RHE11/08-MASS-FLOW-METER-FIELD-DEVICE
SPECIFIC COMMAND SPECIFICATION

Using the HART® Communications Protocol

REVISION 1.0 - preliminary
(First preliminary revision of 1.0)

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1. REFERENCED DOCUMENTS ........................................................................................................ 1
2. DEVICE IDENTIFICATION - AND MANUFACTURER-CODE .................................................... 1
3. PHYSICAL LAYER INFORMATION .......................................................................................... 1
4. RHE11 CONFORMANCE AND COMMAND CLASS SUMMARY ............................................ 2
5. ADDITIONAL RESPONSE CODE INFORMATION .................................................................... 4
  5.1. COMMAND NOT IMPLEMENTED .......................................................................................... 4
  5.2. FIELD DEVICE MALFUNCTION ..................................................................................... 4
  5.3. PRIMARY VARIABLE ANALOG OUTPUT FIXED ................................................................. 4
  5.4. PRIMARY VARIABLE ANALOG OUTPUT SATURATED ......................................................... 4
  5.5. NON-PRIMARY VARIABLE OUT OF LIMITS ................................................................. 4
  5.6. PRIMARY VARIABLE OUT OF LIMITS ............................................................................. 4
6. GENERAL FIELD DEVICE INFORMATION .............................................................................. 5
  6.1. DAMPING IMPLEMENTATION ......................................................................................... 5
  6.2. NONVOLATILE MEMORY DATA STORAGE ..................................................................... 5
  6.3. MULTIDROP OPERATION .................................................................................................. 5
  6.4. BURST MODE ................................................................................................................... 5
  6.5. UNIT CONVERSIONS ........................................................................................................ 5
7. ADDITIONAL UNIVERSAL COMMAND SPECIFICATIONS .................................................... 6
  7.1. COMMAND #0 READ UNIQUE IDENTIFIER ..................................................................... 6
  7.2. COMMAND #1 READ P. V. CURRENT AND PERCENT OF RANGE ................................... 6
  7.3. COMMAND #3 READ DYNAMIC VARIABLES AND P.V.CURRENT ............................. 6
  7.4. COMMAND #6 WRITE POLLING ADDRESS ..................................................................... 7
8. ADDITIONAL COMMON-PRACTICE COMMAND SPECIFICATIONS ......................................... 7
  8.1. COMMAND #42 PERFORM MASTER RESET .................................................................. 7

APPENDIX A (TECHNICAL INFORMATION, FIELD DEVICE WIRING) ........................................ 8
1. REFERENCED DOCUMENTS

   HART Physical Layer Specification - Revision 8.0  HCF_SPEC-54
   HART Data Link Layer Specification - Revision 7.1  HCF_SPEC-81
   HART Command Summary Information - Revision 7.1  HCF_SPEC-99
   HART Universal Command Specification - Revision 5.2  HCF_SPEC-127
   HART Common-Practice Command Specification - Revision 7.1  HCF_SPEC-151
   HART Common Tables - Revision 10.0  HCF_SPEC-183
   Appendix 1 - HART Command-Specific Response Code Definitions
   - Revision 4.1  HCF_SPEC-307

2. DEVICE IDENTIFICATION- AND MANUFACTURER-CODE

   Manufacturer Identification Code = 250 (= not used)

   Manufacturer's Device Type Code  = 139

3. PHYSICAL LAYER INFORMATION

   Field Device Category = C  (Separately-powered field instrument that sources
   current output to the loop; isolated from ground;
   provides the analog signal to the loop)

   High Impedance Device:

   Capacitance, C_{tt}  max. 1600 pF
terminal to terminal

   Capacitance, C_{tg}  max. 280 pF
terminal-to-ground (case)

   Resistance, R_{tt}  min. 100 k Ohm
terminal-to-terminal

   Resistance, R_{tg}  min. 100 k Ohm
terminal-to-ground (case)

   Capacitance Number (CN) = 1
### 4. RHE11 CONFORMANCE AND COMMAND CLASS SUMMARY

<table>
<thead>
<tr>
<th>COMMAND NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>CONFORMANCE CLASS #1</strong></td>
</tr>
<tr>
<td>0</td>
<td>Return Unique Identifier</td>
</tr>
<tr>
<td>1</td>
<td>Read Primary Variable</td>
</tr>
</tbody>
</table>

|                | **CONFORMANCE CLASS #1A** |
| 0              | Return Unique Identifier |
| 2              | Read P. V. Current and Percent of Range |

|                | **CONFORMANCE CLASS #2** |
| 11             | Read Unique Identifier Associated with Tag |
| 12             | Read Message |
| 13             | Read Tag, Descriptor, Date |
| 14             | Read Primary Variable Sensor Information |
| 15             | Read Primary Variable Output Information |
| 16             | Read Final Assembly Number |

|                | **CONFORMANCE CLASS #3** |
| 3              | Read Dynamic Variables and P. V. Current |

|                | **CONFORMANCE CLASS #4** |
| 42             | Perform Master Reset |

- UNIVERSAL
- COMMON-PRACTICE
CONFORMANCE CLASS #5

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Write Polling Address</td>
</tr>
<tr>
<td>17</td>
<td>Write Message</td>
</tr>
<tr>
<td>18</td>
<td>Write Tag, Descriptor, Date</td>
</tr>
<tr>
<td>19</td>
<td>Write Final Assembly Number</td>
</tr>
</tbody>
</table>

Future revisions of this field device will behave as much like the present version as is possible. Enhancements will be handled by expansion of the data field or implementing additional commands. Except for the commands marked with an asterisk (*), all public commands presently implemented will always be supported in the form specified in this revision of this document.
5. ADDITIONAL RESPONSE CODE INFORMATION

FIRST BYTE

5.1 COMMAND NOT IMPLEMENTED
Response Code #64

This Response Code is returned when an unknown command is received, excepted all commands listed in 4.

SECOND BYTE

5.2 FIELD DEVICE MALFUNCTION
Bit #7

When a malfunction (e.g., Pickup-Error or Temperature-Error) is detected by the field device, the Analog Output will alarm high and the Field Device Malfunction Bit will be set.

5.3 PRIMARY VARIABLE ANALOG OUTPUT FIXED
Bit #3

This flag is set whenever the Primary Variable Analog Output and Digital Analog Outputs are held at the requested value. E.g., if Polling address is different from 0.

5.4 PRIMARY VARIABLE ANALOG OUTPUT SATURATED
Bit #2

This flag is set whenever the Primary Variable Analog Output saturates below 4.0 milliamperes and above 20.0 milliamperes, no longer representing the true applied process.

5.5 NON-PRIMARY VARIABLE OUT OF LIMITS
Bit #1

This flag is set whenever Transmitter Variable #3/Sensor Temperature exceeds the sensor operating temperature limits.

5.6 PRIMARY VARIABLE OUT OF LIMITS
Bit #0

This flag is set whenever the primary Variable #1/Flow Rate, exceeds the maximum Sensor limits.
6. GENERAL FIELD DEVICE INFORMATION

6.1 DAMPING IMPLEMENTATION

The RHE11/08 field device implements damping on both the digital Primary Variable and the Primary Variable Analog Output. The Primary Variable Analog Output is calculated from the digital Primary Variable and will remain saturated as long as the damped Primary Variable remains beyond the Primary Variable Upper or Lower Range Values. The Secondary Variable/ Flow Totalizer has no damping value. The Tertiary Variable/ Sensor Temperature has a fixed damping value. The Fourth Variable/ Density (optional) has a fixed damping value.

6.2 NONVOLATILE MEMORY DATA STORAGE

All data sent to the transmitter will be saved automatically into the nonvolatile memory upon receipt of the Write or Set Command. Command #39, EEPROM Control, is not implemented.

6.3 MULTIDROP OPERATION

This revision of the RHE11/08 supports Multidrop Operation.

6.4 BURST MODE

This revision of the RHE11/08 does not support Burst Mode.

6.5 UNIT CONVERSIONS

Flowrate is converted in the field device, depending on flow sensor size, to units of:

\[ g/s, \ g/min, \ g/h^*, \ kg/s, \ kg/min, \ kg/h, \ t/s, \ t/min, \ t/h, \ oz/s^*, \ oz/min^*, \ oz/h^*, \ lb/s, \ lb/min, \ lb/h, \ tn/s^*, \ tn/min, \ tn/h \]

(g = grams, kg = kilogramms, t = metric tons, oz = unces, lb = pounds, tn = short tons, s = second, min = minute, h = hour)

Mass (totalizer) is converted in the field device, depending on flow sensor size, to units of:

\[ g, \ kg, \ t, \ oz, \ lb, \ tn \]

Temperature is converted in the field device to units of:

\[ C, \ F \quad (C = \text{degrees Celsius}, \ F = \text{degrees Fahrenheit}) \]

Density (optional) is converted in the field device to units of:

\[ \text{kg/l}, \ \text{lb/gal} \quad (l = \text{liters}, \ gal = \text{gallons}) \]

Note: Units marked with an asterisk (*) presently have no Engineering Unit Codes according to HART Common Tables, Rev 10.0, unit code 250 (=not used) will be used instead of.
7. ADDITIONAL UNIVERSAL COMMAND SPECIFICATIONS

This section contains information pertaining to those commands that require clarification.

7.1. COMMAND #0  READ UNIQUE IDENTIFIER

Command #0 is available both in Short and Long Frame Address Format. The Data Bytes #9 - #11, representing the Device Identification Number as 24-bit-integer, is the serialnumber NNNN of RHE11/08 Field Device. This number is also printed on the RHE11/08 device typelabel and has the format NNNNMYY. Where NNNN represents the 24-bit identification number, MM is month and YY year of order. This number is also the 3-byte Device Identifier, Address Bytes #2 - #4, in Long Frame Addresses. After Power On Startup the serialnumber is also being displayed on the RHE11/08 LCD-Display for some seconds.

7.2. COMMAND #1  READ P. V. CURRENT AND PERCENT OF RANGE

100% of Range is the Flow Rate corresponding to 20mA, adjusted in RHE11/08 menu (Setup I/O → Ana → 20mA=). See also Basic Level User Menu Chart in RHE11/08 instruction manual.

0 % of Range is the Flow Rate corresponding to 0mA or 4mA, adjusted in RHE11/08 menu (Setup I/O → Ana → 0mA= or Setup I/O → Ana → 4mA=).

During a field device malfunction the percentage can be also more than 100 % (22 mA) or negative (below 4 mA).

Note: Current Output 1 must be programmed as Flow Rate Output! (Setup I/O → Ana → 20mA OUT1 = FLOW)

7.3. COMMAND #3  READ DYNAMIC VARIABLES AND P.V. CURRENT

The Primary Variable returns the Field Device Variable #1/Flow Rate.

The Secondary Variable returns the Field Device Variable #2/Flow Totalizer.

The Tertiary Variable returns the Field Device Variable #3/Sensor Temperature.

The Fourth Variable returns the Field Device Variable #4/Density. This variable is just optional available if the flow sensor size is suitable for performing also Density measurement.

The Non-Primary Variable Out of Limits Response Code is returned whenever the variable #3 is beyond its limits.
7.4. COMMAND #6 WRITE POLLING ADDRESS

The Primary Variable Analog Output responds to the applied process only when the Polling Address of the device is set to 0. When the address assigned to the device is in the range from 1 through 15, the Analog Output is Not Active and does not respond to the applied process. While the Analog Output is not active, it is set to its minimum; the Transmitter Status Bit #3, Primary Variable Analog Output Fixed, is set.

The Primary Variable Analog Output will gain become Active and respond to the applied process only if the Polling Address will be changed back to 0.

8. ADDITIONAL COMMON-PRACTICE COMMAND SPECIFICATIONS

The RHE11/08 implements a subset of the Common-Practice Commands specified in the Common-Practice Command Specification document. This section contains information pertaining to those commands that require clarification.

8.1 COMMAND #42 PERFORM MASTER RESET

The execution of this command will immediately Reset the microprocessor and restart the field device (cold start). After execution all internal registers and variables will be initialized. During this time the device will not be able to respond to another command and time the Primary Variable Analog Output will be set to minimum. The time period will be approximately 30 seconds, communications are disabled during the execution of this command. Before Reset the Mass Totalizer and Run Time Counter will be backuped into the EEPROM memory, so the Field Device will not loose this information.

NOTE: If not necessary this command should not be performed during normal operation. During new startup the field device will not perform correct measurement.
APPENDIX A

1. TECHNICAL DATA .................................................................................................................. 9
2. CABLE RECOMMENDATIONS .......................................................................................... 10
3. METHOD OF OPERATION ............................................................................................... 11
4. POINT-TO-POINT CONNECTION .................................................................................... 12
5. MULTI-DROP-NETWORK ................................................................................................. 13
6. HART PROTOCOL STRUCTURE ....................................................................................... 14
1. TECHNICAL DATA

DATA TRANSMISSION

Type of data transmission:
Frequency shift keying (FSK) in accordance with Bell 202

Transfer rate:
1200 bit/s

‘0’ bit information frequency:
2200 Hz

‘1’ bit information frequency:
1200 Hz

Signal structure:
1 start bit, 8 data bits, 1 bit for odd parity, 1 stop bit

Transfer rate for simple variables:
approx. 2/s (poll/response)

Maximum number of units in bus mode:
15

Multiple variable specification:
max. number of variables per field unit: 256
max. number of variables per message: 4

Maximum number of master systems:
two
2. CABLE RECOMMENDATIONS

Type of connection and length limitations:

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Line type</th>
<th>min. conduct area AWG/(mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=1.500</td>
<td>multiple 2-wire, twisted, common shielding</td>
<td>24/0.2</td>
</tr>
<tr>
<td>&gt;1500 &lt;=3000</td>
<td>single 2-wire, twisted, shielded</td>
<td>20/0.5</td>
</tr>
</tbody>
</table>

The following rule of thumb for determining the max. line length for a particular application can be taken from the restrictions governing the signal:

\[
I = \frac{65 \times 10^6}{R \times C} - (C_f + \frac{10.000}{C})
\]

where

- \( I \) length in meters,
- \( R \) resistance in ohms,
- load plus internal resistance from the barrier/isolator,
- \( C \) line capacity in pF/m,
- \( C_f \) maximum internal capacitance for the Smart field units in pF.

Consider the example of a measurement transducer, a control system and a simple shielded pair with

- \( R = 250 \) ohms,
- \( C = 150 \) [pF/m],
- \( C_f = 5.000 \) [pF]

\[
I = \frac{65 \times 10^6}{250 \times 150} - \frac{5000 + 10000}{150}
\]

Then as is: \( I = 1.633 \) [m]

In intrinsically safe applications, there may be further restrictions.

Note: For an in-depth examination of whether a particular hook-up will work, refer to the specification for the Physical layer in the HART document HART Physical Layer Specification - Revision 8.0, HCF_SPEC-54.
3. METHOD OF OPERATION

The HART protocol uses a frequency shift keying (FSK) technique, based on the Bell 202 Communication Standard which is one of several standards used to transmit digital signals over telephone lines. This technique is used to superimpose digital communication on the 4-20 mA current loop connecting the control room to the transmitter in the field. Two different frequencies, 1200 Hz and 2200Hz, are used to represent binary 1 and 0 respectively. These sinewave tones are superimposed on the DC signal at a low level with the average value of the sinewave being zero. This allows simultaneous analog and digital communications. Additionally, no DC component is added to the existing 4-20 mA signal regardless of the digital data being sent over the line. The phase of the digital FSK signal is continuous, so there are no high frequency components injected onto the 4-20 mA loop. Consequently, existing analog instruments continue to work in systems that implement HART, as the low pass filtering usually present effectively removes the digital signal.

The current signal is converted into a corresponding voltage by the loop load resistor in the control room. Up to two master devices may be connected to each HART loop. The primary one is generally a management system or a PC while the secondary one can be a hand-held terminal or laptop computer. A standard hand-held terminal - called the HART Communicator - is available to make field operations as uniform as possible. Further networking options are provided by gateways.

![Simultaneous analogue and digital](image)

**Figure 1**
Because the mean harmonic signal value is zero, digital communication makes no difference to any existing analogue signal.

This produces genuine, simultaneous communication with a response time of approximately 500ms for each field device, without interrupting any analog signal transmission that might be taking place.
4. POINT-TO-POINT CONNECTION

Figure 2 shows the wiring of point-to-point mode. The conventional 4-20 mA signal continues to be used for analog transmission while measurement and equipment data is transferred digitally. The analog signal remains unaffected and can be used for control in the normal way. HART data gives access to maintenance, diagnostic and other operational data.

Note:

The primary milliamp output will only represent the relevant measured process if a polling address of 0 is assigned to the field device. Otherwise the milliamp output remains at a constant 4 mA level.

Figure 2
Point-to-point mode: with provision for one 4-20 mA device and up to two masters, e.g. one management System and a hand-held terminal.
5. MULTI-DROP-NETWORK

This mode requires only a single pair of wires for up to 15 field devices (see Figure 3). Multi-drop connection is particularly useful for supervising installations that are widely spaced, such as pipelines, feeding stations and tank farms.

Note:

- Using multiple RHE field devices in a Multi-Drop-Network requires assigning a polling address from 1 to 15 to each RHE field device. Assigning an address of 1 to 15 to the RHE field device causes the primary milliamp output to remain at a constant 4 mA level.

- Connect the 4-20 mA output from each RHE field device together so they terminate at a common load resistor with at least 250 ohms.

With multi-drop mode, installation costs are considerably reduced.
6. HART PROTOCOL STRUCTURE

HART follows the basic Open Systems Interconnection (OSI) reference model, developed by the International Organization for Standardization (ISO). The OSI model provides the structure and elements of a communication system. The HART protocol uses a reduced OSI model, implementing only Layers 1, 2 and 7 (see Figure 4).

![OSI reference model](image)

Layer 1, the Physical Layer, operates on the FSK principle, based on the Bell 202 communication standard:

- Data transfer rate: 1200 bit/s
- Logic ‘0’ frequency: 2200 Hz
- Logic ‘1’ frequency: 1200 Hz

The vast majority of existing wiring is used for this type of digital communication. For short distances, unshielded, 0.2 mm² two-wire lines are suitable. For longer distances (up to 1500m), single, shielded bundles of 0.2 mm² twisted pairs can be used. Beyond this, distances up to 3000m can be covered using single, shielded, twisted 0.5 mm² pairs.

A total resistance of between 230 ohms and 1100 ohms must be available in the communication circuit, as indicated in Figures 2 and 3.

Layer 2, the Link layer, establishes the format for a HART message. HART is a master/slave protocol. All the communication activities originate from a master, e.g. a display terminal. This addresses a held device (slave), which interprets the command message and sends a response.

The structure of these messages can be seen in Figure 5. In multi-drop mode this can accommodate the addresses for several field devices and terminals.
A specific size of operand is required to enable the field device to carry out the HART instruction. The byte count indicates the number of subsequent status and data bytes.

Layer 2 improves transmission reliability by adding the parity character derived from all the preceding characters; each character also receives a bit for odd parity.

Layer 7, the Application layer, brings the HART instruction set into play. The master sends messages with requests for specified values, actual values and any other data or parameters available from the device. The field device interprets these instructions as defined in the HART protocol. The response message provides the master with status information and data from the slave.

To make interaction between HART compatible devices as efficient as possible, classes of conformity have been established for masters, and classes of commands for slaves. There are six classes of conformity for a master as seen in Figure 6. For slave devices, logical, uniform communication is provided by the following command sets:

**Universal commands**

understood by all field devices. For details see HART Universal Command Specification – Revision 5.2, HCF_SPEC-127, available at HART Communication Foundation.
Common practice commands

provide functions which can be carried out by many, though not all, field devices. Together, these commands comprise a library of the most common field device functions. Details in HART Common-Practice Command Specification - Revision 7., HCF_SPEC-151, available at HART Communication Foundation.

Device-specific commands

provide functions which are restricted to an individual device, permitting special features to be incorporated that are accessible by all users.

Examples of all three command sets can usually be found in a field device, including all universal commands, some common practice commands and any necessary device-specific commands.

Figure 6
Classes of instructions and classes of conformity