train over a grade that would stall a single expansion locomotive of equivalent capacity.

This advantage of being able to utilize a greater per cent. of the weight on the drivers will also facilitate the starting and the handling of trains under all conditions with less resorting to slacking, which is a destructive and expensive practice.

The reduction of the amount of water and fuel necessary to use in connection with the cross-compound locomotive will make a corresponding reduction in the number of water and coaling stations along the line, which must be considered of large importance by its lessening the cost for maintenance and supply, and by the provision of a lesser number of different qualities of water to be used in the boiler.

The cross-compound locomotive will require from the boiler less steam, owing to its increased rate of expansion and decreased cylinder condensation, and this will facilitate providing a greater efficiency of the boiler by a slower rate of combustion, greater possible absorption of heat from the products of combustion of the reduced temperature, and resulting loss in the waste gases from the smoke stack.

However, cross-compounds, like all other heavy capacity power, must be maintained if good results are to be expected. If the intercepting valves are allowed to leak, piston and slide valves and cylinder packing to blow, and the machinery to be neglected until the locomotive knocks itself to pieces or is unfit to ride on, neither the engineer or fireman will favor them, nor will they be economical on account of the wastefulness in fuel and the hard riding, and for which they will soon be condemned.

As regards repairs and maintenance of the compounding mechanism and the locomotive's machinery, the cross-compound is subject to a much lighter stress at the beginning of, and to less variation in strain, during the stroke, than the single expansion engine, consequently the friction on the journals and guides will be less, and it will run more steadily, which will make a reserve of strength and durability in favor of the cross-compound as compared with the simple, where the working parts are of the same dimensions.

The intercepting valve gear and such other parts of the locomotive as are connected to the cylinders, and which are generally affected by compounding, if properly designed and constructed will require very little, if any, additional cost for maintenance, other than the usual repairs that will be made, the same as to any other part of the locomotive, when it goes into the shop for a general overhauling. At the outside the cost for the maintenance of these parts will amount to not more than 3% of the total cost of the locomotive repairs, and the saving in boiler repairs, due to the compounding feature, will more than offset this.

The cost for the lubrication of the cylinder gear for a cross-compound locomotive as proposed, should not be over 5% more than for a single expansion locomotive of the same capacity.

THE USE OF THE STEAM.

Higher steam pressure is the tendency of the times, and with good reason, for the higher the pressure the greater the opportunity for economy in generating power. The compound and triple expansion engines of the present day have reduced the cost of power some 40% over the performance of a few years ago, this, of course, being where higher initial pressures have been used in order to get the greatest advantage out of the compounding features.

The total heat acquired in the form of steam is expended in three ways:—first, in raising the temperature of the water to boiling point; second, in the work done in transforming water into steam; third, in the additional work done in overcoming the incumbent pressure of the surrounding atmosphere, so that an enlarged volume may take place. To raise the temperature of water from 32° to 212°, which is the sensible heat conveyed, 180.8 heat units are required. The latent heat required in the form of steam is an additional 894 heat units, in the expansion against atmospheric pressure 71.7 heat units, and to increase the pressure to 250 lbs. indicated, 59.2 heat units. This makes a total in work expended of 1,205.8 heat units to raise steam of 250 lbs. indicated pressure per square inch from 1 lb. of water at freezing point.

Steam now being provided in the generator, or boiler, at an indicated pressure of 250 lbs. per square inch, with a temperature of 406.17° Fahr., containing 1,205.8 heat units per pound, and weighing per cubic foot .5705 of a pound, is admitted through the use of a single-seated throttle valve in the dome, to a stand pipe and dry pipe of reduced length, through a crotch and direct steam pipe by the least possible amount of throttling and friction to the high pressure steam chest.

The throttle valve to be single-seated and of such construction and adjustment as will overcome the liability for leakage at a high pressure, balance to give ease of operation, and arranged to throttle the steam with the initial movement in order to prevent too sudden a lunging of the locomotive when it is moved to start the train, and which will overcome the action which usually results in break-in-twos and damage to the equipment.

The capacity of these conveyers of the steam from the throttle valve to the steam chests, not including the latter, on the usual type of simple engines, averages from 12,000 to 13,000 cubic inches, or about 1.3 times the capacity of one cylinder of a locomotive, which would be equivalent in tractive power to the proposed locomotive. In this locomotive, the capacity of the conveyers, not including the high pressure steam chest, is but ½ times the capacity of the high pressure cylinder, which comparison indicates the reduced travel of the steam from the boiler to the steam chest, and the resulting decrease in loss of pressure from friction, not considering the more sensitive control to the engineer over the operation of the motion gear. These conveyers also extend through the combustion chamber, where the temperature of the gases will vary from 1,200° to 1,600° Fahr., as compared with an average of from 700° to 1,200° in the usual type of smokebox. This provides an average increase of 450°, and which is from 800° to 1,200° over and above the temperature of the indicated 250 lbs. boiler pressure itself. This intense heat in direct contact with the conveyers of the direct pressure steam leading to the high pressure cylinder, also the receiver pipe, which conducts the steam from the high to the low pressure cylinder, will, by super-heating, overcome condensation losses, also increase the volume proportionally and maintain the same pressure, which must result in an increased efficiency and at no loss of fuel. This, for the reason that the superheat will be taken from the gases during their passage from the furnace to the atmosphere, and the heat removed from these gases for the superheating effect will not be sufficient to reduce the terminal temperatures of the smokebox gases to below that of the steam in the boiler. It is safe to say that the steam from the boiler will reach the piston valve to the high pressure cylinder with a reduction in pressure of not more than 8%, which will provide an initial cylinder pressure of 230 lbs., with a temperature of 399.2°, containing 1,203.7 heat units. A piston valve will be provided of ample proportions, with large steam passages, positive adjustment to give large and quick port openings, and thoroughly balanced in order to reduce the loss of power necessary to operate it. It will also be located in close proximity to the cylinder, to reduce the clearance spaces and proportionate loss of heat thereby, to the minimum.

By now dividing the use of the steam to be converted into useful energy between the high and low pressure cylinders in accordance with theoretical temperature proportions, the ratio between the two cylinder volumes would be in proportion as 1 is to 3.84, which would give a high pressure cylinder of 18⅜ inches and a low pressure of 36 inches in diameter.

By distributing the steam to equalize the power the ratio would be as 1 is to 3.09, or a high pressure cylinder of 20½ inches, and a low pressure of 36 inches in diameter.

To favor the relation of the slide valve gear cut-off adjustment between the two cylinders, also the effect of steam friction and condensation, and to increase the tractive power, the proportion decided upon is a ratio of 1 to 2.94, or a high pressure cylinder of 21 inches, and a low pressure cylinder of 36 inches in diameter. This proportion is much larger than the ratios of from 1 to 2.3 and 2.5, which are the usual limits for cross-compounds, and approaches more nearly the ratio which can be used in connection with four-cylinder compounds, and without the disadvantages of the latter.

The increased ratio so adapted will give a greater volume of expansion and more useful work out of a given volume of steam, and with the arrangement proposed, the usual disadvantage of large cylinder ratios through wire drawing, compression and impossibility to equalize the power between the two cylinders, will be overcome.

The available pressure per square inch for the high pressure cylinder is now 230 lbs., with a temperature of 399.2°, as compared with 180 lbs. at a temperature of 379.6° in the simple locomotive cylinder of a boiler having a capacity for 200 lbs. initial working pressure, and with an arrangement of throttle valve, stand pipe, dry pipe, steam pipes and location of dome in accordance with the usual American design. It will thus be noted that an increase of 50 lbs. initial steam chest pressure has been gained, with an increased temperature of 19.6° (not considering superheat) at an expense of but 5.6 heat units per pound of evaporation. Assuming that steam of 230 lbs. pressure will be admitted to the 21 inch diameter high pressure cylinder, at an actual cut-off of 24.2% of the stroke of 30 inches, this steam will be expanded 4.13 volumes to a terminal pressure of approximately 55.7 lbs.

Considering that with the large capacity of receiver the drop in the receiver pressure will be not more than 15%, the back pressure in the high pressure cylinder will average not more than 47 lbs., at which pressure the steam will equalize in the receiver pipe for its transmission through the intercepting valve to the steam chest to the low pressure cylinder. This conveying of the high pressure exhaust steam through the receiver pipe, which, as has been stated, is located in the combustion and superheating chamber, will increase the volume by superheating from 10 to 25%, and this with the increased temperature will overcome to a large extent the losses through a drop in the receiver pressure, and by cylinder clearance and condensation.

The low pressure steam chest being provided with passages to and from the cylinder, and with a slide valve, constructed so as to give quick admission and release of a large volume of steam, the latter will commence its work in the low pressure cylinder at about 47 lbs. pressure, and being admitted for an actual cut-off of 34.1% of its stroke of 30 inches, the steam will be further expanded 7.87 volumes, or to 12 times its original volume, when admitted to the high pressure cylinder, which will reduce it to a terminal pressure of about 6 lbs., with a temperature of 230.55° Fahr., and containing 1,152.3 heat units.