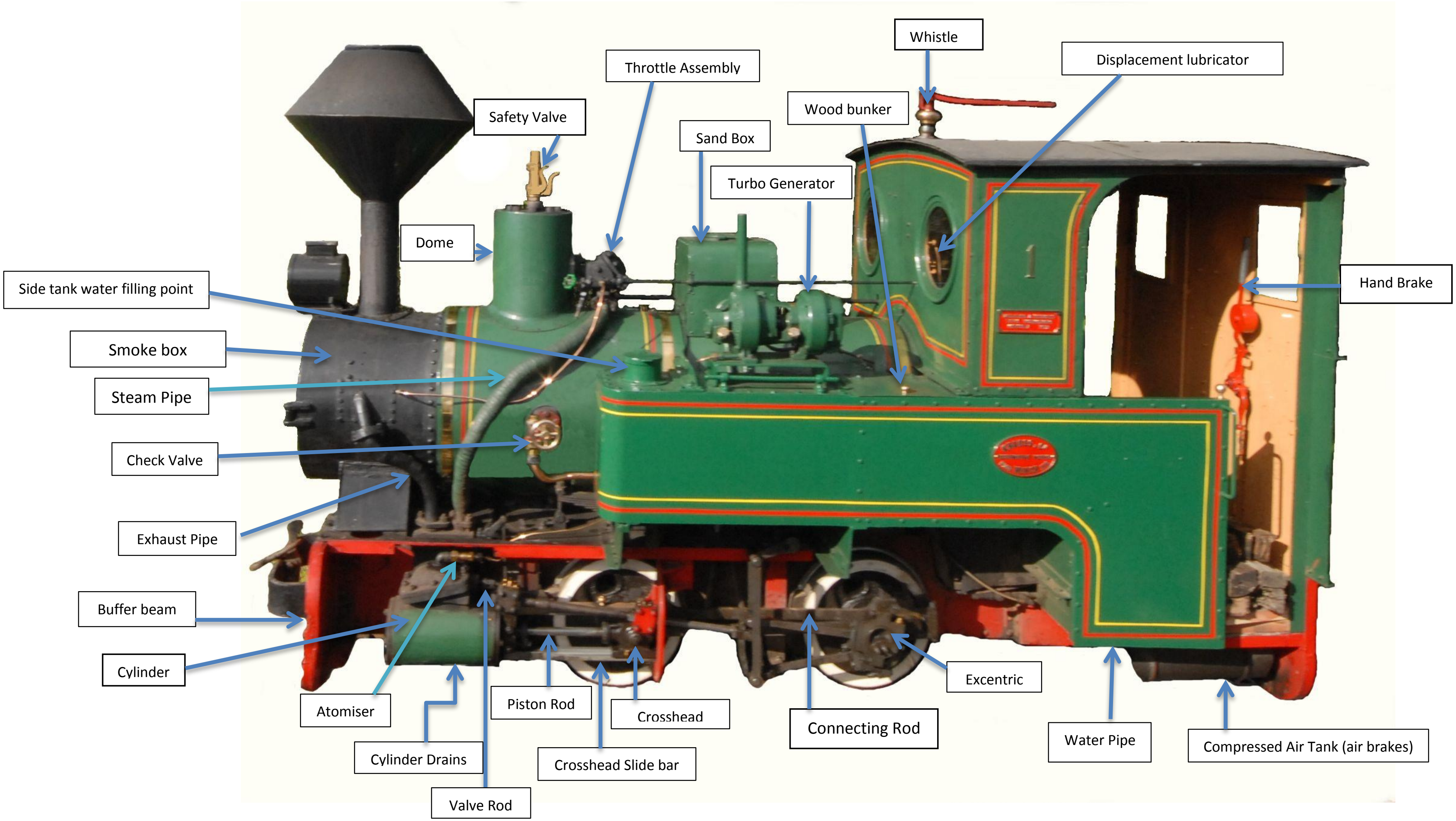
RWCSHS Krauss 0-4-0 Locomotive No 1



Valve and Cylinder Lubrication

Wet Steam

When steam leaves the boiler without superheat it will contain some free water upon reaching the engine throttle valve. Under average conditions wet steam generated at 200 pounds per sq. inch or less will contain 5 to 15 per cent suspended moisture when it reaches the engine throttle valve. When engines are located at some distance from the boilers, or when steam lines are not properly insulated, the moisture content will be correspondingly higher. Very Wet Steam In steam-engine operation the factors, which have the greatest influence on steam conditions are, steam pressure, load, cut off, cylinder size, piston speed and length of steam pipe.

When engines operate on partial load the effect of condensation on cylinder walls and valves is generally pronounced. Early cut off has a similar effect. For engines operating on wet steam and pressures below 150 pounds per sq. inch, a light cylinder oil of about 460 cSt @ 40°C viscosity should be used. Such lubricants will flow readily over the cylinder wall and valve surfaces, and if 5 per cent of compounding is incorporated in the cylinder oil it will provide a strong emulsion that will adhere to the wet surfaces and resist the washing action of moisture. Under the conditions outlined, 5 per cent of compounding will often cut the necessary oil-feed rate to 75% of that of a straight mineral oil.

Normally Wet Steam Steam engines operating continuously at full load and supplied with steam that does not contain more than 5 to 10 per cent of moisture at the throttle valve are seldom difficult to lubricate. Steam velocities are sufficiently high to atomise the oil thoroughly and condensation is not generally excessive. Generally, the cylinder oil should have an approximate viscosity of 680 cSt @ 40°C and 5 per cent of compounding for pressures below 200 pounds.

The higher the pressure, the heavier the oil and as a general rule, slightly less compounding is required to maintain a satisfactory emulsion on he cylinder walls. For example under normal conditions, steam generated at 200 pounds per sq. inch near the engine will not contain much moisture at the throttle valve. The pressure may show a slight drop, but the moisture content will probably be about 5 per cent. Hence, with ample steam velocity to break up the oil and a temperature of approximately 193°C (380°F) a cylinder oil having a viscosity of 680 cSt @ 40°C and 5 per cent of compounding would be a normal recommendation.

The addition of compounding will maintain a good emulsion by mixing with the moisture thereby increasing the tenacity of the oil film and retarding the washing-cut action. With efficient oil-extracting equipment he compounded oil may be taken out of the condensate without difficulty. Otherwise a straight mineral oil should be used. However the benefit of this latter practice is often doubtful because the oil-feed rate must be increased to secure satisfactory lubrication.

Superheat Steam

To explain engine cylinder lubrication under conditions of superheated steam it is helpful to draw conclusions of other types of engines. By following this procedure, factors, which are often difficult to understand in engines operating on superheat steam, can be logically assumed through these comparisons. For example, in the cylinders of any internal-combustion engine, over-all temperatures of the burning and expanding gases are much higher than in steam engines.

In Diesel engines the maximum temperature of combustion is approximately 2000°C, which is sufficient to vaporize and destroy the heaviest oil made, while that of the exhaust is approximately 850°C just before the opening of the valve or port. Yet there is very little difficulty in lubricating the cylinders of average internal-combustion engines with comparatively light oils. In fact, engines of this type never require lubricants comparable in viscosity to steam cylinder oils.

In the cylinders of most gasoline and diesel engines, the lubricating oil is spread over a water-cooled surface. Hence, an oil film of microscopic thickness survives these high temperatures, because it is maintained in a comparatively cool surface. Experiments show that the average surface temperature on the cylinder walls of internal-combustion engines is about 200°C. Even this temperature is comparatively cool because the lubricating oil is being replenished with each stroke piston.

Now consider the steam engines. Steam Cylinder Wall Temperatures Operation of a steam engine cylinder is opposite to that of an internal-combustion engine. Instead of the cylinder walls being cooled, they are insulated against heat losses to reduce condensation and are very often equipped with steam jackets to maintain the highest possible operating temperature on the internal surfaces. Hence, steam cylinder walls are maintained at higher operating temperatures than the walls of internal-combustion engines. For wet-steam operation, these temperatures can be handled with comparative ease by oils of the type known collectively as 'light and medium-viscosity cylinder stocks'.

For example, when the steam pressure at the throttle valve is 250 psi, the steam temperature will be about 210°C (405°F) and an average cylinder wall temperature under these conditions will be about 176°C (350°F) depending on the type of insulation around the cylinder. This range is well within the working temperature range of cylinder stocks. Significance of Viscosity and Flash Point Nature has placed a limit on the temperatures that the heaviest-bodied cylinder oils can withstand. At temperatures above 315°C (600°F) the heaviest steam cylinder oils will commence to "crack and give off volatile vapours but a good average-grade (680 cSt @ 40°C) oil will give off very little vapour.

Nevertheless, at these temperatures, the flash point has been reached or passed for most cylinder stocks. There are cylinder stocks of very heavy body which have flash points higher than 370°C (700°F), but their carbon-forming tendencies are correspondingly high, and for this reason their use for high-superheat conditions is not considered. For use with superheat steam the cylinder oil should have a flash point of not less than 240°C (464°F) for the lighter grades and not below 280°C (536°F) for the heavier grades. However, flash points are only a theoretical guide to the possible behaviour of oil films on hot cylinder walls.

These oil films are only about 25 microns (1/1000 of an mm) in thickness and in that position are extremely vulnerable to disintegration from heat. Furthermore, at high temperatures the heaviest cylinder oils tend to fry up into little spheres. Furthermore, all lubricating oils tend to approach a common viscosity as the temperature rises. For example, when a cylinder oil of medium viscosity is heated to 230°C (450°F) it is not much thinner than heavy cylinder oil at the same temperature. The oil entering a steam is hot before it reaches the internal moving parts because it travels slowly, drop by drop, through the feed line. Upon reaching the hot cylinder, or steam pipe, it is thinned down to an appreciable extent. If the oil travels through a steam jacket before reaching the cylinder, the thinning effect is more pronounced. From this it will be seen that the property of steam cylinder oil is very much changed after leaving the lubricator.

The oil film on a cylinder wall is a light-bodied, tenacious fluid, quite different from its viscous and original state in the drum. Cylinder oils having viscosities above 1000 cSt @ 40°C are not widely available, and their performance data are therefore limited. Most engines operating on superheated steam are lubricated by heavy oils. However, with high-temperature steam, the most important consideration is to provide a sufficient number of oil feeds around the cylinder and thereby maintain the oil film with a small feed of comparatively cool oil at each point Effect of High Temperatures on Compounded Cylinder Oils Whenever moisture is present in engine cylinders, compounding will materially improve lubrication.

These materials combine with moisture to form a tenacious emulsion, and this effect cuts down the rate of feed that would otherwise be required. Owing to the washing effect of moisture, straight mineral oils are easily washed out of cylinders and a higher rate of feed is required to maintain the oil film. However, little or no compounding is generally advisable when the original temperature of the steam is raised more than 38°C (100°F) by means of a superheater. Emulsifying materials of this type tend to increase the rate of the deposit formations at prolonged temperatures above 260°C (500°F). For intermittent operation, early cut off, long steam pipe priming and similar operating factors, a small amount of compounding is sometimes advantageous to produce an emulsion with the resulting moisture.

For example, when hot steam strikes the comparatively cool steam chest and cylinder walls of an engine that is continually starting and stopping, there is always sufficient condensation to warrant adding 5 per cent of compounding, regardless of superheat conditions. Steam that contains 10° to 38°C (50° to 100°F) of superheat should not present a problem in lubrication because a temperature drop occurs between the boiler and engine throttle valve.

Upon expanding a short distance in the high-pressure cylinder, the steam will become wet and the average cylinder wall temperature will not be excessive, even if steam jacketed. Hence, 5 per cent of compounding will usually be found permissible and positively advantageous. High Superheat and Its Effect on Lubrication The real problem begins when there is more than 38°C (100°F) of superheat in the steam. For example, with a boiler pressure of 250 pounds per sq. inch the steam temperature will be 20°C (405°F) if the superheater adds 93°C (200°F), total steam temperature is 318°C (605°F). At temperatures above 315°C (600°F) it should now be obvious that an oil film of microscopic thickness must tend to roll up into little spheres, distil, oxidize rapidly and produce carbon deposits.

Contrary to general belief, there appears to be no particular advantage in using the heaviest oils obtainable. Such oils contain a high percentage of carbon-forming material and tend to defeat their purpose for this reason. It is therefore our opinion that high-temperature steam is often not practical for reciprocating engines. With steam temperatures much above 287°C (550°F) the oil film is far too thin and weak to prevent excessive wear. Furthermore, carbon accumulations necessitate frequent shutdowns for cleaning and any theoretical advantage that may be gained in fuel economy is more than offset by expensive maintenance costs.

For single-cylinder engines, the added temperature should not be more than l0°C (50°F) at the throttle valve if the total steam temperature approaches 260°C (50°F). For multi-cylinder or compounded engines, the added temperature should not be more than 38°C (100°F) at the throttle valve if the total steam temperature approaches 260°C (500°F). This amount of superheat assures the engine of dry steam at the high-pressure valves and at least reduces a lubrication problem, which cannot be solved with any degree of satisfaction. In fact 37°C (100°F) of superheat may be considered high if the total steam temperature is above 260°C (550°F). Auxiliary Steam Engines Where steam is available, one often finds small steam engines to drive such equipment as condensate return pumps, vacuum pumps etc.

These are often neglected because of their small power consumption, low cost and ease of maintenance. These engines are often the source of high oil consumption and this must be taken into consideration when setting feed rates. In addition to the waste of oil, these feeds may be the source of excessive oil in the condensate return to the boilers. Oil in Boilers There is no definite agreement on the safe limit of cylinder oil which may be continually present in a boiler, for the reason that such factors as design, steaming conditions, effect of boiler compounds and similar variables enter into the question. However, the following approximate safe limits are based on a cross-section of conservative opinions by boiler manufacturers, oil extractor manufacturers, feed water treatment chemists and independent investigators. In water-tube boilers equipped with superheaters the oil content should be maintained at less than 5 parts of oil per million parts of water.

Selection of Oil for Steam Engines

The object of internal lubrication in a steam engine is to form a lubricating film between the rubbing surfaces and thus replace the metallic with fluid friction as far as possible and to form an oil-sealing film in order to prevent leakage of steam past the valves, pistons and gland packings. Only by feeding the correct grade of high-quality cylinder oil, specially selected to suit the operating conditions of the engine, applied in the correct manner, to the right place and in the right quantity, will the steam engine continue to operate at its highest efficiency and with the minimum cost of renewals and repairs

Good lubrication is therefore dependent chiefly on the methods of lubrication employed and the selection of the correct oil for each individual case. If too much oil is used lubrication under saturated-steam conditions will not be any better than when the right quantity of oil is used; whereas under superheated-steam conditions, the excess oil is detrimental, leading to the formation of carbonaceous deposits. If too little oil is used, a satisfactory oil film will not be maintained between the frictional surfaces, so that not only will heavy friction and wear occur but also excessive steam leakage. There are a few vertical engines employing saturated steam which can be operated without the use of cylinder oil and without groaning. Non-lubrication will, however, mean excessive friction and excessive leakage of steam past the moving surfaces, which will cost many times that of good lubrication. If an oil too heavy in viscosity is used it will not atomize readily, resulting in poor distribution and necessitating excessive consumption.

Because of its heavy body, the fluid frictional losses will be higher than they need to be and if the steam carries over impurities to the engine which are the results of priming, the use of such an oil will encourage the accumulation of deposits, particularly under conditions of high pressure and superheat. If an oil is too light in viscosity is used, it will readily atomize and distribute itself, but it will not be able to withstand the pressure between the rubbing surfaces; metallic contact will take place, resulting in excessive wear; also, excessive leakage of steam will occur, owing to the rubbing surfaces' not being completely oil sealed. With the right-quality oil in use, correctly selected for the conditions and applied in the right quantity, a satisfactory lubricating film will be maintained on all the internal surfaces: This film will be maintained with a lower consumption of oil than wit any other grade of oil.

Therefore the cost of lubrication will be low, and the frictional losses, because of the fluid friction of the oil itself as welt as the leakage of steam past the moving surfaces, will be reduced to the minimum. For conditions of high pressure and superheat, the use of the right-quality cylinder oil will also mean that, rightly applied and in the right quantity, the danger of the formation of carbonaceous deposits will be minimized and the possibility of excessive wear much reduced. Influence of Pressure - High steam pressure means high temperature, so that, generally speaking, heavy-viscosity oils are used for high steam pressures and low-viscosity oils for low steam pressures (low-pressure cylinders in particular).

Influence of Size, Speed and Construction - the weight of a piston increases very nearly as the cube of its diameter, but its bearing surface more as the square, so that large pistons in horizontal engines, when they are not supported by a tail rod, require very heavy-viscosity oils. Smaller pistons, other things being equal, will be best served with lower viscosity oils. High piston speed, which is found in the later engines, particularly superheated-steam engines, demands lower viscosity oils, so as to minimize the oil drag on pistons.

Influence of Superheat Steam - when steam of moderate superheat is used it will enter the high-pressure cylinder in a dry condition; but during the expansion of the steam in the cylinder it will cool, and, toward the end of the stroke, condensation will occur. In the case of highly superheated steam, it is of the greatest importance that the oil should be thoroughly atomized in the body of the steam. There is no condensation, therefore no washing effect on the cylinder walls.

The oil remains a long time in the high-pressure cylinder; exposed to friction and heat; while, therefore, only a small quantity of oil is required, it should be of such a nature that it will withstand the heat without appreciable decomposition and resultant formation of carbon. As regards compounding superheat cylinder oils, we would recommend a small percentage; say 4 to 6 per cent of compounding additive for most conditions of superheat, as the fixed oil improves lubrication appreciably.

The oil becomes very thin owing to the high temperature, and the fixed oil improves the oiliness of a straight mineral oil; its presence if therefore nearly always desirable. No ill effects, as far as we are aware, have ever been known to be caused by decomposition (formation of tarry acid) of such a small percentage of fixed oil. On the contrary, it will tend to prevent carbonized matter from baking together and forming hard crusts, in this way making the nature of such deposits less dangerous.

Influence of Wet Steam - where the steam is wet it has a tendency to wash away the oil film on the internal surfaces. In compound or triple-expansion engines, even if the steam is dry on entering the high-pressure cylinder, the fail in pressure and expansion taking place produces condensation, so that the steam arriving at the low-pressure cylinder usually is very wet. It is obvious that the problem of lubricating the high-pressure cylinder under dry-steam conditions is different from lubricating the high-pressure cylinder under wet-steam conditions or from lubricating the low-pressure cylinders under very wet-steam conditions.

In order to lubricate cylinders satisfactorily under wet-steam conditions, the cylinder oil must readily combine with the moisture and cling to the cylinder walls; i.e., it must be a compounded cylinder oil. It is therefore frequently desirable to use one grade of cylinder oil for the high- pressure cylinder and a different grade (lower viscosity) for the low-pressure cylinder in large compound or triple-expansion engines. Influence of Engine Load - the greater the engine load the greater the volume of steam passing through the steam pipe into the engine; and the higher its velocity the better it will be able to break up the cylinder oil introduced through the atomizer.

As superheated steam does not atomize and distribute the oil so well as does saturated steam, engines employing superheated steam and likely to operate under light load conditions should have means for lubricating the internal parts direct in addition to introducing the oil where it can be atomized. Light load also means that the steam expands more in the high-pressure cylinder, so that at the end of the piston stroke the steam is much more moist (more condensation) than under full-load conditions.

Wet steam calls for compounded cylinder oil, so that, speaking generally light-load conditions demand compounded oils of low viscosity. Influence of Impurities in the Steam - it has already been mentioned how iron oxides, boiler salts etc., have the effect of combining with the oil and forming deposits. The higher the viscosity of the oil the more difficult will it be to avoid such deposits, as such oils cling tenaciously to the impurities. Low-viscosity oils are therefore to be preferred, where a great deal of impurities enter with the steam; this is particularly the case under conditions of superheat.

As the presence of impurities in the steam usually means that priming of the boilers is responsible, in the first instance, the steam will be wet, so that oils heavily compounded are, as a rule, called for. Influence of Exhaust Steam - as mentioned elsewhere, under certain conditions it is desirable to extract the oil from the exhaust steam and to eliminate, as far as possible, the danger arising from it getting back into the boiler. All compounded cylinder oils are difficult to separate from the exhaust steam and from the feed water. All straight mineral oils are fairly easy to extract; just a trace of the oil goes into a fine emulsion. This separates easily from the feed-water and the oil can be recovered and used on less important work. The feed water will be practically free from emulsified oil.