these erratic agents and from them create a useful system, combining the certainty of flow due to difference of pressure, with the quiet uniformity with which steam condenses, and with the force we see uselessly expended in the hammering of our steam-heating apparatus.

It will be evident that the steam loop, therefore, contains no mysterious factors, even though, like the steam injector, it has been called a paradox.

We have here a working model (see Fig. 1), the steam pipe passing from the boiler to a separator near the engine, which separates the water of condensation and entrainment from the steam. The drip from the separator is below the boiler, and evidently were a pipe run from this drip outlet directly to the boiler, we would not expect the water to return up-hill. Moreover, the pressure in the boiler is (say) 100 pounds, while in the separator it is only ninety-five pounds, due to the decrease in pressure in the steam pipe by reason of which the steam flows to the engine. Thus the water not only must flow up-hill to the boiler, but also must overcome the difference in pressure. The device to return it must perform work, and in so doing heat must be lost. The loop, therefore, may be considered as a peculiar motor doing work, the heat expended being radiation from the upper or horizontal portion.

We are now prepared to examine its mechanical operation, which is best done with the model in action. The form of separator is immaterial, there being many kinds, differing more or less in construction and efficiency. The one in model is simply an elbow turned down into the body of the device (see Fig. 2), throwing the steam against a perforated plate above which the dry steam is removed by a pipe leading to the engine, while the water collects below.

From the separator drain leads the pipe called the "riser," which at a suitable hight empties into the "horizontal." This leads to the "drop-leg," connecting to the boiler anywhere under the water line. The riser, horizontal and drop-leg form the loop, and usually consist of pipes varying in size from three-fourths inch to two inches, and are wholly free from valves, the loop being simply an open pipe giving free communication from separator to boiler.

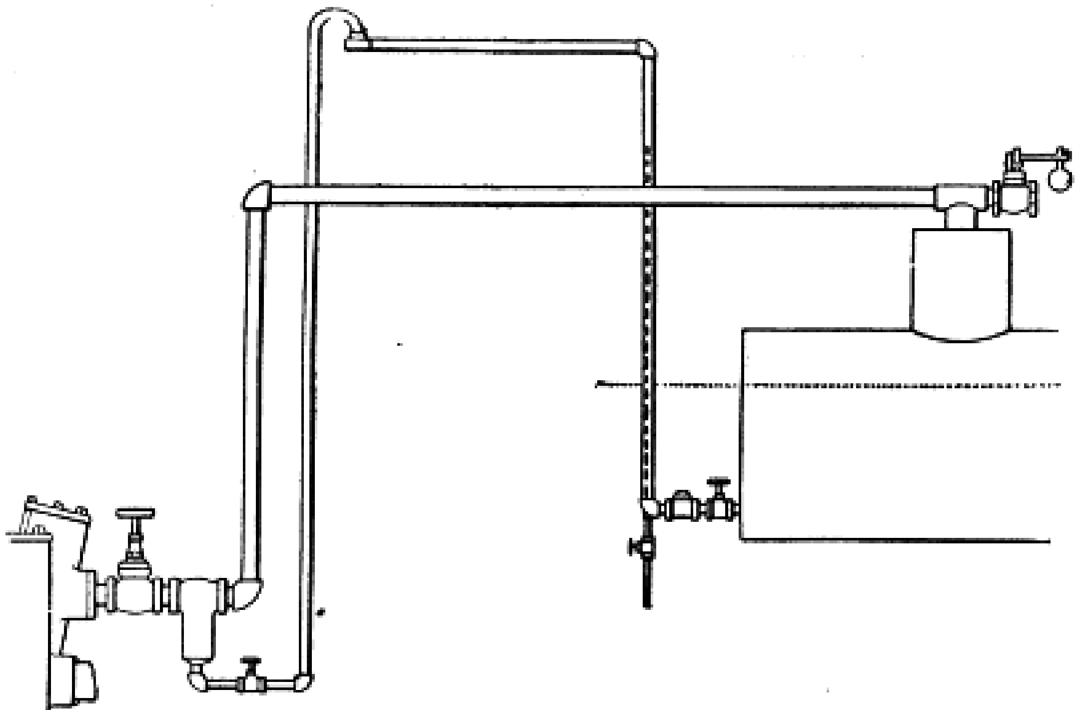

Fig. 1.

(For convenience stop and check valves are inserted, but they take no part in the loop's action.)

Suppose steam is passing, engine running and separator collecting water. The pressure of ninety-five pounds at the separator extends (with even further reduction) back through the loop, but in the drop-leg meets a column of water (indicated by the heavy broken line), which has risen from the boiler where the pressure is 100 pounds, to a hight of about ten feet. That is to the hydrostatic head equivalent to the five pounds difference in pressure. Thus the system is placed in equilibrium.

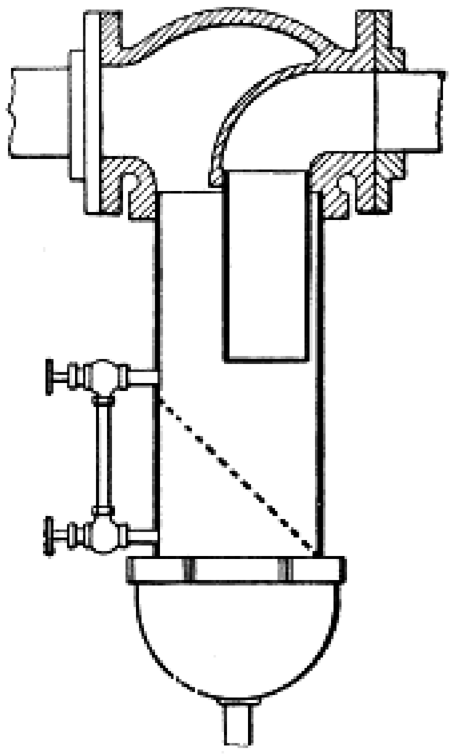

Fig. 2.

Now, the steam in the horizontal condenses slightly, lowering the pressure to ninety-four pounds, and the column in drop-leg rises two feet to balance it, but meanwhile the riser contains a column of mixed vapor, spray and water, which also tends to rise to supply the horizontal as its steam condenses, and being lighter than the solid water of the drop-leg, it, rises much faster. If the contents of the riser have a specific gravity of only .1 that of the water in the drop-leg, the rise will be ten times as rapid, and when the drop-leg column rises one foot, the riser column will lift ten feet. By this process the riser will empty its contents into the horizontal, whence there is a free run to the drop-leg and thence into the boiler. In brief, the above may be summed into the statement that a decrease of pressure in the horizontal produces similar effects on contents of riser and drop-leg, but in degree inversely proportional to their densities. When the condensation in horizontal is maintained at a constant rate sufficient to give the necessary difference in pressure, the drop-leg column reaches a hight corresponding to this constant difference, and rises no further. Thus, the loop is in full action, and will maintain circulation so long as steam is on the system, and the differences of pressure and quantities of water are within the range for which the loop is constructed.

The above may be termed the rational explanation, but for simplicity we have omitted to include some of the features which are of importance in the loop's utility and which will appear later in our consideration of the subject.

"Solid" Water vs. Syray.—In the model the water sometimes appears as a film along the sides of pipes, or as spray, and often as slugs rising quickly and passing over. We cannot definitely state whether slugs form in practice in full size pipes, but their existence is doubtful except when the separator is partly flooded by boiler primage. In the model the pipes are so small that cohesion and capillary attraction are sufficient to account for the existence of the slugs. The resistance of small pipes causes comparatively slow velocity, and the slugs are readily seen. In the full-sized apparatus, however, the velocity is very great, so that even in glass sections a slug's passage would scarcely be discernible. Observations in this line indicate absence of slugs and confirm the belief that the water (other than spray) is carried chiefly by friction of steam current along the sides of pipes, and at a velocity so great that the sweep is distinctly audible when much water is moving.

No water should accumulate in the separator, as it is the mission of the loop to remove it before it assembles into a liquid mass. It is here that the constant and vigorous action is of great practical utility, enabling the loop to act as a preventive of accumulation rather than a device for removing water after it has accumulated. The separator evidently must be of such form as to give the sweep towards and through the loop better opportunity to pick up the entrained water than is afforded the current sweeping toward the engine, pump or steam-using device. It is interesting to know that experiments on very large separators, as large as 5 feet by 12 feet, not discharging their contents, show that if water be allowed to accumulate to a certain hight, no further rise will occur, even though much moisture be present, in the steam, showing that the steam sweeping through carries the water with it, unless that already deposited be drained away. Thus a separator to properly perform its function of drying steam must be empty, while obviously to stop and hold primage, its volume must not be impaired by periodic accumulations. Thus "solid" water in bulk is to be avoided. Condensation and entrainment should be retained and returned as spray or films, while primage should be broken up into particles or masses small as possible and instantly returned before a cumulative effect causes damage. In performing these functions the steam loop offers a new process in the apparently humble mission it serves.

That separators alone do not generally separate all the moisture from the steam is quite clearly shown by the fact that a loop will often return more water when the throttle is closed and the engine is idle, since the separator must then stop all moisture and the loop return it. With engine running, some moisture will always be carried over, the amount of course depending upon the efficiency of separator. Experiments on this feature are difficult because of the interference due to varying amounts of condensation, entrainment and primage, on all of which the draft of steam may have more or less effect.

Limitations.—Generally speaking, the limits within which the steam loop is applicable are very wide, for the principle applies quite as well to great as to small differences of pressure. Similarly, an enormous quantity of water may be handled quite as easily as a small amount. The action will continue reliably through long pipes, overhead or underground. Water may be lifted from levels far below the boilers. The use to which the steam may be applied after the loop and separator have dried it, of course has no effect upon the loop system. Wherever steam is so used that it condenses rapidly, as in dryers, steam-heating systems, jackets, steam kettles, etc., the loop can be applied to the return of this water of condensation the same as from an ordinary separator, and that, too, against any difference of pressure.

The above statements are made to illustrate how thoroughly and completely the loop can be applied to a wide range of conditions, but when we come down to the practical application, and say, how far is it expedient to apply it, the field contracts somewhat.

To take up the different limiting conditions, and comment upon their degree will show most clearly the practical range through which the loop may be made a commercial device.

Difference of Pressure.—The loop's application in this regard is limited most often by the head room for its erection. If the pressure in a separator, dryer, or return from a steam-heating system be ten pounds below the boiler, and a loop about thirty feet high is necessary to make the return, it is evident that a difference of fifty pounds in pressure would require a loop about 150 feet high and the riser, drop leg and large portion of the horizontal being well covered with non-conductor, such a loop would operate efficiently, but generally speaking, a line of small pipe of that hight would seldom be convenient, inasmuch as it would require some peculiar structure to hold it, or possibly, might need to be erected on the side of a smokestack. In high city buildings such a loop may be practicable where convenient air shafts allow easy support, but in ordinary manufacturing plants it would seldom be constructed.

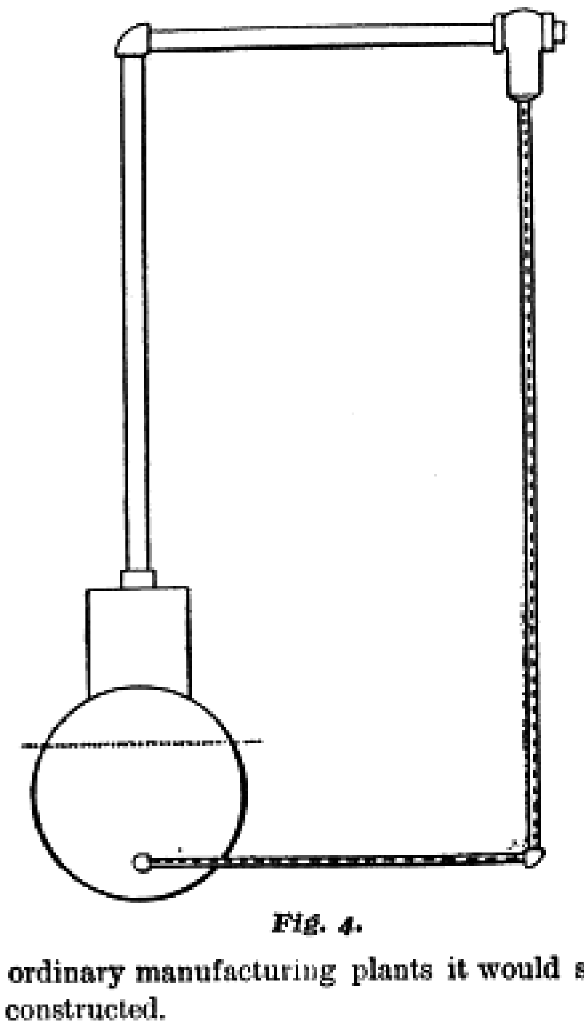

Fig. 4.

While speaking of difference of pressure, attention should be called to the fact that the absolute pressure is of no importance, as a loop will work quite as well under low pressure as high. Its construction and operation recognize only the difference of pressure. A special case occurs, however, where the difference of pressure is very large compared with the lowest pressure in a system. For instance, if a boiler carries twenty-five pounds of steam and at the end of a series of heating or drying coils the pressure is one pound, then with a loop about 100 feet high it would be evident that if the condensation in the horizontal were so performed as to even produce a perfect vacuum, the water column in the drop-leg would stand about 80 feet high, but it is doubtful whether the pressure of one pound at foot of riser plus the 14.7 pounds due to vacuum would be sufficient to force the contents of riser up 100 feet and into the horizontal. It certainly would not be sufficient if there were a considerable quantity of water to be handled, thus causing a high specific gravity of riser contents. Such case, however, is so seldom met in practical loop application, that it scarcely need be considered a limiting condition.

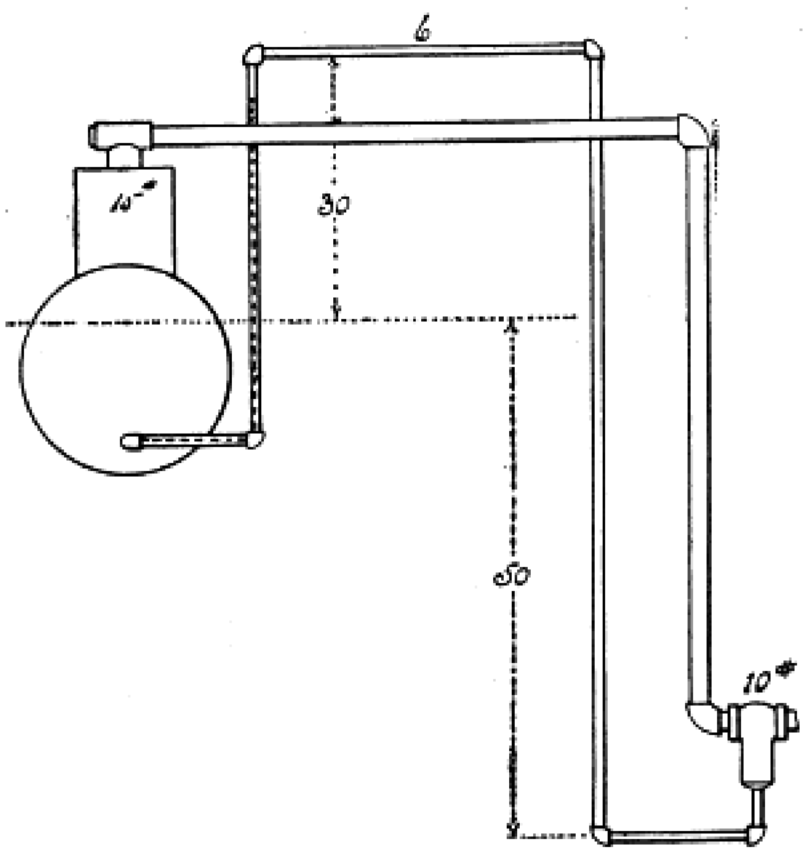

Fig. 3.

Roughly speaking, differences of ten to fifteen pounds are the largest experienced in good practice, and the loop can generally be conveniently erected to operate against such differences, and where excessive discrepancies in pressure are observed, it is usually very desirable to make such changes as will diminish differences, they being usually due to faulty piping. While, therefore, excessive difference of pressure is practically a limiting condition to steam-loop practice, it is not found to be an annoying interference.

Distance of Foot of Riser below Water Level of Boiler.—Since the system is placed in equilibrium by the drop-leg column, and this starts from the boiler, no account need be taken of the distance the riser may extend below water level in the boiler; that is, the engine, separator or drying apparatus may be anywhere below with no effect upon the loop's action except the additional work imposed. This would, however, be a limiting condition when the riser column became so long that the pressure at its lower end is insufficient to lift the total weight of mixture into the horizontal. For instance, if the loop is working under five pounds difference, from fifteen pounds to ten pounds (see Fig. 3), and if the riser is so charged with water that the specific gravity is say .1, then when the horizontal further reduces the pressure to say six pounds, there would be a total forcing pressure up the riser of four pounds, which would support a water column eight feet high or a column one-tenth as heavy eighty feet high. The horizontal in this case would stand about thirty feet above boiler water, hence the foot of riser can extend about fifty feet below boiler. Similar figures for eighty pounds boiler pressure, with seventy-five pounds at engine and drop of ten pounds in horizontal would allow riser to run about 150 feet below boiler level. The above considers only a static column, but if we allow for the sweeping action of the current ascending the riser, the allowable distance of riser foot below boiler will be much increased.

Distance of Foot of Riser above Boiler.—Evidently the foot of riser can be elevated to any required extent, but there will be a hight depending upon difference of pressure at which the true functions of the loop may seem to become superfluous. Consider the case where the drain is just at a hight above boiler water equal to the hydrostatic head due to the difference of pressure (see Fig. 4). Then, with no riser in the system, water collecting in the separator will run directly down a pipe, similar to a drop-leg, into the boiler. This water must collect in ordinary liquid state and exert gravity pressure before the column can move. The velocity of its exit depends wholly on the amount that has collected. Should the difference of pressure increase slightly, accumulation is necessary to cause drainage. This is simply a gravity system. It has no current carrying the water swiftly from separator and over a hill to a point of safety on the top of a water column on the other side, which may rise and fall from time to time without affecting the flow from the point that is to be drained. A gravity system is a water pipe sufficiently high to overcome a difference of pressure. A steam loop may be called a gravity system from the boiler to the top of water column in drop-leg, but a steam loop essentially is a device extending above a balancing column, with such functions as enable it to create a circulation that is not dependent upon gravity or the incoming water of condensation, but wholly upon the flow of steam from a higher to a lower pressure, and so arranging the mechanical device that this flow will carry water with it. Therefore even though the source of condensation is far above the boiler, the principle of the loop is just as applicable to constantly and positively remove water as though it were below and its virtues are just as essential. If the hight above the boiler is far in excess of the head due to maximum difference of pressure, the loop may take the form of a straight pipe, the first section of which may be considered a riser, the second a horizontal and the last or lowest a drop-leg (see Fig. 5). Such a pipe would be a limiting case of steam loop, its shape distorted, but its functions retained. The true action occurring in such a pipe has heretofore been imperfectly understood. Indeed, it is quite probable that no one has considered it deserving of especial consideration until the steam loop was devised and explained.

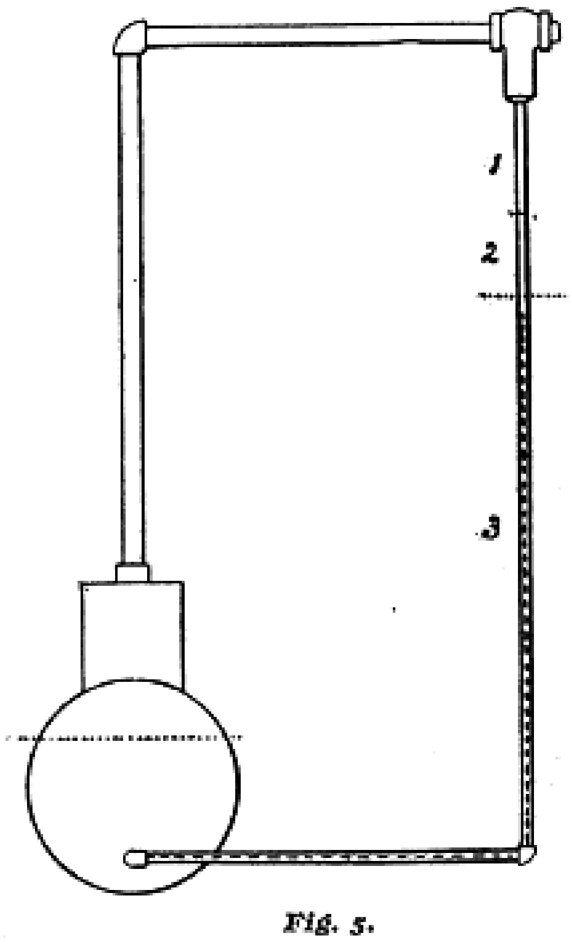

Fig. 5.

Distance.—It might not be unreasonable to suppose that the steam loop's application would be quickly limited by the distance of the separator from the boiler, and that the length would introduce complexity or uncertainty of action. Extreme length might impair its action, although even this is questionable, but at the greatest distances thus far met, of 800 to 1,000 feet, no adverse conditions have been encountered. Great distances cause proportional drop of pressure within the loop itself, requiring proper allowances to be made in hight of drop-leg. The temperature of return is also affected, due to the cooling effect of long pipes, and can be largely controlled by proper covering. The drop of pressure mentioned above, due to the length of loop, occurs only when a horizontal is extremely long, hence is rarely met in practice. In extensive systems the horizontal is made only the functional length, turning into the drop-leg, which descends, and at a proper level can be led away through piping of any form to the boiler (see Fig. 6), it being evident that when the drop-leg has descended to the level of boiler water, all further connection to boiler, whether one foot or 1,000 feet, becomes merely an ordinary pipe through which water will seek its level as through a pipe connecting two barrels into one of which water is poured. Thus, distance will be noted to impose no practical limit on the loop's application, for it causes no change in the loop itself.

Quantity of Water Returned.—This depends upon the amount of moisture entrained in the steam, the condensation in the pipe and the boiler primage. Usually there is little attempt to classify water appearing in a steam system according to the causes of its existence. Its presence is simply regretted until harm results, and then it may be less considerately mentioned. If water is only to be drained out, as by drips, etc., when it accumulates in considerable volume, it matters little how it is formed, but when we come to handle it systematically, continuously, and with certainty, we must consider the source of the product on which we operate. *Water of entrainment* causes steam to be known as wet, and is usually constant in quantity. It may be separated from the steam in several ways, means for this being provided in the various forms of separators, and when so separated must be led away from the main steam current so continuously that it cannot again be picked up. *Water of condensation* is supposed to flow along the bottom or be swept along the sides of pipes, and is also usually constant in quantity. It requires no true separation, but must be led into a chamber of suitable size in such a manner as readily to leave the column of steam with which it is flowing. As most pipes afford opportunity for water to collect at certain points, and then rush on with the steam, the receiving chamber should have ample capacity. *Water of primage* is erratic. Its presence is accidental. We cannot estimate its probable quantity, or the nature of its passage through the pipe. It may be so received by the pipe as to cause excessive entrainment, as is probably the case when an engine labors, clicks and shows very wet exhaust. It may come over as liquid, and mingling with the water of condensation, cause an engine to slow down, pound and collapse, or spurt streams of liquid water from the exhaust. It may be constant or intermittent, and is always dangerous. It must be led away from the steam current, and received in a chamber whose capacity is considerably larger than that required for water of entrainment or condensation.

A separator must, therefore, provide ample facilities for separating the particles of entrained water from the steam and ample capacity for moderate primage. (Extreme primage is, of course, beyond control, and requires cure rather than care.) The loop must have capacity sufficient to continuously discharge the water collected from entrainment and condensation, and a maximum working effort, or single impulse, equal to taking in one liquid stream the contents of separator when filled up to a certain limit by sudden primage. (If filled beyond this limit, we have a flood, whose control is not within the province of the loop or any other instrument, and must be left to providence.)

This double service, for which the loop must be proportioned, involves the ratios existing between the volumes of the separator, riser and horizontal, for the horizontal must have a volume sufficient to take the contents of separator and drop-leg, and still have space left to be occupied by steam, whose condensation will maintain a continuous action while the water in the horizontal is draining through the drop-leg.

This action, while apparently intermittent, is not truly so. It is intermittent with reference to the extra charge of water carried, but the loop is simply exerting, in an emergency, its maximum ability, which, if constantly required, would not be inconsistent with its principle of continuity, although different proportions would then be desirable. Thus, the quantity of water to be handled becomes a limiting condition only when it is so great as to literally flood the system.

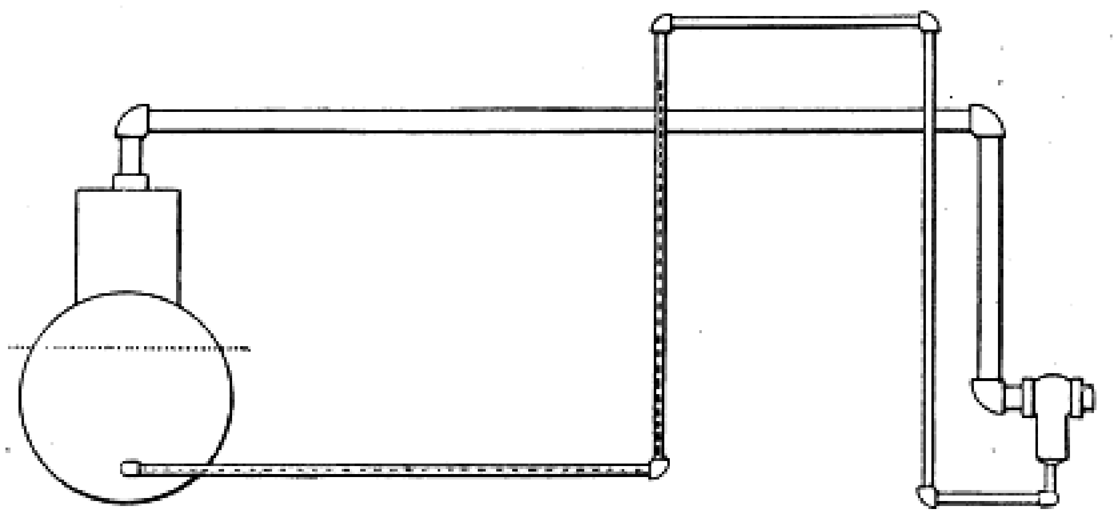

Fig. 6.

Devices for increasing capacity have been employed, such as cored risers, flattened risers, but experimentally they have not, as yet, produced such results as to warrant adoption.

When a loop is not sufficient to give the required capacity, it is not enlarged, but duplicated, and this process may be continued to any extent. When two or more loops are applied to one source, no difficulties are met in their operation, except some competition as to which will secure the business of returning the water. A little influence exerted, in the detail of pipe connections, enables them to form a trust, in which the spoils are equally divided with satisfaction to all concerned, even to the public.

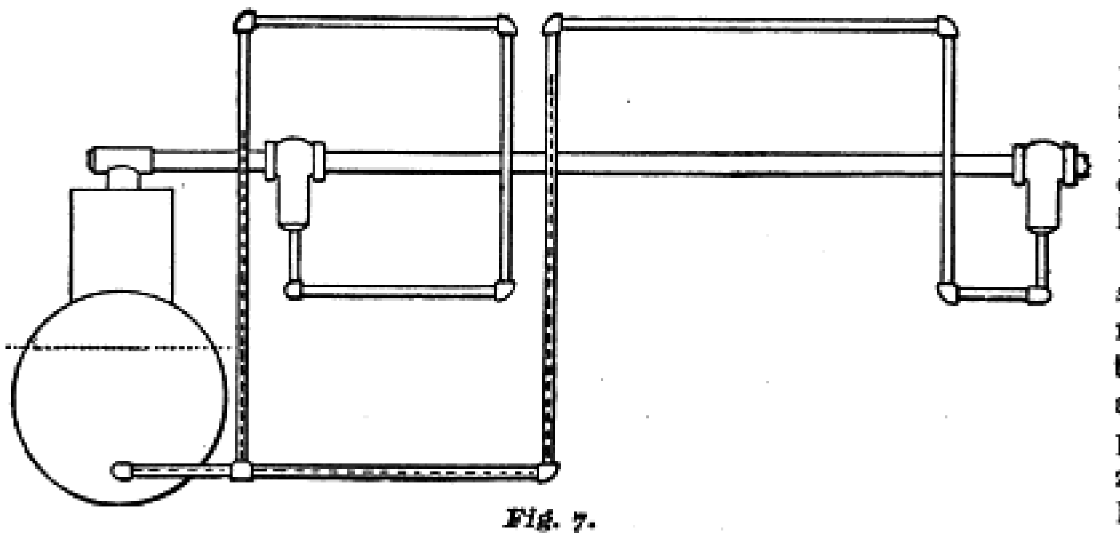

Fig. 7.

Another method, when primage is excessive, is to place a separator on the steam pipe near the boiler, with contents looped back directly, thus compelling the separator and loop at the end of the system to handle the water of condensation only. This method has been used with marked benefit (see Fig. 7).

Presence of Air.—To start the loop's action, the air must be removed by blowing out with steam, hence it is proper to inquire whether air would not collect in the horizontal and gradually reduce the action and make it eventually become "air bound." There is certainly sufficient air in steam to produce this action, but in practice it does not. This may be attributed to the high velocity at which the loop current flows, carrying the air forcibly back to drop-leg where it enters the water and condensing steam, returning to the boiler. Only one instance is known where the loop has met difficulty of this nature, and that was due to boiler water containing much organic matter, the gases from which would collect in the loop. The remedy in such a special case is to apply a small stand pipe to the horizontal in which the air or gas can collect, cool, and, by difference of temperature, operate an air valve, allowing escape until steam rushes in and closes the valve.

To sum up the limitations, we find the loop action is practically independent of the distance that the source of supply is above or below boiler, and also independent of the length of return. It is not interrupted by the presence of air, and is capable of handling such quantities of water as usually exist in steam systems. It is practically limited by excessive differences of pressure and by abnormal quantities of water.

Constructive Features.—When a device is so simple as to consist of a run of one inch, or one and one-fourth-inch pipe, it may seem unnecessary to endow it with so significant an attribute as constructive features, but there is a right and a wrong way to run even an inch pipe. When the mission is so special as that of the foop, there is only one right way and numerous wrong ways. To enter into this matter in detail would be too long for the present discourse, hence we will consider only a few points of especial interest and without extended explanation.

Practice has determined that one inch or one and one-fourth-inch pipe is most suitable for risers, while drop-legs generally take one and one-fourth inches to one and one-half inches, seldom two inches, and never larger. Horizontals commonly are two inches, but, as the volume is material, they may be four inches or even six inches if very short; with reference to them, however, no rule can be considered generally applicable, for the volume of the separator may figure as a large or small element, according to the necessity for handling primage, while the ratio of superficial area to volume is important in giving proper strength to the circulation and determining the economy with which it shall operate.

All horizontal portions of the loop should pitch downward with the current. It may be well to remark here that the terms "riser," "horizontal" and "drop-leg" do not necessarily imply that risers are always vertical, horizontals always horizontal, or that drop-legs follow a plumb line. A riser is the entire run of pipe from separator to highest point of the loop, and may have horizontal portions. The horizontal is the summit level of pipe in which condensation produces the loop's action, and though usually horizontal, is not necessarily so. The drop-leg is frequently inclined, and may have almost any form.

The riser should be provided with a stop valve and the drop-leg with stop, check and blow-off valves. The check must have approximately equal areas on both sides, or when shut it will be much out of balance and become a serious obstacle to the returning water. The return must be made with an independent connection, for if connected to feed pipe, the pulsations caused by pump would affect the drop leg, while if connected through blow-off, especially if it be in a mud drum, the loop may disturb the sediment.

The riser and drop-leg should invariably be covered with good non-conductor to prevent loss of heat, while the horizontal should be covered wholly or in part, according to its length and size, and the necessary condensation.

Combinations of Several Loops.—Thus far we have considered the loop as an isolated device, returning the water from one separator attached to one steam pipe. The application may, however, be extended throughout a large steam system; in fact, it is one of the important features that the entire drainage of a large system of steam pipes can be made with a system of loops forming a network of returns back to the boiler, affording ample opportunity to clear the system of water and with no chance for waste by escaping steam through faulty or open drips. It matters not whether the pipe be overhead or underground. Loops can be attached directly to the bottom of steam pipes at low spots and separators may be used at each steam outlet where engines, pumps, dryers or other apparatus operate. When the system thus extends, it is pertinent to examine to what extent the loops may be combined to simplifying piping. On first thought it may be proposed to simply run all the drains to one point, and there attach a loop of sufficient size, but the impropriety of this is at once apparent, since such loop would be liable to receive nothing but water and would be promptly flooded. Each loop is proportioned and erected with reference to specific difference of pressure and a given quantity of water, hence if the drainage of several separators into one loop is considered at all, these separators must be attached to pipes bearing such relation to each other that they will all be subject to equal differences of pressure. Consider a large and small engine side by side, the large engine having constant load while on the small one the load varies widely. If these separators be drained into one loop, there would be opportunity for a sudden drop of pressure near the small engine, caused by sudden increase of load, bring the contents of the large separator over to and possibly through the small engine. This could be obviated by introduction of check valves, but they are undesirable, and the loop system is so capable of being made to work properly on its own intrinsic principles that it would seem to be bad engineering to create a set of conditions in which the loop needed auxiliary devices to counteract effects which should not be present. Similarly, when large quantities of water are received by one drain or separator, its presence might so overload the loop as to render it inoperative with respect to the several other connected sources. Therefore, one loop should never be connected to several sources of supply, except in rare cases where the different sources may be considered only as subdivision of one source; that is, when they are all subject to the same influencing conditions. Each source of supply should therefore have its own riser. If, now, several risers from various sources enter one horizontal, we would afford opportunity for the loop's fundamental principles to be violated. The circulation must be uninterrupted and end at the point of lowest pressure. There cannot be more than one point of lowest pressure, hence with two or more risers connected into one horizontal, an accidental drop in pressure in any riser or pipe to which it is connected would short-circuit the loop from one riser to another (see Fig. 8). Therefore, each riser must have its own horizontal. We then consider whether several horizontals can enter one drop-leg. The balancing water column whose hight is due to difference of pressure must rise and fall with the variation of pressure. Hence, one loop may have a different hight of balancing water column from another even though they enter the same boiler. At the origin of one loop pressure may be increasing, while at another it is decreasing, calling for corresponding fall and rise of drop-leg columns, and if these loops were both attempting to utilize the same drop-leg we should have the anomalous condition that a column of water is required to rise and fall at the same time, and hence two or more horizontals should not enter one drop-leg. The numerous drop-legs in a given system do not, however, require independent connection to the boiler, for they may discharge into one common manifold or header near to or distant from the boiler. The loop's action is performed when the water has been deposited in the drop-leg; hence, the method of connection beyond that point does not involve the action of the loop. Even if loops could be combined and connected in various ways consistently with safety and reliability, it would not be generally expedient or convenient so to do, for though several loops may be more complex, they are less complicated than several combined into one with numerous shut-off valves, opportunities for leakage and interruption to service which may ensue when for any reason part of the loop system is shut down and the balance in operation. With individual loops the shutting down of part of the steam plant simply cuts out single loops without effect upon the others.

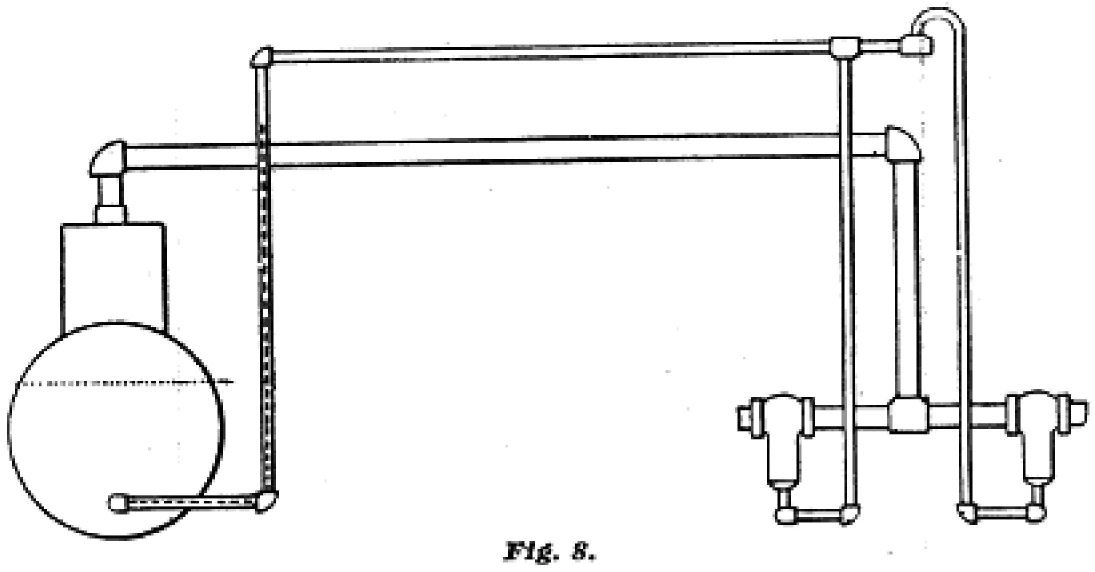

Fig. 8.

Efficiency.—This is a feature of the loop on which it would be interesting to develop thermodynamic equations, and compare the same with experimental results, but the investigations on thermodynamic lines involve numerous assumptions on which the doctors will not agree, while experimentally we labor under the disadvantage of having no general case, each experiment requiring to be conducted on a special case, which may have but little bearing on others. By this it is not implied that the quantitative values of loop action are not or will not be determined mathematically and experimentally, but rather to say that such determinations are not of much import or interest in the present discussion. A statement of general features surrounding the efficiency may, however, be interesting. The loop may, like an engine, operate idly, doing no useful work, because there is no water to return, in which case it would be infinitely wasteful, since the efficiency is the ratio of the cost of operation to the work done. The operative cost being practically constant in any given loop, its efficiency must depend wholly upon the amount of water returned and the maximum efficiency will correspond to the largest quantity that it is capable of handling. This limit, however, would seldom be reached in practice, for if constantly doing its maximum work the loop would be in danger of flooding each moment. Practically, therefore, the wide margin allowed for safety and handling unusual quantities of water compels the loop to usually operate far below its maximum capacity rendering it to that extent less efficient. This feature, however, indicates the inadvisability of making loops unnecessarily large. Since the loop puts water into the boiler against resistance, energy must be expended. This energy represents heat lost, and this loss is the cost of operating the loop. No exact determinations have been made of this loss, but it is obviously very small. This is indicated by the fact that the loop will work even when covered with non-conductor. That the energy required is very small may be deduced as follows:

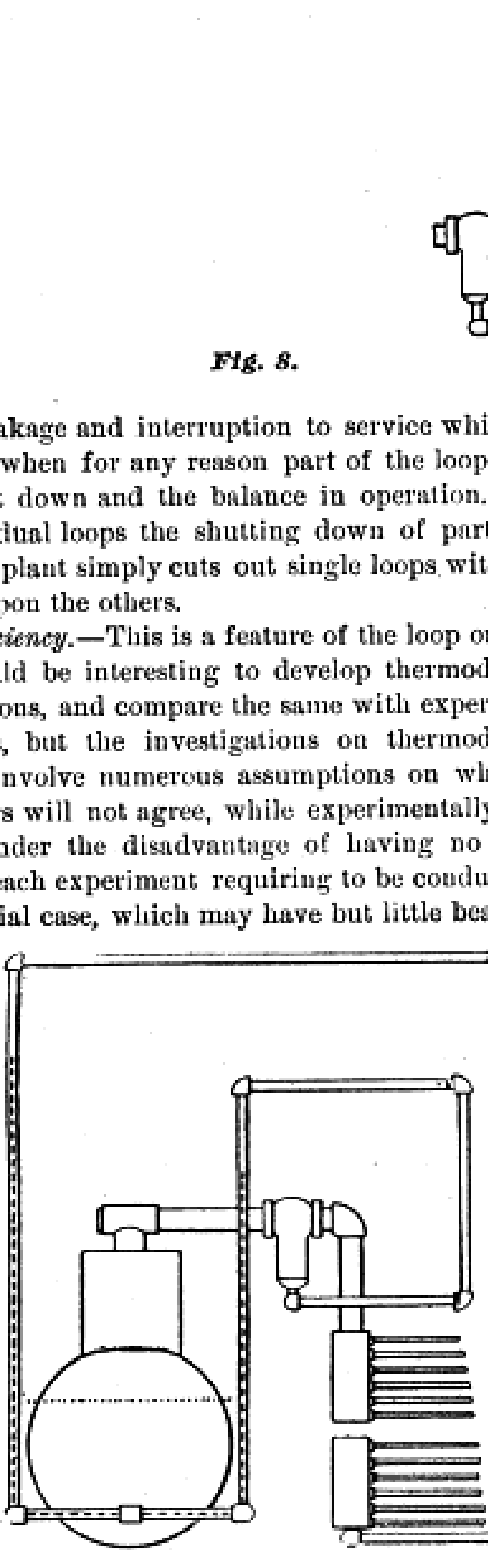

Fig. 9.

A 100 horse-power engine using thirty pounds of water per hourly horse-power requires 3,000 pounds per hour. If ten per cent or 300 pounds be returned to boiler per hour, and difference of pressure between separator and boiler is ten pounds, then about $^{1}/_{275}$ of one horse-power is required to do the work.

In the above it will be noted that we have assumed a very large amount of water to be returned, and have assumed a large difference of pressure against which to return it. Consequently the above figures are more than generous, and it is doubtful whether half this amount of power, or say $^{1}/_{500}$ of one horse-power, is used in the average case. As the loop is required to exert so small a power, it is evident that its efficiency, as measured by our ordinary ideas of economy, might be extremely poor, and yet its efficiency for the purpose for which it is used very high; that is, while its absolute efficiency considered as a pump with which to get water into a boiler might be low, the small amount of energy needed to perform so valuable a service as continuous return, may make it relatively an apparatus of high efficiency.

Another way of looking at this is as follows: A one-inch pipe may be presumed to lose by radiation .1 of the heat which would be lost from a ten-inch pipe. Now, suppose a ten-inch pipe is running from a boiler to an engine, and the loss by condensation is being wasted through a drip, to say nothing of the steam also lost. Now, the loop will add one-tenth to the condensation but to compensate for this it returns to the boiler the original ten-tenths condensation in the pipe, plus the one-tenth condensation in itself, at a temperature (say) of 250° to 300°, which is evidently desirable as compared with wasting the condensation of the ten-inch pipe.

An important factor in its practical efficiency is the improbability of leakage existing, while other methods involve great opportunities in this direction.

There are other interesting developments with relation to efficiency which cannot be explicitly stated because of insufficient experiment. They may be indicated as follows: In any system which involves carrying from the boiler steam at a given temperature and returning a part of same to said boiler, there must be some loss of heat. The amount will depend on the differences of temperature to which the steam or resulting water is subjected and the time. All systems contemplating the collection of water in volume, handling it through pipes in volumn and pumping it back in volume, contemplate or involve the use of apparatus having itself a temperature widely different from that of live steam from said boiler. They also contemplate the moving of a solid body of water which can only be done at a very low rate of speed. Hence, any return made on such system is essentially a wasteful one. The steam loop makes a return through apparatus which is small in mass and kept at a comparatively high temperature, while the current through it is extremely rapid, bearing in this respect no relation to and time are so reduced as to give evidence of suany other device. Both difference of temperature perior efficiency. In fact, it may be said that the steam loop cannot be reasonably compared with any other form of return that has yet been made, as it stands alone in its principle and utility.

This whole question of efficiency is, however, one of curiosity rather than importance, for, as previously stated, the whole matter is relative. The mechanical features of the loop system in removing the objectionable water from pipes, through a continuous closed circuit back to boiler takes precedent over any questions of efficiency, especially considering the very small quantities of power and their heat equivalents involved. Just as an edge several inches wide may be sharp for the bow of a steamship and an edge .01 of an inch broad dull for a razor, so may the expenditure of a few thousand heat units in a lightly loaded steam loop be economical for a loop when the same number of hundreds of units would be uneconomical for a compound condensing engine furnishing the same foot-pounds of work. Loops, therefore, are simply to be compared with each other, and in this field there is still ample room for further accumulation of data.

In practice, the data obtained from large numbers of loops in operation vary so widely on account of various conditions imposed, that it is probably impossible to obtain reliable information from which deductions can be made, except on special apparatus erected on a large scale for experimental purposes only. The useful work done by the loop cannot be measured solely by the amount of water returned to the boiler, for if this water is all condensation and primage, its removal produces less economic effect on an engine than if it were held in suspension in the steam. Thus it may be that the exertion of a small fraction of a horse-power by a loop may cause the steam which it dries to exert many times more power in its expansion in the engine cylinder. The loop to do this might be lightly loaded, so that its own efficiency becomes relatively poor, while near by there might be a loop, heavily charged with water of primage and condensation, whose efficiency is relatively high, yet whose economic effect upon an engine is of less value. Therefore, the thermodynamic efficiency of a given loop is not proportional to its value to the user, even though we make no account of its value as an assurance against accident by water.

Results.—The result of steam loop action may be briefly summed up as follows:

(1) Saving the water of condensation, entrainment and primage.

(2) Saving the heat contained in said water.

(3) Saving the steam systems from water, thereby reducing liability to accident.

(4) Returning pure water to the boiler.

(5) Preserving uniform temperatures, thus obviating difficulties due to expansion and contraction.

(6) Prevention of direct loss which usually exists from open drains, drips, tanks, etc.

(7) Enabling engines to start promptly.

(8) Maintaining higher pressures at the end of long lines.

(9) Maintaining higher temperatures in jackets, dryers, etc.

(10) Increasing the efficiency when steam is used expansively.

All of the above are more or less evident from what has preceded, except the latter, and on this there is some honest difference of opinion. The earlier writers on thermodynamics make little mention of the effect of entrained moisture on the expansive properties of steam, but by common consent rather than any demonstration, they seem to agree that moisture produces an ill effect simply to the percentage amount of its presence. That is, five per cent moisture will increase the water rate of an engine only five per cent. Experimental data on this point seem very meager, the only recent work being that of Prof. James E. Denton, of Stevens Institute, on a comparatively small engine in which the result indicated was substantially as above. Prof. Denton, however, considers further experiment necessary to establish a conclusion. The opinion of other authorities on this question, including Dr. R. H. Thurston, of Cornell University, and Geo. H. Barrus, M. E., of Boston, agree that the presence of moisture in steam should, and doubtless does, cause an injurious effect in excess of its own percentage. Indications of this are observed in superheated steam where a given amount of heat expended in superheating produces more saving in the quantity used by the engine than the equivalent in added heat, and the same condition should extend to supersaturated steam. Definite knowledge of this is, however, yet to be obtained, but it seems to be the general concensus of opinion that moisture is detrimental to an extent about double its percentage; that is, five per cent moisture in steam, affects the efficiency of an engine about ten per cent. Further development and opportunity for experiment with the steam loop system will aid in determining this.

Other Applications.—Throughout this discourse the description has been confined almost wholly to the application of the loop to the one case where moisture is to be removed before steam passes to an engine or pump. It is thought best to keep this one case clearly in mind, for the loop thoroughly understood on this basis may be easily conceived to serve similar purpose in any other connection. Where live steam is used for drying purposes, the loop may be attached directly to the return, thus maintaining a powerful circulation through the heating coils and ridding the system from the condensation which is the natural product of the heating or drying process. In this service, however, the loop has opened up a new feature, that of drying the steam before it enters such heaters, and it is found to yield very beneficial results, by keeping up temperatures and pressures (see Fig. 9). Similarly, steam kettles, jackets of steam-jacketed cylinders, and even steam-heating apparatus can be handled with ease and efficiency. Much apparatus of this nature, however, is throttled down to a degree that seriously interferes with loop application, and in ordinary steam heating the opportunity is exceptionally good for large air leakage, which would be deleterious. It is, therefore, not easy to concisely state to just what purposes the loop may be practically applied, but it is safe to say that it is desirable on any live-steam pipe or any high-pressure or unthrottled dryer, heater or jacket.

The development of the loop system has not stopped with the simple applications here recorded, but has been carried into fields of wider application. Perhaps no device has appeared during late years on which more thought and careful consideration has been bestowed.

Thus, the steam loop becomes a device of much broader proportions than appears from first inspection of its operation or the rudimentary understanding of its principles. It may seem strange that its application has not before been developed, but that is doubtless due to want of clear comprehension of its somewhat peculiar functions and their utility, for those who are connected with steam engineering must in many ways and under various circumstances have had opportunity to observe the phenomena which concern its action. We are, therefore, entitled to respect quite highly this useful combination, whose worth can never be accurately estimated, since its chief service is to prevent certain losses and accidents of variable character, and whose extent is the only measure of the loop's value.

IMPROVEMENTS IN THE MANUFACTURE OF GALVANIZED IRON.—Prof. J. W. Richards has found that the presence of small quantities of aluminum in the galvanizing bath leads to the deposition of a highly crystalline as well as a permanently brilliant and adhesive coating of zinc. The aluminum is best added to the bath in the form of a zinc alloy containing 2 per cent of aluminum, 4 oz. of this alloy being added to the galvanizing bath for every ton of zinc.

In this department we propose to treat of all questions relating to the characteristics and qualities of structural materials, their mode of occurrence, their adaptation to special uses, and the appliances and machinery employed in their production, manipulation and fashioning into useful forms. We shall be pleased to receive communications of general interest for publication in this department.

Comparative Crushing Strength of Various Building-Stones.

The following table, compiled from tests made by Gen. Gillmore and Prof. Woolson, and published in "Haswell's Pocket-Book," contains much valuable information for engineers and architects. Our readers will notice the enormous superiority of the Potsdam sandstone over all other stones tested, the specimen having withstood nearly 43,000 pounds without crushing:

Aberdeen (Scotland) granite	Haswell,	10,760
Albion (New York) sandstone	Gillmore,	13,500
Arbroath (England) sandstone	Haswell,	7,850
Aquia Creek (——) sandstone	Haswell,	5.340
Bardstown (Ky.) limestone	Gillmore,	16,250
Bay of Fundy (Canada) granite	Gillmore,	12,020
Belleville (New Jersey) sandstone	Gillmore,	11,700
Berea (Ohio) sandstone	Gillmore,	10,250
Billingsville (Missouri) limestone	Gillmore,	7,250
Caën (France) limestone	Gillmore,	3.650
City Point (Maine) granite	Gillmore,	15,093
Cleveland (Ohio) sandstone	Gillmore,	7,910
Connecticut freestone	Haswell,	3.319
Common (Italian) marble	Gillmore,	13,062
Cornish (Wales) granite	Haswell,	6,339
Craigleith (Scotland) sandstone	Gillmore,	12,000
Dix Island (Maine) granite	Gillmore,	15,000
Dorset (Vermont) marble	Gillmore,	8.670
Dorchester (N. B.) sandstone	Gillmore,	9.412
Dublin (Ireland) granite	Haswell,	10,450
Duluth (Minnesota) granite	Gillmore,	19,000
English (Magnesian) limestone	Haswell,	3,130
English (Anglesa) limestone	Haswell,	3,600
Fond du Lac (Wis.) sandstone	Gillmore,	6,250
Fox Island (Maine) granite	Gillmore,	15,062
Glens Falls (New York) limestone	Gillmore,	11,475
Greenwich (Connecticut) granite	Gillmore,	11,700
Harbor Quarry (Maine) granite	Gillmore,	16,837
Haverstraw (New York) sandstone	Gillmore,	4,350
Hurricane Island (Maine) granite	Gillmore,	14,937
Joliet (Illinois) limestone	Gillmore,	16,900
Kasota (Minnesota) sandstone	Gillmore,	11,675
Little Falls (N. Y.) sandstone	Gillmore,	9.850
Marquette (Michigan) limestone	Gillmore,	8,050
Marquette (Michigan) sandstone	Gillmore,	7,450
Marblehead (Ohio) limestone	Gillmore,	12,600
Massillon (Ohio) sandstone	Gillmore,	8,750
Medina (New York) sandstone	Gillmore,	17,725
Middletown (Conn.) sandstone	Gillmore,	6,950
New Haven (Conn.) granite	Gillmore,	9.750
Newry (England) granite	Haswell,	12,850
North Amherst (Ohio) sandstone	Gillmore,	6,650
North river limestone	Gillmore,	13,425
Patapsco (Maryland) granite	Haswell,	5.340
Port Deposit (Maryland) granite	Gillmore,	19,750
Potsdam (New York) sandstone (not crushed)	Woolson,	42,804
Quincy (Massachusetts) granite	Gillmore,	17,750
Quincy (Illinois) marble	Gillmore,	9,787
Rockport (Massachusetts) granite	Gillmore,	19,750
Scotch whinstone	Haswell,	8,300
Seneca (Ohio) sandstone	Gillmore,	10,500
Tuckahoe (New York) marble	Gillmore,	13.594
Vermillion (Ohio) sandstone	Gillmore,	8.850
Vinalhaven (Maine) granite	Gillmore,	16,750
Warrensburgh (Missouri) sandstone	Gillmore,	5,000
Westerly (Rhode Island) granite	Gillmore,	17,750
Williamsville (N. Y.) limestone	Gillmore,	12.375
Yorkshire (England) sandstone	Haswell,	5,710