SURFACE VEHICLE INFORMATION REPORT

J2796™ APR2023

Issued 2007-02
Revised 2018-07
Reaffirmed 2023-04

Superseding J2796 JUL2018

(R) Power Cylinder Oil Consumption: Methods of Measurements

RATIONALE

The oil consumption is an important performance metric for an internal combustion engine. Since it is considered to be important, it can only be improved if it can be measured. This is the function of this document to describe the various methods used to measure oil consumption. It does not highlight the best method for measuring oil consumption, but only describes the various methods which can be utilized depending on the accuracy required and capability of the engine development organization.

SAE J2796 has been reaffirmed to comply with the SAE Five-Year Review policy.

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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 additional 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. It should be noted that oil consumption can be derived from a number of contributing engine systems. The salient areas are: power cylinder system (piston, rings, cylinder bore), valve guides (intake and exhaust), turbocharger bearing seals and crankcase ventilation system, oil leaks, etc. Most oil consumption methods can not differentiate between the contributors. There are methods to determine and quantify the contribution that is made by the different engine systems, but their description is beyond the scope and purpose of this document. The purpose of this document is to review the different measurement methods, and outline 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 the 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 four major categories. All of the current measurement methods can be listed under each of these categories. Each category is summarized in this section and then the details of each method will be developed in subsequent sections.

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 that was consumed.

Oil lost methods include:

- Dipstick 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 during engine operation. The oil rate addition to the engine to maintain a constant oil level is a measurement of the oil consumption.

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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 Dipstick 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 drain back while the engine cools. It is important to specify and control the drain back within the engine 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. When adding the oil, the oil should be added in small increments to avoid gross overfilling. The amount of oil added is considered to be the amount of oil consumed.

5.1.1 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.

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5.1.2 Advantages

- The dipstick 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.
- Average oil consumption can be measured over the duration of cyclic or steady state running conditions.

5.1.3 Disadvantages

- The dipstick 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 neither 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. Inconsistent oil level readings on the dipstick will give inaccurate results.
- 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.
- Oil consumption cannot be measured as a function of transient engine operation.
- There is no ability to isolate the source of oil consumption.

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 dipstick 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 dipstick. The weep hole is opened, and oil is added until it starts to leak out of the weep hole. The hole is then closed. The engine is now ready for testing. From this point on, any oil that is added must be measured and recorded. Run the engine on the oil consumption duty cycle or some other appropriate engine operating condition.

At the end of test, the engine needs to cool down and allow all of the oil to drain back into the pan. Remove the weep hole plug. Add oil until oil starts to come out the weep hole. The oil should be added in small increments to avoid gross overfilling. Measure the amount of oil added at the end of test. The oil consumed is the amount of oil added during the test and the amount of oil added at the end of test.

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5.2.1 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 in a test call or the vehicle attitude while parked for a measurement may affect how the oil drains within the engine.
- Oil measurements should be made at consistent oil sump temperatures.

5.2.2 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, it is still affected by drain back and temperature.

5.2.3 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 that the time required by the dipstick 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.
- There is no ability to isolate the source of oil consumption.

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5.3 Drain and Weigh System

The drain and weigh system has been used as a relatively simple system to determine oil consumption. The engine is filled with a predetermined amount of oil. The engine is run a short period of time, then the oil is drained from the engine and weighed. After weighing, it is put back in the engine and the engine is run at the selected desired condition to evaluate oil consumption. Any oil added during the test is recorded. At the end of the test, the oil is drained from the engine and weighed again. The difference in oil weight before and after test, plus the amount of oil added, is the amount of oil consumed.

5.3.1 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 in a test call or the vehicle attitude while parked for a measurement may affect how the oil drains within the engine and as it is drained out of the engine.

5.3.2 Advantages

- The system is very simple and inexpensive.

5.3.3 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.
- There is no ability to isolate the source of oil consumption.

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; however, the oil level that is left in the sump must be consistent. By having a hard-wired pump attached 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.

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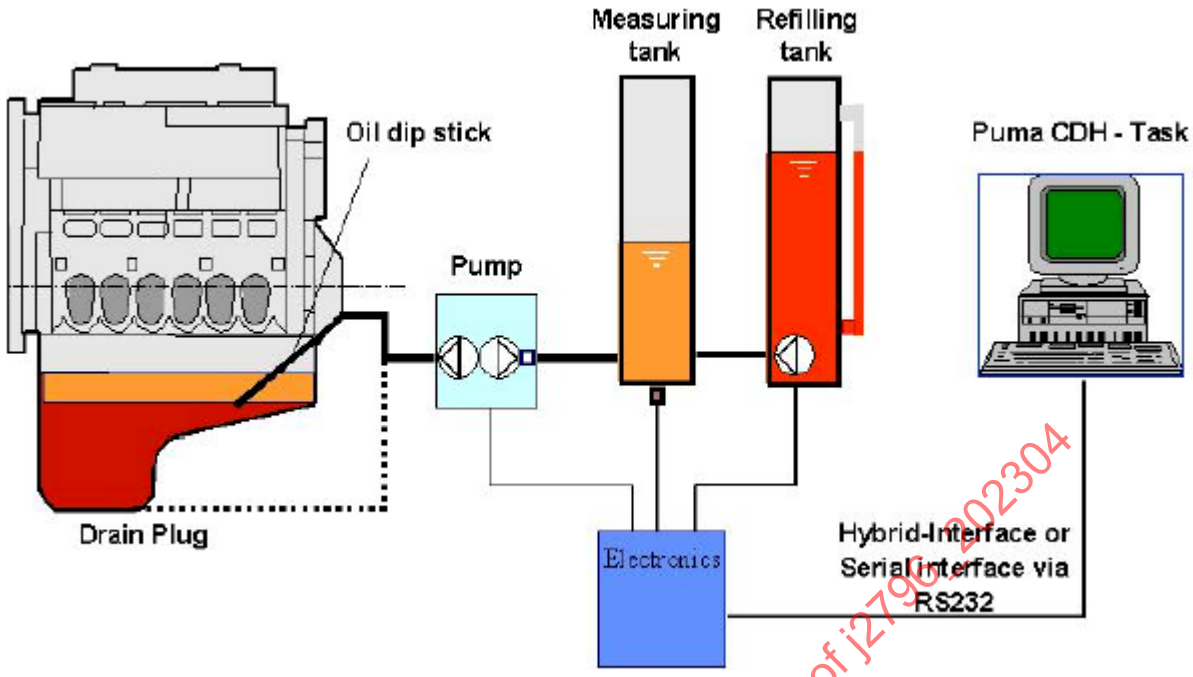

Figure 1 - Example of an automated drain and weigh system

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 type of method, 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.

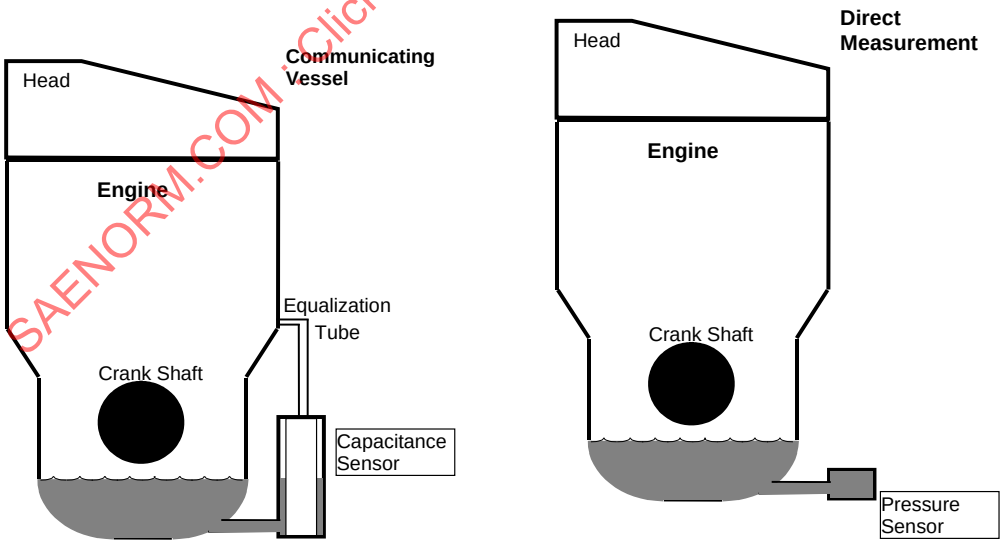

Figure 2 - Oil level measurement systems

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5.4.1 Notes

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

5.4.2 Advantages

- The system is simple in concept.

5.4.3 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.
- There is no ability to isolate the source 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 is put back into the engine is recorded as the oil consumed. Figure 3A determines the amount of oil added by the change in weight of the weigh tank. Figure 3B 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.

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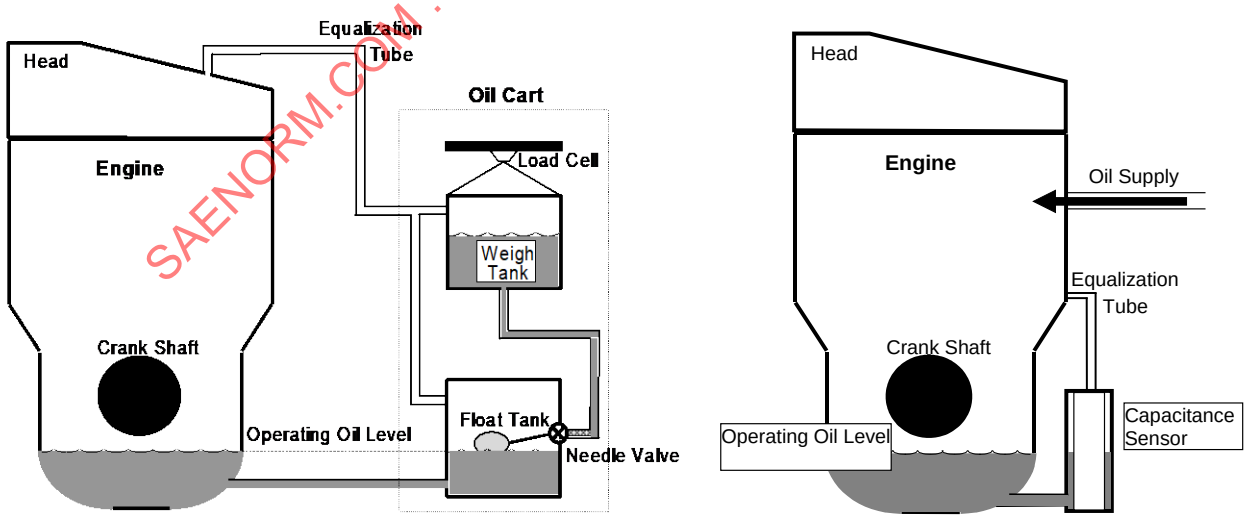

Figure 3A *Figure 3B*

Figure 3 – Gravity-fed oil consumption measurement technique

6.1.1 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.

6.1.2 Advantages

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

6.1.3 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, 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.
- There is no ability to isolate the source of oil consumption.

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.

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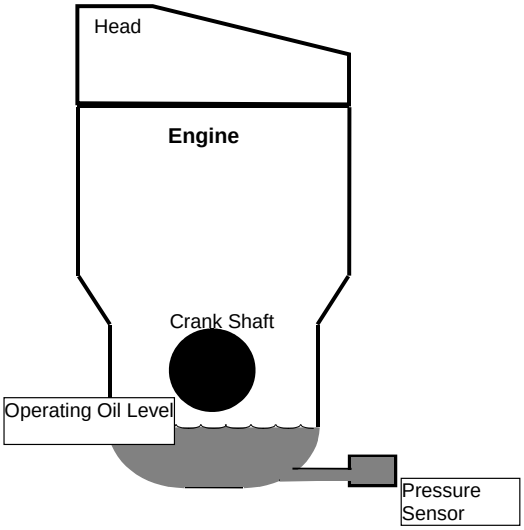

Figure 4 - Example of a direct-level measurement system using a pressure sensor

6.2.1 Notes

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

6.2.2 Advantages

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

6.2.3 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.
- There is no ability to isolate the source of oil consumption.

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 5. 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.

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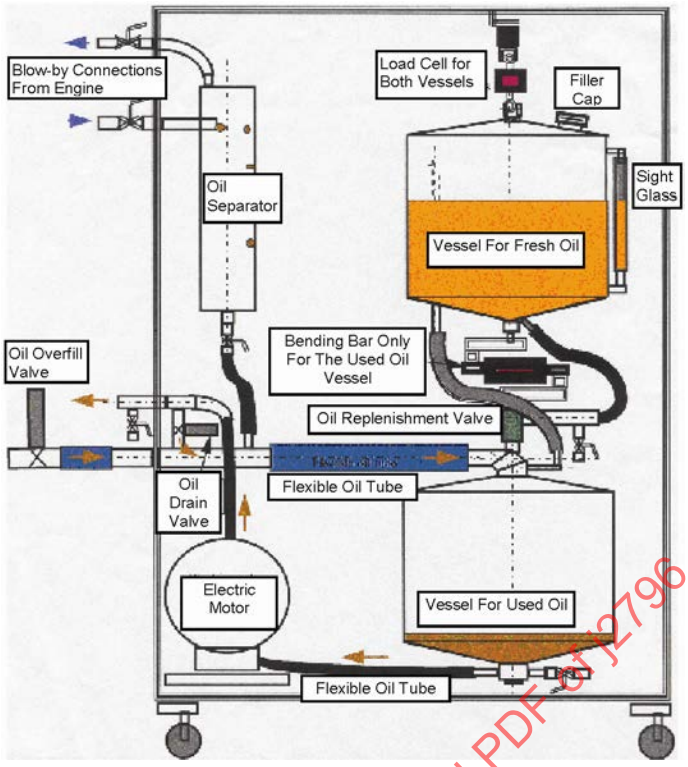

Figure 5 - Oil pump method for measuring oil consumption

6.3.1 Notes

- Proper pressure balance between the engine and measurement devices is important.
- The lines connecting the engine and measurement devise 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.

6.3.2 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.

6.3.3 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.

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- Complex design with more potential leak points.
- There is no ability to isolate the source of oil consumption.

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.

7.1.1 Notes

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

7.1.2 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.

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