

9.	MEASUREMENT CAPABILITY	12
10.	COMPARISON MATRIX.....	14

LIST OF FIGURES

FIGURE 1 - EXAMPLE OF AN AUTOMATED DRAIN AND WEIGH SYSTEM	6
FIGURE 2 - OIL LEVEL MEASUREMENT SYSTEMS.....	6
FIGURE 3 - GRAVITY FED OIL CONSUMPTION MEASUREMENT TECHNIQUE.....	7
FIGURE 4 - EXAMPLE OF A DIRECT LEVEL MEASUREMENT SYSTEM USING A PRESSURE SENSOR.....	8
FIGURE 5 - OIL PUMP METHOD FOR MEASURING OIL CONSUMPTION.....	9
FIGURE 6 - EXAMPLE OF MONITORING THE COEFFICIENT OF VARIANCE DURING AN OIL CONSUMPTION TEST	13

1. SCOPE

This document describes the major techniques for measuring oil consumption. It does not cover all the sub variations that might be used to make this measurement.

1.1 Purpose

The oil consumption of an internal combustion engine is a significant performance attribute. The loss of engine oil through the combustion chamber is critical because it impacts the emissions signature of the engine and potentially poisons any exhaust gas after treatment devices. Also the level of oil consumption is an important quality perception to the customer. The engine should not have to require any add oil between oil changes. While developing new engines or solving oil consumption problems on existing engines, it is important to be able to measure the oil consumption of an engine and have confidence in that measurement. The purpose of this document is to review the different measurement methods, outlining their fundamental operating principles, their advantages, and their disadvantages. There is no attempt to identify the best measurement method because the best method will depend on the situation, the objectives, and on capabilities of the organization.

2. REFERENCES

There are no referenced publications specified herein.

3. DEFINITIONS

There are no unique definitions.

4. BASIC METHODS OF MEASUREMENT

Oil consumption measurement methods can be divided into a few major categories. All of the current measurement methods can be listed under each of these categories.

4.1 Oil Lost Methods

With this technique, the amount of oil is recorded at the beginning of the test. At defined measurement times, the amount of oil lost is determined and recorded as the oil consumed.

Oil lost methods include:

- Dip Stick Method
- Weep Hole Method
- Drain and Weigh Method
- Calibrated Loss Method

4.2 Constant Level Methods

In these methods, the system is set up to maintain a constant oil level in the oil pan. The oil rate addition to the engine to maintain a constant oil level is a measurement of the oil consumption.

Constant level methods include:

- Common Level Systems
- Direct Level Systems
- Oil Pump System

4.3 Oil Tracer Methods

Oil tracer techniques utilize tracer elements in the oil that can be measured in the exhaust when the oil is consumed.

Oil tracer methods include:

- Radiometric tracing
- Elemental tracing
- Emissions measurements

4.4 Indirect Measurement Methods

Indirect methods for measuring oil consumption include:

- Emissions are often a primary concern which drives the need for low oil consumption. Therefore, oil control can be evaluated indirectly through emissions measurements.
- Plugging of the exhaust filters can also be an indication of how much oil the engine is consuming.
- Poisoning of the catalyst is also affected by the oil consumed.

5. OIL LOST MEASUREMENT METHODS

5.1 Dip Stick Method or Level-Top-Up-Method

This is the simplest method of all, but probably the least accurate. This method consists of filling the engine with oil to a specified level on the dipstick. The engine is run, during which time oil is consumed. The engine is shut down and allowed to cool. It is important to specify and control the cool down period. The level is again measured with the dipstick. A measured amount of oil is added to bring the oil level back up to the initial level. The amount of oil added is considered to be the amount of oil consumed.

Notes

- Before establishing the initial oil level for this type of test, the engine should be run first to fill the filters and passages with oil. Otherwise there will be a false first oil consumption measurement reading.
- Internal drain back of oil within the engine to the sump can significantly affect this measurement. Drain back time and position of the engine crank may affect this.
- The installation angle of the engine may affect how the oil drains within the engine.
- Oil level measurements should be made at consistent oil sump temperatures.
- A calibrated dipstick with inscribed marks can help improve accuracy of this method.

Advantages

- The dip stick method is very simple.
- No extra equipment is needed to measure oil consumption.
- This type of measurement can be made on field test engines. However, to get accurate data, a precise and consistent oil fill procedure must be followed.

Disadvantages

- The dip stick method takes a long test time to get acceptable results. The accuracy will be improved with longer test duration and multiple measurements.
- The results are not very accurate nor repeatable. They depend on how well the oil level can be determined on the dipstick and the accuracy in adding oil.
- Inconsistent drain back of oil in the engine can cause erroneous results.
- Inconsistent oil sump temperatures may result in errors.
- Oil leaks from the engine will be measured as oil consumption unless external leakage is quantified and subtracted from gross consumption.
- The system is very operator dependent.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- Extended duration of operation required to get a reading makes it difficult to study break-in effects.

5.2 Weep Hole Method

The weep hole method for measuring oil consumption is very simple in concept but offers the potential to be a little more accurate than the dip stick method. However, it uses the same principle as the dip stick method. A hole is drilled into the oil pan at a specified level in the oil pan. This should correspond to some location between the high and low marks on the dip stick. The hole is opened and oil is added until it starts to leak out of the weep hole. All of the excessive oil is allowed to leak out of the weep hole. The hole is again closed. The engine is run at the desired conditions and any oil added during the test is recorded. At the end of the test, oil is added so that the oil level in the pan slightly exceeds the weep hole level. The amount of oil added is recorded. The weep hole is opened and all of the oil that leaks out is captured, measured, and recorded. The oil consumption is the sum of the oil added during the test plus the difference of the oil added at the end of the test minus the amount of oil that leaks out of the hole at the end of the test.”

Notes

- Before establishing the initial oil level for this type of test, the engine should be run first to fill the filters and passages with oil. Otherwise there will be a false first oil consumption measurement reading.
- Internal drain back of oil within the engine to the sump can significantly affect this measurement. Drain back time and position of the engine crank may affect this.
- Drain time from the engine can also affect this measurement.
- The installation angle of the engine may affect how the oil drains within the engine.
- Oil measurements should be made at consistent oil sump temperatures.

Advantages

- The system is very simple.
- The method of determining the oil level is more accurate than the dipstick method.
- The results should be more accurate than the dipstick method.
- This is not as operator dependent as the dipstick method. However is still affected by drain back and temperature.

Disadvantages

- The system takes a long test time to get accurate results. The accuracy will be improved with longer test duration. However the time duration may be less than the time required by the dip stick method.
- Inconsistent drain back of oil in the engine can cause erroneous results.
- Inconsistent oil sump temperatures may result in errors.
- Oil leaks from the engine will be measured as oil consumption unless external leakage is quantified and subtracted from gross consumption.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- Extended duration of operation required to get a reading makes it difficult to study break-in effects.

5.3 Drain and Weigh System

The drain and weigh system has been used as a relatively simple system to determine oil consumption. A known amount of oil is added to the engine, and the engine is run for a specified length of time. The oil in the engine must be drained precisely and consistently from the engine and weighed. The difference in oil weight before and after test is the amount of oil consumed.

Notes

- Before establishing the initial oil weight for this type of test, the engine should be run first to fill the filters and passages with oil. Otherwise there will be a false first oil consumption measurement reading.
- Internal drain back of oil within the engine to the sump can significantly affect this measurement. Drain back time and position of the engine crank may affect this.
- Drain temperature and time when removing the oil from the engine can affect the measurement.
- If multiple measurements are made, be very careful not to spill the oil.
- The installation angle of the engine may affect how the oil drains within the engine and as it is drained out of the engine.

Advantages

- The system is very simple and inexpensive.

Disadvantages

- The system takes a long test time to get accurate results.
- The results are dependent on how consistently the oil drains from the engine.
- Oil leaks from the engine will be measured as oil consumption.
- This method is susceptible to the operator spilling oil which will give erroneous measurements.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- Extended duration of operation required to get a reading makes it difficult to study break-in effects.

Some of the disadvantages described above are being eliminated by automatic drain and weigh systems. For example, a system can be designed to pump the oil from the oil sump into a measurement tank. This can be done from the oil drain plug or the dipstick. This will reduce the time for the "drain". Also, the full sump does not need to be pumped out which might increase the accuracy of the measurement. By having a hard wired pump to the engine, the chances of operator spillage is less. It might be possible to do this during engine operation which might minimize the internal drain back variability.

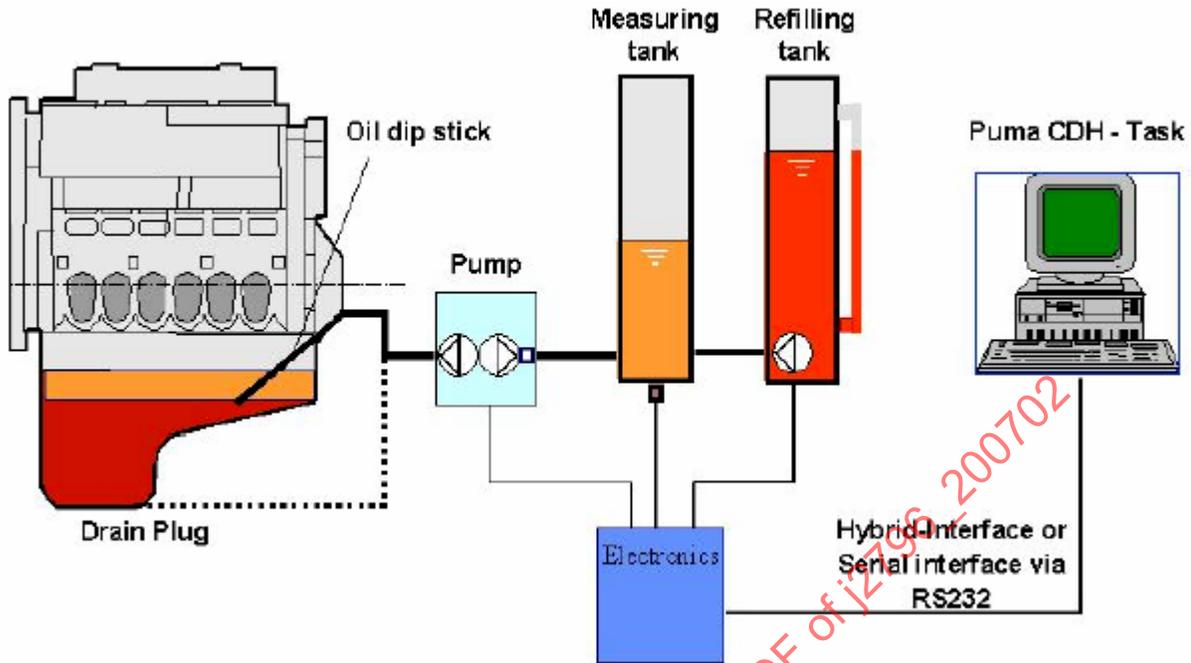


FIGURE 1 - EXAMPLE OF AN AUTOMATED DRAIN AND WEIGH SYSTEM

5.4 Calibrated Loss Measurement

The amount of oil lost can be calibrated to the oil level in the oil pan. Therefore oil is put in the engine in increments. The oil level is recorded with the corresponding amount of oil in the oil pan. Therefore, when the oil level decreases due to oil consumption, the amount of oil lost can be directly related to the oil level in the oil pan. In one common application, a capacitance sensor is proposed to determine the oil level. However other techniques may be used to measure the oil level such as pressure sensors in the oil pan or other oil height measurement systems. See Figure 2.

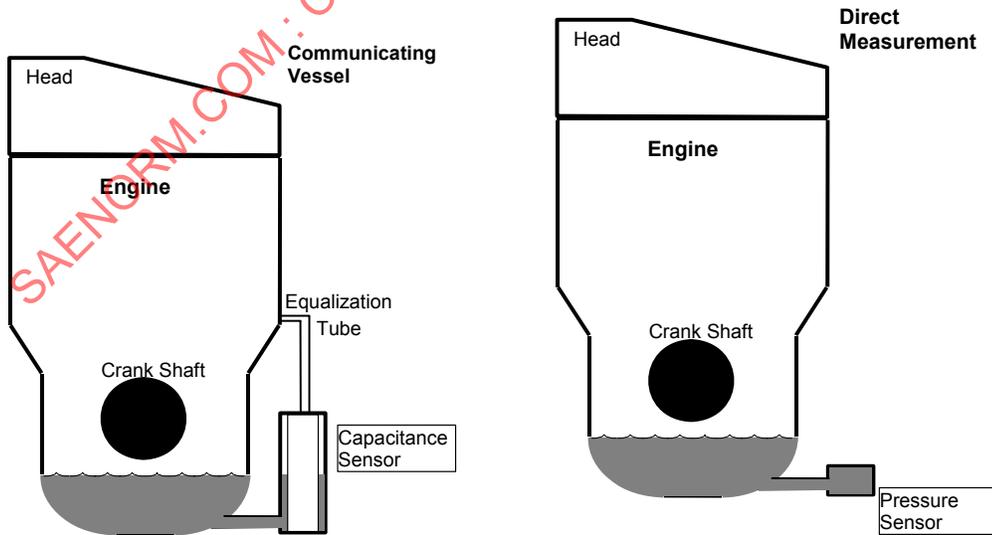


FIGURE 2 - OIL LEVEL MEASUREMENT SYSTEMS

Notes

- Oil sump temperatures can significantly affect this type of measurement. Measurements should be made at consistent oil sump temperatures.

Advantages

- The system is simple in concept.

Disadvantages

- The accuracy of the method is subject to calibration accuracy.
- The method is subject to variations in oil level due to inconsistent oil drain-back within the engine.
- Fuel and coolant dilution in the oil will influence the measured level of oil consumption.

6. CONSTANT LEVEL MEASUREMENT METHODS

6.1 Common Level System

In the common level system, the oil levels in the engine and the oil measurement device are the same. This is accomplished by having a tube that connects the oil measurement device to the oil pan of the engine that allows oil to move back and forth between the engine and the measurement device. The equalization or vent tube maintains the same pressure above the oil in both the engine and the oil cart. A schematic diagram of this device is shown in Figure 1. As the engine consumes oil, the oil level will drop. The oil level should drop in both the engine and the oil vessel at the same rate. When the oil level decreases, the measurement device detects the change in level, and initiates a flow of oil back into the engine to replenish and bring the oil level back to the original level. The amount of oil that put back into the engine is recorded as the oil consumed. In Figure 3, the figure at the left determines the amount of oil added by the change in weight of the weigh tank. The figure on the right illustrates the use of a capacitance sensor for measuring oil level with a capacitance probe. This can be configured so that when the oil level goes down in the engine, an oil supply tube feeds oil into the engine to bring the level back up to the appropriate level.

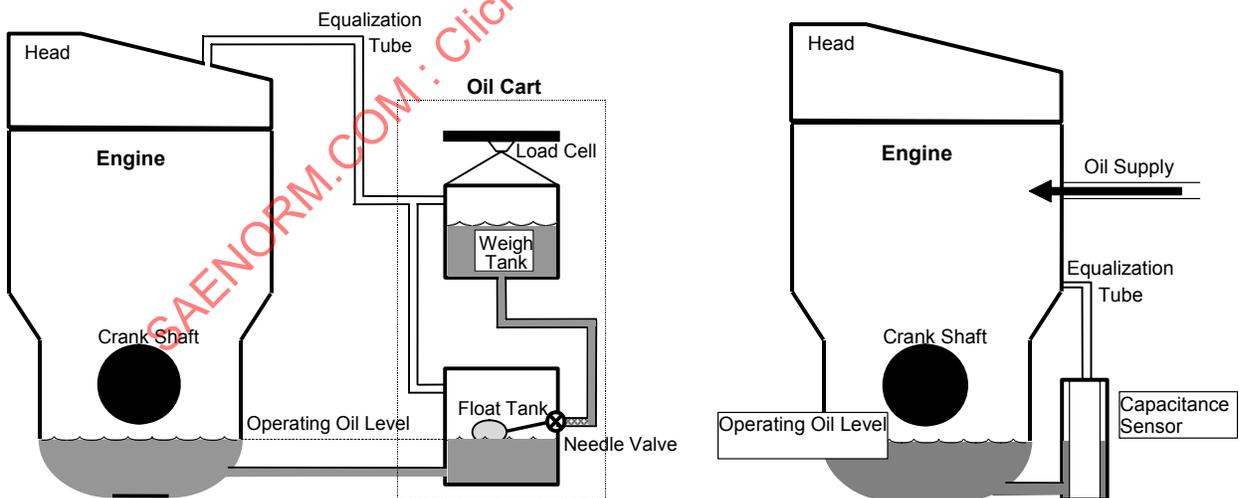


FIGURE 3 - GRAVITY FED OIL CONSUMPTION MEASUREMENT TECHNIQUE

Notes

- Setting the operating level is critical for this measurement system.
- The level in a running engine is not the same as the level of oil when the engine is stopped.
- Proper pressure balance between the engine and measurement devices is very important.
- The lines connecting the engine and measurement device must be free of blockages. On the oil lines there should not be any air bubble or other blockages. On the air equalization side there should not be any blockages due to oil or other factors.
- Oil drain back within the engine may vary even under steady state operating conditions. This will affect the results.

Advantages

- The system is relatively simple in concept.
- The system is not expensive.
- The system is commercially available.

Disadvantages

- If not set up properly the system can give erroneous results. This can come from improper setting of the oil operating level and improper equalization connections.
- The set up of the system appears to be simple. However, it is very operator dependent, because in setting up the system if the operator does not pay close attention to the details, the system will provide inaccurate data.
- Errors can result when measuring oil consumption from a cyclic engine that because the operating oil level in the engine changes with speed and load.
- Oil leaks from the engine will be measured as oil consumption.
- The system can take a long time to stabilize which negates measuring oil consumption during break in of the engine.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- Extended duration of operation required to get a reading makes it difficult to study break-in effects.
- Temperature differential between oil in the sump and the float tank may influence results. Variation in cell temperature can influence results even under engine steady state conditions.

6.2 Direct Level System

In the direct level system, the oil level in the oil pan is measured directly. This may be accomplished by various techniques. One technique that has been used is a pressure sensor attached to the oil pan. The pressure measurement is a direct measurement of oil level.

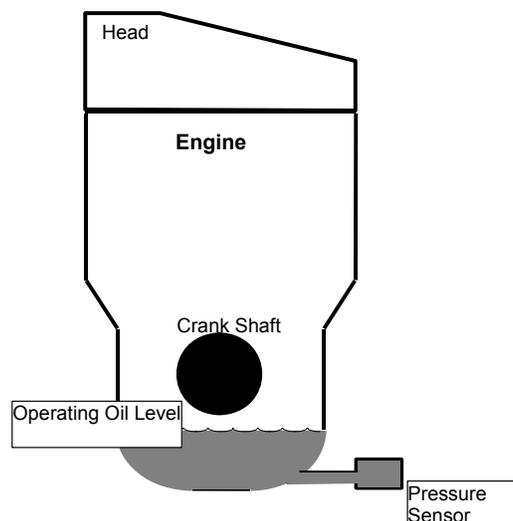


FIGURE 4 - EXAMPLE OF A DIRECT LEVEL MEASUREMENT SYSTEM USING A PRESSURE SENSOR

Notes

- The operating condition at which the oil level sensor works needs to be determined and must be consistent.

Advantages

- The difficulties of maintaining constant oil levels between the engine and a vessel are avoided.

Disadvantages

- Errors can result when measuring oil consumption from an engine that has changing speeds and loads, because the operating oil level in the engine changes with speed and load.
- Oil leaks from the engine will be measured as oil consumption.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- Temperature variations in the test cell may affect the oil level measurement.

6.3 Oil Pump System

The oil pump method for measuring oil consumption has been used by some companies and a schematic diagram is shown in Figure 3. An oil drain tube is connected to the engine at a specified position on the oil pan. This tube will drain into a "vessel for used oil". Oil is then pumped from the vessel back into the engine. The system is designed to maintain the oil level at the oil drain tube location because oil is being constantly circulated between the oil cart and the engine. When the oil level drops below a certain amount in the "vessel for used oil", fresh oil is added from the tank above it. The total weight of the two tanks is constantly measured. The overall decrease in the weight of the two tanks is equivalent to the oil consumption.

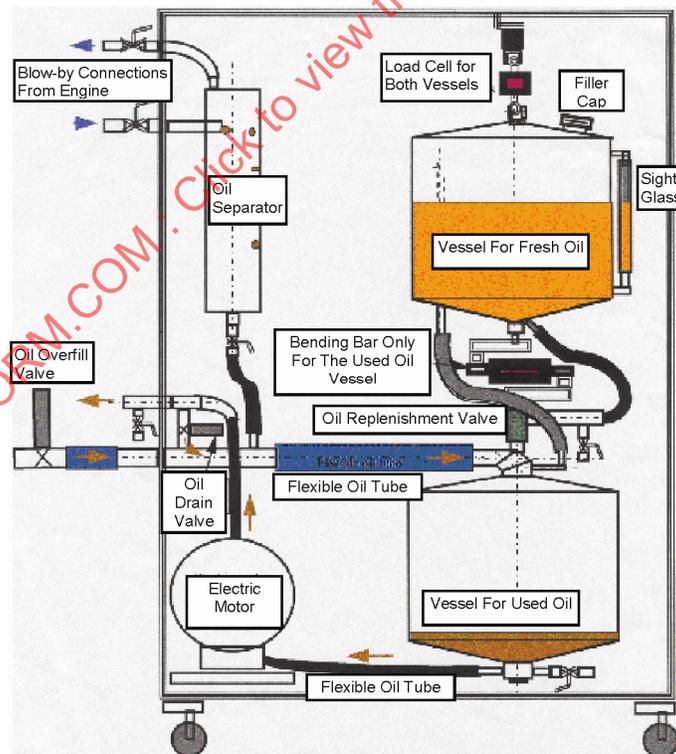


FIGURE 5 - OIL PUMP METHOD FOR MEASURING OIL CONSUMPTION

Notes

- Proper pressure balance between the engine and measurement devices is important.
- The lines connecting the engine and measurement device must be free of blockages. On the oil lines there should not be any air bubble or other blockages. On the air equalization side there should not be any blockages due to oil or other factors.

Advantages

- The oil level is fixed by the oil drain tube. This makes setup easier.
- Pressure balances between the engine and the system is not as critical as the other systems.

Disadvantages

- This is a relatively complex system.
- An oil consumption measurement during cyclic engine operation is not possible.
- The overall system is large in size.
- Oil leaks from the engine will be measured as oil consumption.
- Fuel or coolant dilution in the oil will influence the measured level of oil consumption.
- There is no ability to isolate the source of oil consumption.
- Extended duration of operation required to get a reading makes it difficult to study break-in effects.
- Complex design with more potential leak points.

7. TRACING METHODS

There are various types of tracer systems that have been used, but the most common tracing systems are based on sulfur and tritium tracers. Regardless of the tracer, the basic principles are the same. Oil with a tracer (e.g. sulfur and tritium) is used in the engine. A fuel is used that does not contain the tracer (e.g. no sulfur in the fuel). It is assumed that the oil that is consumed will exit the engine through the exhaust system. In the exhaust gas stream, the tracer is detected. The concentration amount of the tracer measured in the exhaust gas is an indication of how much oil is consumed.

These systems are often called "real time oil consumption systems", because they have the capability to measure oil consumption in such short time periods. However, radiometric tracer systems will generally take a longer period of time than the elemental methods.

TABLE 1 - COMPARISON BETWEEN TRACER SYSTEMS

Feature	Bromine	Tritium	Sulphur
Type of Tracer	Radioactive	Radioactive	Elemental
Radiation Emitter	Gamma	Beta	NA
Half Life	Hours	Years	N/A

7.1 Radiometric Tracing

Radiometric tracers such as Tritium and Bromine are detected in the exhaust gases by the radioactivity in the exhaust stream. Each tracer will utilize a different detection system.

Notes

- The appropriate radioactive licenses need to be obtained
- The appropriate handling and disposal of radioactive materials needs to be followed.

Advantages

- The system is moderately fast depending on the detection system. A measurement can be taken within an hour.
- Good for mapping the speed and load effects of the engine on oil consumption.
- Ability to measure cylinder to cylinder or bank to bank within the same engine.
- Oil leaks are not counted as part of the oil consumption.
- Fuel dilution affects oil consumption only via oil viscosity effect.
- If the various oil systems can be separated within the engine, it is possible to determine the contribution of each. For example if the lubricating oil in the head can be separated from the block then it will be possible to put the tracer in each system separately and determine their contribution.
- Good for mapping the speed and load effects of the engine on oil consumption.

Disadvantages

- The mechanical systems are very complicated.
- There are radioactive material regulations that must be followed.
- The calculation of oil consumption is complicated.
- The system requires special oil with the radioactive tracer.
- Very accurate measurement of air flow is required.
- Instantaneous transient effects cannot be measured. However, the average effect over the measurement time (approximately 1 hour) can be measured.
- Appropriate isolation, handling, and disposal of the radiated parts after test must be done.
- If an engine fails catastrophically, then the radioactive debris might become a radiation hazard needing appropriate attention.

7.2 Elemental Tracing

When an element is used as a trace for oil consumption, specialized equipment must be used to detect that element. Also, an element must be chosen that will be proportionately consumed with the oil as the oil is consumed. In some cases, when the oil is consumed it can leave elements behind in the combustion chamber. Therefore, the assessment of the oil consumed will be affected.

Notes

- The tracer element must be appropriately blended in the oil such that when oil is consumed, the tracer will leave with the oil in a proportional amount.
- A fuel without the tracer element must be used.

Advantages

- The system is very fast. Results can be obtained within minutes.
- Good for mapping the speed and load effects of the engine on oil consumption.
- Instantaneous transient oil consumption measurements are possible.
- Ability to measure cylinder to cylinder or bank to bank within the same engine.
- Oil leaks are not counted as part of the oil consumption.
- Fuel dilution affects oil consumption only via oil viscosity effect.
- If the various oil systems can be separated within the engine, it is possible to determine the contribution of each. For example if the lubricating oil in the head can be separated from the block then it will be possible to put the tracer in each system separately and determine their contribution.