KA 192F/00/en/03.03
52015745
Valid as of software version:
V 01.04.

Tank Side Monitor
NRF 590

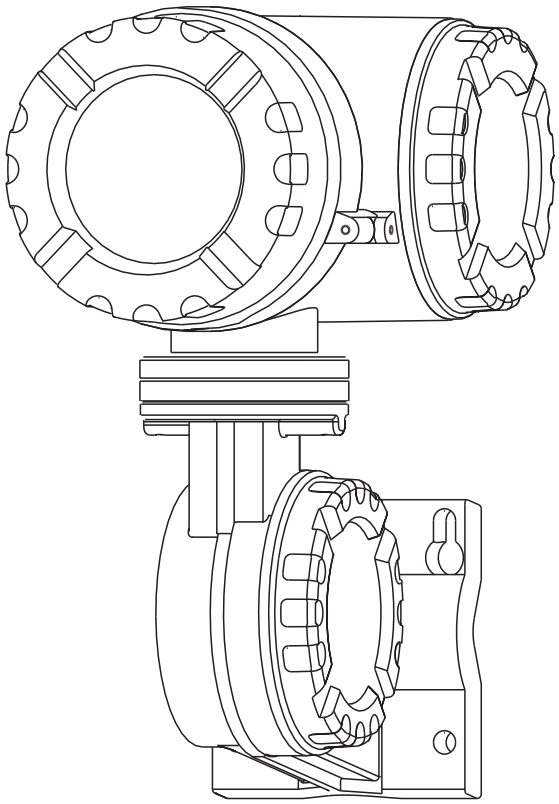








MODBUS communication protocol



Endress+Hauser
The Power of Know How

Table of contents

1 Introduction

This protocol guide explains the operation of the MODBUS protocol per Modicon document PI-MBUS-300 Rev C (1991) implemented in the Endress+Hauser Tank Side Monitor NRF 590.
MODBUS protocol defines the format of data and the techniques used to control the flow of data. In MODBUS, the flow of data between two devices uses a master/slave type arrangement. The Tank Side Monitor acts as a MODBUS slave and runs on the EIA (RS)-485 version of the MODBUS communications board.

2 Implementation

The implementation of MODBUS protocol for the Tank Side Monitor provides a standard form of digital communication. Every effort has been made to parallel current implementations so that the Tank Side Monitor communicates with existing MODBUS masters.
Check compatibility carefully to ensure that the Tank Side Monitor is properly configured for the data format expected by the host computer. Due to the unique application requirements of the Tank Side Monitor, exceptions have been made and noted.

Note!
This is no guarantee, however, that the interpretation made here will be the same as that followed by the MODBUS master.

The Tank Side Monitor implementation of MODBUS protocol provides for the passing of measured and calculated variables, configuration information and diagnostics in data registers. Data is sent in these registers as floating-point values, word values, numeric codes related to configuration lists, status summary words (packed bits) or individual status flags (single bits).
One master and up to 31 Tank Side Monitors may be multidropped on a single EIA (RS) 485 communication bus.
The MODBUS functions implemented in the Tank Side Monitor are listed in the following table.

MODBUS functions

Function code	Function	Information type	MODBUS nomenclature
03	Read	Word, code, status word, floating point	Read output registers
04	Read	Word, code, status word, floating point	Read input registers
06	Write	Word, code, status word	Preset single register
16	Write	Word, code, status word, floating point	Force multiple registers

3 Configuration

The MODBUS port on the Tank Side Monitor must be configured to establish communications. The local display or Time-of-Flight (ToF) tool allows the user to set the Tank Side Monitor MODBUS port to match the MODBUS master.
Tank Side Monitor addresses provide unique identification for the host. The Tank Side Monitor address is configurable through the local display or ToF tool. This address may range from 1 to 247 and must be unique for each MODBUS device on a loop. Each Tank Side Monitor only responds when a query has been sent to its unique address by the host.
The MODBUS protocol supports two modes of transmission, Remote Terminal Unit (RTU) or ASCII (American Standard Code for Information Interchange). The choice between these two modes is dependent on the preference of the host. RTU is often the preferred protocol because of its improved error detection capabilities and higher throughput. ASCII mode uses ASCII printable characters to represent hexadecimal values, this mode of transmission requires almost twice as many characters to pass information compared with the RTU transmission mode.

Note!
The Tank Side Monitor only supports the RTU mode of communications.

3.1 Exception

Because the Tank Side Monitor does not distinguish between inputs and outputs, function codes 01 and 03 as they apply to bits, and function codes 02 and 04 as they apply to numerical values refer to the same data registers. For example, either function code 03 or function code 04 can be used to read the word of the FMR Custody Mode at data address 3027.

3.2 Parameters

The EIA485 port must be configured for a transmission speed (baud rate). Allowable values are 1200, 2400, 4800, 9600, 19200 & 38400 bits per second. This item must be configured using the local display or ToF tool. A summary of the configuration information required by the Tank Side Monitor in order to implement MODBUS is provided in the following table. Default values are highlighted.

MODBUS configuration information

Configuration item	Valid entries	MODBUS configurable	Local display or ToF Tool configurable
MODBUS address	**1** ... 247	No	Yes
Baud rate	• 1200 • 2400 • 4800 • **9600** • 19200 • 38400	No	Yes
Parity	• Odd • Even • **None**	No	Yes
Mode	• **Default no swap** • Swap data • WW swap[1]	No	Yes
Data mode	• **Default** • Convert to Int • Use Conv. Fact • FF for Invalid • Int + FF • Factor + FF	No	Yes
Word type	• **Unsigned** • Signed	No	Yes
Input offset	any floating point number; **Default: 0.0**	No	Yes
Input scale	any floating point number; **Default: 10000.0**	No	Yes
Output offset	any floating point number; **Default: 0.0**	No	Yes
Output scale	any floating point number; **Default: 10000.0**	No	Yes

1) The mode value affects the format for the floating point data returned by the Tank Side Monitor

4 Functions and data formats

The MODBUS data in the Tank Side Monitor is arranged in word registers, floating point registers and status bit registers. The assignment for these registers is found in “MODBUS register assignments”.
The Tank Side Monitor also supports a two 16-bit register floating point data format. Function codes 03 and 04 are used to read these floating point register pairs while function code 16 is used to write the floating point register pairs.
A complete description of all the MODBUS commands, can be found in the Modicon MODBUS Protocol Reference Guide, document number PI-MBUS-300.

4.1 Word registers

Word registers holding 16 bits of data (sometimes referred to as integers) are the most commonly used type of MODB US data and are supported by most MODBUS hosts. In the Tank Side Monitor implementation, the MODBUS word registers are used to transfer one of the following four formats:

- Word Data (unsigned) - a scaled number from 0 to 65535.
- Integer Data (signed) - a scaled number form -32768 to 32767
- Character Data - two ASCII characters per 16-bit register (e.g. tag or date).
- Coded Data - Multiple choice configuration data chosen from a coded list.
- Packed Bit Data - Registers form of 16 packed single bits.

The word, character and coded data registers contain all of the information needed to configure and read process data. Any word register may be read with function code 03 or function code 04. These same registers may be written one at a time with function code 06 or multiple registers can be written with function code 16.
For future compatibility, the Tank Side Monitor accepts reads and writes to reserved registers. Writes to reserved registers has no effect. Reads from reserved registers return either 0x0000 or 0xFFFF depending on the Data Mode setting.
Word registers always hold unsigned values, unless the floating point to integer conversion is enabled and Word Type is configured to be signed, where upon integer values are returned.

4.1.1 Word data

The word data (unsigned) is a whole number between 0 and 65,535 stored as a 16 bit binary number.

4.1.2 Integer data

Integer data (signed) is a scaled number from -32768 to +32767.

4.1.3 Character data

Character data, such as the software version, are returned in multiple registers in ASCII data format. Each MODBUS register holds two ASCII characters.
When interpreting these values, bits 8 to 15 of the word register hold the 1st character while bits 0 to 7 of the word register hold the 2nd character (or 0 if no 2nd character is present).

For example, the software version "01.04" would require three MODBUS registers who's contents would be:
- 1st MODBUS register = 0x3031
- 2nd MODBUS register = 0x2E30
- 3rd MODBUS register = 0x3400

4.1.4 Coded data

Coded data responds to a look-up table value. Data written to these registers must be a valid table entry or the value is rejected. For example, within the Tank Side Monitor the units of a value are represented by the HART standard value look-up table (see “MODBUS register assignments”). Therefore, if the Units value read from a HART device was 45 (002D Hex), the units would be Meters.

4.1.5 Packed bits

Packed bits represent 16 individual status bits packed into one register. The status bits have been packed this way for systems that prefer handling only register information. The bits within the packed registers are grouped by data or function type.

4.1.6 Endress+Hauser Model 8130 RTU configuration

When configuring an Endress+Hauser Model 8130 RTU to read these values, you should make sure the “Operational Mode” parameter of the MIREG point on the Model 8130 RTU is set to 1.

4.2 Floating-point registers

Although not part of the MODBUS protocol specification, floating point numbers have been implemented using the IEEE 754 standard 32-bit representation [see the IEEE Computer Society (1985) "IEEE Standard for Binary Floating-Point Arithmetic, IEEE Std 754-1985" for complete technical information on this format]. Floating point numbers increase accuracy and reduce the complexity required in scaling word values and provide a means to transmit numbers used by the Tank Side Monitor that are not easily scaled.

4.2.1 Two 16-bit register format

The Tank Side Monitor makes these values available through a pair of 16-bit MODBUS registers. Function code 03 or 04 are used to read a floating point register pair. Function code 16 is used to write floating point register pairs. The pair of registers holding the floating point MUST ALWAYS be read and written with a single command.

4.2.2 Endress+Hauser Model 8130 RTU configuration

When configuring a Endress+Hauser Model 8130 RTU to read these values, you should have the Tank Side Monitor MODBUS Mode parameter set to 0 (default) and use a MFPREG point on the Model 8130 RTU with it's Mode parameter set to 1.

MODBUS FP Mode compatibility

TSM modbus mode	Compatibility
Default no swap	Model 8130 RTU MFPREG point (operational mode = 1)
Swap data	Model 8130 RTU MFPREG point (operational mode = 0)
WW swap	Modicon format floating point

4.2.3 Converted to Word registers

The Tank Side Monitor supports a mode where the floating point numbers are converted into WORD values which can then be read from the same register number as the original floating point value.
When this mode is activated ALL floating point values in the Modbus map are converted using the same scaling factors.
This conversion mode is configured using the "Data Mode" value, providing two methods of conversion.

Data Mode	1st Regsiter	2nd Register	Conversion
Default	Floating poit value		No conversion
FF as invalid			
Convert to Int	Converted Value	0x0000	Method 1
Int + FF		0xFFFF	
Use Conv Fact.	Converted Value	0x0000	Method 2
Factor + FF		0xFFFF	

Method 1

First the floating point value is converted to a percentage of the range specified by "Input Offset" and "Input Scale". Then this is converted into a value in the range specified by "Output Offset" and "Output Scale".
The floating point value outside of the "Input Offset" and "Input Scale" range will be limited.

Method 2

The floating point value is multiplied by the "Output Scale" value.

Rounding and Conversion

In both cases the new value is converted into a whole number in the range 0 to 65535 or -32768 to +32767 depending on "Word Type" setting. This value is then rounded such that:

(+/-) N.M = (+/-) N when M < 5
= (+/-) N+1 when M ≥ 5

For example:

+ 12.2 = + 12
+ 12.5 = + 13
- 12.4 = - 12
- 12.5 = - 13

Under / Over Range Values

- If "Word Type" is "Unsigned" then 0 is returned if the value is < 0 and 65535 (0xFFFF) is returned for values > 65535.
- If "Word Type" is "Signed" then, -32768 is returned if the value is < -32768 and +32767 is returned for values > +32767.

Block Reading Notes

Since each floating point register consists of two WORD registers, when you are using the conversion modes, the 1st register of the two will contain the WORD value, while the other will contain a default value, allowing block reads.
For example a block read from 33001 to 33006 would produce the following results:

	Default[1]	**Convert to Int[2]**	**Use Conv. Fact.[3]**
33001	8456.2234	16912	12684
33002		0	0
33003	8456.2234	16912	12684
33004		0	0
33005	42.82	86	64
33006		0	0

1) These are floating point values using all 32 bits from the two registers.

2) Input Offset = 0.0, Input Scale = 10000.0, Output Offset = 0.0, Output Scale = 20000.0;
e.g. Register 33001
= [(value - InputOffset) * (OutputScale - OutputOffset) / (InputScale - InputOffset)] + OutputOffset
= [(8456.2234 - 0.0) * (20000.0 - 0.0) / (10000.0 - 0)] + 0.0
= 16912.4468

3) Output Scale = 1.5;
e.g. Register 33001
= value * OutputScale
= 8456.2234 * 1.5
= 12684.3351

5 Exception responses

The exception responses returned by the Tank Side Monitor are listed below:

MODBUS exception responses

Exception	Response	Reason
02	Illegal data address	Data address (bit or register) is not defined
03	Illegal data value	Data value being written is out of range

In addition, messages that are received with a parity error, checksum error or message format error will be ignored.

6 Hardware implementation

The Tank Side Monitor uses a 2-Wire EIA485 hardware interface to communicate with the MODBUS master. EIA485 is a high speed differential communications network which allows up to 32 devices to operate on one network. The Tank Side Monitor and MODBUS master share a twisted pair of wires to communicate.
The communication distance EIA485 can reliably travel is dependent on baud rate (communication speed), wire quality, environmental electrical noise, wiring configuration and the number of multi-dropped Tank Side Monitors. The recommended wire for EIA485 systems is 18-gauge or larger, shielded, twisted pairs. The shield should be grounded at the MODBUS master (control system or computer) end.

6.1 Termination

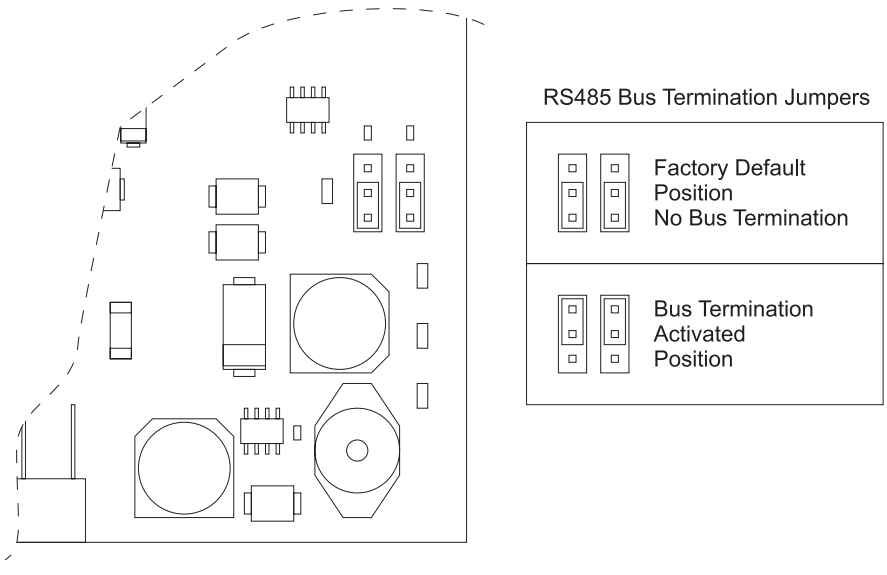
Termination resistors should be placed at each end of the communication bus to minimize reflections on the line. If multiple NRF 590 instruments are connected using MODBUS communication, then an adjustment must be made on the MODBUS communication board. For the last NRF 590 connected on MODBUS, a resistor must be activated by shifting the position of the jumper located on the MODBUS communication board. This adjustment will terminate the MODBUS communication line and allow for correct operation.

Note!
Make sure that no power is being supplied to the NRF 590 before accessing the electronics compartment.

To access the MODBUS communication board:

1. Unscrew the display lid.
2. Remove the two screws on each side of the cover for the electronics compartment.
3. Remove the cover and locate the MODBUS communication board (the display is connected to the communication board).
4. Remove the MODBUS board and make the required adjustment as noted in the diagram below.
5. After completion, replace the communication board, compartment cover and screw the display lid back onto the electronics area.

Tank Side Monitor - ModBus Communication Card - Bus Termination Jumpers



G00-NRF590-04-00-08-ae-010

6.2 RS-485 MODBUS Interface

There are various methods of interfacing a RS-485 MODBUS loop to the control system, such as an Endress+Hauser Model 8130 RTU or a PC RS-485 interface. The method used will depend on the system and software being installed. However, if a direct PC RS-485 interface is required, it is recommended that this be an internal industrial specification interface card (e.g. ISA, PCI, PCMCIA) providing galvanic isolation and lightning protection and not an external RS-232 to RS-485 converter.

7 MODBUS register assignment

7.1 Tank parameters

Tank parameters	Data address	MODBUS register	Data type	Access
Tank Corrected Level	3000	33001	Float	Read only
Tank Level	3002	33003		
Produckt Temperature	3004	33005		
Tank Top (Vapor) Pressure (P3)	3006	33007		
Tank Middle Pressure (P2)	3008	33009		
Tank Bottom Pressure (P1)	3010	33011		
Tank Density (observed)	3012	33013		
Tank Water Level	3014	33015		
Tank Air (Ambient) Temperature	3016	33017		
Level Units	3179	33180	Coded	
Temperature Units	3180	33181		
Pressure Units	3181	33182		
Density Units	3182	33183		
Level Percentage Range	3193	33194	Float	
Hydrostatic Level	3195	33196		
Point Status • Bit #0 - Invalid level • Bit #1 - Invalid temperature • Bit #2 - Invalid water level • Bit #3 - Invalid density • Bit #4 - Invalid top pressure • Bit #5 - Invalid middle pressure • Bit #6 - Invalid bottom pressure • Bit #7 - Invalid standard density • Bit #8 - Invalid volume correction factor • Bit #9 - Level below minimum • Bit #10 - W&M invalid • Bit #11 - Database failed CRC check • Bit #12 - Level out of range • Bit #13 - Invalid air temperature • Bit #14 - Invalid vapor temperature • Bit #15 - Invalid flow	3018	33019	Bits	
Tank W&M Status • Bit #0 - Level W&M status valid • Bit #1 - Temperature W&M valid • Bits #2 ... #15 - Reserved	3176	33177		

7.2 FMR parameters

FMR parameters	Data address	MODBUS register	Data type	Access
FMR Level	3019	33020	Float	Read only
FMR Status (part I)	3021	33022	WORD	
FMR Status (part II)	3022	33023	WORD	
FMR Measured Level	3023	33024	Float	
FMR Measured Distance	3025	33026	Float	
FMR Custody Mode	3027	33028	WORD	
FMR Application Parameters (refer to FMR manual)	3028	33029	WORD	
FMR Level Units	3197	33198	Coded	
FMR Point Status • Bit #0 - Offline (HART device) • Bit #1 - Failed to send command • Bit #2 - Reserved • Bit #3 - Reserved • Bit #4 - Performing dip freeze • Bits #5 ... #13 - Reserved • Bit #14 - Offline (Data not updating) • Bit #15 - Offline (Internal communication	3029	33030	Bits	

7.3 NMT parameters

NMT parameters	Data address	MODBUS register	Data type	Access
NMT53 Average Temperature	3030	33031	Float	Read only
NMT53 Vapor Temprature	3032	33033		
NMT53 Temperature 0	3034	33035		
NMT53 Temperature 1	3036	33037		
NMT53 Temperature 2	3038	33039		
NMT53 Temperature 3	3040	33041		
NMT53 Temperature 4	3042	33043		
NMT53 Temperature 5	3044	33045		
NMT53 Temperature 6	3046	33047		
NMT53 Temperature 7	3048	33049		
NMT53 Temperature 8	3050	33051		
NMT53 Temperature 9	3052	33053		
NMT53 Temperature 10	3054	33055		
NMT53 Temperature 11	3056	33057		
NMT53 Temperature 12	3058	33059		
NMT53 Temperature 13	3060	33061		
NMT53 Temperature 14	3062	33063		
NMT53 Temperature 15	3064	33065		
NMT53 Temperature 16	3208	32209		
NMT53 Temperature 17	3210	33211		
NMT53 Average Number	3066	33067		
NMT53 Measured Level	3068	33069		
NMT53 Error Code (refer to NMT manual)	3070	33071	WORD	
NMT53 Status (part I)	3071	33072		
NMT53 Status (part II)	3072	33073		
NMT53 Diagnostic Code (refer to NMT manual)	3073	33074		
NMT53 Custody Mode (refer to NMT manual	3074	33075		
NMT53 Level Units	3198	33199	Coded	
NMT53 Temperature Units	3199	33200		
NMT53 Point Status • Bit #0 - Offline (HART device) • Bit #1 - Failed to send command • Bits #2 ... #13 - Reserved • Bit #14 - Offline (Data not updating) • Bit #15 - Offline (Internal communication	3075	33076	Bits	

7.4 i.s. RTD parameters

i.s. RTD parameters	Data address	MODBUS register	Data type	Access
i.s RTD Resistance	3095	33096	Float	Read only
i.s. RTD Temperature	3097	33098		
i.s. RTD Temperature Unists	3184	33185	Coded	
Point Status • Bit #0 - Hardware failure • Bit #1 - Resistance under range • Bit #2 - Resistance over range • Bit #3 - Not calibrated • Bit #4 - Element not connected • Bit #5 - Levwel below element positon • Bit #6 - Temp over element W&M range • Bit #7 - Temp under element W&M range • Bit #8 - Element error code (bit 0) • Bit #9 - Element error code (bit 1) • Bit #10 - Element error code (bit 2) • Bit #11 - Element error code (bit 3) • Bit #12 - Checksum invalid • Bit #13 - Reserved • Bit #14 - Offline (Data not updating) • Bit #15 - Offline (Internal communication	3178	33179	Bits	

7.5 i.s. analog input parameters

i.s. analog input parameters	Data address	MODBUS register	Data type	Access
i.s Analog Input Value	3099	33100	Float	Read only
i.s. Analog Input Units	3183	33184	Coded	
Percentage range	3186	33187	Float	
i.s. Analog Input Point Status • Bit #0 - Hardware failure • Bit #1 - Over range • Bit #2 - Under range • Bit #3 - Not calibrated • Bit #4 ... #13 - Reserved • Bit #14 - Offline (Data not updating) • Bit #15 - Offline (Internal communication	3101	33102	Bits	

7.6 Non-i.s. Analog input parameters

Non-i.s. analog input parameters	Data address	MODBUS register	Data type	Access
Analog Input Value	3107	33108	Float	Read only
Analog Input Units	3185	33186	Coded	
Percentage range	3188	33189	Float	
Loop Power Output Voltage	3109	33110		
Analog Input Point Status • Bit #0 - Hardware failure • Bit #1 - Over range • Bit #2 - Underrange • Bit #3 - Not calibrated • Bit #4 ... #15 - Reserved	3111	33112	Bits	

7.7 Non-i.s. Analog output parameters

Non-i.s. analog output parameters	Data address	MODBUS register	Data type	Access
Analog Output Value	3112	33113	Float	Read only
Value Units	3192	33193	Coded	
Percentage range	3190	33191	Float	
Analog Output Point Status • Bit #0 - Invalid source value reference • Bit #1 - Source value is below offset value • Bit #2 - Source value is above scale value • Bit #3 - Not calibrated • Bit #4 - Value has been forced to 0 • Bit #5 - Output is open circuit • Bit #6 - Source value is offline • Bits #7 ... #15 - Reserved	3114	33115	Bits	

7.8 Discrete IO parameters

Discrete IO 0 parameters	Data address	MODBUS register	Data type	Access
Status • 11 (000B Hex) "ON" • 12 (000C Hex) "Off"	3102	33103	Coded	Read only
Command • 11 (000B Hex) "ON" • 12 (000C Hex) "Off"	3103	33104		Read/write
Point Status	3104	33105	Bits	Read only

Discrete IO 1 parameters	Data address	MODBUS register	Data type	Access
Discrete IO 1 Status	3105	33106	Coded	Read only
Discrete IO 1 Command	3177	33178		Read/write
Point Status	3106	33107	Bits	Read only

7.9 Generic HART device parameters

HART parameters	Data address (MODBUS register						Data type	Access
	HART0	HART1	HART2	HART3	HART4	HART5		
PV Value	3077 (33078)	3080 (33078)	3083 (33084)	3086 (33087)	3089 (33090)	3092 (33093)	Float	Read only
PV Units - HART standard code	3116 (33117)	3117 (33118)	3118 (33119)	3119 (33120)	3120 (33121)	3121 (33122)	Coded	
SV Value	3122 (33123)	3124 (33125)	3126 (33127)	3128 (33129)	3130 (33131)	3132 (33133)	Float	
SV Units - HART standard code	3134 (33135)	3135 (33136)	3136 (33137)	3137 (33138)	3138 (33139)	3139 (33140)	Coded	
TV Value	3140 (33141	3142 (33143)	3144 (33145)	3146 (33147)	3148 (33149)	3150 (33151)	Float	
TV Units - HART standard code	3152 (33153)	3153 (33154)	3154 (33155)	3155 (33156)	3156 (33157)	3157 (33158)	Coded	
FV Value	3158 (33159)	3160 (33161)	3162 (33163)	3164 (33165)	3166 (33167)	3168 (33169)	Float	
FV Units - HART standard code	3170 (33171)	3171 (33172)	3172 (33173)	3173 (33174)	3174 (33175)	3175 (33176)	Coded	
Current	3212 (33213)	3216 (33217)	3220 (33221)	3224 (33225)	3228 (33229)	3232 (33233)	Float	
Percentage Range	3214 (33215)	3218 (33219)	3222 (33223)	3226 (33227)	3230 (33231)	3234 (33235)	Float	
HART Polling Address	3236 (33237)	3237 (33238)	3238 (33239)	3239 (33240)	3240 (33241)	3241 (33242)	WORD	
Point Status • Bit #0 - Offline HART device • Bit #1 - Failed to send command • Bits #2 ... #13 - Reserved • Bit #14 - Offline (data not updating) • Bit #15 - Offline (internal communication)	3079 (33080)	3082 (33083)	3085 (33086)	3088 (33089)	3091 (33092)	3094 (33095)	Bits	

8 Tables and reference information

8.1 HART units coded table

As per HART Communications Foundation Document Number: HCF_SPEC-183 “HART - SMART Communications Protocol, Common Tables”
The highlighted units are supported by the NRF 590 Tank parameters. Other generic HART devices may provide any of these values.

8.1.1 Temperature

HART unit code	Unit	Symbol
32	**Degrees Celsius**	**°C**
33	**Degrees Fahrenheit**	**°F**
34	Degrees Rankin	°R
35	**Degrees Kelvin**	**Kelvin**

8.1.2 Pressure

HART unit code	Unit	Symbol
1	**Inches of Water (68 °F)**	**inH^2O**
2	Inches of Mercury (0°C)	InHg
3	Feet of Water (68 °F)	FtH^2O
4	Millimeters of Water (68 °F)	mmH^2O
5	Millimeters of Mercury (0°C)	mmHg
6	**Pounds per Square Inch**	**PSI**
7	**Bars**	**bar**
8	**Millibars**	**mbar**
9	Grams per Square Centimeter	g/cm^2
10	Kilograms per Square Centimeter	kg/cm^2
11	**Pascals**	**PA**
12	**Kilopascals**	**kPA**
13	Torr	torr
14	Atmospheres	ATM
237	**Megapascals**	**MPA**
238	Inches of Water (4 °C)	inH^2O 4 °C
239	Millimeters of Water (4 °C)	mmH^2O 4°C

8.1.3 Volumetric flow

HART unit code	Unit	Symbol
15	Cubic Feet per Minute	ft^3/min
16	**Gallons per Minute (US)**	**gal/min**
17	**Liters per Minute**	**l/min**
18	Imperial Galons per Minute	ImpGal/min
19	**Cubic Meters per Hour**	m^3/hr

HART unit code	Unit	Symbol
22	Gallons per Second (US)	gal/sec
23	Million Gallons per Day	MilGal/day
24	Liters per Second	lt/sec
25	Million Liters per Day	MilL/day
26	Cubic Feet per Second	ft^3/sec
27	Cubic Feet per Day	ft^3/day
28	Cubic Meters per Second	m^3/sec
29	Cubic Meters per Day	m^3/day
30	Imperial Gallons per Hour	ImpGal/hr
31	Imperial Gallons per Day	ImpGal/day
121	Normal Cubic Meters per Hour "MKS System"	m^3/hr
122	Normal Liters per Hour "MKS System"	l/hr
123	Standard Cubic Feet per Minute "US System"	ft^3/min
130	Cubic Feet per Hour	ft^3/hr
131	**Cubic Meters per Minute**	m^3/min
132	Barrels per Second (1 barrel = 42 US gallons)	bbl/s
133	**Barrels per Minute (1 barrel = 42 US gallons)**	**bbl/min**
134	**Barrels per Hour (1 barrel = 42 US gallons)**	**bbl/hr**
135	Barrels per Day (1 barrel = 42 US gallons)	bbl/day
136	**Gallons per Hour (US)**	**gal/hr**
137	Imperial Gallons per Second	ImpGal/s
138	**Liters per Hour**	**l/hr**
235	Gallons per Day (US)	gal/day

8.1.4 Velocity

HART unit code	Unit	Symbol
20	Feet per Second	ft/s
21	Meters per Second	mtr/s
114	Inches per Second	in/s
115	Inches per Minute	in/min
116	Feet per Minute	ft/min
120	Meters per Hour	mtr/hr

8.1.5 Volume

HART unit code	Unit	Symbol
40	**Gallons**	**gal**
41	**Liters**	**lt**
42	Imperial Gallons	ImpGal
43	**Cubic Meters**	**m^3**
46	**Barrels (1 barrel = 42 US gallons)**	**bbl**
110	Bushels	bush

HART unit code	Unit	Symbol
111	Cubic Yards	yd^3
112	Cubic Feet	ft^3
113	Cubic Inches	in^3
124	Liquid Barrel (= 31.5 US gallons)	bblLiq
166	Normal Cubic Meter "MKS System"	m^3
167	Normal Liter "MKS System"	lt
168	Standard Cubic Feet "US System"	ft^3
236	Hectoliters	hecto lt

8.1.6 Length

HART unit code	Unit	Symbol
44	**Feet**	**ft**
45	**Meters**	**m**
47	**Inches**	**in**
48	**Centimeters**	**cm**
49	**Millimeters**	**mm**

8.1.7 Time

HART unit code	Unit	Symbol
50	**Minutes**	**min**
51	**Seconds**	**sec**
52	**Hours**	**hr**
53	Days	day

8.1.8 Mass

HART unit code	Unit	Symbol
60	Grams	g
61	Kilograms	kg
62	Metric Tons	MetTon
63	Pounds	lb
64	Short Tons	ShTon
65	Long Ton	LTon
125	Ounce	ounce

8.1.9 Mass Flow

HART unit code	Unit	Symbol
70	Grams per Second	g/s
71	Grams per Minute	g/min
72	Grams per Hour	g/hr
73	Kilograms per Second	kg/s

HART unit code	Unit	Symbol
74	Kilograms per Minute	kg/min
75	Kilograms per Hour	kg/hr
76	Kilograms per Day	kg/day
77	Metric Tons per Minute	MetTon/min
78	Metric Tons per Hour	MetTon/hr
79	Metric Tons per Day	MetTon/day
80	Pounds per Second	lb/s
81	Pounds per Minute	lb/min
82	Pounds per Hour	lb/hr
83	Pounds per Day	lb/day
84	Short Topns per Minute	ShTon/min
85	Short Tons per Hour	ShTon/hr
86	Short Tons per Day	ShTon/day
87	Long Tons per Hour	LTon/hr
88	Long Tons per Day	LTon/day

8.1.10 Mass per volume

HART unit code	Unit	Symbol
90	Specific Gravity Units	SGU
91	Grams per Cubic Centimeter	g/cm^3
92	**Kilograms per Cubic Meter**	**kg/m^3**
93	Pounds per Gallon (US)	lb/gal
94	**Pounds per Cubic Feet**	**lb/ft^3**
95	**Grams per Milliliter**	**g/ml**
96	Kilograms per Liter	kg/l
97	Grams per Liter	g/l
98	Pounds per Cubic inch	lb/CuIn
99	Short Topns per Cubic Yard	ShTon/CuYd
100	Degrees Twaddell	°Twad
102	Degrees Baume Heavy	°BaumHv
103	Degrees Baume Light	°BaumLt
104	**Degrees API**	**°API**

8.1.11 Viscosity

HART unit code	Unit	Symbol
54	Centistokes	centi stokes
55	Centipoise	cpoise

8.1.12 Electromagnetic Unit of Electric Potential

HART unit code	Unit	Symbol
36	**Millivolts**	**mV**
58	**Volts**	**V**

8.1.13 Electrostatic Unit of Current

HART unit code	Unit	Symbol
39	**Milliamperes**	**mA**

8.1.14 Electromagnetic Unit of Resistance

HART unit code	Unit	Symbol
37	**Ohms**	**Ohm**
163	Kiloohms	kOhm

8.1.15 Energy (includes Work)

HART unit code	Unit	Symbol
69	Newton Meter	NM
89	Deka Therm	
126	Foot Pounds Force	
128	Kilo Watt Hour	kWh
164	Mega Joule	MJ
165	British Thermal Unit	BTU
162	Mega Calorie	MCal

8.1.16 Power

HART unit code	Unit	Symbol
127	Kilo Watt	kW
129	Horsepower	HP
140	Mega Calories per Hour	
141	Mega Joule per Hour	kWh
142	British Thermal Unit per Hour	BTU/hr

8.1.17 Radial Velocity

HART unit code	Unit	Symbol
117	Degrees per Second	deg/s
118	Revolutions per Second	rev/s
119	Revolutions per Minute	rpm

8.1.18 Miscellaneous

HART unit code	Unit	Symbol
38	Herts	Hz
56	Microsiemens	uMho
57	**Percent**	**%**
59	pH	pH
66	Milli Siemens per Centimeter	mSiemen/cm
67	Micro Siemens per Centimeter	uSiemen/cm
68	Newton	N
101	Degree Brix	°Brix
105	Percent Solids per Weight	%Sol/wt
106	Percent Solids per Volume	%Sol/vol
107	Degrees Balling	°Ball
108	Proof per Volume	proof/vol
109	Proof per Mass	proof/mass
139	Parts per Million	ppm
143	Degrees	°
150	Percent Steam Quality	%StmQual
151	Feet-Inch-1/16ths	Ftin16
152	Cubic Feet per Pound	ft^3/lb
153	Picofarads	pF
160	Percent Plato	%Plato

8.1.19 Special

HART unit code	Unit	Symbol
250	Not Used	
251	**No Units**	
252 & 0	Unknown Units	
253	Special	

8.1.20 Manufacturer Specific NRF 590 Definitions

HART unit code	Unit	Symbol
240	**1/16th Inch**	**1/16in**
241	**Feet-Inch-1/16ths (stored as ft)**	**Ftin16**
242	**Meters per second per second**	**m/s^2**
243	**Feet-Inch-1/8ths (stored as ft)**	**Ftin8**
244		
245		
246		
247		
248		
249		

Europe

Austria – Wien
❑ Endress+Hauser Ges.m.b.H.
Tel. (01) 88 05 60, Fax (01) 88 05 63 35

Belarus – Minsk
Belorgsintez
Tel. (017) 2 50 84 73, Fax (017) 2 50 85 83

Belgium / Luxembourg – Bruxelles
❑ Endress+Hauser S.A. / N.V.
Tel. (02) 2 48 06 00, Fax (02) 2 48 05 53

Bulgaria – Sofia
Intertech-Automation Ltd.
Tel. (02) 9 62 71 52, Fax (02) 9 62 14 71

Croatia – Zagreb
❑ Endress+Hauser GmbH+Co.
Tel. (01) 6 63 77 85, Fax (01) 6 63 78 23

Cyprus – Nicosia
I+G Electrical Services Co. Ltd.
Tel. (02) 48 47 88, Fax (02) 48 46 90

Czech Republic – Praha
❑ Endress+Hauser Czech s.r.o.
Tel. (02) 66 78 42 31, Fax (026) 66 78 41 79

Denmark – Søborg
❑ Endress+Hauser A/S
Tel. (70) 13 11 32, Fax (70) 13 21 33

Estonia – Tartu
Elvi-Aqua
Tel. (7) 30 27 32, Fax (7) 30 27 31

Finland – Helsinki
❑ Metso Endress+Hauser Oy
Tel. (204) 8 31 60, Fax (204) 8 31 61

France – Huningue
❑ Endress+Hauser S.A.
Tel. (389) 69 67 68, Fax (389) 69 48 02

Germany – Weil am Rhein
❑ Endress+Hauser Messtechnik GmbH+Co. KG
Tel. (07621) 9 75 01, Fax (07621) 97 55 55

Greece – Athens
I & G Building Services Automation S.A.
Tel. (01) 9 24 15 00, Fax (01) 9 22 17 14

Hungary – Budapest
❑ Endress+Hauser Magyarország
Tel. (01) 4 12 04 21, Fax (01) 4 12 04 24

Iceland – Reykjavik
Sindra-Stál hf
Tel. 5 75 00 00, Fax 5 75 00 10

Ireland – Clane / County Kildare
❑ Flomeaco Endress+Hauser Ltd.
Tel. (045) 86 86 15, Fax (045) 86 81 82

Italy – Cernusco s/N, Milano
❑ Endress+Hauser S.p.A.
Tel. (02) 92 19 21, Fax (02) 92 19 23 62

Latvia – Riga
Elekoms Ltd.
Tel. (07) 33 64 44, Fax (07) 33 64 48

Lithuania – Kaunas
UAB Agava Ltd.
Tel. (03) 7 20 24 10, Fax (03) 7 20 74 14

Netherlands – Naarden
❑ Endress+Hauser B.V.
Tel. (035) 6 95 86 11, Fax (035) 6 95 88 25

Norway – Lierskogen
❑ Endress+Hauser A/S
Tel. 32 85 98 50, Fax 32 85 98 51

Poland – Wroclaw
❑ Endress+Hauser Polska Sp. z o.o.
Tel. (071) 7 80 37 00, Fax (071) 7 80 37 60

Portugal – Cacem
❑ Endress+Hauser Lda.
Tel. (21) 4 26 72 90, Fax (21) 4 26 72 99

Romania – Bucharest
Romconseng S.R.L.
Tel. (01) 4 10 16 34, Fax (01) 4 11 25 01

Russia – Moscow
❑ Endress+Hauser GmbH+Co
Tel. (095) 1 58 75 64, Fax (095) 7 84 63 91

Slovak Republic – Bratislava
Transcom Technik s.r.o.
Tel. (2) 44 88 86 90, Fax (2) 44 88 71 12

Slovenia – Ljubljana
❑ Endress+Hauser (Slovenija) D.O.O.
Tel. (01) 5 19 22 17, Fax (01) 5 19 22 98

Spain – Sant Just Desvern
❑ Endress+Hauser S.A.
Tel. (93) 4 80 33 66, Fax (93) 4 73 38 39

Sweden – Sollentuna
❑ Endress+Hauser AB
Tel. (08) 55 51 16 00, Fax (08) 55 51 16 55

Switzerland – Reinach/BL 1
❑ Endress+Hauser Metso AG
Tel. (061) 7 15 75 75, Fax (061) 7 11 16 50

Turkey – Levent/Istanbul
Intek Endüstriyel Ölcü ve Kontrol Sistemleri
Tel. (0212) 2 75 13 55, Fax (0212) 2 66 27 75

Ukraine – Kiev
Photonika GmbH
Tel. (44) 2 68 81 02, Fax (44) 2 69 07 05

Great Britain – Manchester
❑ Endress+Hauser Ltd.
Tel. (0161) 2 86 50 00, Fax (0161) 9 98 18 41

Yugoslavia Republic – Beograd
Meris d.o.o.
Tel. (11) 4 44 29 66, Fax (11) 3 08 57 78

Africa

Algeria – Annaba
Symes Systemes et Mesures
Tel. (38) 88 30 03, Fax (38) 88 30 02

Egypt – Heliopolis/Cairo
Anasia Egypt For Trading (S.A.E.)
Tel. (02) 2 68 41 59, Fax (02) 2 68 41 69

Morocco – Casablanca
Oussama S.A.
Tel. (02) 22 24 13 38, Fax (02) 2 40 26 57

Rep. South Africa – Sandton
❑ Endress+Hauser (Pty.) Ltd.
Tel. (011) 2 62 80 00, Fax (011) 2 62 80 62

Tunisia – Tunis
CMR Controle, Maintenance et Regulation
Tel. (01) 79 30 77, Fax (01) 78 85 95

America

Argentina – Buenos Aires
❑ Endress+Hauser Argentina S.A.
Tel. (11) 45 22 79 70, Fax (11) 45 22 79 09

Brazil – Sao Paulo
❑ Samson Endress+Hauser Ltda.
Tel. (011) 50 31 34 55, Fax (011) 50 31 30 67

Canada – Burlington, Ontario
❑ Endress+Hauser (Canada) Ltd.
Tel. (905) 6 81 92 92, Fax (905) 6 81 94 44

Chile – Santiago de Chile
❑ Endress+Hauser (Chile) Ltd.
Tel. (02) 3 21 30 09, Fax (02) 3 21 30 25

Colombia – Bogota D.C.
Colsein Ltda.
Tel. (01) 2 36 76 59, Fax (01) 6 10 78 68

Costa Rica – San Jose
Euro-Tec (Costa Rica) S.A.
Tel. 2 20 28 08, Fax 2 96 15 42

Ecuador – Quito
Insetec Cia. Ltda.
Tel. (02) 2 26 91 48, Fax (02) 2 46 18 33

El Salvador – San Salvador
Automatizacion y Control Industrial de El Salvador, S.A. de C.V.
Tel. 2 84 31 51, Fax 2 74 92 48

Guatemala – Ciudad de Guatemala
Automatizacion y Control Industrial, S.A.
Tel. (03) 34 59 85, Fax (03) 32 74 31

Honduras – San Pedro Sula, Cortes
Automatizacion y Control Industrial de Honduras, S.A. de C.V.
Tel. 5 57 91 36, Fax 5 57 91 39

Mexico – México, D.F
❑ Endress+Hauser (México), S.A. de C.V.
Tel. (5) 5 55 68 24 07, Fax (5) 5 55 68 74 59

Nicaragua – Managua
Automatización y Control Industrial de Nicaragua, S.A.
Tel. 2 22 61 90, Fax 2 28 70 24

Peru – Lima
Process Control S.A.
Tel. (2) 61 05 15, Fax (2) 61 29 78

USA – Greenwood, Indiana
❑ Endress+Hauser Inc.
Tel. (317) 5 35 71 38, Fax (317) 5 35 84 98

USA – Norcross, Atlanta
❑ Endress+Hauser Systems & Gauging Inc.
Tel. (770) 4 47 92 02, Fax (770) 4 47 57 67

Venezuela – Caracas
Controval C.A.
Tel. (212) 9 44 09 66, Fax (212) 9 44 45 54

Asia

Azerbaijan – Baku
Modcon Systems
Tel. (12) 92 98 59, Fax (12) 92 98 59

Brunei – Negara Brunei Darussalam
American International Industries (B) Sdn. Bhd.
Tel. (3) 22 37 37, Fax (3) 22 54 58

Cambodia – Khan Daun Penh, Phom Penh
Comin Khmere Co. Ltd.
Tel. (23) 42 60 56, Fax (23) 42 66 22

China – Shanghai
❑ Endress+Hauser (Shanghai) Instrumentation Co. Ltd.
Tel. (021) 54 90 23 00, Fax (021) 54 90 23 03

China – Beijing
❑ Endress+Hauser (Beijing) Instrumentation Co. Ltd.
Tel. (010) 65 88 24 68, Fax (010) 65 88 17 25

Hong Kong – Tsimshatsui / Kowloon
❑ Endress+Hauser (H.K.) Ltd.
Tel. 8 52 25 28 31 20, Fax 8 52 28 65 41 71

India – Mumbai
❑ Endress+Hauser (India) Pvt. Ltd.
Tel. (022) 6 93 83 36, Fax (022) 6 93 83 30

Indonesia – Jakarta
PT Grama Bazita
Tel. (21) 7 95 50 83, Fax (21) 7 97 50 89

Iran – Tehran
Patsa Industry
Tel. (021) 8 72 68 69, Fax (021) 8 71 96 66

Israel – Netanya
Instrumetrics Industrial Control Ltd.
Tel. (09) 8 35 70 90, Fax (09) 8 35 06 19

Japan – Tokyo
❑ Sakura Endress Co. Ltd.
Tel. (0422) 54 06 11, Fax (0422) 55 02 75

Jordan – Amman
A.P. Parpas Engineering S.A.
Tel. (06) 5 53 92 83, Fax (06) 5 53 92 05

Kazakhstan – Almaty
BEI Electro
Tel. (72) 30 00 28, Fax (72) 50 71 30

Saudi Arabia – Jeddah
Anasia Industrial Agencies
Tel. (02) 6 53 36 61, Fax (02) 6 53 35 04

Kuwait – Safat
United Technical Services Est. For General Trading
Tel. 2 41 12 63, Fax 2 41 15 93

Lebanon – Jbeil Main Entry
Network Engineering
Tel. (3) 94 40 80, Fax (9) 54 80 38

Malaysia – Shah Alam, Selangor Darul Ehsan
❑ Endress+Hauser (M) Sdn. Bhd.
Tel. (03) 78 46 48 48, Fax (03) 78 46 88 00

Pakistan – Karachi
Speedy Automation
Tel. (021) 7 72 29 53, Fax (021) 7 73 68 84

Philippines – Pasig City, Metro Manila
❑ Endress+Hauser (Phillipines) Inc.
Tel. (2) 6 38 18 71, Fax (2) 6 38 80 42

Singapore – Singapore
❑ Endress+Hauser (S.E.A.) Pte. Ltd.
Tel. (65) 66 82 22, Fax (65) 66 68 48

Korea, South – Seoul
❑ Endress+Hauser (Korea) Co. Ltd.
Tel. (02) 6 58 72 00, Fax (02) 6 59 28 38

Sultanate of Oman – Ruwi
Mustafa & Sultan Sience & Industry Co. L.L.C.
Tel. 63 60 00, Fax 60 70 66

Taiwan – Taipei
Kingjarl Corporation
Tel. (02) 27 18 39 38, Fax (02) 27 13 41 90

Thailand – Bangkok 10210
❑ Endress+Hauser (Thailand) Ltd.
Tel. (2) 9 96 78 11-20, Fax (2) 9 96 78 10

United Arab Emirates – Dubai
Descon Trading L.L.C.
Tel. (04) 2 65 36 51, Fax (04) 2 65 32 64

Uzbekistan – Tashkent
Im Mexatronika-Tes
Tel. (71) 1 91 77 07, Fax (71) 1 91 76 94

Vietnam – Ho Chi Minh City
Tan Viet Bao Co. Ltd.
Tel. (08) 8 33 52 25, Fax (08) 8 33 52 27

Australia + New Zealand

Australia – Sydney, N.S.W.
❑ Endress+Hauser (Australia) Pty. Ltd.
Tel. (02) 88 77 70 00, Fax (02) 88 77 70 99

New Zealand – Auckland
EMC Industrial Group Ltd.
Tel. (09) 4 15 51 10, Fax (09) 4 15 51 15

All other countries

❑ Endress+Hauser GmbH+Co. KG
Instruments International
Weil am Rhein, Germany
Tel. (07621) 9 75 02, Fax (07621) 97 53 45

http://www.endress.com

Endress+Hauser
The Power of Know How

❑ Members of the Endress+Hauser group 09.02

KA 192F/00/en/03.03
FM+SGML 6.0/ProMoDo