Standard Calibration and Maintenance Procedures for Wet Test Meters and Coal-Mine Respirable Dust Samplers (Supersedes IR 1073)

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STANDARD CALIBRATION AND MAINTENANCE PROCEDURES FOR WET TEST METERS AND COAL MINE RESPIRABLE DUST SAMPLERS (SUPERSEDES IR 1073)

by

Thomas F. Tomb[1] and Harry N. Treaftis[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, Education, and Welfare. Title 30, Code of Federal Regulations, Part 70, specifies that approved sampling devices be calibrated at a flowrate of 2.0 liters per minute or at a different flowrate as prescribed by the Secretary of Labor and the Secretary of Health, Education, and Welfare for the particular device. This informational report presents the standard procedures used by the Mine Safety and Health Administration (MSHA) for calibration of currently approved personal samplers and associated equipment and maintenance procedures for the equipment.

INTRODUCTION

Currently there are five samplers approved by the Secretary of Labor and the Secretary of Health, Education, and Welfare. They are the Bendix 3900 Micronair, Bendix BDX 30/31 and 44, Bendix C-115, and the MSA Model G Monitaire.[3] These samplers use similar sampling heads and have an operational flowrate of 2.0 liters per minute. The purpose of this report is to make standard procedures for calibration available to all MSHA and industry personnel that use these samplers in their daily routines. Use of standard calibration procedures will reduce or eliminate measurement differences resulting from different calibration procedures.

CALIBRATION PROCEDURES

Personal Respirable Dust Sampler Calibration

Title 30, Code of Federal Regulations, Part 70, states that the flowrate of the specified personal samplers shall be 2.0 liters per minute. This

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[1]Chief, Dust Branch.
[2]Supervisory physicist, Dust Branch.
[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.

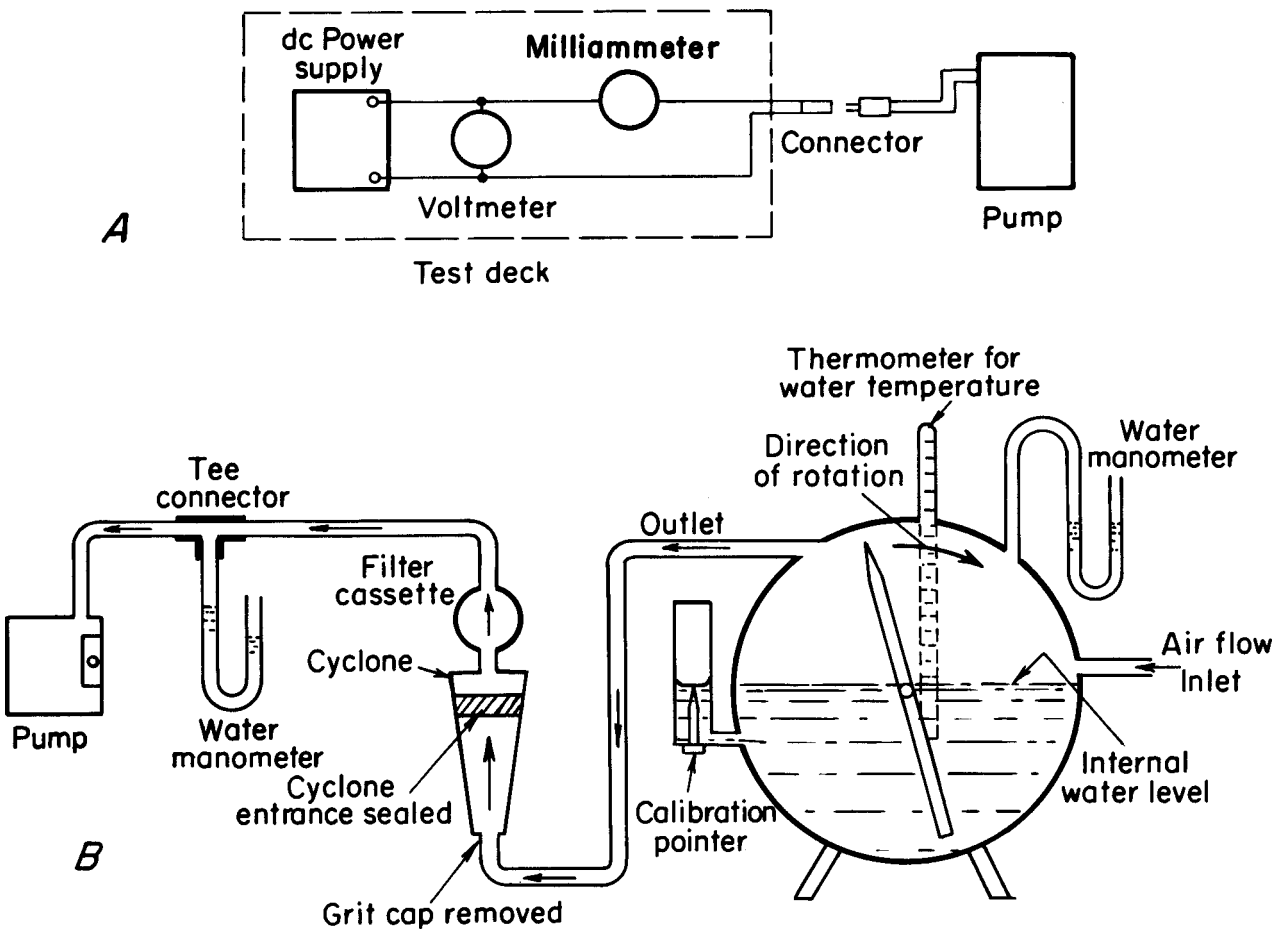

FIGURE 1. - Schematic showing (A) electrical circuit; (B) calibration setup.

flowrate is necessary in order that the elutriators 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 Catalog Number 63-115 or 63-126, or SKC Model 302 film flowmeter (soap film calibrator), 1.0-liter capacity, or equivalent equipment.

2. A test deck, equivalent to Precision Scientific Number 914364-15 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 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 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.

3. A water manometer capable of measuring a pressure differential of about 10 inches of water and a timer or stopwatch, preferably 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 gage on top. Refer to figures 1A and 1B in performing the following steps:

1. Connect the pump inlet by means of a "T" connector to one side of the water manometer and to the appropriate sampling head (the Bendix instruments use the Bendix sampling head; the MSA instrument uses the MSA 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.

NOTE.--An alternate procedure, as shown in figure 2A, is to seal the cyclone in an airtight container. This eliminates sealing cyclone or removing grit cap.

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

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

6. Adjust the potentiometer on the front of the test deck or power supply to the appropriate voltage for the number of Ni/Cd cells in the battery (p. 10, specification 2).

7. 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.)

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 3.0 inches of water pressure differential. If this differential is greater than

3.0 inches, there may be an obstruction in the system or the flowrate 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. The milliammeter should read less than 100 milliamps for the Bendix 3900 pump and the BDX 30/31; 100 or 150 milliamps for the BDX 44 depending on the battery used; and 200 milliamps for the C-115 and the MSA. 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.

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

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

10. To obtain the average flowrate in liters per minute, divide the total number of liters (9 or more) by the time (to 0.01 minute). To be acceptable, the flowrate must be 2.0 ± 0.1 liters per minute. If the flowrate is not within these limits, then readjust the flow control on the pump and repeat steps 8 through 10 until the proper flowrate is obtained. Table 1 can be used to determine the flowrate.

11. When the correct flowrate 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.

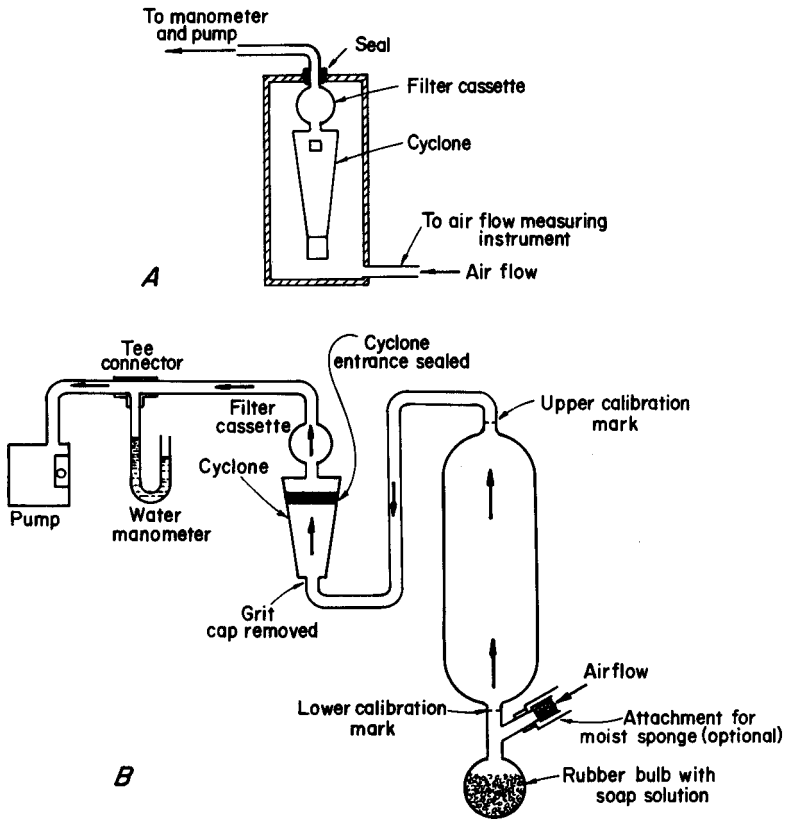

FIGURE 2. - Schematic showing (A) cyclone in airtight container; (B) soap film calibrator calibration setup.

Calibration of Personal Sampler Using Soap Film Calibrator

A soap film calibrator equivalent to SKC Model 302 film flowmeter, 1.0-liter capacity, may be used instead of a WTM for calibrating the personal sampler (see fig. 2B). This calibration procedure requires the timing of a soap film as it travels between two calibration marks. At least six repetitive calibration runs shall be made, and the results averaged. This

assures (with 95 percent confidence) that the calculated flowrate is actually between 1.9 and 2.1 liters per minute.

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

2. 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.

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 stopwatch to time the film between the etched lines.

3. Start the 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 5-6 seconds apart, and time the last film.

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

MAINTENANCE PROCEDURES

Personal Sampler Maintenance

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 flowrate indicator walls appear dirty inside and out, they should be thoroughly cleaned. Low flowrate 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 flowrate, should be cause enough for a sampling pump to be checked immediately, regardless of how recently it has been calibrated.

Wet Test Meter Maintenance

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.

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 fig. 1B).

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

4. Calibrate the WTM at least every 12 months.

Wet Test Meter Calibration

Equipment Description

The calibrating equipment consists of a bottle, a saturator, a reservoir tank, a Magnahelix pressure gage, and three stopcocks. The bottle terminates at the top and bottom in a gage glass with fixed marker (see fig. 3). There is a two-way stopcock at the top of the upper gage glass, and a water outlet at the bottom of the lower gage glass. The bottle is so constructed that the volume between both fixed gage markers is 0.10 cubic foot (2.83 liters).

A Bureau of Standards certificate must accompany each 0.1 cubic foot bottle, indicating the volume of the bottle and the temperature at which it

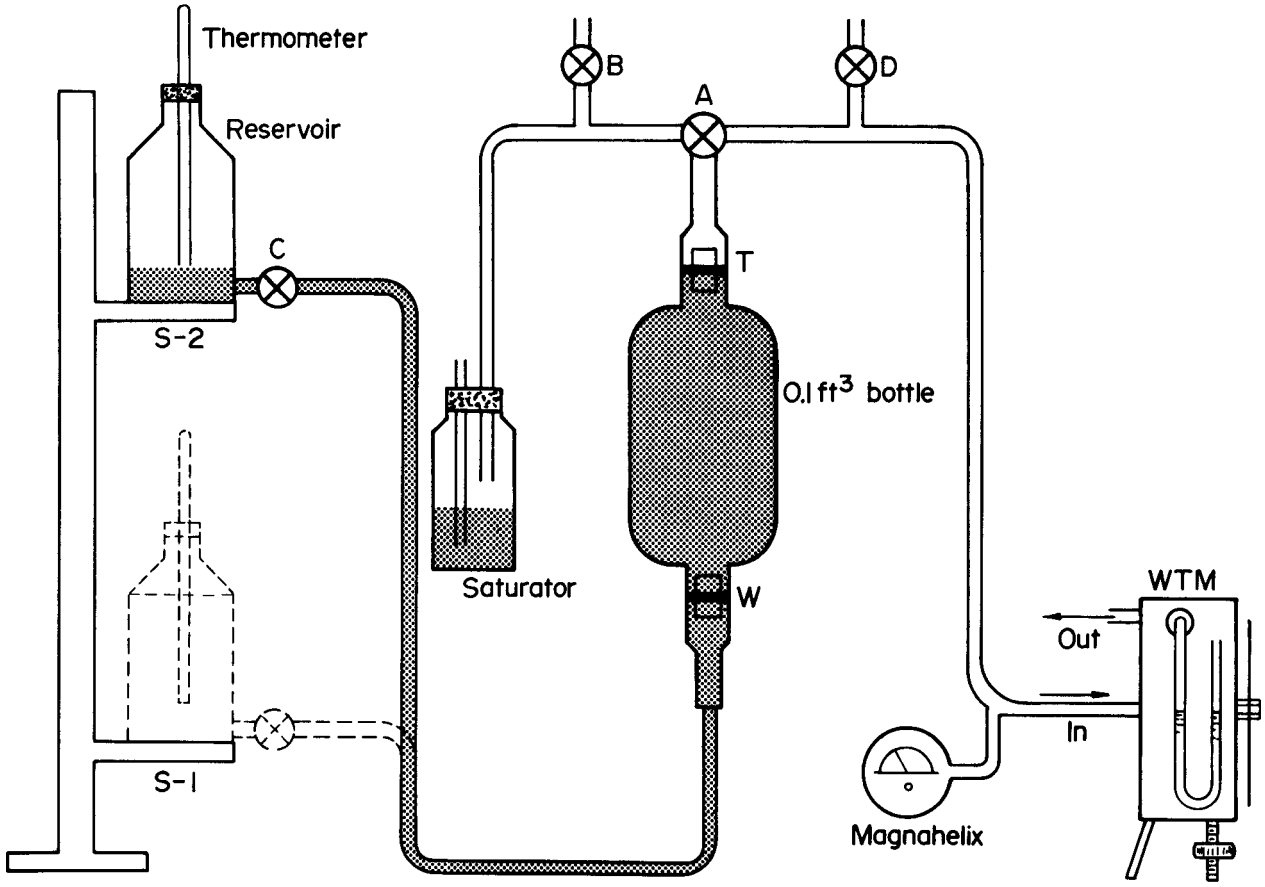

FIGURE 3. - Schematic showing equipment used for calibrating wet test meter.

was measured. This is the volume to be used when calibrating a wet test meter (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 within ±0.01 liter (smallest division on WTM dial) at the completion of the calibration procedure. Figure 3 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 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 gage marker (T), and add or remove distilled water from reservoir so that water level is at upper gage mark. With bottle still vented to atmosphere, move reservoir to lower shelf, S-1.

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

The WTM should be level as indicated by the leveling gage located on the top and there must be about 3 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 Magnahelix gage registers zero pressure.

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

11. Place reservoir on 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 gage marker T of the bottle, the Magnahelix 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 reading is too low or drained out of the WTM if 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 Magnahelix gage 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 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 gage, by raising it from below the water surface until the tip touches the surface. The pointer should then be locked in position (see fig. 1B). The WTM is then ready for use. The reservoir should be left on 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]

Battery Maintenance

All samplers approved for coal mine dust sampling are equipped with a rechargeable nickel-cadmium 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 cells are connected in series to achieve the desired voltage. 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 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 the sealed cells is such that the gases generated during the charging cycle are taken care of. The battery should not be discharged below 1.1 volts/cell because cell polarity reversal may occur when the battery is placed on charge; that is, the role of the nickel and cadmium plates may be reversed. If this occurs, the safety mechanisms do not operate to eliminate gas buildup and the cell may explode. The battery voltage should be checked (with the pump on) when the equipment is returned at the end of a sampling shift. If the voltage is less than 1.1 volts times the number of cells, do not put the battery on charge, but set it aside and let the cell or cells recover. After 1 day, measure the battery voltage and if the voltage is equal to or greater than 1.1 volts per cell, the battery can be charged in the regular manner. If the battery voltage remains less than 1.1 volts per cell, connect to 7 ma trickle charge source and run for 24 hours. At the end of this period, if voltage remains below 1.1 volts per cell, discard battery.

Specifications

1. Cells are connected in series.

2. Voltage rating/NiCd cell = 1.25 volts.

   a. 3 cells--3.75 volts
   b. 4 cells--5.00 volts
   c. 5 cells--6.25 volts
   d. 6 cells--7.50 volts

3. Nominal capacity for batteries in use now.

   a. Micronair, BDX 30/31--1,000 milliamp hours (mah) or 1 amp hour (ah)
   b. BDX 44--1,500 mah or 1.5 ah
   c. C-115, MSA--2,000 mah or 2 ah

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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.

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

   a. 90 ma (900 mah battery)
   b. 100 ma (1,000 mah battery)
   c. 150 ma (1,500 mah battery)
   d. 200 ma (2,000 mah battery)

5. Charging rate and cycle.

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

6. Charging voltage/NiCd cell--1.35 to 1.5.

   a. 3 cells--4.05 to 4.50
   b. 4 cells--5.40 to 6.00
   c. 5 cells--6.75 to 7.50
   d. 6 cells--8.10 to 9.0

7. Cutoff voltage/NiCd cell--1.1.

   a. 3 cells--3.3
   b. 4 cells--4.4
   c. 5 cells--5.5
   d. 6 cells--6.6

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

9. Range of temperature applicable to operation of most nickel-cadmium batteries.

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

TABLE 1. - Personal pump flowrate 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

$$(F = 1.8C + 32;\ C = \frac{5}{9}(F - 32))$$

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

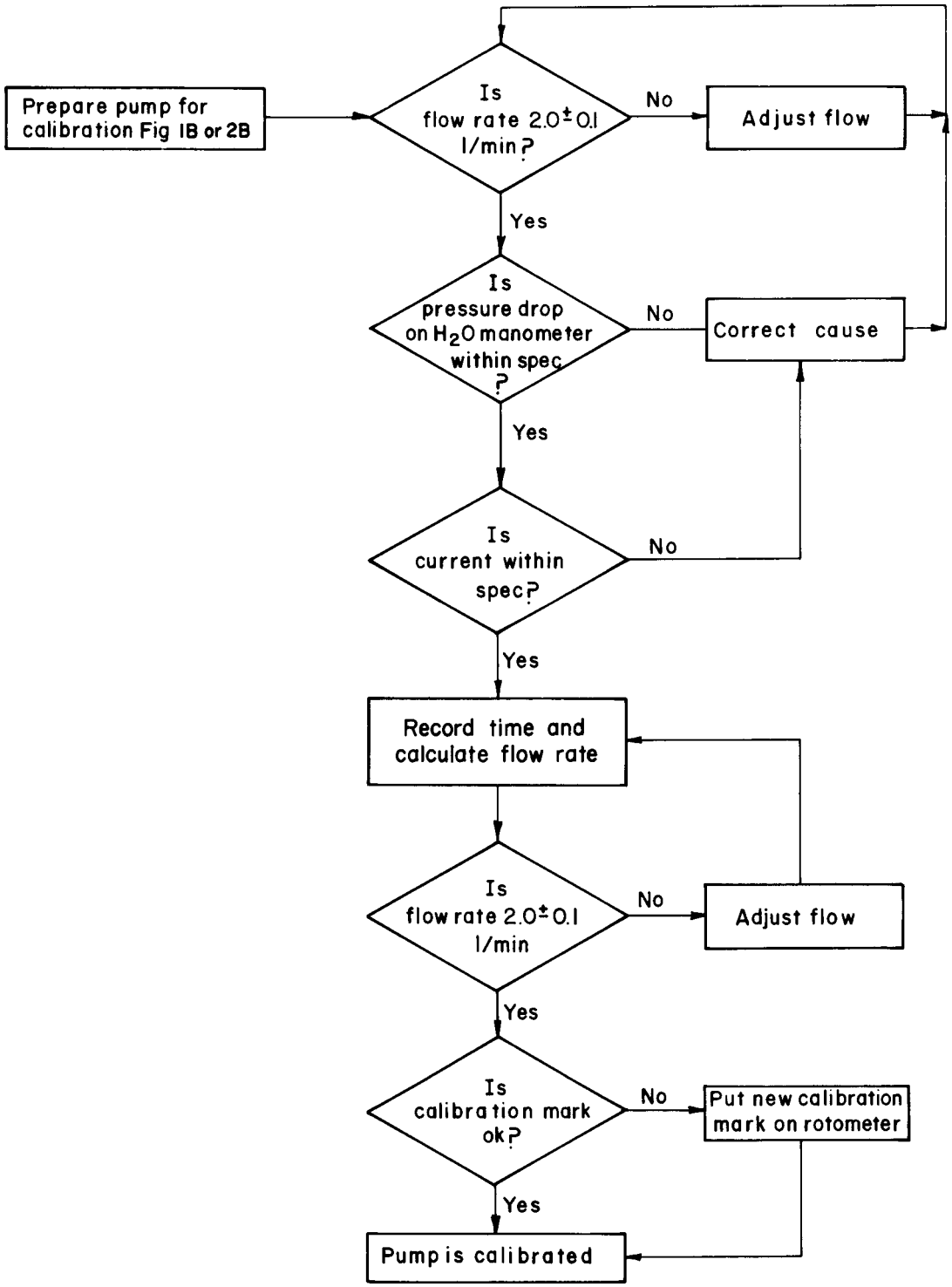

FIGURE 4. - Flow diagram for personal sampler calibration.

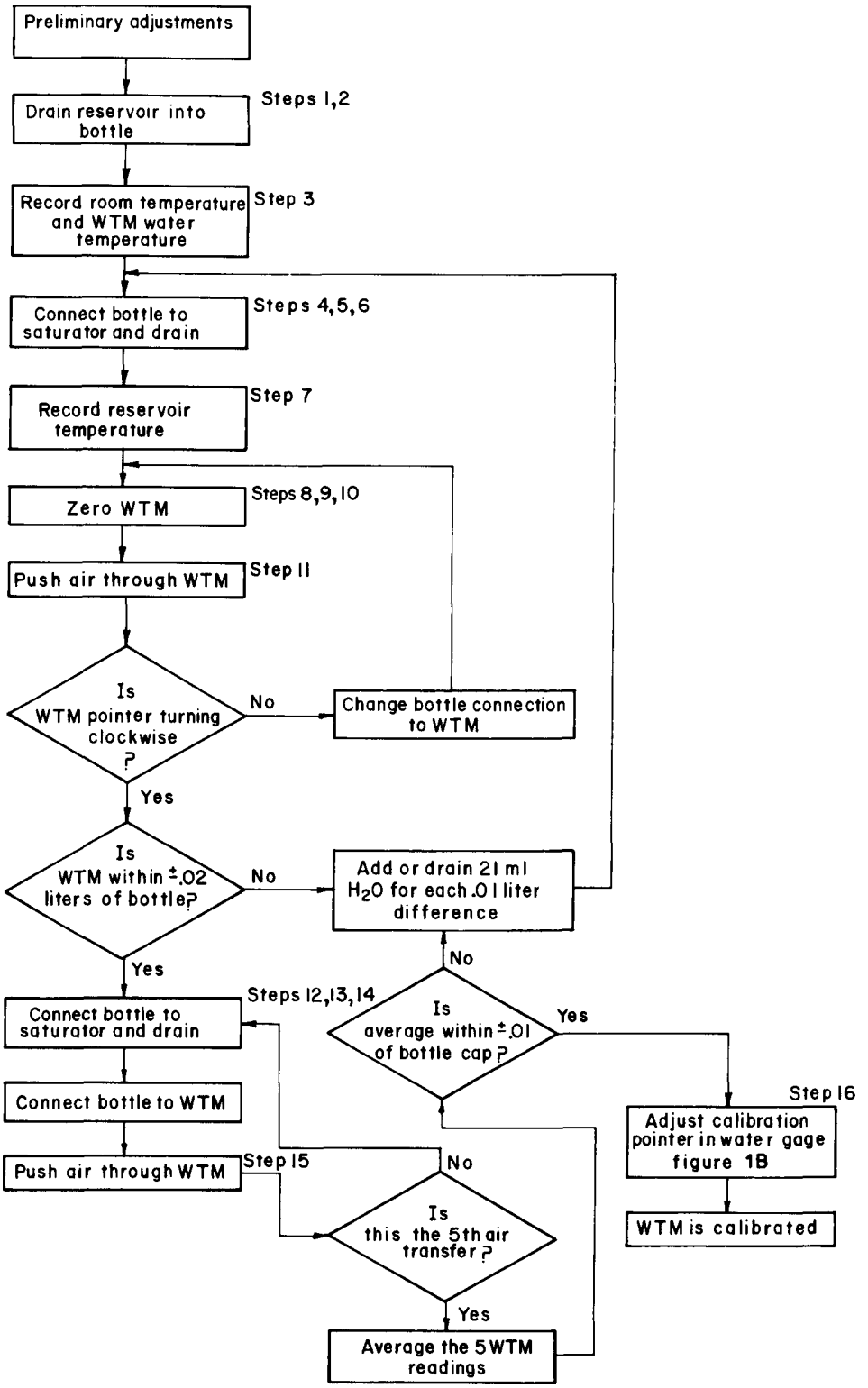

FIGURE 5. - Flow diagram for wet test meter calibration.

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