DCS MODBUS
INTERFACE SPECIFICATION
for
MODEL 6290
TANK GAUGING SYSTEM

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1 GENERAL DESCRIPTION

This document defines a limited implementation of the "Modbus" Protocol for the Scientific Instruments Model 6290 (M6290) for the purpose of interfacing with DCS host computers. This document should provide programmers with the details necessary to prepare the user interface on the host computer.

The M6290 is a tank gauging system designed to measure level, temperature, and density in large tanks of cryogenic liquids (such as liquid natural gas). A probe is driven throughout the tank to collect temperature and density data as specified by the operator. The data is stored in memory for output to the host computer on demand. The programmer should read and be familiar with the Operation Manual (090-248) for the M6290, as the basic system operation information is not duplicated here.

Certain characteristics of the general Modbus protocol specification are fixed, such as frame format and frame sequence. Other characteristics are variable, including the type of interface (e.g. RS232, RS485), baud rate, parity, number of stop bits, and transmission mode (ASCII or RTU). In the M6290 implementation of the Modbus interface, the interface type is RS485. If it is desired to interface with the host computer using RS232, a converter must be used. The baud rate is variable, while the other parameters are fixed. The transmission mode used is RTU.

The Modbus interface allows the host computer access to the M6290's current mode of operation, the direction and speed of the probe, individual system status and alarm bits, profile data, and current tank conditions. The mode of operation can be changed via Modbus, and the probe can be driven manually at several different speeds.

Output quantities of level, temperature, and density are completely scalable according to the programmer's preferences. These and other configuration changes are made using a Hand Held PC (HHPC) supplied with the M6290; for more information about using the HHPC, consult the Hand Held PC User Interface Manual (090-252).

Programming suggestions are given to assist the programmer in handling important information and status bits appropriately. Instructions are also given on how to use the special software test modes and the simulator mode, which provide an easy means of checking the user interface.

2 DATA ADDRESSING & DATA DEFINITION

2.1 GENERAL

Six Modbus functions are utilized in the M6290 DCS Interface. Function 1 provides the ability to read bits relating to system mode and motor drive direction and speed; Function 5 makes it possible to set them. Function 2 provides the ability to read individual status and alarm bits. Function 3 makes it possible to read profile and alarm configuration registers and Function 6 makes it possible to set them. Function 4 allows the host computer to read sensor data from the M6290.

If more than one tank is connected to a host computer, each tank must be addressed and scanned individually, as there is no communication from one 6290 system to another 6290 system. The device I.D. is the Unit I.D. of each system, as explained below in the Communication Settings section of the chapter on Hardware Specifications. The addresses and definition of the data are given below.

2.2 MODE, SPEED (Digital Output or Input, 1 Bit) (Functions 1, 5)

Information about the current mode of operation and the probe's direction of travel and speed can be accessed using Function 1. Any of these quantities may be set using Function 5 with the same address.

2.2.1 ADDRESSING

Mode, Speed Base Address = 0001
Maximum Legal Address = 0016

In order to access individual bits, the bit address must be calculated by adding base address to bit number as defined in the next section.

Examples:
The Manual Mode is 0001 + 0 = 0001
"Up Fast" is 0001 + 11 = 0012

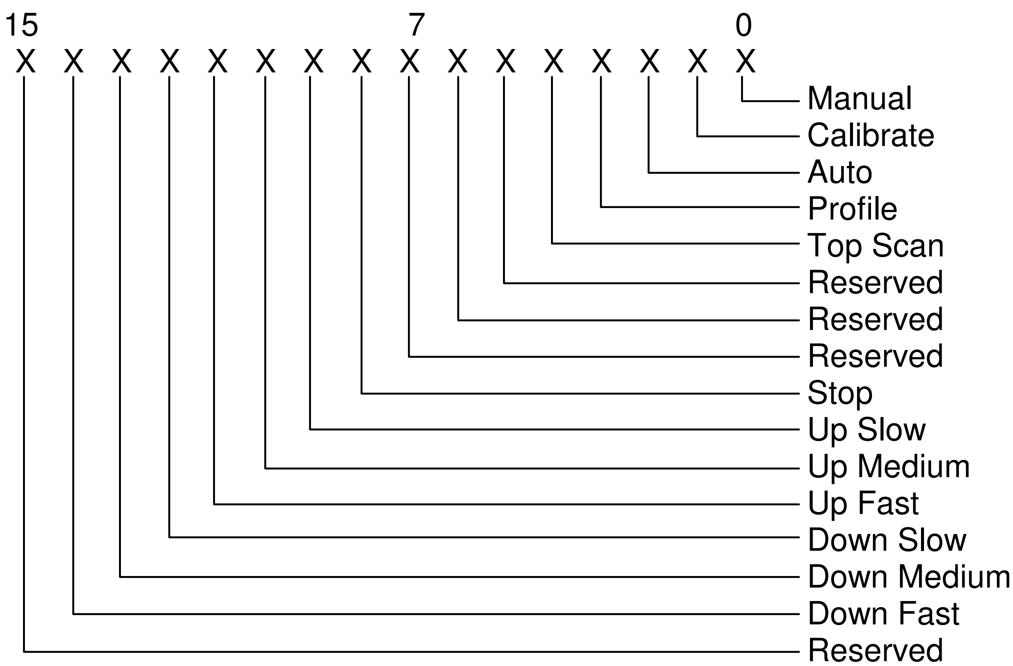
2.2.2 DEFINITION

The current mode of operation is indicated by bits 0 – 4 in the register. Each mode is mutually exclusive, so that if one bit is set, the others are cleared. When using Function 5 to change the system mode, it is only necessary to set the bit corresponding to the new mode. It is not necessary (or possible) to manually clear the bit corresponding to the old mode.

The probe's direction and speed of travel are indicated by bits 8 – 14 in the register. Again, each drive speed is mutually exclusive, so that if one bit is set, the others are cleared. These bits may be read to determine current system status without any effect on the system mode of operation, and the bits relating to system mode may be used to change the current mode of operation. However, it should be noted that manually setting any of the bits relating to the probe's direction and speed of travel will halt any profile activity or tracking of liquid level that is taking place and put the system in the Manual drive mode. The system will continue indefinitely in this mode until it is set back to “Auto”, “Cal”, or one of the profile modes. The system will not be able to perform any of its automatic functions while it remains in the Manual drive mode. One suggestion to bring attention to this condition would be to indicate the manual mode in red to alert the operator that this is not the normal mode of operation. The “Auto” mode, on the other hand, could be indicated in green, since this is the normal mode of operation where liquid level will be tracked continuously.

Also note that if it is necessary to drive the probe to a precise position, it is usually better to use the HHPC, if possible, since it is somewhat difficult to drive the 6290 probe from the DCS and control it precisely. Response times may be slow, due to the nature of the Modbus interface.

The bits are defined as follows:



2.3 STATUS, ALARMS (Digital Input, 1 Bit) (Function 2)

The status bits provide important information about various aspects of system operation and are quite essential for verifying that data is current and valid. Alarm bits relate to conditions of liquid in the tank and are important with respect to plant operation. Each of these alarm bits should be handled appropriately. The relative importance and the significance of each of these bits are explained in the "Programming Suggestions" chapter.

2.3.1 ADDRESSING

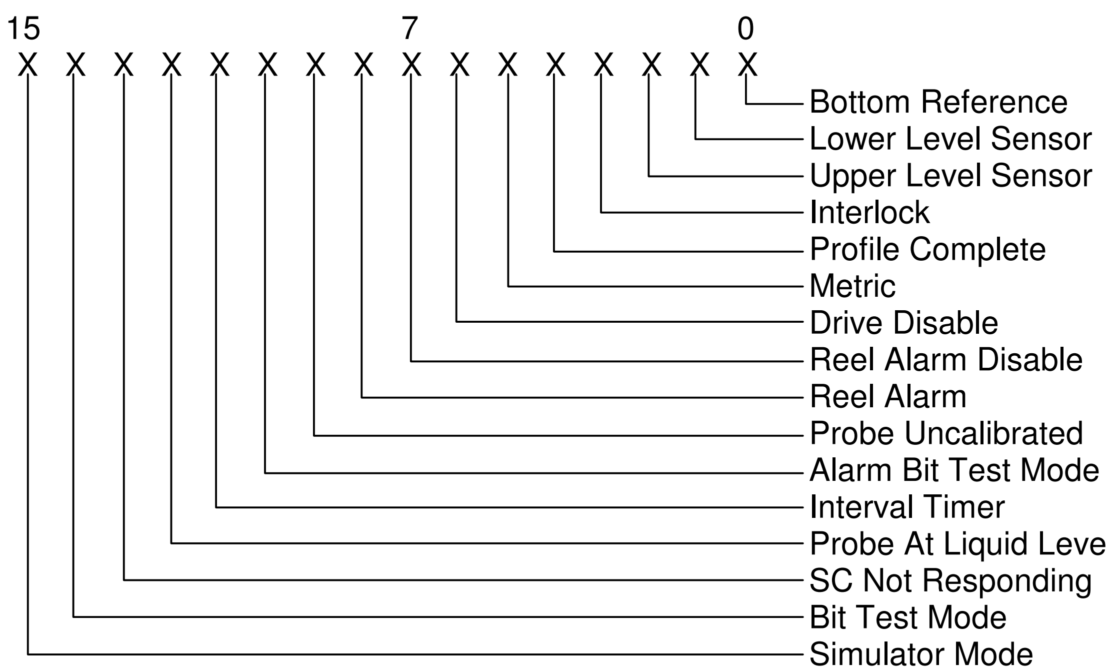
Status Base Address = 10001
Alarms Base Address = 10017
Maximum Legal Address = 10032

To obtain bit address, add base address to bit number as defined below.

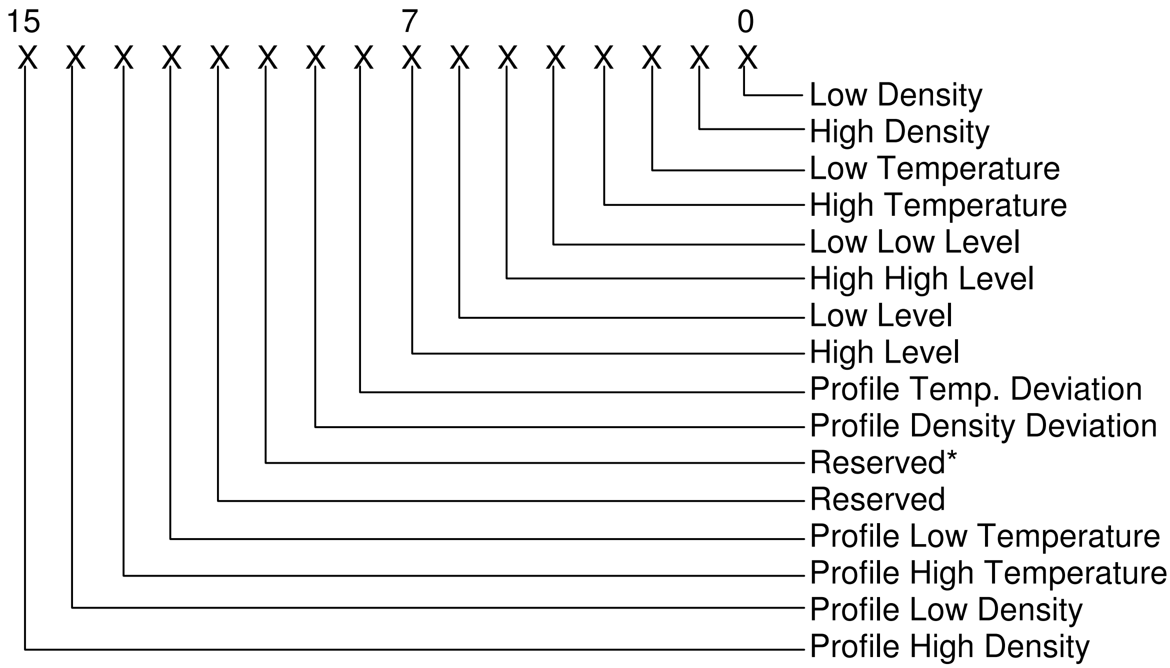
Examples:
The Lower Level Sensor is 10001 + 1 = 10002
A Low Temperature alarm would be 10017 + 2 = 10019

2.3.2 DEFINITION

The Status word is defined as 16 individual bits of information that show the status of the system. They are defined as follows:



The alarms are defined as follows:



*NOTE: While it might be expected that pressing Shift-3 on the HHPC would toggle this bit on and off in the Alarm Bit Test Mode, pressing Shift-3 actually causes Alarm Bit Test Mode to be turned on and off.

2.4 Profile & Alarm Control (Analog Output or Input) (Functions 3, 6)

Functions 3 and 6 make it possible to read and control profile settings and product alarm settings. This makes it possible for operators to completely control the profiles and change alarm settings from the DCS, eliminating the need to use the HHPC to program these functions.

2.4.1 ADDRESSING

Base Address = 40001
Maximum Legal Address = 40023

To obtain data address, add base address to offset as defined below.

Parameter	Offset
Profile First Point	000
Profile Increment	001
Profile Dwell Time	002
Top Scan First Point	003
Top Scan Increment	004
Top Scan Total Distance	005
Top Scan Direction	006
Top Scan Dwell Time	007
Automatic Profile Mode	008
Automatic Profile Interval	009
Automatic Profile Enable	010

Automatic Profile Hour	011
Automatic Profile Minute	012
Low Density Limit	013
High Density Limit	014
Low Temperature Limit	015
High Temperature Limit	016
Low Low Level Limit	017
High High Level Limit	018
Low Level Limit	019
High Level Limit	020
Temperature Deviation Limit	021
Density Deviation Limit	022

Example:

Profile increment is 40001 + 001 = 40002

2.4.2 SCALING

Each quantity is scaled between low and high limits that are programmable. These limits can be changed at any time using the HHPC. The proper values for each site are usually established during commissioning.

Complete instructions for operating the HHPC are given in the Hand Held PC User Interface Manual (090-252), but an effort has been made to make operation of the HHPC simple and somewhat intuitive. To access the scaling factors, press Edit to bring up the edit menu. Choose Modbus, and then Level, Temperature, or Density. Each option presents a low limit and a high limit for the characteristic being measured. There is also a low scale value and a high scale value. For temperature, there is an additional parameter, “Temperature Offset.” This was provided for situations where it is necessary to be compatible with previously programmed 6280 installations. It should not normally be necessary and the value should be set to 0.00.

As an example of scaling, if level is to be displayed in the range of 0 to 40 m, a simple way to set up the scaling would be to make the low limit 0.000 and the high limit 40.000. The low scale value could be set as 0 and the high scale value could be 40000. In this manner, the 16 bit integer value in the Modbus register would read directly in millimeters of liquid level. If the customer DCS is configured to use only signed numbers from -32768 to 32767, another option would be to make the low scale value -32000 (representing 0 m) and the high scale 32000 (representing 40 m). This would provide even more resolution, though it may not be as easy to read. A choice that would make it easier to read would be setting the low scale to -20000 (0 m) and the high scale 20000 (40 m). This would again cause each lsb to represent 1 mm.

In functions 3 & 6, quantities related to level and distance are scaled using the settings for level; quantities relating to temperature are scaled using the settings for temperature, and likewise for density; dwell times are in seconds. This applies both to quantities received and transmitted. Quantities received from the host computer are interpreted according to the current scaling values.

2.4.3 DEFINITION

When a regular profile is initiated, the probe drives to the tank bottom and starts the profile there. “Profile First Point” is the first point at which the probe will stop on the way up to take temperature and density measurements. “Profile Increment” is the distance that is added to the first point and each successive point to determine where to stop and take readings on the way back to the surface of the liquid. “Profile Dwell Time” is the time in seconds that the probe will pause at each point to allow readings to stabilize.

A normal tank profile starts at the bottom of the tank, but Top Scan can be started at any point in the tank (even in vapor). “Top Scan First Point” defines where the Top Scan will begin. If this value is set to zero, the Top Scan will start at the current probe position when the system is switched to Top Scan mode. “Top Scan Increment” defines how far the probe will move before stopping at the next point to collect data. “Top Scan Total Distance” defines the total distance that will be scanned. A Top Scan will terminate when the end point is reached, or sooner if the 200 point limit is reached. “Top Scan Direction” defines whether the probe will move down (value = 0) or up (value = 1) when the Top Scan is started. “Top Scan Dwell Time” defines the number of seconds that the probe will pause at each point for readings to stabilize before data is collected.

A profile can be started manually by switching the mode to Profile Mode. A Top Scan can also be initiated by switching the mode to Top Scan Mode. Alternatively, a profile or a Top Scan can be run automatically at either a fixed time each day or at regularly repeated intervals. “Automatic Profile Mode” designates the type of profile that will be initiated if this method is used. A value of 1 indicates that a regular profile will be run; a value of 2 indicates that a Top Scan will be run. “Automatic Profile Interval” designates the number of minutes between each successive profile run, if this method of starting a profile is chosen.

“Automatic Profile Enable” designates whether profiles will be run automatically, and if so, whether they will be run at fixed intervals or at a fixed time each day. A value of 0 disables automatic profiles. A value of 1 causes profiles to be initiated at the interval designated in “Automatic Profile Interval.” A value of 2 causes profiles to be initiated at a fixed time each day, as programmed in “Automatic Profile Hour” and “Automatic Profile Minute.”

The remaining quantities set the alarm limits for low and high density values, temperature values, liquid level, and temperature and density deviations. “Temperature Deviation Limit” is the amount of change in temperature from one point to the next in a profile that will cause an alarm. “Density Deviation Limit” is the amount of change in density from one point to the next in a profile that will cause an alarm.

2.5 SENSOR DATA, PROFILE DATA (Analog Input) (Function 4)

The current conditions in the tank at the location of the probe and information about the condition of the tank when the last profile was run are given by the sensor data and profile data quantities. There are two different types of profiles, i.e. a regular tank profile, and a Top Scan. In a profile, the probe starts at the bottom of the tank, then moves up to the programmed first point. After pausing to collect data, the probe continues to move up, pausing at fixed increments until liquid level is reached.

In Top Scan, the probe starts at any point in the tank (even in vapor) and moves in either direction, stopping at fixed increments to collect data. As explained in Function 3, “Top Scan First Point” defines where the Top Scan will begin. If this value is set to zero, the Top Scan will start at the current probe position when the system is switched to Top Scan mode. The end is reached when the maximum number of points has been collected or the prescribed distance has been scanned. Top Scan is normally used to analyze a small section of liquid near liquid level.

In order to conserve resources on the host computer, both profiles use the same set of registers to store their results. The register “Profile Type” specifies the type of profile stored in memory.

2.5.1 ADDRESSING

Base Address for Sensor Data = 30001
Maximum Legal Address = 30620

To obtain data address, add base address to offset as defined below.

Parameter	Offset
Current Position	000
Current Temperature	001
Current Density	002
Liquid Level	003
Profile Type	004
Number of Points	005
Profile Month	006
Profile Day	007
Profile Hour	008
Profile Minute	009
Current Hour	010
Current Minute	011
Current Second	012
Reserved	013-019

Example:

Current temperature is 30001 + 001 = 30002

Profile Point	Level Offset	Temp Offset	Dens Offset
0	020	021	022
1	023	024	025
•			
•			
199	617	618	619

Examples:

Level for point 1 is 30001 + 023 = 30024
Density for point 199 is 30001 + 619 = 30620

Note that 200 points (0 – 199) is the maximum number of points allowed, but the actual number of points collected in a profile will be determined by the profile increment and the liquid level. If it is desirable to limit the number of points to a lower value, this can be accomplished by setting the profile increment such that at maximum liquid level, the number of points will not exceed the desired limit. For example, if maximum liquid level is 30 m and the profile increment is 1 m, the maximum number of points would be 31 (including the bottom reference point) and the total number of registers needed for level, temperature, and density would be 93 (31 x 3). Profile readings are taken only until liquid level is found; so, with lower liquid levels there will be fewer profile points. With Top Scan, the number of points is determined by the increment and the total distance to be scanned. Scanning a distance of 5 m with an increment of 0.05 m will produce 101 points (including both end points). With 3 registers per point, the total number of registers needed would be 303.

2.5.2 SCALING

The scaling for Function 4 values is controlled by the same parameters that are used for values in Functions 3 & 6. Please refer to that section for more information about scaling.

2.5.3 DEFINITION

The values for the current position of the probe and current temperature and density are stored in the positions indicated in the Addressing section. The register labeled "Liquid Level" holds the most recent liquid level reading. Since there can be two different types of profiles stored in the registers used for profile readings, the next register, labeled “Profile Type,” is used to distinguish the type of profile. A value of 1 indicates a regular tank profile, and a value of 2 indicates a Top Scan. If no profile is available, the value will be zero.

The register labeled "Number of Points" contains the number of profile points collected during the last profile. In a regular profile, only points in liquid are collected, thus this number will vary according to the liquid level. In a Top Scan, the number of points is determined by the profile increment and the distance to be scanned. Data for points beyond the number of points collected will be zero.

Registers 6 - 9 contain the month, day, hour and minute of the time when the first data point is collected. Registers 10 – 12 contain the current hour, minute, and second. One way to constantly verify communications with the M6290 is to monitor the system time and verify that it is constantly changing. If it stops changing for some reason, an alarm should be generated.

The level, temperature, and density for each point collected in a profile are available at the offsets shown. These are labeled “Level Offset,” “Temp Offset,” and “Dens Offset” and are available for points 0 - 199. Unless the maximum number of points is reached before liquid level is reached, the last point will be at liquid level.

3 HARDWARE SPECIFICATIONS

3.1 GENERAL

A host computer may be connected directly to the M6290 using the RS485 field wiring. A site-wiring diagram is provided in the manual for each site. There are a number of data parameters that must be set properly in order to establish communication, as described below.

3.2 COMMUNICATION SETTINGS

The M6290 has two links that may be used for communication with a host computer; these are referred to as Host 1 and Host 2. Each link must be configured as a Modbus link using the HHPC. These may have been configured for use with the HHPC or the Scientific Instruments data acquisition program instead of as a Modbus link. This makes it possible to check communications on all links using the HHPC. No Modbus communications will be possible until the communication links are configured again as Modbus links. See the HHPC User Manual (090-252) for more information.

The M6290 communication links use RS485. If it is desired to interface with the host computer using RS232, a converter must be used.

The default settings for the communication links when configured for Modbus are 9600 baud, odd parity, 8 data bits, and 1 stop bit. The baud rate is programmable and may be changed via the HHPC. The other parameters are fixed. The transmission mode used is RTU.

The Modbus protocol also requires the use of an address. The Unit I.D. in the M6290 may be set with the HHPC, and serves as the address used in Modbus. If the Unit I.D. does not correspond to the address used in transmissions from the host computer, no communication will be possible. If more than one M6290 is connected on the same data bus, it is important to set a unique address for each unit.

Further details on how to set the parameters described in this section are available in the Hand Held PC manual (090-252). A system of menus provides access to each parameter.

4 PROGRAMMING SUGGESTIONS

4.1 INTRODUCTION

To understand system operation, the programmer should read and be familiar with the Operation Manual (090-248) for the M6290, as this information is not duplicated here. Following are some suggestions on how to use the information available in the specified memory locations. In addition, some important details are given on finding liquid level with the Calibrate mode while in the simulator mode or while using a sensor replacement card.

The primary uses of the M6290 are 1) to obtain accurate liquid level information, and 2) to obtain temperature and density profile information, which will enable the detection of unsafe layering conditions. Layers detected by the M6290 are indicated by the Temperature Deviation alarm and the Density Deviation alarm.

4.2 RELATIVE IMPORTANTANCE OF STATUS BITS

There are some status bits that are more crucial to the system's operation than others. The ones that are essential and should definitely be reported are Bottom Reference, Lower Level Sensor, Upper Level Sensor, Interlock, Reel Alarm, Probe Uncalibrated, Interval Timer, Probe At Liquid Level, and SC Not Responding. The others are somewhat optional, as explained below.

Bottom Reference is activated whenever the bottom reference switch is closed. Lower Level Sensor and Upper Level Sensor are set whenever the sensors are in liquid. These are important for observing the physical conditions around the probe and observing where it is in the tank.

Interlock is set whenever the probe position is at or above the interlock value. The probe will not drive up as long as the Interlock bit is set, since this is the maximum probe position allowed. There is usually some kind of error condition when the probe reaches Interlock.

When Reel Alarm is set, it indicates that a physical drive problem has occurred and manual intervention is necessary. This status bit is absolutely essential for monitoring the status of the equipment.

As explained in the following section, Probe Uncalibrated is activated whenever it is possible that the current probe position is not accurate. This status bit is also important, since liquid level may be incorrect as well.

When Interval Timer is set, it indicates that the system will perform profiles automatically at the prescribed interval. If this bit is not set, profiles will have to be run manually.

Probe At Liquid Level is set whenever the system is in Auto and the probe is at the liquid/vapor interface. This means that the level reported is current.

Special note should be made of the status bit labeled "SC Not Responding." This bit is set whenever there is no response from the Signal Conditioning Card. All of the sensor information (except bottom reference) comes from the Signal Conditioning Card; communications between the Control Module CPU and the Signal Conditioning card are by means of a serial link. If the Control Module CPU is not receiving data from the Signal Conditioning Card, then any data reported via Modbus may be invalid. It could be because maintenance personnel have plugged the HHPC into the Signal Conditioning Card, thereby interrupting the communication link, or it could mean that the Signal Conditioning Card has had a failure. All data should be ignored until this status bit is cleared.

The status bit, Profile Complete, may be of more importance to the programmer than to the operator. When this bit is cleared, the M6290 is in the process of running a profile. When this bit is set, it means that the profile is complete and the data can be collected and analyzed. If any processing of the data is to be done, this bit could be used to signal that the data is ready.

Although they should not enter into everyday operation, it would also be helpful to have Drive Disable and Reel Alarm Disable reported. Drive Disable would normally only be set during maintenance activities, but knowing that it is activated would explain why the probe does not move at all. Reel Alarm Disable should not normally be set. In fact, having this bit set overrides a safety feature in the equipment that could prevent possible damage to the equipment. For this reason, it would be good to know if this bit is set.

The status bit, Metric, may not be as important for the Modbus interface since its state will not normally change. If this bit is set, quantities are reported in metric units; if it is cleared, they are reported in English units. Most likely the system of measurement will be set during system installation and not changed after that, in which case it will not be necessary to monitor this status bit. If units are changed with the HHPC, then it will be necessary to monitor this bit.

The remaining status bits, Alarm Bit Test Mode, Bit Test Mode, and Simulator Mode, should not be a part of everyday operation. These modes will most likely be utilized during system installation and commissioning, and not thereafter. It is important to realize that values for level, temperature, and density and the status and alarm bits can be set artificially in these modes, so no data should be considered valid if one or more of these bits is set. These test modes are explained in greater detail in a following section.

4.3 LIQUID LEVEL

Accurate liquid level information is available after power up only after the system has found bottom reference and the probe has been driven back to the liquid level interface. The system stores the current probe position in non-volatile memory when power is removed, but after a power loss, the system marks the current probe position as “Uncal,” since it is possible that this information is not correct.

When using the simulator mode or the sensor replacement card, it is important to understand the sequence used in finding liquid level in the Calibrate mode. The

Calibrate mode drives the probe to the bottom of the tank (where the bottom reference switch is activated and the “Probe Uncal” status bit is cleared). Both sensors must be in liquid at this point. The bottom reference switch will short the upper level sensor, causing it to indicate vapor while the bottom reference switch is closed. If the lower level sensor is also in vapor, the Calibrate mode will be terminated and the system will switch to Auto, believing there is no liquid in the tank. Provided both sensors are in liquid, after hitting bottom, the probe will drive up until both sensors are out of liquid. Since the level sensors are somewhat slow to respond when coming out of liquid, there will be some overshoot. The probe will drive down in Medium until one sensor is in liquid. (The sensors are quicker to respond when going from vapor to liquid.) The probe will drive up in slow until both are in vapor, and then down slow until one (preferably the lower) is in liquid again. This is the liquid level interface. The system is then put into Auto, where it tracks liquid level. The same sequence of events occurs at the end of the Profile mode when finding liquid level.

Liquid level is continuously updated as long as the probe is at the liquid level interface and the system is in Auto. This is indicated by the status bit, “At Liquid Level.” Any time this status bit is not on, the liquid level reading may not be current.

4.4 PROFILE INFORMATION

A profile is initiated by placing the controller into the Profile mode. This may be done by an operator using the HHPC, by the interval timer, or by a command sent from the host computer. Point 0 is always the bottom point, and the liquid level is the last point. The number of points collected is given in the "Number of Points" variable. At each point, the probe is stopped for a specified "wait" time to allow readings to stabilize. The readings are then taken, and the probe is driven to the next point. When the profile is completed, the unit is returned to the AUTO mode.

As a profile is being collected, the “Number of Points” variable is incremented after each new point. Using this variable, it is possible to import only valid data points. When the probe first touches the bottom of the tank at the beginning of a new profile, all the previous data points in memory are cleared and the “New Profile” status bit is cleared. When the profile is complete and all data is available, the “New Profile” status bit is set.

4.5 PROFILE GRAPHING

The easiest way to see layering of temperature and density in a tank of liquid is by graphing the data. In order for this graphing to be meaningful, it must have a high resolution. In other words, the expected changes in the data are small, and the graphing must be able to show those changes. It is recommended that the graphing range of temperature and density be kept as small as possible. One way to achieve this is to make the values read at the first point at the bottom of the tank as the center of the graph, and then plot a deviation from those values as the level increases.

5 SOFTWARE TESTING

Many times it is necessary to program and test the Modbus operator interface without having the complete M6290 system installed and running in the tank. In addition, it is difficult to create the scenarios that exercise all the various status bits. For these reasons, three special modes of operation have been created for the M6290.

The simulator mode allows an operator using the HHPC to cycle through the various modes of operation by providing the ability to manually control the bottom reference switch and the upper and lower level sensors. In addition, the values for level, temperature and density can be set to arbitrary values as desired. The other two modes, the bit test mode and the alarm bit test mode are extensions of the simulator mode. These allow individual status bits and alarm bits to be set and cleared apart from other program logic.

5.1 SIMULATOR MODE

The basic simulator mode allows the bottom reference switch and the upper and lower level sensors to be set and cleared. All of the other status indicators are set and cleared depending on the current state and normal program logic of the M6290. Values for probe position, level, temperature and density may be entered using the simulator menu on the HHPC.

To enter the simulator mode, press Shift – 8 on the HHPC while in the continuous display mode. (The continuous display mode is the default mode on power up when the HHPC is plugged into the Control Module. The quantities for probe position, temperature and density are displayed and continuously updated. For more information, see the Hand Held PC section of the manual (090-252).) This will cause the “Simulator Mode” status bit to be set and a corresponding message to appear on the Hand Held PC display.

After the simulator mode has been set, the following commands are available in the continuous display mode. Pressing 1 will change the state of bottom reference switch, 2 will change the state of the lower level sensor, and 3 will change the state of the upper level sensor. Pressing Escape will cause the HHPC to return from the continuous display mode to the system of menus.

To change the values for level, temperature, and density, press “Edit” to access the Edit Menu and then select the option for the Simulator. This brings up the Simulator Functions menu, which gives the option to edit regular values or edit basic values, and to save and recall profiles.

Editing the regular values allows probe position, level, temperature, and density to be changed directly. Editing the basic values allows the temperature sensor resistance and the density signal period to be changed. Temperature is calculated from the resistance, and density is calculated from the period.

The options to store and recall profiles are useful for generating profile alarms. By using the simulator functions, it is possible to cycle through a profile and enter values that will cause alarms. This profile can then be saved to a designated number (1-7). Another profile can be generated which does not generate alarms. Switching back and forth between the two profiles will cause the corresponding alarms to be set and cleared. (As will be shown below, there is an easier way to set and clear individual alarm bits.)

It should be mentioned that in the simulator mode, no pulses are actually sent out to the motor, so if a motor were connected, it would not be driven. This makes it possible to drive up and down and run imaginary profiles without being concerned about the actual conditions around the probe. The probe position and the states of the sensors are returned to their original conditions when simulator mode is exited.

5.2 BIT TEST MODE

The status bits for mode and speed can be set by issuing the appropriate drive command from the HHPC, but the general system status bits are not as easy, since they depend on physical conditions around the probe. Special sequences of events are required to set some of the status bits. The bit test mode has been created to provide an easier way to set and clear individual status bits.

To enter the bit test mode, in the continuous display mode, press Shift-7. This will cause the "Bit Test Mode" status bit to be set and a corresponding message to appear on the HHPC display. In this mode, as in the simulator mode, pressing 1 changes the state of bottom reference, 2 changes the lower level sensor, and 3 changes the upper level sensor.

In addition, pressing 4 changes the Interlock status bit and so on. The numbers correspond to the status bits given in the preceding section containing the definition of status and alarms. The first 8 status bits are controlled by the numbers 1 – 8. The bits 9 – 16 are accessed using the shift key, so that bit 9 (Reel Alarm) is changed by pressing Shift-1. Pressing Shift-2 changes the state of bit 10 (Probe Uncal).

The only exception to this is that pressing Shift-3 will not change the state of bit 11 (Alarm Bit Test Mode) since it is not permitted to enter the Alarm Bit Test mode directly from the Bit Test Mode. It is necessary to first exit the Bit Test Mode. Pressing Shift-7 will exit from the Bit Test Mode to the system mode in effect when Bit Test Mode was entered. If the system was in the Simulator Mode when Bit Test Mode was entered, it will return there, otherwise it will return to normal system operation. Pressing Shift-8 will exit the simulator mode completely.

It is possible to enter the Alarm Bit Test Mode by pressing Shift-3 from either the simulator mode or the normal system mode. Since the Bit Test Mode and the Alarm Bit Test Mode are subsets of the simulator mode, the simulator mode status bit (bit 16) will be set when the system is in either of these two modes.

5.3 ALARM BIT TEST MODE

While the Bit Test Mode provides access to the status bits, the Alarm Bit Test Mode allows access to the alarm status bits. The Alarm Bit Test Mode was created so that it is not necessary to go through the process that would create each alarm in order to test the user interface software. To enter the Alarm Bit Test Mode, press Shift – 3 on the HHPC in the continuous display mode. (As mentioned above, this will work as long as the system is not currently in the Bit Test Mode.)

As with the status bits above, the numbers 1 – 8 control the lower 8 alarm status bits as listed in section above containing the definition of the Status and Alarm registers. Shift –1 to Shift – 8 control the upper 8 alarm status bits.

For example, pressing 1 will toggle the state of the Low Density alarm and pressing 2 will toggle the state of the High Density alarm. Pressing Shift – 1 will toggle the Profile Temperature Deviation alarm, and pressing Shift – 2 will toggle the Profile Density Deviation alarm. The next 2 bits (bits 11 and 12) are reserved alarm bits, and pressing Shift – 3 will exit the Alarm Bit Test Mode.