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ELECTRONIC DIRECT-READ INSTRUMENTS

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CHAPTER 13
ELECTRONIC DIRECT-READ INSTRUMENTS

I. Introduction

Electronic direct-read instruments (DRI) are battery operated devices that take real-time measurements of contaminant gases and vapors. Some electronic direct-read instruments can be operated from an electrical outlet. They are important tools available to inspectors for detecting and quantifying health hazards because they eliminate the lag time between collecting the sample and receiving the results from the laboratory.

DRIs are used to sample for a variety of contaminants such as the common mine gases: oxygen (O_2), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), methane (CH_4), and mercury (Hg) vapor. They may be used to obtain short term or continuous environmental measurements. These instruments may also be used to sample for combustible gas mixtures. Combustible gases are displayed as the percent of the Lower Explosive Limit (LEL).

Ambient air contains about 78% nitrogen, 21% oxygen, 0.04% (400 ppm) carbon dioxide, and small amounts of argon, helium, and other gases. If the concentrations of these gases change due to the displacement of oxygen by other gases, aerobic bacterial activity, combustion, or oxidation of metal, there may be adverse health effects. Human beings can tolerate moderate variations in the amount of oxygen in the air. Breathing becomes labored when the air contains less than 19.0 % oxygen. Oxygen concentrations below 16.0 % present a life-threatening condition.

II. Definitions

Accuracy - how close to the "true" concentration measured by the instrument.

Calibration - determining the variation of an instrument's response from a standard, and adjusting the instrument to indicate the true value.

Grab sample - a sample taken over a very short period of time by a DRI or other instrument (e.g., detector tube) to assess the concentration of a given contaminant.

Lower Explosive Limit (LEL) - the minimum concentration in air of a flammable vapor or gas-air mixture at which ignition can occur. Concentrations below the LEL are too lean to burn. Note: Although hydrogen sulfide (H_2S) is combustible and explosive, its Threshold Limit Value® (TLV®) is considerably lower than its LEL.

Over-Range - concentrations of a particular contaminant that exceed the range of accurate measurement of a particular instrument. For example: concentrations of carbon monoxide (CO) greater than 1000 ppm would be over-range for an instrument which can accurately measure concentrations of CO between 0 and 999 ppm.

Precision - repeatability, that is, how close several readings taken in the same atmosphere are to each other.

Real Time - characteristic of a DRI that enables it to measure concentration levels of a contaminant instantaneously, or almost instantaneously, and display them as they occur.

Sensitivity (lower detectable limit) - the minimum concentration detectable by the instrument.

Span Calibration (spanning) - using a gas of known concentration to check the accuracy of the response of an instrument to the same type of gas.

III. Exposure Limits

DRIs are normally used to assess compliance with the following standards. They may also be used to determine whether an imminent danger exists.

- 30 CFR §§ 56/57.5001(a) - Threshold Limit Values® (TLVs®), short-term exposure limits (STELs), Ceiling limits, and Excursion Limits for contaminants are listed or referenced in the ***TLVs® Threshold Limit Values for Chemical Substances in Workroom Air Adopted by the ACGIH for 1973*** and incorporated by reference in this MSHA standard.

- 30 CFR § 57.5015 requires minimum oxygen levels of 19.5% by volume in all active working areas.

- 30 CFR Part 57 Subpart T and Section 103(i) of the Mine Act specify criteria for maintenance of methane gas levels at or below certain concentrations depending on the classification of the underground mine.

IV. Sampling Equipment

There are various types of electronic direct-read instruments used by MSHA, including:

1. Industrial Scientific Corporation; models TMX-410 & TMX-412; and the MSA; "Solaris", multi-gas monitors.

2. Jerome; Models 411 and 431X, mercury analyzers.

Check, calibrate, and maintain these instruments according to the manufacturer's recommendations (see the Appendix to this Chapter for operating instructions for DRIs). Perform a field calibration check or function test ("bump" test for TMXs) and periodic calibration as specified in the Appendix.

Note: The internal gas sensors of the TMXs have limited shelf and service lives (as little as 6 months).

Each electronic direct-reading instrument has an operating manual that lists operating parameters, accuracy of the instrument reading, and instrument sensitivity. For example, if the instrument sensitivity is 2 ppm, the instrument will not accurately measure concentrations of less than 2 ppm.

Usually the accuracy of the reading is reported as a percentage. Some manufacturers may list a different accuracy for different concentration ranges. In all cases, however, increasing the number of samples taken in a given area increases confidence in the measurements. Error factors for the DRIs are given in the Appendix of this chapter.

V. Equipment Factors and Environmental Considerations.

Where safety procedures require, as in gassy mines, all electronic battery-operated instruments must be intrinsically safe (permissible) according to MSHA Part 18, and must be labeled accordingly. Many variables can affect the measurement accuracy of DRIs and must be controlled.

1. Temperature and Humidity - Use a sling psychrometer or a digital thermometer/hygrometer to determine temperature and humidity conditions. Record these readings in the Health Field Notes. Do not use DRIs outside the recommended temperature or humidity range. If sampling conditions are outside the manufacturer's specified limits, contact your District Office for guidance. Heavy moisture (steam, rain, snow, mist, or fog) can reduce collection efficiency by interfering with the measurement of the contaminant.

2. **Interferences** - Sampling may be adversely affected when there is an interfering influence caused by the presence of other gases or vapors. These gases or vapors can react with the same sensor in the DRI. Refer to the instructions for each DRI and applicable sensor to ensure that your sampling result shows only the contaminant you intend to measure. For example:

a. The TMX-412 gives erroneously low readings for combustible gas in oxygen deficient atmospheres. (Conversely, oxygen enriched atmospheres cause erroneously high readings for combustible gas.)

b. Silicone compound vapors may cause desensitization of the combustible gas sensor and cause the reading to be lower than actual.

c. Combustible gases affect the methane concentration measured by an instrument. When other combustible gases are present, the measured methane concentration may not be accurate.

d. The Jerome mercury analyzer reads erroneously if high concentrations of ammonia are present.

In these cases, contact your District Office for guidance.

VI. Sampling Procedures for Electronic Direct-Read Instruments (DRIs)

Grab samples taken with electronic direct-read instruments (e.g., TMX-412) may be used to corroborate full-shift data or to determine if short-term exposure limits (STEL), excursion limits, or ceiling limits have been exceeded during suspected periods of peak exposure. When monitoring for short-term exposure limits, refer to the minimum sampling times listed in Chapter 3.

Full-shift sampling can also be accomplished using partial-period sampling by taking a series of grab samples (with DRIs) spaced periodically throughout the shift. Each grab sample serves the dual purpose of being part of the full-shift sampling process as well as being a stand-alone, short-term sample. See Chapter 2 for calculating full-shift exposure from partial-period data.

1. **Instructions to the miner** - Tell the miner what you are doing, what the sampling device does, and the reason for the sampling (i.e., the hazard). If available, issue a Miner Health Hazard Information Sheet or Card. Emphasize the need for the

miner to continue to work in a routine manner and report to you any unusual occurrences during the sampling period.

2. **Procedure** - Position the DRI in the breathing zone of the miner, taking care not to endanger the miner.

3. **Ceiling limit** - compare the reading with the ceiling limit concentration. A single reading may be used to determine an imminent danger situation.

4. **Low Oxygen**- as with Ceiling Limits, a single reading may be used to determine if an imminent danger situation exists. (See 30 CFR 57.5015.)

5. **Short-term exposure limit (STEL) and excursion limit** - determine the time (refer to Chapter 3) allowed for the exposure limit of the gas or vapor you intend to measure (typical range is from 5 to 30 minutes). Use partial-period sampling by taking DRI readings over this entire time period and calculate the average concentration.

   Example (for a 15 minute STEL):

   a. Take one DRI reading during the first 5-minute period;

   b. Take the second DRI reading during the second 5-minute period;

   c. Take the third DRI reading in the final 5-minute period; and

   d. Add all three readings and average (divide by 3) to obtain the concentration of the short-term exposure.

6. **Record** - the DRI readings and calculations in the Health Field Notes. In addition, record the following:

   a. Miners present and equipment operating in the area;

   b. General description of controls in use (e.g., ventilation) and whether or not they seem adequate;

   c. Potential sources of exposure, a general description of these sources, number of persons affected, and possible additional control measures;

d. Any other samples taken and the results, if available (e.g., noise, detector tubes, and organic vapor badges); and

e. Environmental conditions such as temperature and humidity.

VII. Post-Inspection Procedures

A. Review Health Field Notes

Check that you have recorded all necessary information in the Health Field Notes (MSHA Form 4000-31); refer to Chapter 21, Section V.

B. Post-Survey Calibration Test

Perform a post-survey test as described in the Appendix of this chapter. If the DRI fails the test, void the results of any grab samples taken.

C. Compliance Determination

Electronic direct-read instruments may be used to measure compliance with oxygen and methane standards as well as exposure limits for specific contaminants. They can also be used to corroborate data collected with other sampling media (e.g., diffusion or detector tubes). When using the DRI for enforcement purposes, use the error factor (EF) for the instrument and multiply it times the TLV®. When determining compliance with exposure limits, the sampling strategy must be in accordance with Chapter 3 of this Handbook.

Determine compliance by comparing direct-read exposure concentrations with respective enforcement exposure limits.

Example:
The ceiling limit for nitrogen dioxide is 5 ppm. A DRI grab sample taken near a miner's breathing zone reads 7 ppm.

- The error factor for this DRI is 1.25 (25 percent).
- The enforcement ceiling limit is TLV® X EF = 5 ppm X 1.25 = 6.25 ppm.
- The sample indicates a citable overexposure has occurred.

Example:
The short-term exposure limit (STEL) for carbon monoxide (CO) is 400 ppm for a 15-minute exposure. Take partial-period sampling to determine compliance:

1. DRI reading during the first 5-minute period was 250 ppm.
2. DRI reading during the second 5-minute period was 600 ppm.
3. DRI reading during the final 5-minute period was 150 ppm.
4. Add all three readings and average (divide by 3) to obtain the concentration of the short-term exposure.

$$\text{Exposure Concentration} = \frac{250 \text{ ppm} + 600 \text{ ppm} + 150 \text{ ppm}}{3} = 333 \text{ ppm}$$

- The error factor for this DRI is 1.25
- The enforcement STEL is STEL X EF = 400 ppm X 1.25 = 500 ppm
- The sample indicates compliance.

D. Additive Effects

See Chapter 2 for a discussion of additive effects and calculation examples.

E. Recordkeeping

1. Complete the Area Sample Data Summary (refer to Chapter 21, Section IX) or Personal Exposure Data Summary (refer to Chapter 21, Section VIII) as applicable. Be sure that the concentration and exposure limit units of measurement are the same as those listed for the contaminant code (refer to Chapter 3).

2. Inspection reports should include a copy of the Health Field Notes, the completed Area Sample Data Summary (ASDS), Personal Exposure Data Summary (PEDS), citation/orders, and any other supplemental information collected during the inspection.

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I. Industrial Scientific Model TMX-410 Multi-Gas Monitor (Figure 13A-1)

Note: This instrument has interchangeable sensors for various gases. If the instrument fails to indicate a particular contaminant or fails calibration for a particular sensor, contact your field office supervisor for sensor replacement or instrument repair procedures.

Figure 13A-1. Industrial Scientific Corporation Models TMX – 410 and TMX – 412

A. Characteristics

Error Factor: 1.25

Sensors: Combustible Gases and Methane - Catalytic
Oxygen and Toxic Gases – Electrochemical

Measuring Range:

LEL (combustible gases)	0 - 100% in 1% increments
CH_4 (methane)	0 - 5% Volume in 0.1% increments
O_2 (oxygen)	0 - 30% Volume in 0.1% increments
CO (carbon monoxide)	0 - 999 ppm in 1 ppm increments
H_2S (hydrogen sulfide)	0 - 999 ppm in 1 ppm increments
SO_2 (sulfur dioxide)	0 - 99.9 ppm in 0.1 ppm increments
NO_2 (nitrogen dioxide)	0 - 99.9 ppm in 0.1 ppm increments
$C1_2$ (chlorine)	0 - 99.9 ppm in 0.1 ppm increments

Temperature Range:
Continuous Operation is 5° to 104° F (-15° to 40° C)
Continuous Operation in CO mode is 23° to 104° F (-5° to 40° C)

Humidity Range: 15 - 90 % relative humidity non-condensing

B. Summarized Operating Instructions

The TMX-410 is powered by a rechargeable 7.5 volt nickel-cadmium battery that can be replaced in the field. The instrument is certified as intrinsically safe.

1. Turning ON the TMX-410

a. Loosen the finger nut at the base of the instrument and rotate the calibration cover to expose five switches.

b. Slide the ON/OFF switch to the left. The four LEDs will flash once and the instrument will emit a short beep.

c. The following screens are displayed during start-up sequence:

Display test - All display segments are activated briefly to verify that they are operating properly.

Battery - If the battery is not fully charged, the voltage reading will blink.

Sensor configuration - Displays installed sensors.

Code - Normal startup continues without any operator response. The calibration procedure can be accessed by entering the correct code.

Hygiene - Startup continues without any operator response. A new data logging session is started if (E) is pressed while the HYGIENE screen is displayed (if instrument is equipped with hygiene option).

d. The TMX-410 begins operating in the INSTANT (default) mode. This mode displays the current levels of each installed gas sensor. At this point, the calibration cover can be repositioned and the finger nut tightened.

2. Changing Viewing Modes

To view the sensor configuration, press and hold the MODE switch. The sensor configuration is displayed for 5 seconds. If the MODE switch is released while the sensor configuration is displayed, the instrument will return to the INSTANT mode. To access the remaining viewing modes, continue holding the MODE switch until ZERO appears.

3. Instrument Check

A functional ("bump") test should be performed on each instrument prior to each day's use. The test is a brief exposure, until the instrument goes into visual or audible alarms, of the instrument to a known concentration of gas for the purpose of verifying sensor and alarm operation. Each sensor on the instrument should be tested.

If an instrument fails to operate properly following any functional ("bump") test, a full instrument calibration should be performed prior to its use.

4. Accessing the Calibration Procedure

In order to calibrate the instrument you must enter the correct code or use the factory code of zero (0). The following are the steps preceding calibration.

a. Ensure that the battery is fully charged.

b. Turn on the instrument and follow the start-up sequence from the operating manual.

c. Enter the code and press (E), and the calibration cycle is accessed.

d. The calibration procedure consists of four functions identified by the following:

- ZERO
- SPAN
- ALARMS
- CODE

The scrolled prompt "PRESS (+) TO STEP (E) to SELECT (M) TO EXIT" appears on each screen.

5. Zeroing the Instrument

a. To select Zero, press (E) when the word appears on the display. At this point the scrolled prompt reads, PRESS (E) TO START (M) TO EXIT.

b. Press (E) to start zeroing in fresh air. If air purity is a concern, move to an uncontaminated location. The zero process will continue for two minutes. At the end of the two minute period, the sensors should display 20.9% oxygen and zero for all other combustible and toxic sensors. The instrument will emit a short beep and return to the zero screen.

6. Span Calibration (see Figure 13A-2)

Figure 13A-2. Calibration of TMX-410 and TMX-412 Instruments

The instrument should be zeroed before calibrating low oxygen span and the combustible or toxic gas spans.

a. Press (+) to advance from the ZERO screen to the SPAN sequence. Press (+) to step through the list of available gas sensors. The name of the gas and the current reading are displayed as each gas is accessed. Only installed sensors are displayed.

b. Press (E) when the desired gas is displayed. The last span concentration used is displayed and the gas identifier blinks, indicating that the displayed gas has been selected for calibration. The scrolled prompt reads: PRESS (+) OR (-) TO SET (E) TO ENTER (M) TO EXIT.

c. Press (+) or (-) to adjust the displayed number so that it reads as closely as possible to the concentration printed on the calibration gas cylinder. Press (E) to enter the set concentration. When the instrument accepts the number, the gas identifier stops blinking and the scrolled prompt reads: APPLY GAS PRESS (E) TO START (M) TO EXIT.

d. Connect the calibration cup to the appropriate calibration gas cylinder. Place the calibration cap on the instrument and turn on the gas supply. Press (E) to start the automatic span cycle. The gas reading is displayed to full sensitivity. A displayed value greater than the span gas indicates reserve sensitivity of the gas sensor.

e. Upon completion of the automatic span cycle, the instrument will respond to one of the following conditions:

- The sensor sensitivity is at least 70 % of a new sensor. A short beep is heard, verifying calibration. The instrument returns to the gas identifier screen and displays the current measured value.

- The sensor activity is less than 70% but greater than 50% of a new sensor. A short beep is heard and the instrument returns to the identifier screen. However, the current displayed value flashes until the screen is changed, indicating the sensor should be changed soon.

- The sensor sensitivity is below 50% of a new sensor. The calibration FAIL screen appears and a fault alarm sounds until a key switch is pressed. If a new sensor is installed without a follow up calibration, a sensor fail will be indicated during normal operation.

7. Changing Alarm Settings

a. Press (+) to advance from SPAN screen to ALARMS screen.

b. Press (E) to select ALARMS. The INSTANT screen then appears and the scrolled prompt reads, PRESS (+) TO SELECT (M) TO EXIT.

c. To access the INSTANT alarms, press (E). The current low-level alarm setting of the first available gas then appears on the display. Pressing (+) allows you to step through the current low and high alarm settings for the available gases.

d. To change any alarm setting, press (E) when the desired alarm is displayed. The gas identifier then blinks, indicating that you may change the existing alarm. The scrolled prompt reads, PRESS (+) OR (-) TO SET (E) TO ENTER (M) TO EXIT.

e. Press (+) or (-) to change the concentration (numerical value) of the alarm. Press (E) to enter the new setting. The display then stops flashing.

- As a guide, low and high alarm values may be set at:

  LOW ALARM SETTING - 50 % of a TLV® or PEL
  HIGH ALARM SETTING - 80-100 % of the TLV® or PEL

- To provide an additional measure of warning protection for the miner and MSHA field personnel, it is recommended that the factory Default Alarm Setting for CO High Alarm be reduced from 70 ppm to 50 ppm; the factory Default Alarm Setting for NO_2 Low Alarm be reduced from 3 ppm to 2 ppm; and the NO_2 factory Default Alarm Setting for NO_2 High Alarm be reduced from 6 ppm to 4 ppm.

II. Industrial Scientific Model TMX-412 Multi-gas Monitor (Figure 13A-1)

Note: This instrument has interchangeable sensors for various gases. If the instrument fails to indicate a particular contaminant or fails calibration for a particular sensor, contact your field office supervisor for sensor replacement or instrument repair procedures.

A. Characteristics

Error Factor: 1.25

Sensors: Combustible Gases and Methane - Catalytic
Oxygen and Toxic Gases - Electrochemical

Measuring Range:

LEL (combustible gases)	0 - 100% in 1% increments
CH_4 (methane)	0 - 5% Volume in 0.1% increments
O_2 (oxygen)	0 - 30% Volume in 0.1% increments
CO (carbon monoxide)	0 - 999 ppm in 1 ppm increments
H_2S (hydrogen sulfide)	0 - 999 ppm in 1 ppm increments
SO_2 (sulfur dioxide)	0 - 99.9 ppm in 0.1 ppm increments
NO_2 (nitrogen dioxide)	0 - 99.9 ppm in 0.1 ppm increments
$C1_2$ (chlorine)	0 - 99.9 ppm in 0.1 ppm increments

Temperature Range:
Continuous Operation is -4° to 122° F (-20° to 50° C)

Humidity Range:
15 - 90 % relative humidity (continuous operation)
0 % to 99 % relative humidity (intermittent operation)

See Figures 13A-3 through 5 for the original version, Figure 13A-6 through 9 for the new version. The TMX-412 is powered by a rechargeable 7.5 volt nickel cadmium battery that can be replaced in the field. The instrument is certified as intrinsically safe.

B. Summarized Operating Instructions

1. Turning ON the TMX-412

Start with Figure 13A-3 for the original version or Figure 13A-6 for the new version.

Press and hold the MODE key. All segments of the display are activated for about a second to verify proper operation. The HOLD screen appears and the instrument sounds a beep once every second. Continue pressing the MODE key for five beeps until the RELEASE screen appears. The RELEASE screen will remain for a few seconds.

The following start-up screens are displayed during the start-up sequence:

a. Sensor configuration - Displays the type and position of installed sensors.

b. Code - Normal start-up continues without any operator response. The calibration system may be accessed while this screen is displayed by entering the correct code.

c. Hygiene (only on instruments with this option) - Normal start-up continues without any operator response.

The TMX-412 begins normal operation in the INSTANT readings mode, monitoring all installed and calibrated gases.

2. Changing Viewing Modes

The TMX-412 offers different display modes for accessing various features. To change viewing modes, press the MODE switch and release it when the next screen appears. The modes are accessed in the following sequence:

a. Instant - The instantaneous levels of all gases are continuously displayed. The battery charge level is shown graphically.

b. Sensor configuration - All installed sensor types are displayed ZERO. This mode allows the user to zero the instrument and span oxygen without accessing the calibration system.

c. PK (peak readings) - This mode displays the highest measured levels of installed combustible and toxic gas, as well as the lowest measured level of oxygen since the peaks were last cleared.

d. PK CLR - Allows the operator to clear the peak values.

After the PK CLR screen, the standard TMX-412 repeats the mode sequence beginning with the INSTANT readings. If the instrument is equipped with the HYGIENE option, the sequence continues with viewing modes for this application. (See Figure 13A-5 for original version.)

3. Daily Instrument Check

A functional ("bump") test should be performed on each instrument prior to each day's use. The test is a brief exposure, until the instrument goes into visual or audible alarms, of the instrument to a known concentration of gas for the purpose of verifying sensor and alarm operation. Each sensor on the instrument should be tested.

If an instrument fails to operate properly following any functional ("bump") test, a full instrument calibration should be performed prior to use.

4. To Zero the Instrument and Span Oxygen

The instrument may be zeroed and the oxygen sensor, if installed, may be spanned without accessing the calibration system. Note: The instrument can only be successfully zeroed in clean air with a normal oxygen level of 20.9 %.

a. Press MODE to access the zero screen.

b. Press (E) to start the ZEROING function. The instrument returns to the INSTANT mode after the ZEROING and OXYGEN SPAN sequence is completed.

5. To Clear Peak Readings

The TMX-412 continuously saves the highest measured values of toxic and combustible gases and the lowest measured value of oxygen. These readings are displayed in the PK (peak readings) mode. To clear the peak readings:

a. Press mode to access the PK CLR screen.

b. Press (E) to clear peaks. The PK screen (Peak Readings) verifies that peak values have been cleared.

6. To Clear Combustible Gas Over-Range

When the TMX-412 detects combustible gas in excess of 100 % of LEL, or 5.0 % of CH_4 by volume, a high alarm condition is engaged, and +OR (for over-range) is displayed for the combustible gas. This feature protects the combustible gas sensor from damage. If this occurs, exit the contaminated area, turn off the instrument temporarily, restart the TMX-412, and clear the instrument in clean air.

Note: The calibration procedure outlined in items 7 and 8 are illustrated in the manufacturer's instruction flowsheets at the end of this section (see Figures 13A-3 through 13A-9). The TMX-412 can be electronically calibrated with the use of test span gas by using the sequence of push-button steps as described in the manufacturer's instruction flowsheet. However, first you must determine which program version the instrument has. To determine if you have the original older version TMX-412 or the new version TMX-412, observe the following at start up. If the display reads "CODE 0" after displaying the sensor configuration, you have the older original version. If your instrument counts backwards after displaying the sensor configuration, you have the new version. The instructions that follow are summarized from the TMX-412 original version instruction manual.

7. Accessing the Calibration System

See Figure 13A-4 for the original version, or Figure 13A-7 for the new version. New version screen commands that are different are given in brackets [ ].

To access the calibration system, the correct code must be entered upon initial start-up. TMX-412 units have a factory code of zero (0). Be sure the unit is fully charged. In order to ensure user safety, a calibration check should be performed prior to each use.

a. Turn on the instrument and follow the start-up sequence.

b. When the CODE screen appears, the number 0 is displayed. The scrolled prompt reads: PRESS (+) OR (-) TO SET (E) TO ENTER (M) TO EXIT. If the access code has been changed from 0, you must enter the correct number on the display by pressing (+).

c. Press (E) to enter set code. The calibration system main menu is accessed. If the correct code is not entered in 40 seconds, the unit will begin normal operation. The calibration system can be exited by pressing the MODE key at any time. To access the Calibration system again, the instrument must be turned off and on again.

The calibration system menu consists of the following three functions:

- CAL [GO CAL]
- ALARMS
- CODE

The scrolled prompt PRESS (+) TO STEP (E) TO SELECT (M) TO EXIT appears on each screen.

8. Calibrating the Instrument (see Figure 13A-2)

a. To select CAL [GO CAL], press (E) when the word CAL [GO CAL] is displayed. The zeroing sequence is started. Zeroing in room air is preferred provided there is no contaminant present.

b. The instrument remains in the zeroing sequence for two minutes. During the sequence, the word zeroing is displayed and the scrolled prompt reads PRESS (M) TO EXIT. To zero the instrument on zero grade air, apply gas before pressing (E) to select CAL [GO CAL].

c. APPLY GAS means to connect the calibration cup to the appropriate calibration gas cylinder. Place the calibration cap on the instrument and turn on the gas supply.

d. When the zeroing sequence ends, the instrument emits a short beep and the first available gas appears.

e. Press (+) to step through the available gases. The name of the gas and the current reading are displayed as each gas is accessed. The scrolled prompt reads: PRESS (+) TO STEP (E) TO SELECT (M) TO EXIT.

f. Press (E) when the desired gas appears on the display. The most recent span concentration used is displayed and the gas identifier blinks, indicating that the gas was selected for calibration. The scrolled prompt reads: APPLY GAS [APPLY] PRESS (+) OR (-) TO SET (E) TO START (M) TO EXIT.

g. Apply the span gas and press (+) or (-) to adjust the displayed number to agree as closely as possible with the concentration printed on the gas cylinder.

h. Press (E) to enter the set concentration and start the calibration sequence. When the instrument accepts the number, the gas identifier stops blinking and the scrolled prompt reads: PRESS (M) TO EXIT. During the span cycle the gas reading is displayed to full sensitivity. A value greater than the span gas concentration indicates reserve sensitivity.

i. When the automatic span cycle ends, the instrument will respond to one of the following conditions.

1) The sensor sensitivity is at least 70 % of a new sensor. A short beep is heard, verifying calibration. The instrument returns to the gas identifier screen and displays the current measured value.

2) The sensor activity is less than 70 % but greater than 50 % of a new sensor. A short beep is heard and the instrument returns to the identifier screen. However, the current value displayed flashes until the screen is changed, indicating the sensor should be changed soon.

3) The sensor sensitivity is below 50 % of a new sensor. The calibration FAIL screen appears and a fault alarm sounds until a key switch is pressed. If new sensor installation followed by calibration is not conducted; a sensor fail will be indicated during normal operation.

If calibration fails, check whether the gas cylinder emptied during calibration gas application. If this occurred, recalibrate with a new calibration cylinder. If the instrument still fails calibration, the sensor may need to be replaced.

9. Changing Alarm Settings

See Figure 13A-4 for the original version or Figure 13A-8 for the new version.

a. Press (+) to advance from the CAL screen to the ALARMS screen.

b. Press (E) to select ALARMS. The INSTANT screen appears and the scrolled prompt reads: PRESS (+) TO STEP (E) TO SELECT (M) TO EXIT.

c. Press (E) to select INSTANT alarms. The current low-level alarm setting of the first available gas appears on the display.

d. Press (+) to step through the current alarm settings for all available gases. The display will identify the gas and the INSTANT alarm type as either high (H) or low (L).

e. To change any alarm setting, Press (E) when the desired alarm is displayed. The gas identifier then blinks, indicating that you may change the existing alarm. The scrolled prompt reads: PRESS (+) OR (-) TO SET (E) TO ENTER (M) TO EXIT.

f. Press (+) or (-) to change the alarm setting.

g. Press (E) to enter the new setting. The display then stops flashing.

Follow this procedure to change the alarm settings for any available gas. Once the changes are complete, press (M) to return to the instant screen.

As a guide, low and high alarm values may be set at:

LOW ALARM SETTING - 50 % of a TLV® or PEL.
HIGH ALARM SETTING - 80 - 100 % of the TLV® or PEL.

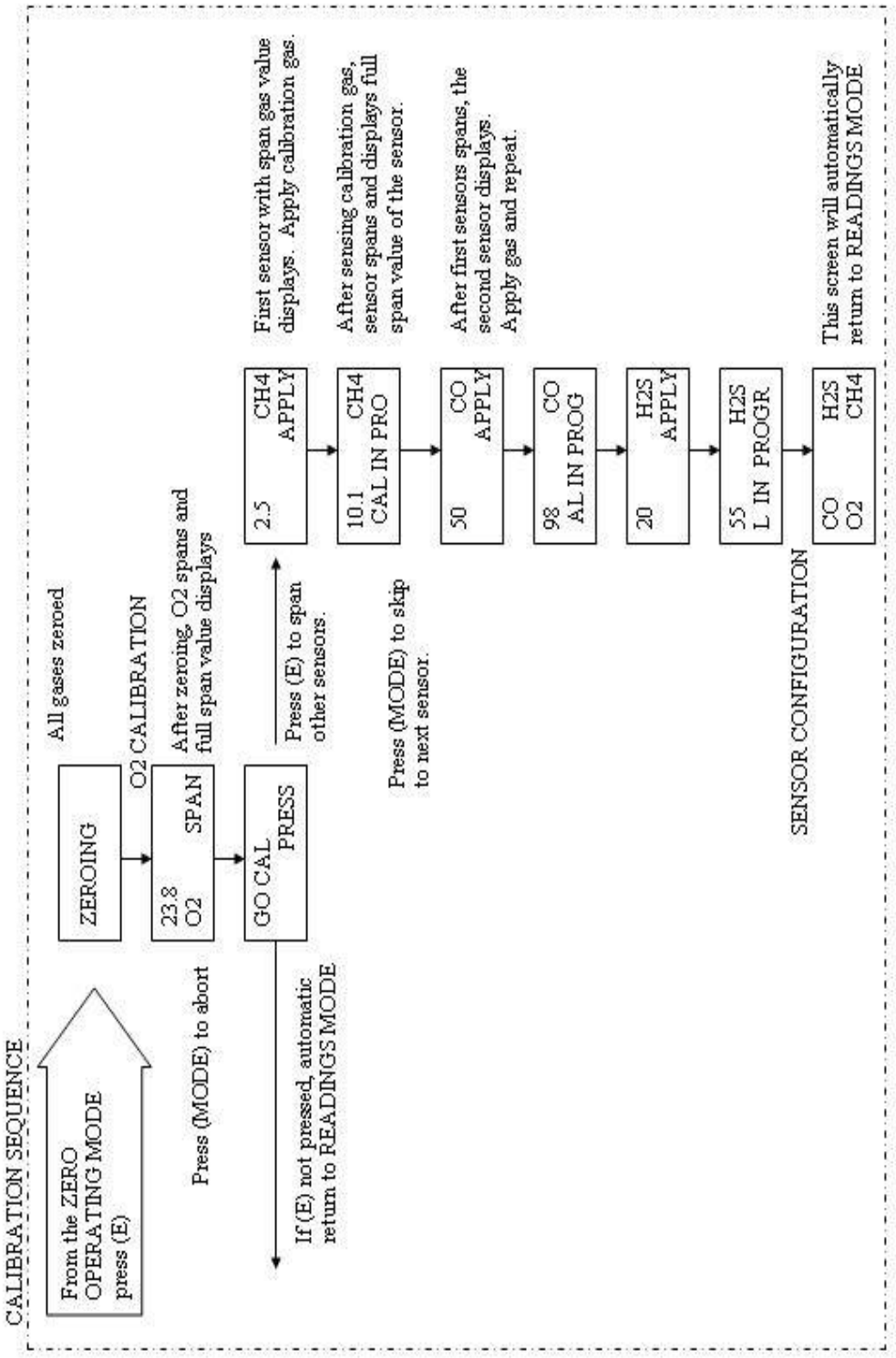

Figure 13A-3. Command Flowsheet for TMX-412 (Original Version), page 1

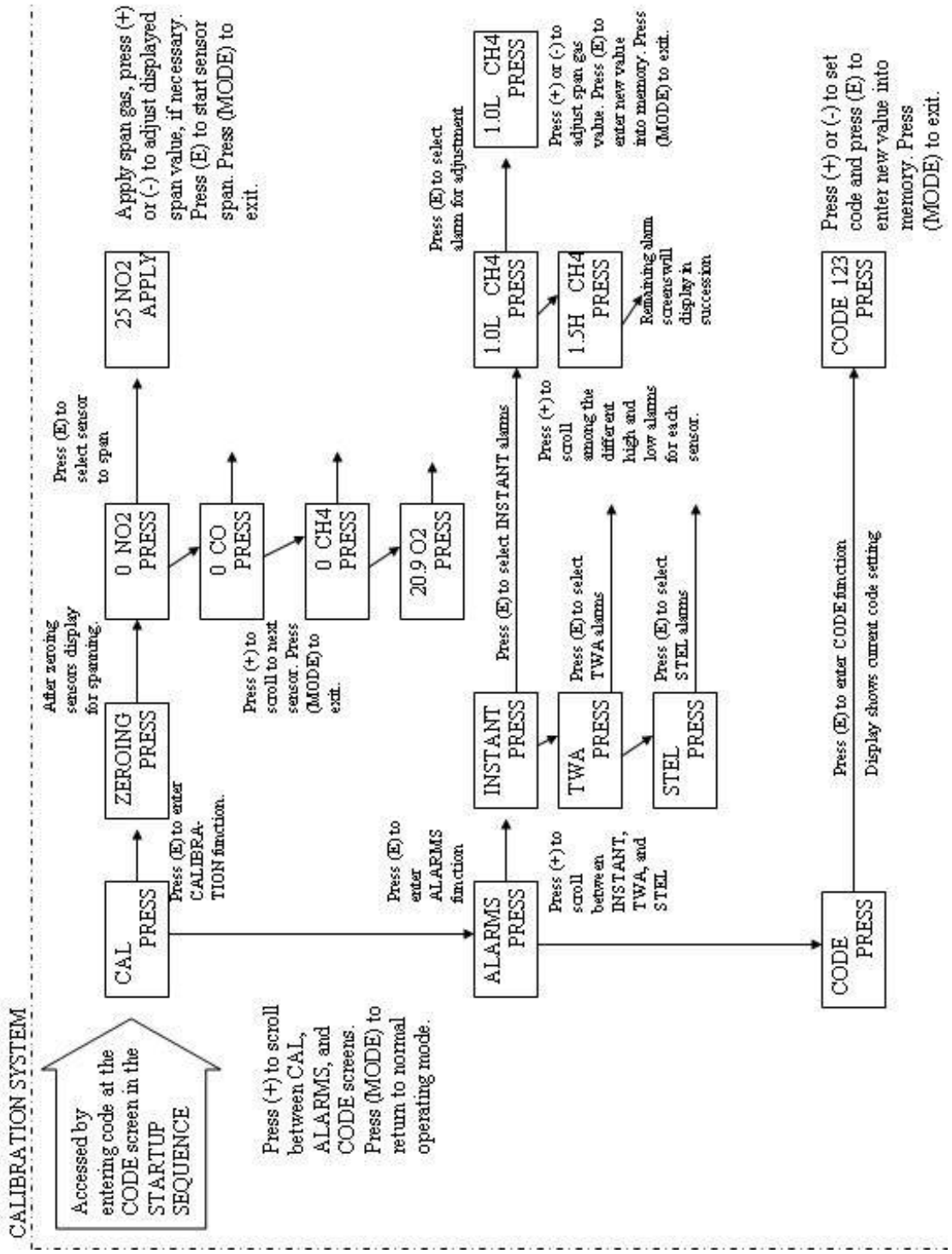

Figure 13A-4. Command Flowsheet for TMX-412 (Original Version), page 2

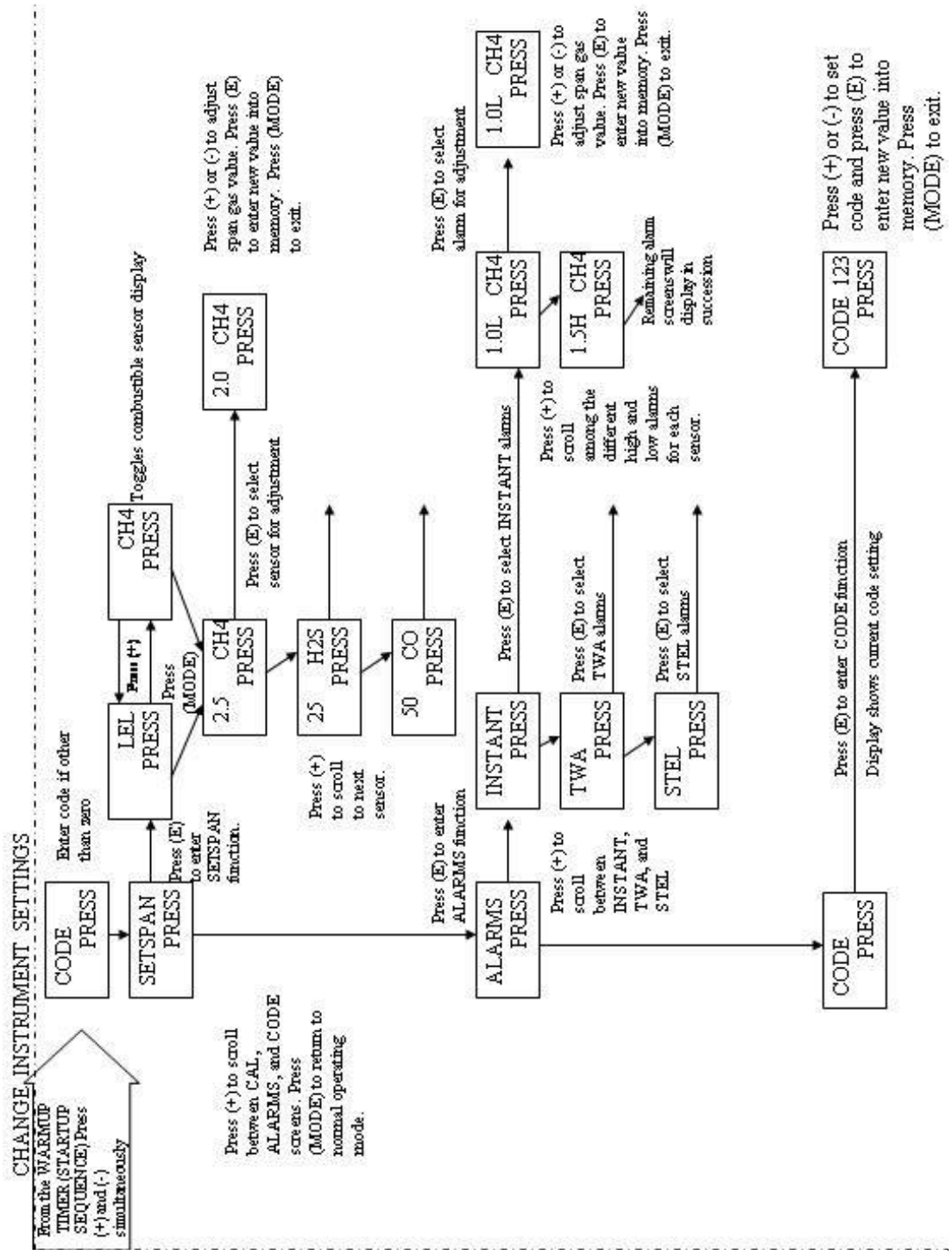

Figure 13A-5, Command Flowsheet for TMX-412 (Original Version), page 3

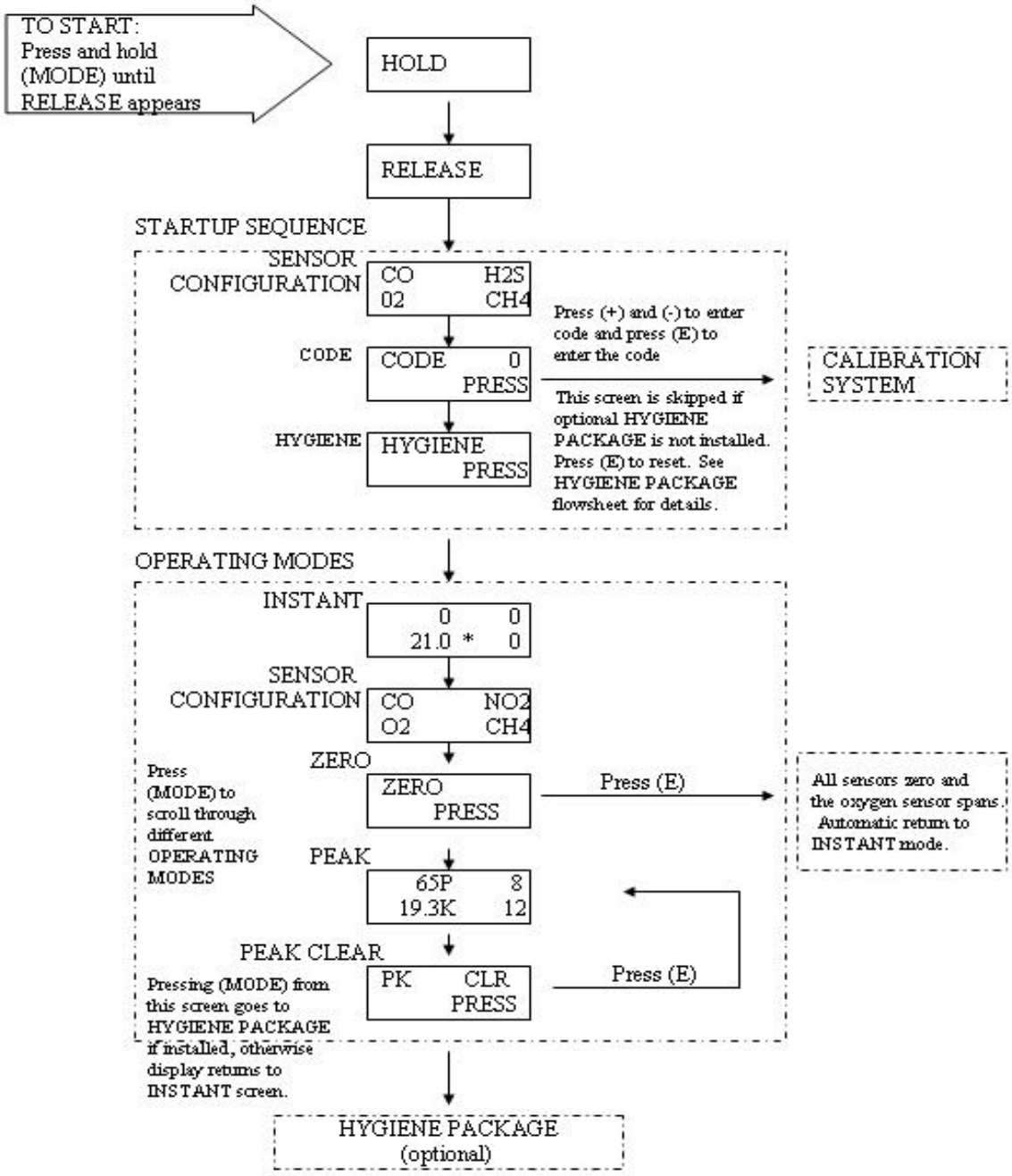

Figure 13A-6. Command Flowsheet for TMX-412 (New Version), page 1

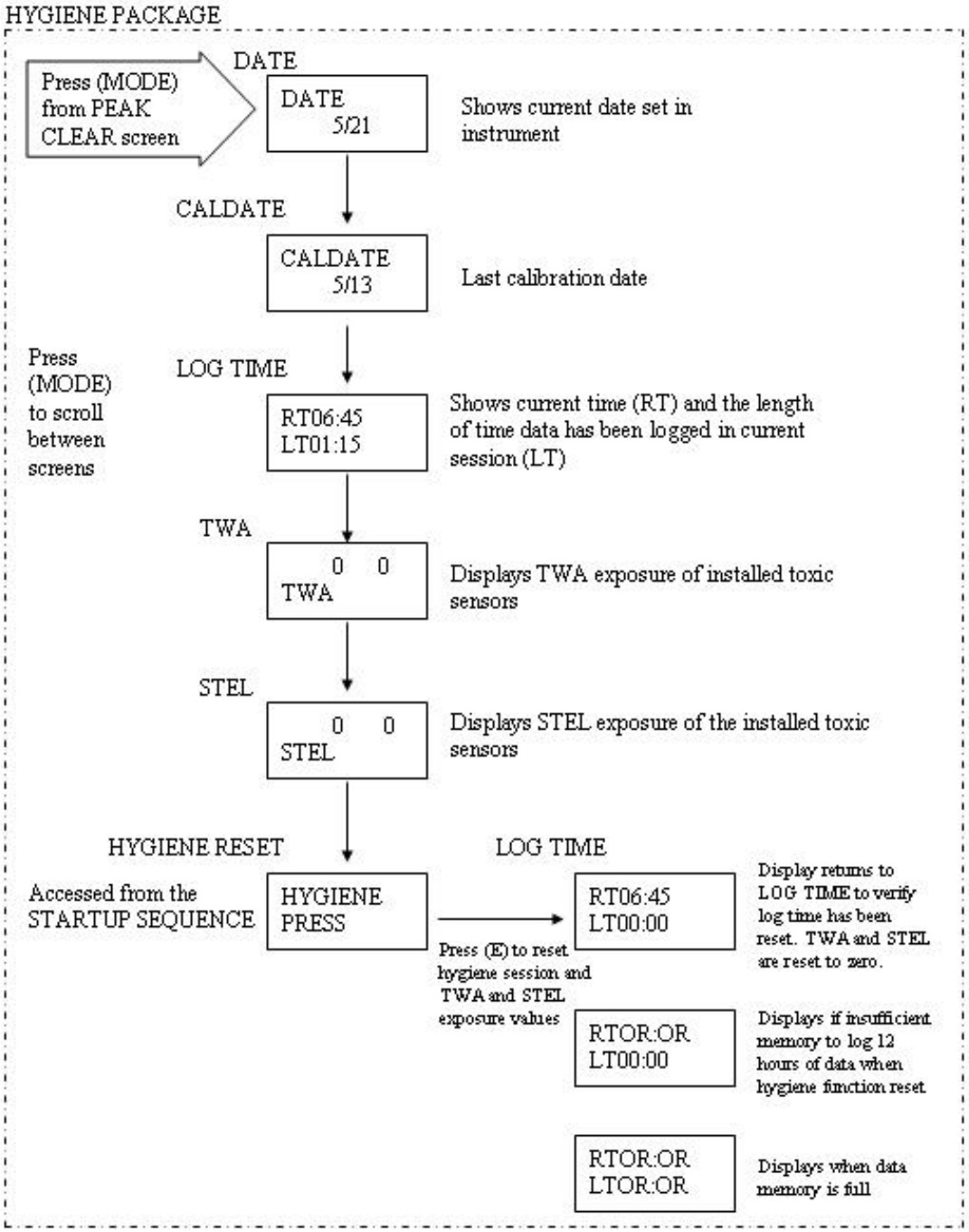

Figure 13A-7. Command Flowsheet for TMX-412 (New Version), page 2

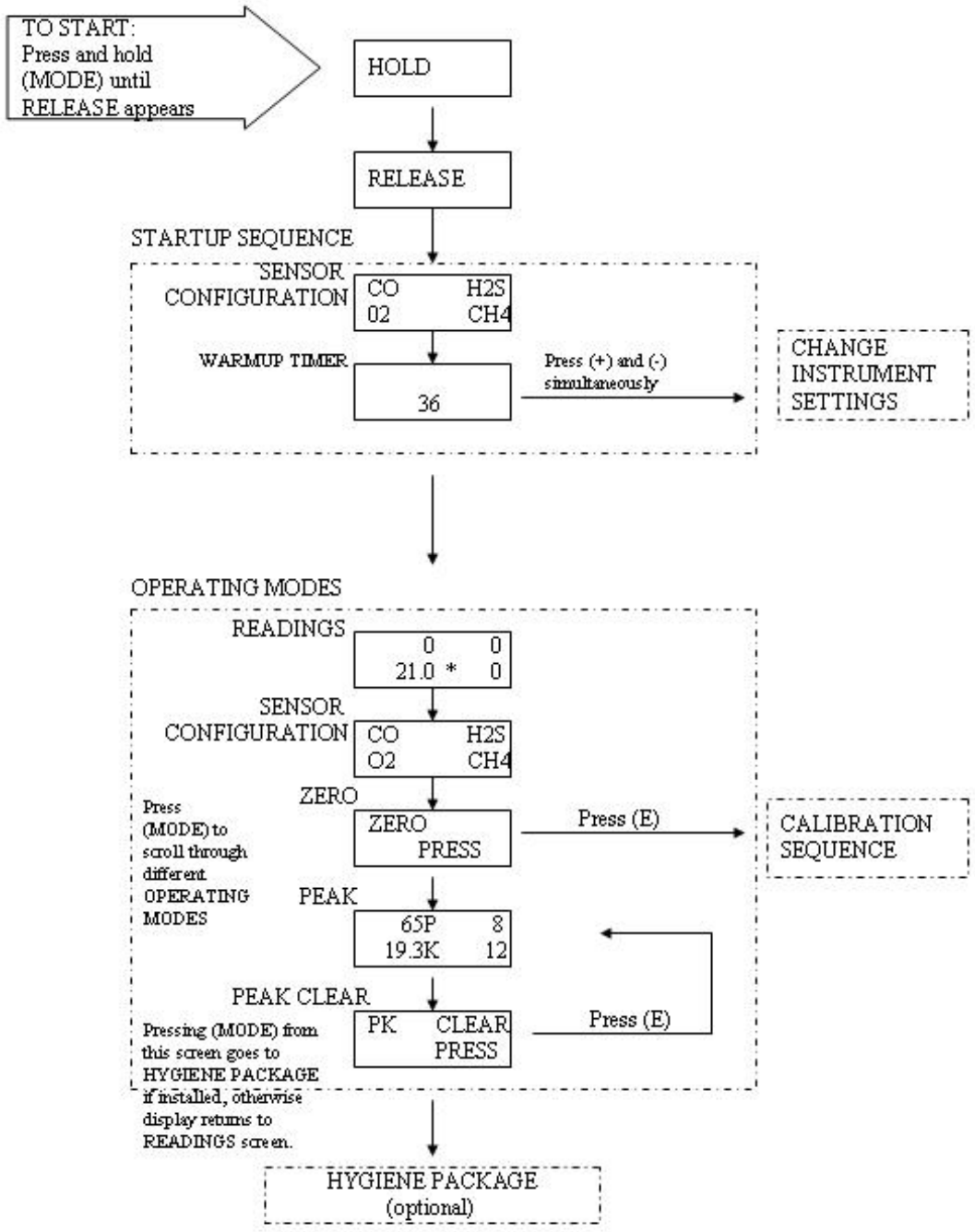

Figure 13A-8. Command Flowsheet for TMX-412 (New Version), page 3

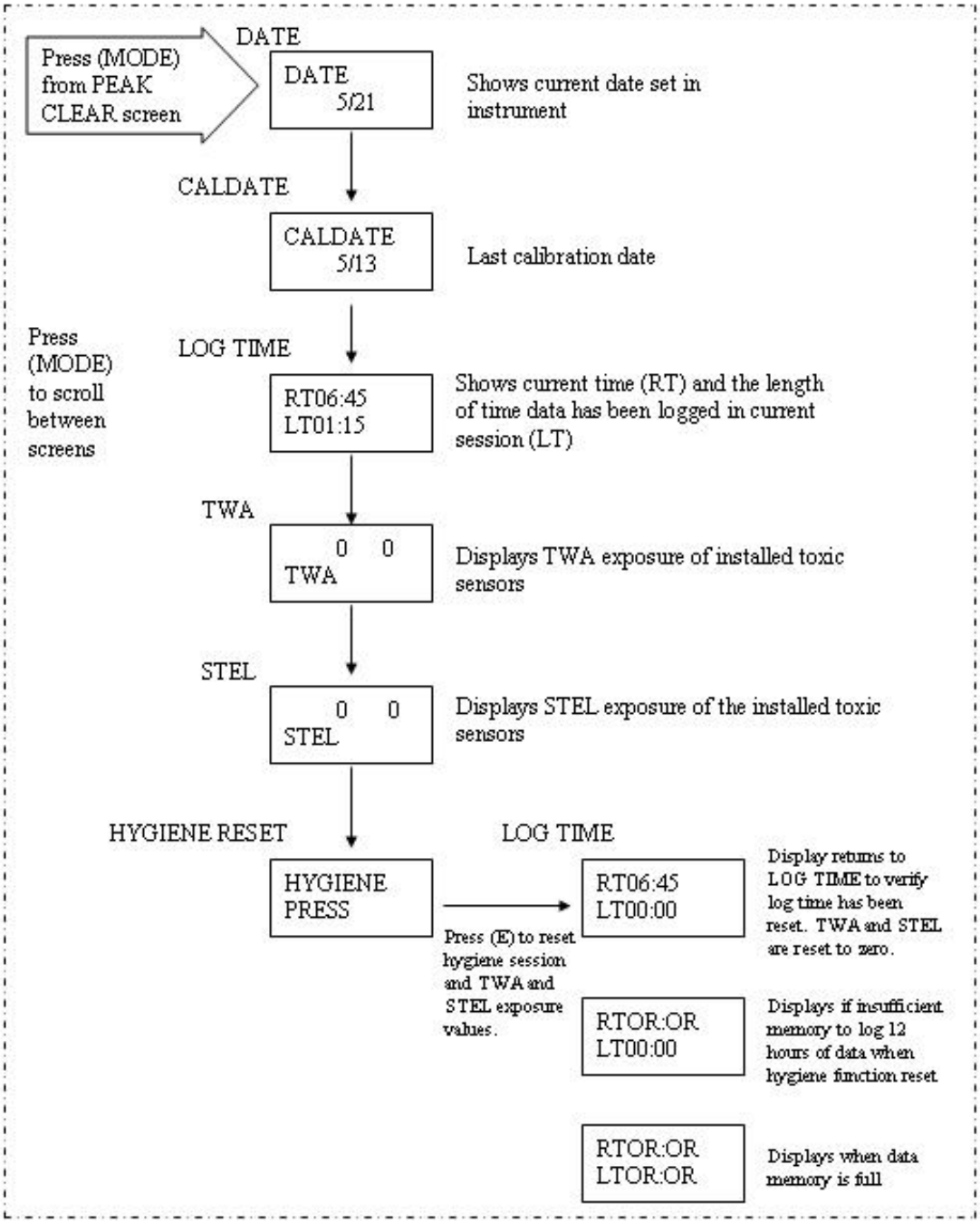

Figure 13A-9. Command Flowsheet for TMX-412 (New Version), page 4

III. Jerome Model 411 Gold Film Mercury Vapor Analyzer (Figure 13A-10)

A. Characteristics

Error Factor: 1.09

Flow rate: 0.75 Liters/min = 750 cc/min

Sensitivity: 0.003 mg/m^3

Range: 0.000 - 1.999 mg/m^3

Accuracy: ± 5 % at 0.107 mg/m^3 Hg

Temperature Range: 32° to 104° F (0° to 40° C)

B. Summarized Operating Instructions

1. Press power ON.

2. Check battery status. If LOW BAT (low battery) shows, recharge or replace.

3. Check Sensor Status %. The LCD display in % saturation must be between 01 and 99 for the instrument to operate.

4. If the meter reads .L.L.L, the bridge balance needs adjustment.

5. Press SAMPLE. If after 10 seconds the meter reads .8.8.8, the gold film sensor is 100% saturated and the films must be heated. The meter must go through a 15-minute film heat cycle at the following times:

- When the meter reads .8.8.8;
- At the end of each day of use; and
- After periods of storage longer than 3 months.

Film Heat Procedure:

a. Attach a clean air filter to the intake filter housing.

b. Attach the line cord to the 411 and plug into an AC electrical outlet.

c. Connect the battery charger to the 411 and plug the battery charger into an AC electrical outlet.

d. Press POWER ON.

e. Press FILM HEAT. The meter reads .H.H.H during the 15-minute cycle.

f. Press SENSOR STATUS and hold down. Disregard this reading.

g. Adjust BRIDGE BALANCE; use trimmer tool to read between 02 and 06.

h. Press POWER OFF.

i. Disconnect battery charger and line cord.

j. Remove clean air filter.

6. Press SURVEY (1 sec) or SAMPLE (10 sec).

7. Read the meter. The number displayed is the mercury concentration in mg/m^3.

8. For locating spills, keep the SURVEY button pressed down so that each reading will be a discrete one second sample.

9. Occasionally check SENSOR STATUS %.

10. Press POWER OFF when not in use.

C. Calibration

The manufacturer recommends calibration by the factory every 12 months, depending on use. The following field calibration check or "Functional Test" should be performed after 20 hours of use or every 3 months (whichever comes first).

1. Set up Test Vapor

a. Unwrap the thermometer assembly.

b. Remove the cap from the calibration vessel (thermos).

c. In your calibration kit locate the vial labeled "Caution: Hg."

d. Wearing gloves and any other appropriate PPE, hold the vial over a lipped container. Remove the cap from the vial containing mercury and carefully pour the liquid mercury into the calibration vessel.

e. Install the thermometer assembly securely in the mouth of the calibration vessel (i.e., thermos).

f. Place the calibration vessel in a location with a stable ambient temperature, preferably between 64°F and 72° F (18°C and 22° C).

2. Procedure (see Figure 13A-10)

a. Lightly shake the calibration vessel.

b. Leave the calibration vessel at a stable room temperature for 2 hours.

c. Unplug line cord and battery charger.

d. Change the intake filter disc and septum. Plug the septum assembly into the intake filter housing.

e. Attach the clean air filter to the septum assembly.

f. Press POWER ON.

g. Note the temperature of the calibration vessel.

h. Inject 1 cc of mercury vapor from the calibration vessel (Thermos) using the syringe, and record the meter reading.

i. Repeat step h. three times. The three readings must be ± 5 % of each other.

j. Refer to the Temperature Conversion Chart, Figure 13A-11, acceptable range, and compare to 411 meter display.

k. If the average of the three meter readings does not fall within the acceptable range, perform a film heat, adjust the bridge balance, and repeat the calibration procedure.

l. If the meter cannot be brought into calibration range, return to the manufacturer according to District procedures.

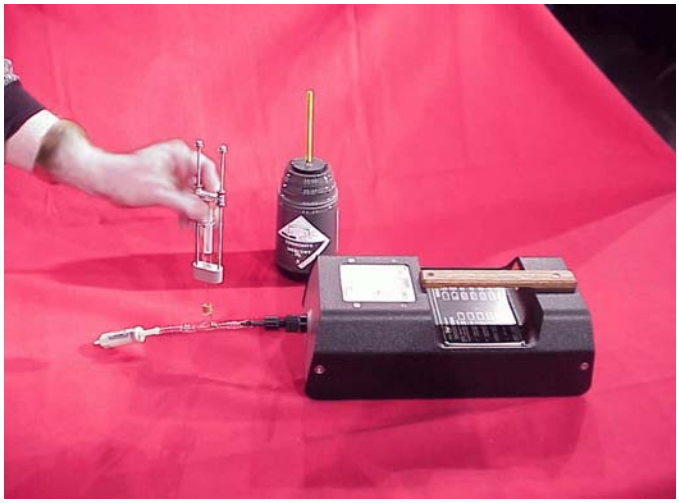

Figure 13A-10. Calibration of the Jerome Mercury Analyzer

Figure 13A-11. 411 Temperature Conversion Chart	
Temperature °C	**Acceptable Range of Digital Meter Response**
16	0.064 to 0.086
17	0.070 to 0.094
18	0.076 to 0.102
19	0.082 to 0.112
20	0.090 to 0.122
21	0.097 to 0.131
22	0.105 to 0.143
23	0.115 to 0.155
24	0.124 to 0.168

D. Maintenance and Repair

1. Battery Charging

To obtain maximum battery life, wait until LOW BAT appears on the LCD meter, and then charge the battery with instrument power OFF for 16 hours. Battery life under normal use is 1 - 2 years. Replace batteries when they fail to hold a charge.

2. Replacing Battery Pack

a. Disconnect the battery charger and line cord from the 411 and turn power OFF.

b. Open the 411 by removing two side screws from the meter end of the case.

c. Disconnect battery jacks.

d. Remove the two screws holding the battery pack.

e. Install new battery pack.

f. Replace the battery pack bracket and tighten the screws.

g. Reconnect the battery jacks.

h. Close the case and replace the screws.

3. Replace the intake filter disc after 20 hours of use or every 3 months, as needed.

a. Unscrew the intake filter housing from the 411.

b. Remove the disc by pushing it out with the trimmer tool.

c. Replace with a new disc. Do not touch the disc with your fingers - use tweezers.

d. Screw the intake filter housing back on the 411.

4. Change the internal filter cartridge and tubing after 6 months of use, or as needed.

a. Remove the two side screws on the 411 meter end and open the case.

b. Disconnect Tygon Tubing and discard.

c. Remove the filter cartridge and discard.

d. Attach tubing “A” to intake filter housing. Gently expand the end of tubing with needle nose pliers and moisten end of filter cartridge. Attach new pre-cut Tygon tubing “B” to the arrow end of the new filter.

e. Install this assembly in the 411.

f. Push the filter into the mounting clip.

g. Remove kinks in the tubing and check that tubing connections are secure.

h. Close the case and replace the screws.

5. Exterior zero air filter and the interior Hg Exhaust Filter should be replaced at least annually.

IV. JEROME 431X GOLD FILM MERCURY VAPOR ANALYZER (Figure 13A-12)

Figure 13 A-12. Jerome Model 431X Mercury Vapor Analyzer

A. Characteristics

Error Factor: 1.09

Flow rate: 0.75 Liters/min = 750 cc/min

Sensitivity: 0.003 mg/m^3

Range: 0.003 - 0.999 mg/m^3

Accuracy: ± 5 % at 0.100 mg/m^3 Hg

Temperature Range: 32° to 104° F (0° to 40° C)

B. Summarized Operating Instructions

1. Press power ON. Allow a 1 minute warm-up period.

2. Perform a sensor regeneration according to the procedure in Section C below. Thirty minutes after completion of this cycle, re-zero the instrument.

3. Press the SAMPLE button once.

4. At the end of the 12 second cycle, read the digital meter. The number on the meter is the mercury concentration in mg/m^3.

5. At the end of each day's use, perform a sensor regeneration. Do not allow contamination to remain on film overnight.

C. Sensor Regeneration Procedure

A sensor regeneration is needed to clear the 431X sensor of any accumulated mercury under the following circumstances:

- When the meter displays .8.8.8, indicating saturation;
- At the beginning of the day on which it is to be used;
- During the mercury survey, if the sensor becomes saturated; and
- At the end of the day's survey before storage.

1. Attach power cord and plug into an AC electrical outlet.

2. Press the power ON button.

3. Press the REGEN (regeneration) button. The meter will flash .H.H.H for 10 minutes and display .0.0.0 when completed. Do not interrupt this cycle.

4. While pressing the ZERO button, turn the ZERO ADJUST, using the tool, until the meter reads 0. Note: Wait at least 30 minutes after the sensor regeneration cycle is completed to ensure maximum sample accuracy.

5. Press OFF button and disconnect power cord.

D. Survey Mode (to locate spills or access potentially high concentrations)

1. Press the power ON and allow a 1 minute warm-up.

2. Press and hold the SAMPLE button. The instrument has a 12 second cycle and in the survey mode, a sample is taken every 3 seconds. The display flashes the measured concentration at the end of each 3 second period.

3. When the survey has been completed, release the sample button. The final survey value remains displayed until the next sample is taken.

4. Press the power OFF button when not in use.

E. Calibration (see Figure 13A-12)

The manufacturer recommends calibration by the factory every 12 months, depending on use. The following field calibration check or "Functional Test" should be performed after 20 hours of use, or every 3 months (whichever comes first).

1. Carefully unpack and inspect the parts of the kit.

2. In a ventilated area, remove the mercury vial.

3. Wearing gloves and any other appropriate PPE, open the vial and carefully pour the mercury into the center of the functional test kit's vessel's opening.

4. Install the stopper assembly to prevent breakage of the thermometer.

5. Allow 2 hours for the kit to adjust to room temperature: 64°F - 72° F (18°C - 22° C).

6. Loosen, but do not remove, the base of the vessel. The base unscrews from the body.

7. Set on a firm surface. Hold the base stationary and unscrew the body from the base.

8. Hold the base and inner glass vessel with one hand while removing the body and gasket with the other.

9. After the mercury is transferred into the glass inner vessel, reassemble in the reverse order.

10. Replace the 0.25 mm fritware.

11. Replace the septum on the septum holder assembly.

12. Attach a zero air filter to the septum assembly.

13. Press power on.

14. Take 3 samples. If the average meter reading is less than 0.005, continue to next step. If not, the instrument may be contaminated. Stop here.

15. Note the temperature of the calibration vessel.

16. Press the SAMPLE button, and wait 2 seconds. When the display flashes, inject 1 cc of mercury vapor using the syringe technique.

17. Record reading.

18. Repeat last two steps. The average of the last 3 readings should fall within the range shown in Figure 13A-13. If within range, the meter is functioning properly.

Figure 13A-13. 431X Temperature Conversion Chart

Temperature °C	Acceptable Range of Digital Meter Response
16	0.091 to 0.123
17	0.100 to 0.135
18	0.108 to 0.146
19	0.118 to 0.159
20	0.129 to 0.174
21	0.138 to 0.187
22	0.151 to 0.204
23	0.164 to 0.222
24	0.177 to 0.240

19. If the calibration was successful, perform another "Sensor Regeneration" (see Section C. above). If the meter cannot be brought into calibration range after repeating the complete procedure, return to the manufacturer according to District procedures.

F. Maintenance

Refer to the manufacturer's operations manual for a preventive maintenance calendar. Follow these general guidelines. Note: Maintenance frequency depends on the amount of use, rather than a set time interval.

1. Replace the 0.25 mm fritware once a week, or more often in a dusty environment.

a. Unscrew and remove the intake.

b. Push the old fritware disk out, using trimmer tool.

c. Use tweezers to insert new fritware. Avoid using fingers.

d. Use blunt end of trimmer tool to seat fritware disc firmly against inner ledge of intake.

e. Screw the intake back on.

2. Change internal filters after 6 months or as needed. Change the external zero air filter annually.

a. Turn instrument off and unplug power cord.

b. Remove the two side screws from the intake end of instrument and open case.

c. Carefully disconnect the Tygon tubing from both ends of the internal filters (C/M filter and scrubber filter) and discard.

d. Connect new filters to Tygon tubing, ensuring all filter nipples point toward the intake. Push the Tygon tubing as far as it will go onto the filter fittings.

e. Push the filters into the mounting clips.

f. Remove any crimps in the tubing and ensure connections are secure.

g. Close case and replace screws.

G. Operating on Battery Power

Battery power will allow use of the Jerome 431X as a portable instrument. Be aware of the following conditions.

1. A fully charged battery pack provides power for a minimum of 6 hours operation.

2. For use beyond 6 hours, a new fully charged battery pack is needed.

3. A complete battery recharging requires 14 hours.

The 431X contains a trickle charger so it may be continually plugged into an AC power source without damaging the battery pack. Replace batteries annually or as needed.

Caution**:** The Jerome 431X is intended for vapor use only. Do not allow the probe or the instrument's intake to come in contact with liquids.

V. MSA SOLARIS GAS MULTI-TESTER (FIGURE 13A-14)

Figure 13A-14. MSA SOLARIS GAS MULTI-TESTER

When activated, MSA Solaris detects and measures concentrations of carbon monoxide, methane, and oxygen in the ambient air continuously and simultaneously. It has also been configured, upon MSHA request, for nitrogen dioxide testing as the fourth sensor.

A. Characteristics

Error Factor: 1.25

Sensors: Combustible Gases and Methane - Catalytic
Oxygen and Toxic Gases - Electrochemical

Measuring Range:

LEL (combustible gases)	0 - 100% in 1% increments
CH_4 (methane)	0 - 5% Volume in 0.1% increments
O_2 (oxygen)	0 - 25% Volume in 0.1% increments
CO (carbon monoxide)	0 - 500 ppm in 1 ppm increments
NO_2 (nitrogen dioxide)	0 - 50 ppm in 0.1 ppm increments

(the manufacturer can configure the instrument for NO_2 upon request)

Temperature Range:
Normal: 0 to 40°C
Extended * -20 to 0°C, 40 to 50°C
(*Extended temperature range indicates gas readings may vary slightly if calibrated at room temperature. For optimal performance, calibrate instrument at temperature of use.)
Short Periods: -40 to -20°C (15 minutes)

Humidity Range: If humidity changes to any significant degree (*e.g.*, going from a dry, air conditioned environment to outdoor, moisture-laden air), oxygen levels can change up to 0.5%. This is due to water vapor in the air displacing oxygen, thus reducing oxygen readings as humidity increases. The oxygen sensor has a special filter to reduce the affects of humidity changes on oxygen readings. This effect will not be noticed immediately, but will slowly impact oxygen readings over a several hour period.

Hazardous US Locations: (see instrument label to determine applicable approval):
(Non-Mining) UL913 for Class I, Div. 1, Groups A, B, C and D, T3C,
T_{amb} = -20°C to +50°C
US (Mining) 30 CFR Part 22, Methane Detector

Factory-Set Alarm Setpoints:
(Low Alarm, High Alarm, STEL, TWA)
CO: 35 ppm, 100 ppm, 400 ppm, 35 ppm
NO_2: 2.5 ppm, 5.0 ppm, 5 ppm, 2.5 ppm
H_2S: 10 ppm, 15 ppm, 15 ppm, 10 ppm
LEL: 10%, 20%, NA, NA

B. Summarized Operating Instructions

1. Turning ON the Solaris Multigas Detector

Press the Power ON button; turn the instrument on by pressing the power button on the control face panel for one beep. This is the second button from the left and is identified by the international symbol for power: a circle with a slash at the 12 o'clock position.

The instrument displays:

a. Self-test:

- Alarm setpoints: Low; High; STEL (if activated); TWA (if activated)
- Calibration gas (expected calibration gas values)
- Time and date (if data logging option installed)
- Last CAL date (if data logging option installed)
- CAL due date (if activated and if data logging option installed)
- Instrument warm-up period
- Fresh Air Setup option.

b. Last Cal Date

- The Solaris Multigas Detector is equipped with a "last successful calibration date" feature. The date shown is the last date on which all installed sensors were successfully calibrated. "**LAST CAL**" is displayed with this date in the following format: **MM:DD:YY.** If any of the sensors were not previously calibrated, "**LAST CAL, INVALID**" is displayed.

c. Cal Due Date

- The Solaris Multigas Detector (with data logging and software version 1.1 or higher) is equipped with a Calibration Due Date feature. To activate this feature, see Chapter 3 of the operating manual.
- If the calibration due date feature is activated, following Last Cal Date, the message "**CAL DUE, X DAYS**" appears on the instrument LCD, where x = the number of days until a calibration is due, user selectable for 1 to 180 days. If the number of days

until calibration is due reaches 0, an alert occurs and "**CAL DUE, --NOW--**" displays.

- Press the RESET button to clear the alert and continue with the instrument warm-up period. During Normal Measure mode, if the calibration due date feature is activated and calibration is due, the instrument beeps and displays "**CAL DUE**" every 30 seconds until the unit is calibrated.
- Perform a calibration check before each day's use to verify proper instrument operation (see Chapter 2 of the operating manual, "Calibration Check").

2. Instrument Alarm Bypass Options

The Solaris Multigas Detector (with software version 1.1 or higher) is equipped with a feature to disable or silence the visual, backlight, audible, and vibrator options. To activate this feature, see Chapter 3 of the operating manual, "Accessing the Instrument Setup Mode". If any of these options (visual, backlight, audible, or vibrator) are disabled during instrument startup, the Solaris Detector displays:

- "VISUAL OFF" if the red LEDs are disabled
- "BACKLITE OFF" if backlight is disabled
- "AUDIBLE OFF" if audible buzzer is disabled
- "VIBRATE OFF" if the vibrator is disabled.
- If the visual, audible, or vibrator options are disabled, "ALARM OFF" flashes on the LCD during Normal Measure mode.

3. Instrument Zeroing

a. Fresh Air Set Up Option (for automatic zero adjustment of the Solaris Multigas Detector sensors). **NOTE:** The Fresh Air Setup (FAS) has limits. If a hazardous level of gas is present, the Solaris Multigas Detector ignores the FAS command and goes into alarm. **Do not activate the Fresh Air Setup unless you are certain you are in fresh, uncontaminated air; otherwise, inaccurate readings can occur which can falsely indicate that a hazardous atmosphere is safe. If you have any doubts as to the quality of the surrounding air, do not use the Fresh Air Setup feature. Do not use the Fresh Air Setup as a substitute for daily calibration checks. The calibration check is required to verify**

span accuracy. Failure to follow this warning can result in serious personal injury or death.

b. Persons using the Solaris Multigas Detector must determine whether or not the Fresh Air Setup option should be used. The user's abilities, training and normal work practices must be considered when making this decision.

- Turn ON the Solaris Multigas Detector. Once the instrument self check is complete, **ZERO?** flashes for 10 seconds.
- To perform a Fresh Air Setup, push the ON/OFF button while **ZERO?** is flashing.
- To immediately skip the Fresh Air Setup, push the RESET button. If no buttons are pushed, the **ZERO?** automatically stops flashing after the 10 seconds have expired and the Fresh Air Setup is not performed.

4. Battery Life Indicator (FIGURE 2-1)

The battery condition icon continuously displays in the upper portion of the screen, regardless of the selected page. As the battery charge dissipates, segments of the battery icon go blank until only the outline of the battery icon remains.

a. Battery Warning

A Battery Warning indicates that a nominal 15 minutes of operation remain before instrument batteries are completely depleted. **NOTE:** Duration of remaining instrument operation during Battery Warning depends on ambient temperatures. When the Solaris Multigas Detector goes into Battery Warning:

- Battery Life indicator flashes
- "BATT WRN" flashes every 15 seconds
- Alarm sounds
- Lights flash every 15 seconds
- The Solaris Multigas Detector continues to operate until the instrument is turned OFF or battery shutdown occurs.

b. Battery Shutdown

When the batteries can no longer operate the instrument, the instrument goes into Battery Shutdown mode:

- **LOW** and **BATTERY** flash on the display
- Alarm sounds and lights flash
- Alarm can be silenced by pressing the RESET button
- No other pages can be viewed
- After approximately one minute, the instrument automatically turns OFF.

When Battery Shutdown condition sounds, stop using the instrument; it can no longer alert you of potential hazards because it does not have enough power to operate properly:

- **Warn others and leave the area immediately**
- **Turn OFF the instrument if it is ON**
- **Report the problem to the person responsible for maintenance**
- **Recharge the battery**

Failure to follow this procedure could result in serious personal injury or death. During "Battery Low" condition, prepare to exit the work area since the instrument could go into "Battery Shutdown" at any time, resulting in loss of sensor function. Depending on the age of the batteries, ambient temperature and other conditions, the instrument "Battery Low" and "Battery Shutdown" times could be shorter than anticipated. Recharge the instrument when the "Battery Low" or "Battery Shutdown" conditions occur.

5. Sensor Missing Alarm

The Solaris Multigas Detector will enter the Sensor Missing alarm if the instrument detects that an enabled sensor is not properly installed in the instrument. For O_2, CO, and H_2S sensors, the Sensor Missing feature is checked when the instrument is turned ON and when leaving the Setup mode. The combustible Sensor Missing feature is continually monitored. If a sensor is detected as missing, the following occurs:

- **SENSOR** and **MISSING** flash on the display
  The flag above the sensor detected as missing flashes on the display
- Alarm sounds and lights flash
- Alarm can be silenced by pressing the RESET button
- No other pages can be viewed
- After approximately one minute, the instrument automatically turns OFF

If a Sensor Missing condition occurs, stop using the instrument; it can no longer alert you of potential hazards.

- **Warn others and leave the area immediately.**
- **Turn OFF the instrument if it is ON.**
- **Report the problem to the person responsible for maintenance**
- **Failure to follow this procedure could result in serious personal injury or death.**

6. Calibration Check

The calibration check is simple and should only take about one minute. Perform this calibration check before each day's use.

- Turn ON the Solaris Multigas Detector in clean, fresh air.
- Verify that readings indicate no gas is present.
- Attach calibration cap to the Solaris Multigas Detector.
- Ensure that "TOP" and "↑" on the calibration cap are oriented so that “TOP” is positioned at the top of the instrument.
- Attach regulator (supplied with calibration kit) to the cylinder.
- Connect tubing (supplied with calibration kit) to the regulator.
- Attach other end of tubing to the calibration cap.
- Open the valve on the regulator.
- The regulator flow rate is 0.25 Lpm.
- The reading on the Solaris Multigas Detector display should be within the limits stated on the calibration cylinder.
- If necessary, change cylinder to introduce other calibration gases.
- If readings are not within these limits, the Solaris Multigas Detector requires recalibration. See Chapter 4 of the operating manual, "Calibration."

7. Measuring Gas Concentrations

a. Combustible Gases (% LEL) (FIGURE 2-2)

The Solaris Multigas Detector can be equipped to detect combustible gases in the atmosphere.

Alarms sound under three conditions: when concentrations reach the Alarm Setpoint, 100% of LEL (Lower Explosive Limit), or 5% CH_4.

When the combustible gas indication reaches the Alarm Setpoint:

- Alarm sounds
- Alarm lights flash
- % LEL or CH_4 flag above the concentration flashes.

To silence the alarm, press the RESET button.

NOTE: The alarm will stay silent if the alarm condition has cleared.

When the combustible gas indication reaches either 100% LEL or 5% CH_4, the LockAlarm™ circuit locks the combustible gas reading and alarm and:

- Alarm sounds
- Alarm lights flash
- 100 or 5.00 appears on the display and flashes.
- This alarm cannot be reset with the RESET button.

If the 100% LEL or 5.00% CH_4 alarm condition is reached, you may be in a life-threatening situation; there is enough gas in the atmosphere for an explosion to occur. In addition, any rapid up-scale reading followed by a declining or erratic reading can also be an indication that there is enough gas for an explosion. If either of these indications occur, warn others and leave the contaminated area immediately. Failure to follow this warning can result in serious personal injury or death.

After moving to a safe, fresh-air environment, reset the alarm by turning OFF the instrument and turning it ON again.

b. Oxygen Measurements (% O_2)

The Solaris Multigas Detector can be equipped to detect the amount of oxygen in the atmosphere.

Two conditions trigger the alarm:
- Too little oxygen (deficient)
- Too much oxygen (enriched).

When the alarm setpoint is reached for either of the above:
- Alarm sounds
- Alarm lights flash
- % O_2 flag above the concentration flashes.

If the Oxygen alarm condition is reached while using the instrument as a personal or area monitor, warn others and leave the area immediately; the ambient condition has reached a preset alarm level. If using the instrument as an inspection device, do not enter the area without proper protection. Failure to follow this warning will cause exposure to a hazardous environment which can result in serious personal injury or death.

c. Toxic Gas Measurements

The Solaris Multigas Detector can be equipped to detect:
- Carbon Monoxide (CO) and/or
- Hydrogen Sulfide (H_2S), and/or
- Nitrogen Dioxide (NO_2) in the atmosphere.

When the alarm setpoint is reached for Carbon Monoxide (CO), and/or Hydrogen Sulfide (H_2S), and/or Nitrogen Dioxide (NO_2):
- Alarm Sounds
- Alarm Lights flash
- PPM CO or PPM H_2S flag above the concentration flashes.

If the Toxic Gas alarm condition is reached while using the instrument as a personal or area monitor, warn others and leave the area immediately; the ambient condition has reached a preset alarm level. If using the instrument as an inspection device, do not enter the area without proper protection.

Failure to follow this warning will cause over-exposure to toxic gases, which can result in serious personal injury or death.

8. Safe LED

The Solaris Multigas Detector is equipped with a green "SAFE LED". This green SAFE LED will flash every 15 seconds under the following conditions:

- The green SAFE LED is enabled
- Instrument is on the normal Measure Gases page
- Combustible reading is 0% LEL or 0% CH_4
- Oxygen (O_2) reading is 20.9%
- Carbon Monoxide (CO) reading is 0 ppm
- Hydrogen Sulfide (H_2S) reading is 0 ppm
- Nitrogen Dioxide (NO_2) reading is 0 ppm
- No gas alarms are present (low or high)
- Instrument is not in Low Battery warning or alarm
- STEL and TWA readings are 0 ppm

9. Operating Beep

The Solaris Multigas Detector is equipped with an operating beep. This operating beep activates every 30 seconds by momentarily sounding the horn and flashing the alarm LEDs under the following conditions:

- Operating beep is enabled
- Instrument is in the normal Measure Gases page
- Instrument is not in Battery Warning
- Instrument is not in Gas Alarm
- Audible and visible options enabled

10. Peak and Minimum Readings (PEAK and MIN)

a. PEAK appears in the upper portion of the display to show the highest levels of gas recorded by the Solaris Multigas Detector since:
   - Turn-ON, or
   - Peak readings were reset

To Reset the Peak Readings:
- Access the Peak page.
- Press the RESET button.

b. MIN appears in the upper portion of the display to show the lowest level of oxygen recorded by the Solaris Multigas Detector since:
- Turn-ON, or
- Minimum readings were reset

To Reset the Minimum Readings:
- Access the Min page.
- Press the RESET button.

11. Short Term Exposure Limits (STEL)

a. The STEL flag appear in the upper portion of the display to show the average exposure over a 15-minute period.

b. When the amount of gas detected by the Solaris Multigas Detector is greater than the STEL limit:
- Alarm sounds
- Alarm lights flash
- STEL flashes.

To Reset the STEL:
- Access the STEL page.
- Press the RESET button.

c. The STEL alarm is calculated over a 15-minute exposure. Calculation examples are as follows:
Assume the Detector has been running for at least 15 minutes:

1) 15-minute exposure of 35 ppm:

$$\frac{(15 \text{ minutes} \times 35 \text{ PPM})}{15 \text{ minutes}} = 35 \text{ ppm}$$

2) 10-minute exposure of 35 PPM + 5-minute exposure of 5 ppm:

$$\frac{(10 \text{ minutes} \times 35 \text{ PPM}) + (5 \text{ minutes} \times 5 \text{ PPM})}{15 \text{ minutes}} = \frac{350 + 25}{15} = 25 \text{ ppm}$$

d. If the STEL alarm condition is reached while using the instrument as a personal or area monitor, warn others and leave the contaminated area immediately; the ambient gas concentration has reached the preset STEL alarm level. Failure to follow this warning will cause over-exposure to toxic gases, which can result in serious personal injury or death.

12. Time Weighted Average (TWA)

a. The TWA flag will appear in the upper portion of the display to show the average exposure since the instrument was turned ON or the TWA reading was reset.
When the amount of gas detected by the Solaris Multigas Detector is greater than the eight-hour TWA limit:
- Alarm sounds
- Alarm lights flash
- TWA flashes.

To Reset the TWA:
- Access the TWA page.
- Press the RESET button.

b. The TWA alarm is calculated over an eight-hour exposure. Calculation examples are as follows:

1) 1-hour exposure of 50 PPM:
$$\frac{(1 \text{ hour} \times 50 \text{ PPM}) + (7 \text{ hours} \times 0 \text{ PPM})}{8 \text{ hours}} = 6.25 \text{ ppm}$$

2) 4-hour exposure of 50 PPM + 4-hour exposure of 100 PPM:
$$\frac{(4 \text{ hours} \times 50 \text{ PPM}) + (4 \text{ hours} \times 100 \text{ PPM})}{8 \text{ hours}} = 75 \text{ ppm}$$

3) 12-hour exposure of 100 PPM:
$$\frac{(12 \text{ hours} \times 100 \text{ PPM})}{8 \text{ hours}} = 150 \text{ ppm}$$

NOTE: The accumulated reading is always divided by eight hours.

c. If the TWA alarm condition is reached while using the instrument as a personal or area monitor, warn others and leave the contaminated area immediately; the ambient gas concentration has reached the preset TWA alarm level. Failure to follow this warning will cause over-exposure to toxic gases, which can result in serious personal injury or death.

13. Time Display
TIME appears on the display to show the current time of day in a 24-hour format.

14. Date Display
DATE appears on the display with the current date displayed in the following format: MM:DD:YY

15. Turning OFF the Solaris Multigas Detector
Push and Hold the ON-OFF button for three seconds.
NOTE: Releasing the ON-OFF button before the three seconds elapse returns the instrument to the Measure page.