Calibration and Maintenance Procedures for Coal Mine Respirable Dust Samplers

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CALIBRATION AND MAINTENANCE PROCEDURES FOR COAL MINE RESPIRABLE DUST SAMPLERS

by

Thomas F. Tomb[1] and Paul S. Parobeck[2]

ABSTRACT

The Federal Mine Safety and Health Act of 1977 requires that the average concentration of respirable coal mine dust be measured with a device approved by the Secretary of Labor and the Secretary of Health and Human Services. Title 30, Code of Federal Regulations, Parts 70, 71 and 90 specify that approved sampling devices be calibrated at a flow rate of 2.0 liters per minute or at a different flow rate as prescribed by the Secretary of Labor and the Secretary of Health and Human Services for the particular device. This informational report describes the standard procedures used by the Mine Safety and Health Administration (MSHA) for calibration of currently approved personal samplers and associated equipment and for maintenance of this equipment.

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INTRODUCTION

There are four samplers currently approved by the Secretary of Labor and the Secretary of Health and Human Services for measuring concentrations of respirable dust in underground and surface coal mine environments. They are the MSA Model G Monitaire[3], the MSA Flow-Lite, the MSA Flow-Lite ET (all three no longer commercially available) and the MSA Escort Elf®. The Flow-Lite, Flow-Lite ET, and Escort Elf® pumps are constant flow pumps. All four samplers use identical sampling heads and have operational flow rates that range from 1.0 to 2.5 liters per minute for the Model G, from 0.5 to 3.5 liters per minute for the Flow-Lite and Flow-Lite ET, and 0.5 to 3.0 liters per minute for the Escort Elf®. The purpose of this report is to make standardized procedures for calibration available to all MSHA and industry personnel that use these samplers. This will reduce or eliminate measurement differences resulting from the use of different calibration procedures.

CALIBRATION PROCEDURES

Personal Respirable Dust Sampler Calibration

Title 30, Code of Federal Regulations, Parts 70, 71 and 90, state that the flow rate of the specified personal samplers shall be 2.0 liters per minute. This flow rate is necessary in order that the particle classifiers of the respective samplers perform in accordance with accepted respirable dust deposition criteria. The following procedures shall be used for calibrating the approved respirable dust samplers currently used in mines for the sampling of respirable coal mine dust.

Equipment requirements:

1. A wet test meter, 3.0-liter capacity, equivalent to Precision Scientific (Varlen Instruments) Model Number 63126, or SKC Model 302 film flowmeter (soap film calibrator), 1.0-liter capacity, or a fast-response flow measurement device which measures volume and whose calibration is traceable to the National Institute of Standards and Technology (NIST).

2. A test deck, equivalent to Preiser Scientific Model Number 914364-25, is recommended. If a test deck is not available, separate components shall be used. A regulated dc power supply is needed with an adjustable output. The regulated output is necessary so that the motor speed and thus the flow will not vary

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[3] Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Mine Safety and Health Administration.

during calibration. The power supply should have a range from 0 to 10 volts dc. A dc voltmeter with a similar range and a rating of at least 1,000 ohms per volt and a dc milliammeter with a range of 0 to 500 milliamps (ma) are required. Provisions should be made for connecting the pump motor leads to the power supply. Figure 1A shows how a system using separate components should be interconnected. (Note: Because the MSA Flow-Lite, Flow-Lite ET, and Escort Elf® are constant flow sampling pumps, they do not need to be connected to an external power source. For these pumps, the pump battery, provided it is fully charged, can be used in place of the regulated power supply.)

3. A water manometer capable of measuring a pressure differential of about 10 inches of water.

4. A timer or stopwatch capable of reading to 0.01 minute.

Calibration of Personal Sampler Using Wet Test Meter

Run the wet test meter (WTM) about 10 minutes prior to use in order to saturate the WTM water with air and to equalize air-water temperature. The WTM water temperature should not differ from room temperature by more than ±3° F; otherwise inaccuracies may result. Table 2 gives centigrade to Fahrenheit conversions. The WTM must be level as indicated by the level gauge on top. Refer to Figures 1A and 1B when performing the following steps:

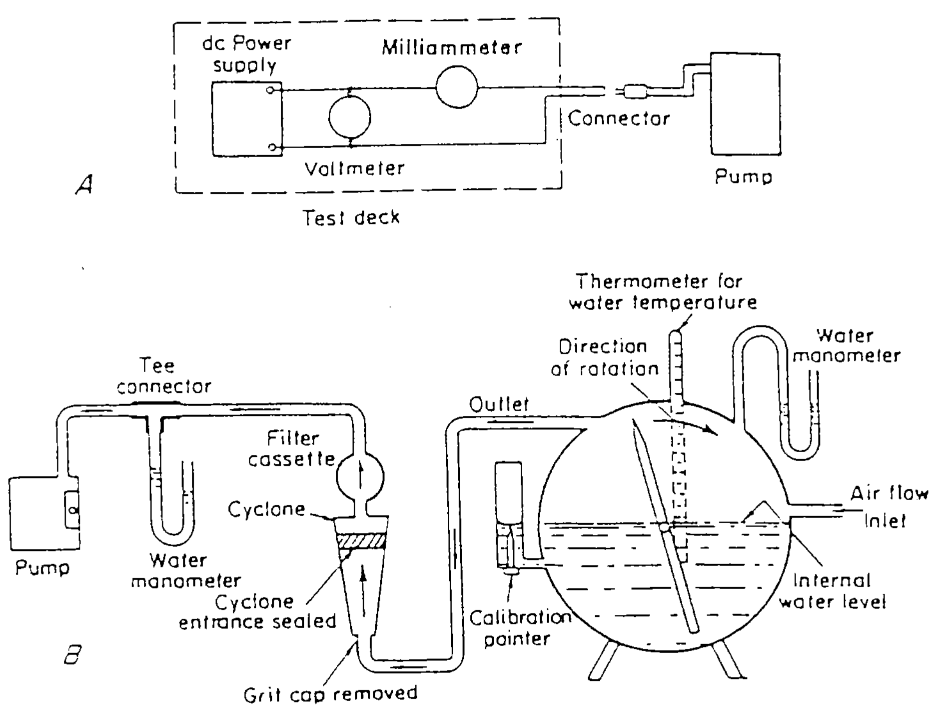

Figure 1. - Schematic showing (A) electrical circuit; (B) calibration setup.

NOTE.--An alternate procedure (preferred method), as shown in Figure 2A, is to seal the cyclone in an airtight container. This eliminates sealing the cyclone or removing the grit pot.

1. Connect the pump inlet by means of a "T" connector to one side of the water manometer and to the appropriate sampling head.

2. Remove the grit pot from the bottom of the cyclone.

3. Seal the 2.0 by 2.0 mm cyclone inlet with tape or modeling clay and connect the WTM outlet to the bottom of the cyclone.

4. If using a test deck for supplying power:

a. Remove the back cover of the pump and disconnect the battery leads from the pump motor.

b. Connect the pump motor leads to the dc power output jacks of the test deck dc power supply.

c. Adjust the potentiometer on the front of the test deck or power supply to the appropriate voltage for the number of nickel-cadmium (Ni/Cd) cells in the battery (page 13, Specification 2).

5. For the pumps with rotameters, turn on the pump and adjust the flow so that the lowest part of the float is tangent to the top of the 2.0 liters per minute calibration mark. The bottom of the ball should be just touching the top edge of the calibration mark. (The hand of the WTM should turn in a clockwise direction.) For the Escort Elf® pump, the digital flow readout should be 2.00 liters per minute.

NOTE.--The WTM manometer should indicate 0.1 to 0.2 inch water pressure differential. The water manometer (connected between the pump inlet and sampling head) should show less than plus one inch of the water pressure differential noted for filter assemblies in Title 30, CFR, Part 74.3(b)(2)(i). If this differential is greater than allowed, there may be an obstruction in the system or the flow rate may be too high. However, if the pressure differential is less than 1.0 inch the system should be checked to insure there are no leaks. If using a test deck, the milliammeter should read less than 100 milliamps for the MSA Flow-Lite and Flow-Lite ET pumps, less than 180 milliamps for the Escort Elf® pump and less than 200 milliamps for the Model G pump. Readings that exceed the upper value indicate that the pump and pump motor should be inspected for faulty operation and the tubing for kinks or other blockage.

6. Start the timer or stopwatch as the WTM pointer passes the zero mark on the WTM dial (any predetermined mark on the dial may be used).

7. Stop the timer or stopwatch when the pointer has completed at least three revolutions (9 liters) and is exactly over the starting point.

8. To obtain the average flow rate in liters per minute, divide the total number of liters (9 or more) by the time (to 0.01 minute). To be acceptable, the flow rate must be 2.0 ±0.1 liters per minute. If the flow rate is not within these limits, then readjust the flow control on the pump and repeat Steps 6 through 8 until the proper flow rate is obtained. Table 1 can be used to determine the flow rate.

9. When the correct flow rate is obtained, the lowest part of the float is tangent to the top of the calibration mark. If not, change the position of the calibration mark.

Calibration of Personal Sampler Using Soap Film Calibrator

A soap film calibrator equivalent to SKC Model 302 film flowmeter, 1.0 liter capacity, may also be used for calibrating the personal sampler (see Figure 2B). This calibration procedure requires the timing of a soap film as it travels between two calibration marks. When using a calibrator of this type at least two repetitive calibration runs shall be made, and the results averaged. This assures (with 95 percent confidence) that the calculated flow rate is actually between 1.9 and 2.1 liters per minute.

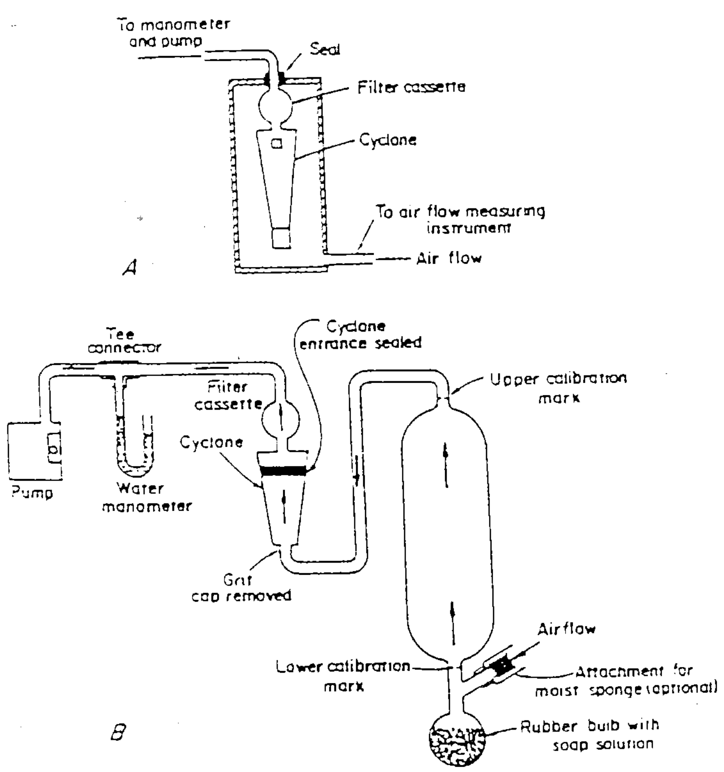

Figure 2. - Schematic showing (A) cyclone in an airtight container; (B) soap film calibrator calibration setup.

If the air is excessively dry, a water-saturated sponge (supplied with the calibrator) should be attached to the inlet to add moisture to the air. Care must be taken that the sponge is not too wet or pushed in so far that the pressure drop across the calibrator becomes greater than 0.1 to 0.2 inch of water. The water manometer should indicate the same pressure differentials, within 0.1 inch, when using either the WTM or the soap film calibrator.

Preparing for Operation

1. Connect the pump by means of the tubing provided, as shown in Figure 2B. Be sure that there are no sharp bends or kinks in the tubing.

2. Remove the rubber bulb from the side tube only (air entrance). (Do not remove the bottom bulb which contains the soap solution.)

3. Add film solution as follows:

   a. Open the small bottle of film solution.

   b. Gently press the bottle outlet tip against the side arm and squeeze to add solution.

   c. Press the bottom bulb occasionally to release trapped air.

   d. Add solution until the bottom rubber bulb is filled and the solution is just below the arm inlet.

Wetting the Walls

The walls of the glass flowmeter must be wet for the film to travel without rupturing. This can be done by turning the entire flowmeter on its side to allow the film solution to run out of the bulb and into the enlarged section. Rotate the flowmeter so that the solution coats the entire inner surface.

Measuring the Flow

1. Squeeze the rubber bulb on the flowmeter to force liquid above the inlet. Squeeze for an instant only; a film will form.

2. Use a timer or stopwatch to time the film between the etched lines.

3. Start the timer or stopwatch as film passes the first line and turn watch off when it reaches the top line.

4. It is usually best to form several films five to six seconds apart, and time the last film.

5. Note time in minutes (to 0.01 minute). Compare the average time for two runs with the time given on the chart supplied with

the soap film calibrator. If conversion chart times are specified in seconds, convert to minutes using the following equation:

$$\text{time in minutes} = \frac{\text{time in seconds}}{60}$$

If no chart is available, then the volume of the calibrator (1.0 liter) divided by the time in minutes gives the flow rate in liters per minute.

Calibration of Personal Sampler Using Fast-Response Flow Measurement Devices

Several fast-response calibrators are commercially available. Such devices allow for a more rapid measurement of flow rate without the necessity of ancillary equipment. Only those fast flow calibrators which measure volume, and whose volumetric tube has a calibration traceable to the NIST should be used. Since volume is measured on the basis of the physical dimensions of an enclosed space, such calibrators are considered a primary standard. Primary standards require no adjustment; however, follow all care and maintenance procedures outlined in the specific instruction manual for the calibrator used.

<u>Procedure</u>

1. Connect the pump to the calibrator according to manufacturer's instructions provided with the calibrator and as shown in Figure 3.

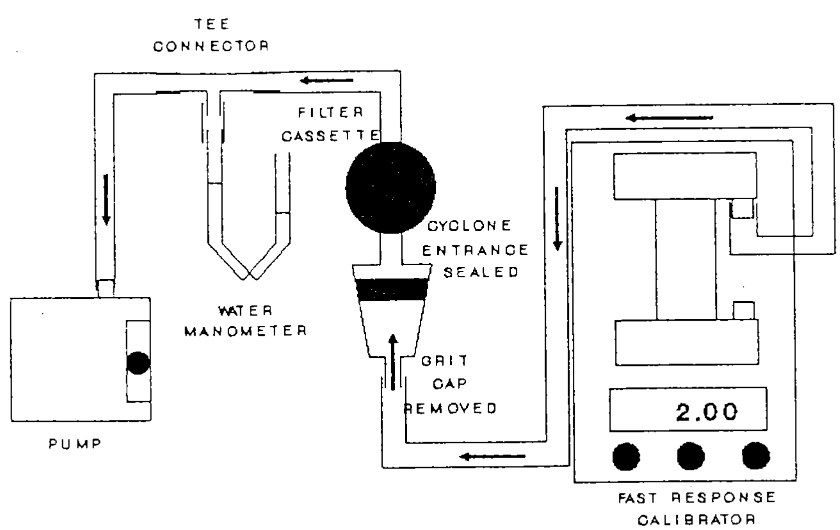

Figure 3. - Schematic showing fast response calibrator setup.

2. Measure the flow and adjust the flow rate following the instructions provided with the specific calibrator in use.

3. Perform three repetitive calibration runs and average the results obtained. At a flow rate determination of 2.0 liters per minute (average of three runs), this should assure (with 95 percent confidence) that the measured flow rate is actually between 1.9 and 2.1 liters per minute.

Wet Test Meter Calibration

Equipment Description

The calibrating equipment consists of a bottle, a saturator, a reservoir tank, a Magnehelic pressure gauge, and three stopcocks. The bottle terminates at the top and bottom in a gauge glass with fixed marker (see Figure 4). There is a two-way stopcock at the top of the upper gauge glass, and a water outlet at the bottom of the lower gauge glass. The bottle is so constructed that the volume between both fixed gauge markers is 0.10 cubic foot (2.83 liters).

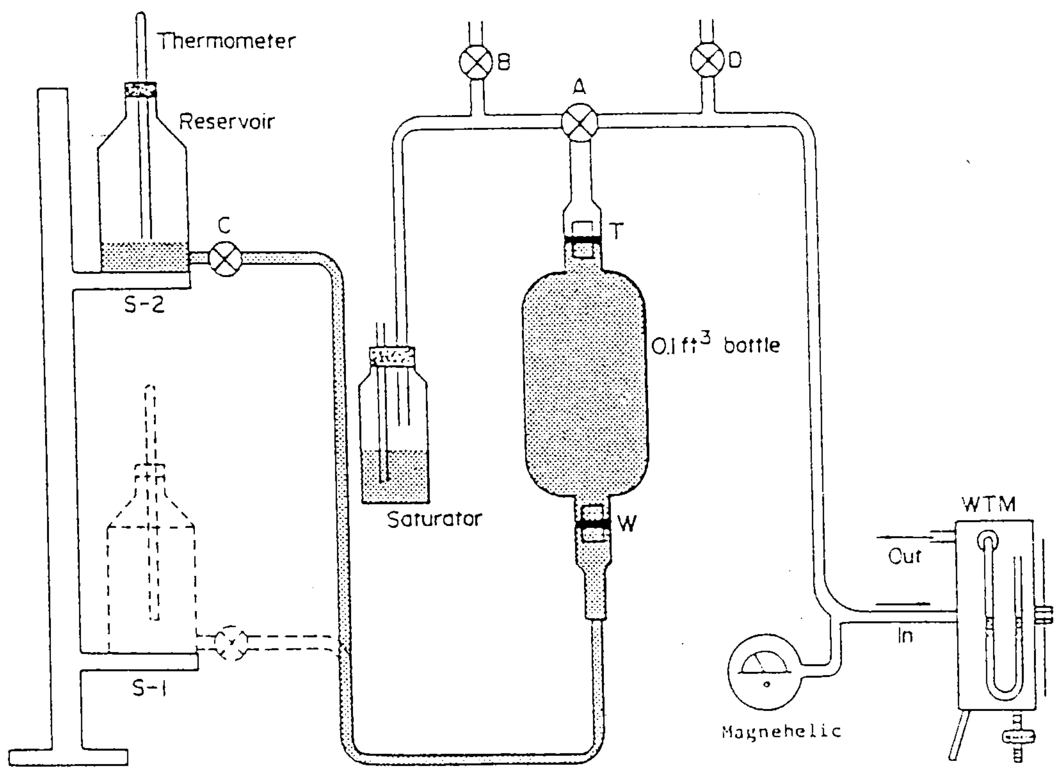

Figure 4. - Schematic showing equipment used for calibrating wet test meter.

A NIST certificate must accompany each 0.1 cubic foot bottle, indicating the volume of the bottle and the temperature at which it was measured. This is the volume to be used when calibrating a WTM or other instrument. The bottle volume should be converted from cubic feet to liters when calibrating metric instruments. The WTM is calibrated when the WTM dial indicates the volume shown on the bottle certificate to be within ±0.01 liter (smallest division on WTM dial) at the completion of the calibration procedure. Figure 4 shows the equipment connected for calibrating the WTM.

Use distilled water in both the reservoir and the WTM. If possible, locate the meter and calibration equipment in a temperature-regulated room. In any event, the temperature of the water in the reservoir tank and the WTM should be within ±1.0° F of room temperature. Table 2 gives centigrade to Fahrenheit conversion. The saturator water should be at or above room temperature but not to exceed 3.0° F higher.

Preliminary Adjustments

Vent bottle to atmosphere using stopcocks A and B. Place reservoir on upper shelf, S-2, check water level at upper bottle gauge marker (T), and add or remove distilled water from the reservoir so that the water level is at the upper gauge mark. With bottle still vented to atmosphere, move reservoir to lower shelf, S-1.

When water level passes lower bottle gauge marker (W), wait 30 seconds, check water level in gauge and adjust lower shelf to bring water level to lower gauge marker. The calibrating equipment is now ready for use.

The WTM should be level as indicated by the leveling gauge located on the top and there must be about three inches of water in the WTM manometer. Saturate the WTM water with air by passing approximately 30 liters of air through it. This can be done by connecting a personal sampler pump to the WTM and turning it on for 15 minutes. Connect the rubber hose from stopcock A to the WTM input.

Calibration Procedure

1. Connect the bottle to the WTM input by turning stopcock A, closing stopcocks B and D, and opening stopcock C.

2. Place the reservoir on upper shelf, S-2.

3. While the water is draining out of the reservoir into the bottle, record room temperature and WTM water temperature.

4. Connect the bottle to the saturator by means of stopcock A.

5. Move reservoir to lower shelf, S-1. Air should start bubbling through the saturator and filling the bottle.

6. When air ceases bubbling through the saturator, open stopcock B and wait 30 seconds for drainage.

7. Record reservoir temperature.

8. Connect bottle to the WTM by means of stopcock A.

9. Open stopcock D and move WTM hand to zero and hold until Magnehelic gauge registers zero pressure.

10. Close stopcock D and do not open again for duration of calibration.

11. Place reservoir on upper shelf, S-2. Water is displacing the air in the bottle and saturated air is flowing through the WTM. (The WTM hand should be moving clockwise.) After the water comes to rest at the upper gauge marker T of the bottle, the Magnehelic will indicate a slight pressure in the WTM. This pressure will remain throughout the calibration period. It is not necessary to record the WTM reading at this time if it is within ± 0.02 liter of the bottle capacity. Continue the calibration (step 12, etc.) until a total of five transfers have been made. If the WTM indication is not within ± 0.02 liter of the bottle capacity after the first transfer, distilled water must be added if the reading is too low or drained out of the WTM if the reading is too high. About 21 ml of water results in a change of 0.01 liter per WTM revolution. Start calibration at step 4 if water volume of WTM is changed.

12. Connect bottle to saturator by turning stopcock A and close stopcock B.

13. Move reservoir to S-1.

14. When air no longer bubbles through saturator, open stopcock B and allow 30 seconds drainage.

15. Turn stopcock A so that the bottle is connected to the WTM.

16. Repeat steps 11 through 15 four more times making a total of five transfers without resetting the WTM reading to zero but continuing each time. At the end of the fifth transfer, force the Magnehelic gauge to zero by turning the WTM hand clockwise very slowly and relieving the pressure inside the WTM. Record dial reading of the WTM. Five transfers through the WTM will cause the hand to make more than four but less than five revolutions (that is, for a 3 liters per revolution capacity

WTM). Therefore, adding the final WTM reading to 12.00 liters and dividing by 5 gives the WTM calibration.

If the WTM reading is within ±0.01 liter of the bottle capacity, the WTM is considered accurately calibrated. If the reading of the WTM is too high (by more than 0.01 liter) water should be removed from the WTM or added if the reading is too low (by more than 0.01). If the volume of the WTM water is altered, repeat the whole calibration procedure. When the calibration is satisfactorily completed, set the calibration pointer tip, located in the water gauge, by raising it from below the water surface until the tip touches the surface. The pointer should then be locked in position (see Figure 1B). The WTM is then ready for use. The reservoir should be left on the lower shelf, S-1, so that any contamination from the water will result in the reservoir instead of the bottle and so that the bottle mounts will not have to support the weight of the water.[4]

MAINTENANCE

Wet Test Meter

In order to obtain reliable, reproducible results from the WTM, the following precautions should be observed:

1. When the WTM has been accidentally abused, it should be tested for leaks against a static pressure or vacuum of 6.0 inches of water as follows:

   a. With a short length of rubber hose and a hose clamp, seal off the WTM outlet (the upper tube on the back side of the WTM).

   b. Connect a 2-foot length of hose to the WTM inlet (the middle tube on the back side of the WTM).

   c. While watching the WTM manometer, gently blow into hose until there is a difference of 6 inches in the height of the water columns of the manometer. (This is the maximum difference possible.)

   d. Pinch off hose so that height difference is maintained. If height does not change more than 0.2 inch in a minute, there is no air leak in the WTM.

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[4] Precision Scientific Company. Operating Instructions TS-63110-5. Standard Methods for Measurement of Gaseous Fuel Samples, ASTM Designation D1071-55.

2. At atmospheric condition (when the WTM outlet and inlet are open), the internal water level of the WTM should be at the level indicated by the calibration pointer tip (see Figure 1B).

3. There must always be about 3 inches of water in the WTM manometer.

4. Calibrate the WTM at least every 12 months.

Personal Sampler

Before calibrating, the sampler should first be completely cleaned of dust inside and out and examined for physical damage and missing parts (switch covers, screws, etc.). If the flow rate indicator walls appear dirty inside and out, they should be thoroughly cleaned. Low flow rate normally results from a decrease in the efficiency of the pump caused by poor valve operation or air leaks. If the pump cannot be adjusted to a flow greater than 2.0 liters per minute, it is faulty and the cause should be found and corrected. It is required that the samplers be calibrated and completely checked at intervals no greater than 200 hours of running time. However, indications of malfunction during use, such as laboring of the pump or inability to obtain a 2.0 liters per minute flow rate, should be cause for a sampling pump to be checked immediately, regardless of how recently it has been calibrated.

Battery

All samplers approved for coal mine dust sampling are equipped with a rechargeable Ni/Cd battery. A certain amount of care is necessary when charging or using this type of battery. Each battery consists of a number of cells, each cell having a nominal voltage of 1.25 volts (the Escort Elf® has four cells, each having a nominal voltage of 1.2 volts). The cells are connected in series to achieve the desired voltages. A 1-Ohm resistor is usually connected in series with the cells to limit the current in case the battery terminals are shorted. Sampler unit approval includes intrinsic safety approval of the pump by MSHA as well as performance approval by the National Institute for Occupational Safety and Health (NIOSH). In order to maintain intrinsic safety status, neither the electrical circuit nor the battery pack may be altered in any way.

The design of modern sealed nickel-cadmium cells is such that evolution of gases during charging or overcharging is suppressed or disposed of within the cell. When three or more cells are connected in series for higher voltage, the possibility exists that during discharge a cell with lower capacity than the others will be driven to zero and then into reverse. During reversal, gases may be evolved and cause cell damage. To avoid damage, cells are built with reversal protection so that hydrogen evolution is suppressed and the oxygen evolved is recombined with the positive electrode. Excessive gas pressure may cause a cell to vent and this is undesirable since venting shortens cell life. The end point voltage of a cell depends on the discharge rate. For the 10 hour discharge rate (100 ma for the 1 amp hour cell and 200 ma for the 2 amp hour cell) most battery manufacturers recommend a cutoff voltage of 1.0 volt per cell. Discharge below the cutoff voltage leads to cell reversal. Prolonged, frequent or deep reversals should be avoided as they can shorten cell life or cause venting. However, batteries can usually be successfully charged if the end voltage for 3, 4, 5 and 6 cell batteries are not lower than 2.0, 3.0, 4.0 and 5 volts respectively. The criterion for discarding batteries is if after a full charge cycle they will not operate a sampler at 2.0 liters per minute with only 2 adjustments for an eight hour period under conditions of normal use.

Specifications

1. Cells are connected in series.

2. Voltage rating: Ni/Cd cell = 1.25 volts (on Escort Elf® pump, each cell is rated at 1.2 volts).

3. Nominal capacity for batteries in use now.

   a. MSA - 2,000 (mah) (Flow-Lite with large battery, Model G)
   b. MSA - 1,000 (mah) (Flow-Lite with small battery)
   c. MSA - 1,800 (mah) (Escort Elf®)

4. Current discharge (10-hour rate--not to be exceeded).

   a. 100 ma (1,000 mah battery)
   b. 180 ma (1,800 mah battery)
   c. 200 ma (2,000 mah battery)

5. Charging rate and cycle.

   14 to 16 hours at a charging current not in excess of current discharge limit.

6. Charging current.

   a. 1,000 mah battery, 100 ma current
   b. 1,800 mah battery, 180 ma current (must be charged with Omega charger)
   c. 2,000 mah battery, 200 ma current

   NOTE: If 1,000 mah battery is charged at higher rate, it will damage the battery.

7. Cutoff voltage: Ni/Cd--1.0 volts.

   5 cells--5.0 volts

8. Trickle charge--7 ma to maintain full charge.

   NOTE: Low charge rate on an MSA dual setting charger is not a trickle charge, it is 100 ma.

9. Range of temperature applicable to operation of most Ni/Cd batteries.

   a. Charge: +32° to +113° F
   b. Discharge: - 4° to +113° F
   c. Storage: -40° to +140° F

TABLE 1. - Personal Pump Flow Rate Based on Time for 9 Liters

Time (minutes)	Liters per minute	Time (minutes)	Liters per minute
4.29	2.10	4.52	1.99
4.30	2.09	4.53	1.99
4.31	2.09	4.54	1.98
4.32	2.08	4.55	1.98
4.33	2.08	4.56	1.97
4.34	2.07	4.57	1.97
4.35	2.07	4.58	1.97
4.36	2.06	4.59	1.96
4.37	2.06	4.60	1.96
4.38	2.05	4.61	1.95
4.39	2.05	4.62	1.95
4.40	2.05	4.63	1.94
4.41	2.04	4.64	1.94
4.42	2.04	4.65	1.94
4.43	2.03	4.66	1.93
4.44	2.03	4.67	1.93
4.45	2.02	4.68	1.92
4.46	2.02	4.69	1.92
4.47	2.01	4.70	1.91
4.48	2.01	4.71	1.91
4.49	2.00	4.72	1.91
4.50	2.00	4.73	1.90
4.51	2.00		

TABLE 2. - Temperature Conversion Chart

$(F = 1.8C + 32; C = (5/9)(F - 32))$

centigrade	to Fahrenheit	centigrade	to Fahrenheit
19° C	66.2° F	29° C	84.2° F
20° C	68.0° F	30° C	86.0° F
21° C	69.8° F	31° C	87.8° F
22° C	71.6° F	32° C	89.6° F
23° C	73.4° F	33° C	91.4° F
24° C	75.2° F	34° C	93.2° F
25° C	77.0° F	35° C	95.0° F
26° C	78.8° F	36° C	96.8° F
27° C	80.6° F	37° C	98.6° F
28° C	82.4° F	38° C	100.4° F

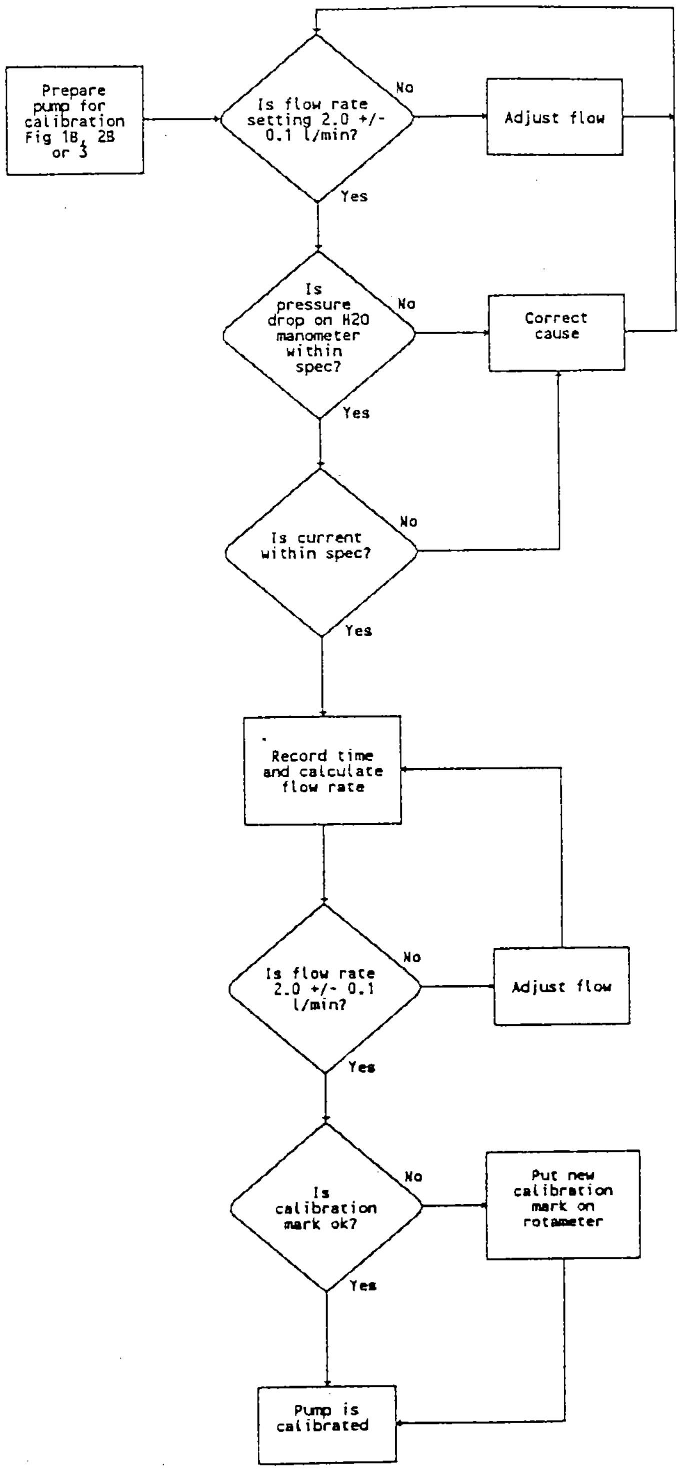

Figure 5. - Flow diagram for personal sampler calibration.

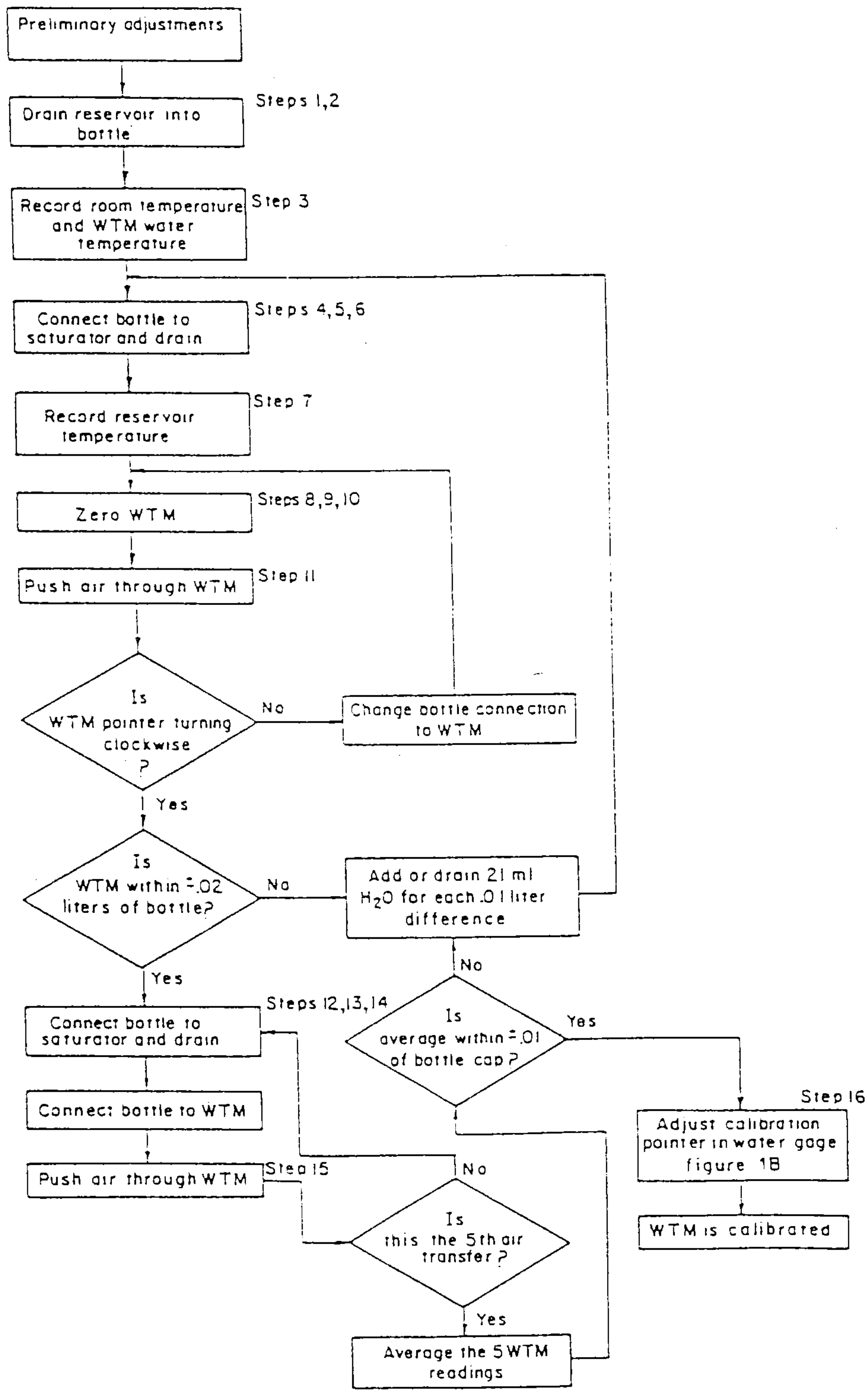

Figure 6. - Flow diagram for wet test meter calibration.