supply of air and the higher temperature at which the fires are worked. There is also a reduced liability for failure to steam on account of steam pipe joint leaks which may occur, and which destroy the steaming qualities of the present type of locomotive, but which will have no effect with the mechanical stoking and draft.

The boilers can be operated at considerably above the rated capacity with less wastefulness of fuel.

The fires can be banked at any time by discontinuing the blower, which operates the mechanical forced draft, and they can be steamed up quickly by starting the same. This, especially, is of advantage in connection with large grate areas, where the burning of a large amount of fuel on the grates at a time when it may not be needed, will result in considerable waste of fuel and water.

The draft and stoking being under the direct control of the engineer and fireman, the fire can be reduced or forced as desired, on account of station stops, going down or up grades, waiting at meeting points, etc. Much less air being required than with hand firing, the volume of the heated gases passing out of the stack is reduced, and which allows for more time for the absorption of the heat by the boiler surface.

By the introduction of a boiler with a sufficient amount of heating surface, the products of combustion can be cooled down, as nearly as possible, to the temperature of the water in the boiler, which is of especial advantage, considering that one of the very important factors in connection with steam boilers is the proper amount of air necessary for the complete combustion of the coal and the consequent loss of heat from the products of imperfect combustion.

The failures to steam on account of irregularities in the alignment of exhaust nozzles and smoke stacks, steam and air leaks in the smokebox, draft pipes, dead, baffle and deflector plates out of adjustment, and netting choked and inefficient, will also be entirely eliminated. As these causes contribute largely to steam failures and increased fuel consumption, the attachments which are responsible for the same being dispensed with, will be appreciated by all mechanics who have been concerned in the adjustment of exhaust nozzle and smokebox devices to give the proper draft and for the removal of the cinders to provide for the necessary steaming qualities, no matter what the results may be as regards fuel economy.

THE PRE-HEATING OF THE MECHANICAL FORCED DRAFT.

While no arrangement or construction has been shown in the design, or made mention of in connection with the other economical features for combustion and evaporative efficiency, the intention will be to provide a simple, economical and efficient means for pre-heating the forced draft, by the utilization of the heat from the escaping smokebox gases.

As these gases after leaving the boiler proper will still be of a higher temperature than the maximum pressure of the steam, and will contain from 450° to 550° Fahr. of temperature, this heat can and should be used to advantage in the pre-heating of the air before it enters the furnace, thereby securing a higher temperature and an increased evaporative efficiency.

The tendency of the colder air admitted to the furnace when rapid combustion takes place is to chill the fire, and through pre-heating, providing this can be done by the waste gases, the chemical affinities between the air and the fuel will be intensified, and just that much less heat wil be absorbed from the fire, and from doing useful work in the furnace, to bring the temperature of the air to its igniting point.

As to make use of pre-heated air to advantage, mechanical means must be resorted to, to overcome the increased resistance, the arrangement of mechanical forced draft will prove to be a decided benefit in connection therewith.

INCRUSTATION AND SEDIMENT IN LOCOMOTIVE BOILERS.

Water as found in nature always contains impurities, and nearly all natural water contains more or less mineral matter held in solution, as well as the organic and mineral matter held in suspension. While the latter may be removed by filtration or settling, the former can be removed only by the agency of heat. The amount of mineral matter held in suspension in ordinary water, as generally supplied from cities, and what is found in rivers, streams, canals, fresh water lakes, etc., varies from 10 to 40 grains per gallon of 231 cubic inches, while well and mine waters will contain more. In some instances water containing as much as 200 grains of mineral matter per gallon must be used for steam boilers, and the effect of incrustations or deposits which will accumulate from the use of such water in locomotive boilers is in every way detrimental, adding much to the expense for fuel and repairs, as well as increasing the risk for damage and the deterioration of the life of the boiler.

In boiler practice the exact composition of the water is of very marked importance, for, as stated, upon the impurities held in suspension or solution may depend not only the economy of operation, but the life of the boiler itself. Some of the more common impurities are as follows : Sediment, mud, clay, readily soluble salts, bicarbonates of lime, magnesia and iron, and sulphate of lime, all of which produce incrustation ; chloride or sulphate of magnesium, acid in mine water, dissolved carbonic acid, oxygen and organic matter which cause corrosion, and carbonate of soda in large amounts and organic matter from sewerage which cause priming.

Considering the substances that cause incrustation, the most reliable remedy to overcome this difficulty is filtration of the water or the precipitation of the foreign matter by chemical action before it is supplied to the tenders. If this cannot be done, the next best method is the heating of the feed water and the precipitation of a proportion, if not all, of the foreign matter before the water is fed to the boiler. As regards the balance of the incrustation and corroding and priming substances, with the exception of their precipitation or elimination by chemical action before reaching the boiler, the best remedy is subsequent blowing out and a thorough washing out with hot water under heavy pressure at periodical intervals.

Tests and practice have proven that fine, insoluble powders, such as calcium carbide or magnesia, when fed into boiling water, will cause foaming, while it has been the common practice to attribute this to alkaline water. From this we can conclude that it is the loosened scale matter in boilers that is mostly responsible for foaming, as, when the water contains a very large number of suspended particles, each serves to release the heat in its immediate vicinity. Steam bubbles are formed not merely at the heating surface, but in every part of the water, and the result is to increase the space occupied by the water to such an extent that priming may result. A sudden reduction of pressure outside of the boiler may carry over the water in any quantity, and water saturated with air or gas will boil with great disturbance. While animal matter put into a boiler will produce priming, under the ordinary conditions of service, priming is produced by suspended matter in the boiler, and without regard to the amount of alkaline salts. The foaming occasions loss of water and of heat, creates much danger in the boiler from the uncertainty as to the height of the water, and detracts from the power and efficiency of the engine.

Referring to the effect that incrustation on the sheets has on the cost for fuel, it is acknowledged by all authorities that an accumulation of dense, hard scale increases very materially the difficulty of heating water. Scale, whether hard or crystalline, or deposited soft and slushy, is a very poor conductor of heat, being relatively as to iron as 1 to 37, or $\frac{1}{32}$ in. of scale is almost equivalent to one inch of iron interposed between the heat of the fire and the water. Of the various estimates that have been made to determine as to the proportionate loss in fuel from dense, hard scale, the one most generally accepted is that $\frac{1}{16}$ in. of scale requires nine, $\frac{1}{8}$ in. seventeen, $\frac{1}{4}$ in. thirty-three, $\frac{1}{2}$ in. sixty-four $\frac{3}{4}$ in. ninety-one per cent. excess of heat to generate steam than what would be required if the boiler was clean.

As regards the repairs when a boiler has an accumulation of scale, the heating power between the fire and the water is reduced in proportion, readily increasing with each successive film on the iron, so that with a furnace or tube plate on which there might be an accumulation of scale or deposit $\frac{1}{2}$ in. thick, if it be necessary to impart over one-half more in the amount of heat to the iron, in order to produce the same temperature in the water, this excessive heating will result in defects to the plates, which will necessitate early detention of the boiler in the shop for repairs, if nothing worse.

A properly designed and well-constructed steam locomotive boiler, when of the capacity to perform the work required of it and intelligently cared for, should last in good condition from 20 to 30 years. In almost all cases, the depreciation of boilers is caused from the giving out of the fire sheets, and this trouble is almost entirely owing to deposits of sediment and scale which are composed of chlorides, carbonates and sulphates.

The proposed arrangement of the hot feed heating is such whereby the steam that is admitted will be in close proximity to the outlet of the hot feed to the pumps that will supply it to the boiler ; this will cause an evolution at this point of the water, which will agitate and keep in motion the currents of heated water in the hot feed supplies. The tendency will be for the sulphates and carbonates to settle at the farthest distance from the point of evolution, seeking the most quiet location, which will be at the mud basin connected with the tank cistern feed outlet, and from where the accumulation can be readily removed each time the boiler is washed.

This precipitation of this foreign matter into the tender, instead of into the boiler where it would come in contact with and probably be baked to the sheets exposed to the greatest heat, will overcome considerable of the formation of scale in the boiler and its consequent disadvantages.

HEATED FEED WATER.

The weight of one cubic foot of pure water at 32° Fahr. (freezing point) is 62.418 lbs., and a pound contains no heat units ; at 60° Fahr. it weighs 62.37 lbs. and contains 28.12 heat units, and at 212° Fahr. (boiling point) it weighs but 59.76 lbs. and contains 180.79 heat units. For general purposes the weight of water as taken in round numbers is 62.5 lbs. per cubic foot. Supposing that the specific heat of water at 32° temperature is considered as one, at 60° it is 1.0011 and at 212° it is 1.013. The pressure of water at 60° is .433 lbs. per square inch, and a pressure of one pound per square inch will be produced by a head of 2.309 ft.

The temperature of the water as delivered to locomotive tenders varies during the year on an average of from 50° to 60° Fahr. This temperature of the feed, if it can be raised by