DETERMINATION OF CLOSED SYSTEM VOLUME

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by

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REASONS

A reasonably accurate estimate of the volume of a closed system is required for the following reasons:

1. The determination of the source(s) of air ingression.
2. The determination of the amount of glycol addition.
3. The determination of the amount of inhibitor addition.

METHODS

The following methods may be used to determine the volume of a closed system:

1. Mathematical calculation.
2. Direct measurement.
3. Rule of thumb estimate.
4. Tracer addition.

Mathematical Calculation of System Volume

The mathematical method of estimating the volume of a closed system involves the field measurement of the larger pieces of equipment in the system and the use of established mathematical formulae, such as the following formula for the volume of a cylinder:

$$V = 0.0785 \times d^2 \times l \qquad (1)$$

where,

V : volume of cylinder, litres

d : diameter of cylinder, cm

l : length of cylinder, m

As one may expect, this method is very tedious and time consuming for large systems, but it is simple and straight forward for small systems.

Direct Method of System Volume Determination

The direct method of determining the system volume involves the use of the water meter in the fresh water make-up line to the system.

The system is drained completely, the initial make-up water meter reading is recorded, the system is filled to its operating level, and the final make-up water meter reading is recorded. The system volume is simply the difference between the two meter readings.

This method is an accurate method of determining the system volume, provided that the system is completely drained initially. However, its disadvantage lies in the fact that the system must be drained, thus exposing the wetted surfaces to oxygen and causing corrosion.

Rule of Thumb Estimate of System Volume

The rule of thumb method of estimating the volume of a closed system involves the use of proportional relationships between the capacities of certain key pieces of equipment in the system and the total volume of the system.

That is, for closed hot water heating systems that are heated by a hot water boiler, the **estimated** total volume of the system is determined by multiplying the boiler horsepower by 10. For example, for a 50 hp boiler, the **estimated** total system volume would be 50 X 10 = 500 USG.

Similarly, for chilled/hot water systems that are cooled/heated by a heat exchanger, the **estimated** total system volume is determined by multiplying the circulating pump capacity by 3. For example, for a circulating pump capacity of 150 USG/min, the **estimated** total system volume would be 150 X 3 = 450 USG.

Although the estimated volume is determined very quickly with this method, it should be considered to be only a "ball-park" estimate.

Tracer Addition Method of System Volume Determination

The tracer addition method of determining the system volume involves the addition of a measured quantity of unreactive foreign material to the system, determining the tracer material concentration by chemical analysis, and calculating the system volume by a mathematical formula.

The most common tracer material in use to-day is lithium chloride. It is very soluble, it does not chemically react with other elements in the system water, its concentration is reasonably easy to accurately measure, and it is readily available.

A detailed procedure is presented overleaf, but generally, the system volume is estimated, a calculated amount of lithium chloride is added to the system, the lithium concentration in the system is determined by chemical analysis, and the volume of the system is calculated.

This method of system volume determination is easy to implement, and it is accurate.

Procedure for System Volume Determination by Tracer Method

1. Obtain a water sample of the system and determine the lithium concentration initially in the system by chemical analysis;
2. Determine the estimated volume of the system by the mathematical or rule of thumb methods described previously;
3. Determine the amount of lithium chloride addition as follows:

   $$W = 15.27 \times V_1/P \qquad (2)$$

   where,

   W : calculated weight of lithium chloride, grams

   V_1 : estimated volume of system, litres

   P : purity of lithium chloride, %
4. Add the calculated weight of lithium chloride, or a known amount close to the calculated weight, to the system;
5. After 2-5 days of system circulation, obtain a sample of the system water and determine its lithium concentration by chemical analysis;
6. Determine the system volume as follows:

   $$V_2 = 1.637 \times P \times W/(C_2 - C_1) \qquad (3)$$

   where,

   V_2 : calculated volume of system, litres

   P : purity of lithium chloride, %

   W : weight of lithium chloride added, grams

   C_2 : final lithium concentration, mg/l;

   C_1 : initial lithium concentration, mg/l.

APPLICATIONS

Source(s) of Air Ingression

In order to reduce air ingression into a closed system, a positive pressure of at least 5 psig is maintained at the top of the system by air addition to the expansion tank. The required pressure is calculated as follows:

$$P = (H \times 0.4335) + 5 \qquad (4)$$

where,

P : static pressure at the circulating pump, psig

H : head of water to top of system, feet

OR,

$$PM = (HM \times 9.805) + 34.47 \qquad (5)$$

where,

PM: static pressure at the circulating pump, kPag

HM: head of water to top of system, meters

The quantity of make-up water for a closed system should average less than 0.1% of the system volume per day. That is, for a 1000 gallon system, the water make-up rate should be less than 30 gallons per month. This equates to a sodium sulphite consumption of approximately 10 ml per month per 1000 gallons of water in the system. If the sodium consumption is considerably higher than this amount, there is excessive air ingression into the system.

The tracer method of system volume determination may be used to determine the source of this air ingression.

That is, if the difference between the lithium chloride concentrations on two successive tests after it is added to the system is large, the air ingression is caused by excessive water loss from the system, and the volume of this water loss can be calculated. Alternately, if the difference between the lithium chloride concentrations on two successive tests after it is added to the system is small, the air ingression is caused by low system static pressure, faulty valve & pump seals, faulty automatic air vents, etc.

Amount of Glycol Addition

The amount of glycol addition required may be determined by the following formula after the volume of the system is determined:

$$G = V \times (100/P) \times (CD - CP)/(100 - CP) \qquad (6)$$

where,

G: volume of glycol to be drained & added, litres

V: volume of system, litres

P: purity of fresh glycol, vol%

CD: desired glycol concentration, vol%

CP: present glycol concentration, vol%

Amount of Inhibitor Addition to Glycol System

If the RA (100%) value is less than 9.0 in an ethylene glycol system, the following equation may be used to calculate the first estimate for the amount of inhibitor required to increase the inhibitor concentration:

$$I = 1.75 \times V/100$$

where,

I: volume of proprietary inhibitor, litres

V: system volume, litres

Similarly, if the RA (100%) value is less than 9.8 in a propylene glycol system, the specific gravity, system volume, and phosphate concentration are required in order to determine the correct amount of food grade dipotassium phosphate to add to the system.