

tube placed in the fire box for inserting the pyrometer should be located opposite the stay bolt drilled for the draft. This tube should be a piece of 2 in. boiler tube and located on the centre line of a stay bolt.

The gas sampling pipe should be located at the smallest area under the draft plate, and in the centre of this area. This pipe should have numerous drilled holes equally spaced and the total area of the holes should not be more than the inside area of the sampling pipe.

A steam calorimeter should be attached either at the dome at a point close to the throttle valve, or to the branch pipe according as it is desired to obtain the character of the steam at one point or the other. The former location is preferred. A perforated $\frac{1}{2}$ in. pipe should be used for sampling and conveying the steam to the calorimeter.

OPERATING CONDITIONS.—In a laboratory test where maximum efficiency is the object in view, there should be uniformity in such matters as steam pressure, quantity of coal supplied at each firing, thickness of fire and in other firing operations. The rate of supplying the feed water should be uniform through the entire test, and a certain level (about second gauge cock), should be maintained from start to finish of test.

THE DURATION of a laboratory test of a locomotive will depend on the character of the fuel used, rate of combustion and working limitations of the revolving parts. The test should preferably be continued until at least 25 lbs. equivalent evaporation of water per sq. ft. of heating surface has been obtained. If from the graphical log the coal and water performance are uniform, tests of 3 hours will be the limit.

STARTING AND STOPPING.—The fire having been thoroughly cleaned and banked when necessary to permit coking, previous to starting the test, the bank should be broken up and fresh fuel supplied. The locomotive should be started and run at the speed of the test a sufficient length of time to build up a level fire, and which should be, as near as possible, so maintained throughout the test. When all conditions of fire and speed have become uniform, the thickness of the fire should be noted, but the starting signal for the beginning of the test proper should not be given until the locomotive has been run at least 10 minutes. Observe the steam pressure and time and record the latter as the starting time of test. Water level should be maintained uniformly throughout the test. The ash pan should be cleaned at the starting signal. When the end of the test approaches, the fire having been kept at a uniform thickness during the run, the time and water level should be noted and test stopped. When the test is completed the ash pan should be cleaned and cinders, if any, should be removed from the smoke box.

RECORDS.—A log of the data should be entered on printed forms and records taken at 10 min. intervals, unless a special test is in progress, where the readings may be taken more frequently. The coal should be weighed out in not less than 300 lb. lots and the time taken for each lot burned. Weighing tanks of sufficient capacity should be provided to maintain water in the supply, varying in head not more than 6 ins., and readings of the water consumed should be plotted upon the graphical logs at convenient regular intervals. Indicator diagrams should be taken at the same periods the other data are taken.

A sufficient number of observers should be supplied in order that all important observations should be taken simultaneously. At a laboratory where 2 tests are made each day, the number of men required is as follows:—Foreman; assistant foreman; stenographer; chemist; 7 computers; brake

wheel operator; dynamometer observer; smoke observer; cab and coal observer; temperature and pressures; speed, boiler pressure, drafts and pyrometers; water observer; 2 indicator observers; gas sampler; 2 oilers; engine operator; 2 firemen; 3 draftsmen; and 3 coal passers and janitors; totaling 32 men. The force would have to be increased should a Mallet locomotive be tested. All observers, operators, oilers and firemen should assist in dismantling and fitting up laboratory when locomotives are changed.

THE ASH AND REFUSE withdrawn from the ash pan and smoke box at the end of the test should be weighed in a dry state, and if desired, sample taken for analysis of heating value and unburned carbon.

SAMPLING COAL.—If the coal to be tried is more than the amount necessary to make the test, it should be sampled according to the recommendations of the committee of the American Chemical Society governing carload sampling, which are as follows:—6 shovelfuls should be taken along each side and 6 across the centre of the car. If the car is to be unloaded into bins, a small amount of coal should be taken off the conveyor buckets or wagons while the entire car is being unloaded. In all events the sample should not be less than 300 lbs., and after it is crushed and quartered about one quart should be taken and placed in an air tight jar for chemical analysis. On all tests the total moisture should be used in the calculations.

CALORIFIC TESTS OF COAL.—The analyses commonly made are what are termed "proximate" analyses; these consist in the determination of the following items:—Fixed carbon, volatile matter, moisture hydroscopic, moisture total, ash and sulphur, and the B. t. u. per pound of fuel.

For complete determinations of the quality of coal, it is necessary to make ultimate analysis, which requires the determination of the following additional items:—Carbon, hydrogen, nitrogen and oxygen by difference.

THE DATA AND RESULTS of the laboratory test should be compiled in a tabular form as detailed in the report, 792 items in all being considered. These items are divided into the following general groups, with the number of items in each group accompanying:—Driving wheels, 25; engine truck wheels, 7; trailing wheels, 6; wheel base, 9; weight of locomotive, 17; cylinders, 12; piston stroke, 9; clearance in per cent. of piston displacement, 13; receiver volume, 7; steam ports, 29; piston rods, 9; tail rods, 9; valves, 9; valve travel, 9; valve steam lap, 13; valve exhaust lap, 13; miscellaneous, 7; boiler, 7; tubes, 12; superheater, 11; fire box, 10; fire doors, 7; grates, 9; air inlets, 11; heating surface, 11; boiler volumes, 7; exhaust nozzle, 11; reverse lever, 7; ratio, 11; constants, 14; piston displacement, 13; observed data, 6; speed, 9; position of levers, 6; temperatures, 14; pressures, 14; draft, 9; injectors, 4; quality of steam, 10; coal, sparks and ashes, 14; smoke, 6; analysis of coal, 9; calorific value, 8; analysis of smoke box gases, 10; water, 11; dynamometer, 8; cutoff, 15; release, 15; compression, 15; pressure from indicator cards, 15; steam chest pressures, 11; pressures at cutoff, 15; pressure at release, 15; pressure at compression, 15; least back pressure, 15; boiler, 7; evaporation, 12; equivalent evaporation, 29; summary of engine results, 15; receiver, 8; expansions, 10; i.h.p., 15; division of power, 12; per i.h.p. hour, 9; summary of locomotive results, 9; per 1,000,000 ft. lbs. at drawbar, 18; machine friction of locomotive, 8; efficiency, 7; ratios, 8; summarized statement of average results, 41.

Road Tests.

THE OBJECT of a road test is to determine the steam and coal consumption of a locomotive per unit of power under practical conditions of the locomotive in railway service.

ALL OF THE PREPARATIONS given in laboratory tests should be carried out preparatory to placing the locomotive in service, with the possible exception of not having all driving wheels newly turned, and equipping the locomotive with the various instruments that can be done while the locomotive is in the shops for repairs.

FUEL.—The same consideration should be given to the fuel as on a laboratory test. To facilitate the measurement of coal and the determination of the quantity used during any desired period of the run, it is desirable to provide a sufficient number of sacks, of a size holding 100 lbs., and to weigh the coal into these sacks preparatory to starting on the test.

THE APPARATUS AND INSTRUMENTS required for a road test of a locomotive are as follows: Platform scale for weighing coal. Crane, spring balance and bucket for weighing ash. Tank and scales for calibrating the tank. Graduated scale attached to water glass on boiler. Float for measuring height of water in tank, or, if preferred, graduated scales on all four corners of the tank. Pressure gauges graduated to pounds for boiler, branch pipe, receiver and exhaust. Draft gauges for smoke box, fire box and ash pan. Thermometers for calorimeter, branch pipe, receiver and exhaust. Pyrometers for fire box, smoke box, and at other points as required. Air pump counters. Water meters. Steam calorimeter. Steam cylinder indicators. Speed recorder for the revolutions for the driving wheels in case no dynamometer is accessible; on Mallet locomotives two recorders should be used. Some form of pendulum indicator rigging. Traction dynamometer for determining pull at drawbar, with its complete equipment. Electrical connection between locomotive and dynamometer. Planimeters, micro-meters, scales and calculating machines, etc. Steam used for auxiliary purpose other than the cylinders, such as air pump, calorimeter, injector overflow, train lighting and heating, and what escapes from the safety valves, may be estimated from data obtained by testing them either before or after the trial. The scales, gauges and pyrometers should be calibrated before and after the tests are made.

APPLICATION OF INSTRUMENTS. All of the instruments given under laboratory test should be carried on road tests as far as practicable, with a few exceptions. The indicator rig should be some form of pendulum motion with a light tube for transmitting the reduced motion to a point near the indicator. The apparatus which is most suitable consists of a three-way cock for the attachment of the indicator, with a steam chest connection, so that diagrams can be drawn on each cylinder card and pressure determined. The three-way cock should be provided with a clamp rigidly secured to the cylinder and thus overcome any tendency of the indicator to move longitudinally with reference to the driving rig. The support for the motion rod should be secured to some point on the steam chest. Care should be taken to set the indicators in such a position that the finger on the end of the motion rod travels in a direction pointing to a groove in the drum proper. The pipes leading from the cock to the cylinder should be not less than $\frac{1}{2}$ in. inside diameter, and if possible not exceeding 36 ins. long. They should be connected into the side of the cylinder, rather than into