From replies received and from the experience of members of your committee, there seems to be no doubt that an oil connection into steam passageway only, near entrance to steam chest, is the best arrangement for obtaining satisfactory lubrication. It reduces the number of feeds to a minimum and furnishes sufficient oil to valves and cylinders.

The allowance of valve oil per 100 miles for superheater locomotives varies according to type and service. The maximum allowance reported for Pacific type locomotives with fire-tube superheaters is 3.25 pints per 100 miles and the minimum 1.25 pints, the average allowance being 2.25 pints. For consolidation locomotives with fire-tube superheaters, the allowance of oil varies from 2.50 pints to 1.25 pints, the average being 1.75 pints per 100 miles. The average allowance of oil for Mikado locomotives with fire-tube superneaters is 4 pints and the allowance for Mallets is about 6 pints per 100 miles.

Answers indicate that the allowance of valve oil for superheated steam locomotives varies in about the same proportion as for saturated steam locomotives, according to type and service. It is customary to allow about 45% more oil for the fire-tube superheaters than for saturated steam locomotives, while locomotives with smoke-box superheaters usually have the same allowance of oil as saturated steam locomotives.

Twelve roads report using special superheater oil exclusively on superheater locomotives and 13 roads report using the ordinary grade of valve oil, but all the roads using superheater oil report it is more satisfactory, and tests which have been made of the two kinds of oil, on superheater locomotives, bear out this statement.

None of the roads report the admission of steam automatically to the cylinders when drifting, but 12 roads report good results from keeping the throttle slightly open when engine is drifting, and this practice seems to meet with most general approval.

Answers show that the use of vacuum valves on superheater locomotives is quite general on American railways, as 23 roads report their use gives satisfactory results and five report using by-pass valves.

There are a number of different makes of metallic piston-rod packing in use on superheater locomotives, all reported as giving satisfactory service. In general, the same types are used as on saturated steam locomotives, the principal difference, if any, being in the composition of the rings. The chemical composition of the rings is in most cases unknown to the railways, the rings being purchased in finished state from the manufacturers. Where reports are given, a mixture of 80% lead on 20% antimony has been used with several makes of packing. Some roads have tried a mixture containing a small percentage of tin, but this has been found unsatisfactory. A widely different mixture containing approximately one-half copper and one-half lead has given exceedingly good results, but is expensive. In general, the preferable composition for packing rings is still largely a matter of experiment.

The committee received a great many suggestions and much information that is embodied in the report. The replies were so general as to indicate that this is a very live subject, and the committee feels that a report based on replies from such a large number of railways may be considered as representing conditions prevailing on practically all the railways in the country.

SUMMARY.—An analysis of the replies indicates that the results obtained from superheater locomotives have been very satisfactory. It is interesting to note that five years ago there were less than a dozen superheater locomotives operating in the United States, whereas at the present time there are about 2,500 in the U.S. and Canada having fire-tube superheaters.

Minor difficulties have been experienced on a number of railways, but the great advantages to be derived from the use of superheated steam, such as increased economy of coal and water, increased power, due to the absence of cylinder condensation, the permissible reduction of steam pressure combined with the use of larger cylinders—all obtained without material increase in the size or weight of boiler—leads us to believe that the use of superheated steam in locomotives will increase rapidly. This being so, it is of great importance to determine the metal best suited for use for bushings and packing rings on modern superheater locomotives, because the use of highly superheated steam increases the difficulty of obtaining proper lubrication, and thus the metal is subjected to more severe working conditions than are usually found with saturated steam locomotives. It is also important that we know the best means of securing proper lubrication because the efficiency of lubrication has a direct bearing on the life of bushings and packing rings. A metal suitable for use as cylinder and steam-chest bushings of superheater locomotives should be homogeneous, close grained, tough and of good wearing quality, combined with sufficient strength. It should be tough in order to resist wear, but at the same time it must be of such composition that it can be readily machined.

Replies to the circular indicate that Hunt-Spiller gun iron has been used on many railways with excellent results. This is stated to be an air-furnace charcoal iron, and the process of manufacture, combined with proper chemical composition, seems to result in a metal which is well adapted for use with highly superheated steam. The analysis of this iron, obtained by your committee, is as follows:

Silicon	1.40	per cent.
Phosphorus	0.35	"
Sulphur	0.07	"
Manganese	0.49	"
Combined carbon	0.80	"
Graphite carbon	2.20	"

Replies indicate that this same iron has been used extensively for piston and valve packing rings on superheater locomotives with very satisfactory results and that an iron of this character is the best metal so far produced for piston and valve packing rings of superheater locomotives.

The importance of properly lubricating cylinders and steam chests of superheater locomotives, especially those using a high degree of superheat, can hardly be overestimated, because if proper lubrication is not obtained, many of the advantages derived from the use of superheated steam are offset by continual troubles from excessive cutting of bushings and packing rings, which keep the engine in the engine house when its proper place is on the road.

There seems to be a tendency to use too much oil in superheater locomotives, with the result that there is trouble from the oil carbonizing on the cylinder heads, pistons and steam passages. The deposit of carbon also tends to diminish the life of the metallic piston-rod packing, as it builds up in the stuffing boxes and under the vibrating cups to such an extent that the packing in a short time is forced to carry a part of the weight of the piston rod and piston head.

On certain classes of locomotives, possibly those having pistons exceeding 24-in. diameter, it is considered by some advisable to lubricate the cylinder independent of the steam chest, but in most cases we believe better results will be obtained by eliminating the connection to the cylinders and delivering the oil to the steam passageway.

We do not approve of the arrangement of oil pipes in which the oil is delivered near the end of the steam chest, as in this case it is probable that part of the oil is lost in the exhaust, due to the difference in pressure between the live and exhaust steam. A number of roads report that when superheater locomotives were received from the builders oil was delivered to both ends of the steam chest and to the centre of the top of the cylinder; but this arrangement has since been changed so that the oil is now delivered into the steam passageway above the entrance to the steam chest, and the feed to the cylinder has been discontinued. The allowance or oil has also been reduced and it has been found that the locomotives are much better lubricated than formerly and there is a marked diminution in the quantity of oil adhering to the cylinder heads, piston heads and steam passages.

There can be no doubt of the advisability of using a good grade of mineral oil having a high flash point, for locomotives using highly superheated steam, because the temperature of the superheated steam is sometimes as high as 600° F. A number of the roads state they have used valve oil having a flash point of about 520° and also special superheater oil having a flash point of at least 585°, and in every case better results have been obtained from the oil having the higher flash point.

Tests have shown that a moderately high temperature has very little effect on the lubricating properties of a good grade of valve oil when the oil is protected by steam, but when the engine is drifting there is, in most cases, no steam in the cylinders, and the bushings are apt to become hot. There does, however, appear to be a difference in the results obtained on superheater and saturated-steam locomotives. When drifting the conditions are the same on both, but on saturated-steam locomotives the oil deposit on the cylinders is fluid and the condition of the oil does not appear to have changed; while on superheater locomotives the deposit is gummy and sticky to the touch. This difference may possibly account to a large degree for the rapid wear of piston rings and bushings occasionally experienced on superheater locomotives.

When an engine is drifting a good deal with a closed throttle, there is a considerable vacuum in the cylinders and steam chests, and cinders may be drawn through the exhaust and dirt through the relief valves. This dirt may adhere to the gummy oil on the cylinder walls and convert them into a lap which will wear away the packing rings and piston heads very rapidly. This theory explains the good results obtained on locomotives where the drifting throttle has been carefully used and is supported by analyses of the deposit found on the cylinders, which show the presence of cinders and dirt in considerable quantities. The remedy is obviously to obtain a quality of oil that does not make a deposit of this nature at the temperature to which it is exposed, and to provide means either by ample vacuum or by-pass valves, or by the admission of steam to prevent over-heating when drifting.

Many roads use a tandem type of metallic packing on account of the importance of preventing the blowing out of the lubricating oil, which might result in the cutting of the cylinder bushings. During the past year or two, several alloys have been tried that have given satisfactory results, and while the preferable mixture will vary with the type of packing employed, this question is not now a serious one. It is important to use a type of piston-rod packing which will stand up under the high temperature met with in the use of super-