intervals by the operation of the valves as has been described.

Other than as above stated, there will be no difference in the operation, except that the labor and grief to which some of the engineers and firemen are now heir, will be considerably reduced.

THE GENERAL FEATURES OF ADVANTAGE AND DISADVANTAGE OF THE PROPOSED LOCOMOTIVE.

To learn the greatest efficiency of any locomotive boiler, the ideal basis for comparison is the number of heat units usefully applied, divided by the heat units supplied to the furnace. Considering the heat units supplied to the furnace, these are from the coal, from the air and from the feed water. The heat units usefully applied are the heat in dry steam, in moisture and water mechanically suspended in steam, in dry flue gases, in moisture in coal, in water resulting from combustion, in vapor in air (the latter three at the temperature of the flue gases), and losses through incomplete combustion to carbon monoxide, in ashes and unconsumed fuel, through radiation and otherwise unaccounted for.

The efficiency of a boiler is totally dependent upon the relation of its grate area to its heating surface and upon the rate of combustion of the fuel. Under the same conditions of boiler and of fuel, the greater the quantity of fuel consumed per hour, the greater is the amount of water evaporated per hour, but, at the same time, the quantity of water evaporated per pound of coal deereases, because of the higher temperature of the escaping gases. This loss can be diminished only by increasing the heating surface either in the boiler or in a separate heater, while the decreased draft, due to the lowered temperature, can easily be made good if necessary, by mechanical means. It is to be carefully noted that all this relates to a condition of increased boiler capacity, resulting from a greater coal consumption. The desirable features to give the best results with low grades of fuel are : an ample draft and thick beds of fuel to produce high firebox temperatures, large ratio of heating to grate surface, so that while burning coal at a high rate of combustion there is sufficient heating surface to reduce the temperature of the escaping gases to 450° Fahr., or less if possible, and not come within the limit of the temperature of the water in the boiler, and a combustion chamber, if possible, to be provided, and separated as much as practicable from the heating surfaces, so as to avoid their cooling effect.

The relation between the area of the grate and the heating surface, which may be expressed as surface ratio, can be represented by the area of the heating surface as divided by the area of the grate surface. This relation usually varies in locomotive boilers from 30 to 100, and as compared with 60 in the proposed boiler.

Making use of the above basis for comparison, and noting the requirements which are necessary for efficiency and economy in the transforming of energy into useful work, it will be convincing that the features involved in the construction and operation of the proposed type of locomotive boiler will quite satisfactorily utilize to the best advantage the heat contained in the fuel supplied.

A summary of the advantageous features combined in this proposed locomotive, which will give practical results as compared with the present American type of locomotive are as follows: Increased initial steam pressure; reduced terminal and back pressure, clearance spaces, cylinder condensation and loss through radiation; superheating; cross-compounding; automatic and mechanical underfeed stoking; mechanical forced draft; all cylinder exhaust steam at least partially condensed, and the heat contained therein utilized for heating feed water; increased furnace fire area; increased efficient firebox, combustion flue, and boiler tube heating surface; increased draft area and less liability of becoming inefficient through choking; increased length of boiler tubes; increased travel and reduced terminal temperature of the furnace gases before release to the atmosphere; reduced amount of air for dilution; elimination of smokebox draft restrictions giving a free, natural and slow passage for the gases and more time for the heat to be transmitted to the water; practically perfect combustion; reduction of unconsumed fuel drawn from the furnace and exhausted through the stack or lost through the grates; proper depth of firebox from the crown sheet to the fire area and for the depth of the fire from the fire surface to the flues; increased width of furnace fire surface; a boiler economical to maintaid in good order and with freedom from water leaks; increased boiler, heat and water storage, and capacity; a storage for heated feed water; the utilization of turbine, water pump, air pump and other exhausts by condensation and heating of feed water; the use of water and condensed steam which is partially freed of mineral matter and heated to a high degree of temperature for boiler feed; the use of high-duty duplex pumps instead of injectors to feed hot water to the boiler; practically perfectly balanced piston and slide valves proportioned and adjusted to produce the most practical expansive use of steam; a reduced range of expansion in the cylinders, and a more uniform turning effort applied to the drivers will eliminate the tendency to slip; less liability of casualty on account of the location of the engineer where he can get an unobstructed view of the track and right-of-way on all sides and ahead, and a locomotive adapted to give the efficient and continual service required with no increase in cost for maintenance or despatching and a 50% reduced cost for operation.

Another decided advantage in the use of this locomotive will be its adaptability to service through tunnels and subways, as the usual objections to the present type on account of the smoke nuisance, also the gases and the noise from the exhausted steam, will be entirely eliminated.

The location of the coal space in relation to both the front and rear cabs, and its capacity to hold much more fuel than will at any time be required for any ordinary run, will promote cleaner quarters for the crew.

The large coal and water storages have not been designed as a necessity for the successful operation of the locomotive, but more as a surplus capacity in event it is required, owing to long haulage between coaling or water stations.

The larger water tank capacity will also permit of more opportunity to store heat in and facilitate maintaining a high temperature of the feed water.

Some of the disadvantages as compared with the present modern type of locomotive are: Separation of the engineer and fireman; restriction of the amount of room for passage from the rear of the boiler to the engineer's cab; more operating mechanism, and a greater first cost for the entire locomotive. However, as regards the separation of the engineer and fireman when they are at their individual locations for duty, an arrangement of speaking tube has been provided for between the two cabs, which will facilitate communication, as may be required, between them.

THE ECONOMY TO RESULT FROM THE GENERAL OPERATION AND MAINTENANCE.

A summary of the minimum economy which will result from the general operation and maintenance of the proposed type of locomotive as compared with a simple cylinder, modern American type of the same haulage capacity, may be estimated as follows :—

Considering first the operation, and presuming that for the engineer's and fireman's wages, fuel, water, sand, lubrication and supplies, the total cost for the operation per locomotive mile run will be 19.79 cents, distributed as follows: Engineer and fireman, 5.56 cents; fuel, 13.56 cents; water, .33 of a cent; sand and miscellaneous supplies, .09 of a cent. While the labor of the fireman will be considerably reduced as regards the firing of the boiler proper, and as the ability now required in that regard will not be so essential, his services will be given to more advantage in assisting the engineer in looking out for signals and in the operation of the other parts of the locomotive, and this cost for their wages will be considered as remaining constant, or 5.56 cents per mile run. Taking next the fuel cost as being 13.56 cents per locomotive mile run, this will be reduced proportionately as follows :—

Means to Effect Saving.	Effected per cent. saving on total cost.	Effected saving in cents.	Reduction in total cost for fuel per mile run.
By two-cylinder cross-compounding	15	2.03	11.53
By more perfect combustion, through automatic underfeed, stoking and mechanical forced draft	10	1.15	10.38
Heating of feed water with waste steam	10	1.04	9.34
Higher initial and lower terminal pressure	10	0.93	8.41
More thorough radiation and convection of heat, from the gases passing through the boiler, on account of the constructive features of the latter, and reduction of the terminal temperature of the gases	10	0.84	7.57
Superheating of the direct and low pressure cylinder initial steam in the combustion chamber, increasing the volume and eliminating cylinder condensation	5	0.38	7.19
Reduction of clearance, made possible by reduced terminal and back pressure, and compression.	5	0.36	6.83
By the feeding of the boiler with steam pumps instead of injectors	5	0.34	6.49
By other means, as follows: No loss of unconsumed fuel through the grates or stack; use of a cheaper and inferior grade of fuel; possibility to force the boiler to over its rating with less waste of fuel; less loss through hauling a dead weight of coal and water; by partial elimination of incrustation on the water side of the boiler sheets by the heating of feed water and the precipitation of the sediment into the tank; less steam to operate the air pump on account of the higher pressure and superheating; less radiation from the boiler and cylinder sheets, on account of thorough lagging	15	0.97	5.52

These figures show a reduction of 8.04 cents in the cost for fuel alone, or a decrease of almost 60%. To bear out that this statement is based on facts, and that such results can be easily obtained by the methods referred to, it is only necessary to cite one instance, which is that the present modern type of locomotives in freight service does not, as an average, evaporate more than 6 lbs. of water per pound of coal, and as a boiler which evaporates 7½ lbs. of water per each pound of combustible utilizes but 50% of the total heat, it is not an unreliable statement to say that a locomotive service giving 12 lbs. of evaporation should be looked to, and even this would still allow a loss of 15% in gases, or a terminal temperature of from 450° to 500° for escaping gases. However, the above statement considers the evaporative efficiency of the boiler alone, and