OPERATION
MANUAL
for
MODEL 6290
TANK GAUGING SYSTEM

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SCIENTIFIC INSTRUMENTS, INC.
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1 INTRODUCTION

1.1 GENERAL DESCRIPTION

The Scientific Instruments, Inc. Model 6290 (M6290) is a state of the art electro-mechanical system designed to measure liquid level, temperature, and density in cryogenic liquids, including liquid natural gas (LNG), propane, and butane. The system has been designed with an emphasis on reliability, modularity, and ease of maintenance and operation. With its computer-controlled operation, the M6290 gives operators access to critical data necessary for intelligent and safe operation of the plant.

In addition to providing an accurate measure of the liquid level in a tank, the M6290 provides for precise measurement of temperature and density throughout the tank by positioning a multi-sensor probe assembly at any height in the tank. This makes it possible to obtain a profile that gives an accurate representation of the current conditions in the tank. This information is crucial for the safe storage and handling of cryogenic liquids, since they are subject to layering, and over time, possible "rollover" conditions.

1.2 APPLICATION

A significant safety concern in the storage of cryogenic liquids such as LNG is a phenomenon known as "rollover." If this occurs, pressures inside the storage tank may rise to excessive levels. The tanks are equipped with safety vent valves that are designed to keep the pressures from rising to levels that could cause structural damage. However, when these valves operate, gas is vented to the atmosphere at an uncontrolled rate, which is an additional safety concern. LNG is heavier than air and could settle in pockets of explosive mixtures.

Rollover occurs under certain conditions as stratified LNG comes to equilibrium. Stratification occurs when the product in the tank forms in layers with different densities and different temperatures. Sudden mixing of LNG in any storage tank occurs as two or more layer densities approach equality. Any heat trapped in the system is released rapidly during mixing, generating a vapor which may exceed the venting capability of the tank.

By periodically taking a profile of the tank, the Scientific Instruments M6290 can detect stratification and possible rollover conditions and generate an alarm signaling the need for operator intervention. Operators can take preventative measures (such as mixing the liquid).

1.3 SYSTEM CONFIGURATION

The primary diagnostic and maintenance tool for the M6290 is a Hand Held PC (HHPC) which is supplied with the system. This is also the tool used for setting all system parameters. Once the M6290 has been installed and commissioned, it should not be necessary to change the system configuration, so the HHPC is not

required for daily operation. If configuration changes are required, it will be necessary to use the HHPC. The Hand Held PC User Interface manual describes all system parameters and provides detailed instructions on how to change them.

2 THEORY OF OPERATION

2.1 OVERVIEW

The M6290 consists of a computer-based control unit and a mechanical unit. The two operate as a unit to control the movement of a multi-sensor probe assembly suspended within the tank. Two level sensors inside the probe indicate to the control unit whether the probe is in liquid, in vapor or at the interface between liquid and vapor. The control unit monitors the signals from the temperature sensor and the density meter, and continuously calculates updated information for transmittal to a host computer.

The system has several modes of operation to accommodate maintenance activities and daily operation. The system may be programmed to perform a profile at regular intervals (usually once per day) to provide updated information about the conditions in the tank. When not performing a profile, the system is usually set to track liquid level, providing the most up-to-date reading of liquid level.

2.2 LIQUID LEVEL

The liquid level sensors produce different voltages depending on whether they are in liquid or vapor. The control unit uses these differences in the sensor voltages to determine their state. By vertically spacing the level sensors a short distance apart, the control unit can "recognize" liquid level at the point where the lower level sensor is "in liquid" and the upper level sensor is "in vapor".

2.3 TEMPERATURE

The temperature sensor is a four-leaded platinum element with a resistance of 100 Ω at 0 degrees centigrade. Using a one-milliamp excitation current, a sensor voltage is developed across the sensor proportional to its resistance. This voltage is digitized by an analog to digital converter and compared to data tables by the computer. The appropriate temperature is calculated and constantly updated as the temperature changes.

2.4 DENSITY

The density meter and its associated maintaining amplifier output to the control unit a square wave signal whose frequency is proportional to density. The control unit determines the frequency of this signal, and using a density conversion formula along with calibration parameters for the particular density meter, calculates the density of the medium into which the densitometer is submerged.

2.5 BOTTOM REFERENCE SWITCH

A mechanical switch assembly is employed to signal the control unit when the probe is in contact with the tank floor. When the control unit senses this "Probe at Reference" condition, it ceases downward movement of the probe and sets the

probe position to the pre-programmed bottom reference value. The bottom reference value accounts for the distance of the level sensors from the bottom of the probe.

2.6 OPERATIONAL MODES

The system can be operated in any one of five principal modes, namely Automatic, Calibration, Profile, Top Scan, and Manual. The most commonly used modes in daily operation are Automatic, Profile, and Top Scan. Manual is used normally only for maintenance activities. The Calibration mode can be used when it is needed, such as after maintenance activities when power has been removed, or whenever it is desirable to establish the most accurate liquid level possible.

2.6.1 AUTOMATIC MODE (AUTO)

When the system is placed into its Automatic drive mode, the control unit causes the probe to locate and track the liquid/vapor interface. The system is at the interface when the lower sensor is in liquid and the upper sensor is in vapor. The Automatic mode is the normal mode of operation; all alarms are reported and profile runs can start automatically if they are programmed. The system returns to Auto upon completion of a profile run or a calibration run (described below).

2.6.2 CALIBRATION MODE (CAL)

When the Calibration mode is selected, the control unit drives the probe to the bottom of the tank to establish bottom reference and then back to the liquid level interface, upon which the system is returned to Auto. A calibration is necessary after a power loss or after maintenance activities.

The system has a unique memory saving feature such that the last known position is saved during a power loss. However, the system marks the position as “Uncal” on power-up, since it is possible that the probe has been manually moved while power was off. A calibration should be done after a power loss to re-establish bottom reference and remove the “Uncal” indication. A calibration run should also be done before and after a transfer of liquid to ensure the greatest possible accuracy.

2.6.3 PROFILE MODE (PROFILE)

In the Profile mode, temperature and density readings are taken from the bottom of the tank up to liquid level, providing operators with an accurate representation of the current conditions in the tank.

When the Profile mode is selected, the probe is driven to the tank floor where it re-establishes bottom reference. At the bottom, the probe pauses for a programmed delay time to allow conditions in the tank around the probe to stabilize. After the prescribed delay, position, temperature, and density readings are taken, and then the probe is driven up, stopping at programmed increments

to collect temperature and density data. The same delay occurs at each point to allow readings to stabilize. The profile is terminated when the maximum number of points is taken or liquid level is found.

The parameters that control a profile must be entered with the HHPC; these settings are described in the "Hand Held PC User Interface" section of the manual.

After all readings are taken, the data is analyzed and alarms are generated as applicable. The system is returned to Auto after completion of the profile. In this manner, a complete profile of the tank is collected and stored for output to a host computer.

2.6.4 TOP SCAN MODE (TOP SCAN)

The Top Scan mode is similar to the Profile mode in that it allows an operator to take readings at various levels in the tank. It differs from a regular profile in that a Top Scan starts at the current probe position instead of at the bottom of the tank. In addition, it can move in either direction (up or down) and it terminates when the maximum number of points is reached or when the prescribed distance has been scanned.

As its name implies, Top Scan is usually used to examine a small section of liquid near the surface in greater detail than a profile allows, since a profile begins at the bottom of the tank and extends up to liquid level. Actually, the Top Scan mode is quite flexible and can be used to examine any part of the tank, even vapor. While a regular profile terminates when the liquid interface is found, the level sensors are ignored during a Top Scan.

The parameters that control a Top Scan must be entered with the HHPC; these settings are described in the "Hand Held PC User Interface" section of the manual.

After all readings are taken, the data is analyzed and alarms are generated as applicable. The system is returned to Auto after completion of the Top Scan.

2.6.5 MANUAL MODE (MANUAL)

The Manual mode is used whenever it is desirable to take control of the probe and give specific commands to drive up or down. This would occur most often during maintenance activities. The probe may be stopped so that it will not track liquid level, or it may be driven up or down in fast, medium, or slow.

NOTE: No alarms are reported in the Manual mode and the liquid level reading is not updated. It is important to realize that the system will remain in the Manual mode indefinitely until it is returned to Auto by an operator or by maintenance personnel.

2.7 POWER UP CONDITION

The M6290 takes its reference from the floor of the tank; therefore, it is important to re-establish this bottom reference after power up. If this reference has not been established, the current probe position will be marked as "Uncal".

The system can be set so that it will automatically reestablish its bottom reference after a power loss, or it can be set so that it will power up in Manual with the motor stopped. This setting is accomplished with the HHPC and is described in the "Hand Held PC User Interface" section of the manual.

If the system is not set to reestablish bottom reference automatically, it is only necessary to change the system mode to Calibrate. The probe will travel to the bottom of the tank, re-establish bottom reference and then return to liquid level, where it will return to the Auto mode.

3 OPERATOR INTERFACE

3.1 INTRODUCTION

Information about the system status is usually transmitted to a host computer (or DCS) using the Modbus protocol. The information transmitted includes the current mode of operation, direction and speed of travel of the probe, current values for the position, liquid level, temperature, and density, profile data, and various status indications and alarms. The programming and implementation of the operator interface for the M6290 is different at each site; therefore, some of the features described below may not appear.

The other option for the operator interface would be the PC User Interface. The same information is reported, so the description below would apply, but a separate section of the manual describes the unique features of the PC User Interface.

3.2 MODE OF OPERATION

The mode of operation dictates the action of the probe and determines what information will be available for the operator. The normal mode of operation is Auto, in which the probe simply tracks the liquid level and reports current temperature and density, along with all status indications and alarms.

If the operator desires to re-verify the liquid level for greater accuracy or if the "Uncal" status indication is shown, the Calibration mode can be selected and the probe will travel to the bottom of the tank, reestablish bottom reference and then drive back up to the liquid level. Reporting of alarms is temporarily halted while the system is in the Calibration mode. The system is returned to Auto upon completion of the calibration run.

If it is desired to obtain the most recent profile information, the Profile mode can be selected. The probe will travel to the bottom of the tank, reestablish bottom reference, and then start a new profile run. Reporting of alarms is temporarily halted while the probe performs this action. When the profile is finished, the system will return to the Auto mode and applicable alarms will be reported.

The system enters the Manual mode whenever any specific drive commands are issued. If an operator gives a command to drive up, drive down, or stop via the Modbus interface (from the DCS), via the PC User Interface, or via the HHPC, the system accepts the command and changes to the Manual mode. It will remain in this state until an operator returns it to Auto. No alarms are reported in the Manual mode.

3.3 PROBE DIRECTION AND SPEED

The probe can be driven up or down, or it can be stopped. While driving, it has three speeds: fast, medium, and slow. While in Auto, the probe usually drives in slow to

track liquid level, but it can accelerate to a faster speed if needed. The other modes use a combination of speeds.

3.4 CURRENT VALUES

The current values for position, temperature, and density are the values where the probe is located. If the density is at a very low value (near zero), it is possible that the probe is in vapor instead of liquid. This could happen near the end of a profile or calibration run. The logic that drives the probe when performing a profile or a calibration run relies on the level sensors. Since the level sensors are slower to respond when coming out of liquid than when going into liquid, it is normal for there to be some overshoot when coming out of the liquid. The probe could travel up into vapor before the level sensors react and the probe begins to travel down again.

The current value for liquid level should also be displayed. Note that the liquid level can only be guaranteed to be correct when the probe is actually at liquid level. This is indicated by the "At Liquid Level" indicator as described below. In addition, to guarantee an accurate liquid level there should be no "Probe Uncal" status indication (also described below).

3.5 PROFILE DATA

One of the most important features of the M6290 is the ability to collect data at various points in the tank. There are two types of profile data. A regular profile starts at the bottom of the tank and points are taken in the upward direction until the maximum number of points is reached or liquid level is found. Top Scan starts at the current probe position and a specified number of profile points are read in the upward or downward direction at an increment that is usually smaller than the increment used in a regular profile. Depending on the implementation of the operator interface and how profile data is stored, either one of these types of profile may be displayed.

3.6 STATUS INDICATIONS

There are a number of status indications that are very important to system operation. The meaning of each of these must be properly understood to properly gauge system operation.

3.6.1 LEVEL SENSORS, BOTTOM REFERENCE

The most basic indicators are the level sensors and the bottom reference switch. The level sensors have an on/off state, where "on" is in liquid and "off" is in vapor. Likewise, if the bottom reference indicator is on, this means that the probe is at the bottom of the tank and the switch is closed. Since the bottom reference switch is wired across the upper level sensor, the state of the upper level sensor must be disregarded when the bottom reference indicator is on.

3.6.2 PROBE UNCAL

The "Probe Uncal" indication is normal after the unit has been powered off. Initiating a calibration run should clear this condition. This indicator will also come on if the probe position decreases below where bottom reference was found previously without finding bottom reference there again.

If this reference has not been established, the current probe position will be marked as "Uncal". The system saves its last position and incorporates a unique memory feature such that the last position of the probe is stored when power is lost. However, since it is possible that maintenance personnel have physically moved the probe and its cable during a power loss, the position of the probe is always marked as "Uncal" when the system is first powered up. Bottom reference must be reestablished to clear this condition.

3.6.3 INTERLOCK

If the Interlock indicator is on, it means that the probe has reached the highest position allowed. This is an abnormal situation and maintenance personnel should investigate if this occurs. The interlock limit is set using the HHPC.

3.6.4 REEL ALARM

If the Reel Alarm indicator is on, it could be indicative of a mechanical failure in the drive mechanism. Maintenance personnel should investigate.

3.6.5 DISABLE REEL ALARM

The "Disable Reel Alarm" feature may be activated for a short time by maintenance personnel while performing checks and working with the system, but it should not be left on during normal operation. Disabling the reel alarm bypasses a normal safety feature and physical damage to the equipment could occur.

3.6.6 INTERVAL TIMER

When the "Interval Timer" indicator is on, profile runs will be initiated automatically at the programmed interval. Note that the profile run will not start if the system is in Manual; the system should be in Auto.

3.6.7 PROBE AT LIQUID LEVEL

"Probe at Liquid Level" should be on when the system is in its Auto mode of operation and is tracking liquid level. If this indicator is not on, the operator cannot be assured that the current liquid level reading is correct. If the probe is beneath the surface or it is up in the vapor, there is no way of knowing if liquid level is changing.

3.6.8 SC NOT RESPONDING

"SC Not Responding" means that the Signal Conditioning Card is not responding to the CPU card when it requests new data. All sensor information comes from the Signal Conditioning Card, so if it is not responding, level, temperature, and density information may not be correct. This problem should be referred to maintenance personnel for resolution.

3.7 ALARMS

The M6290 provides a number of alarms to alert operators to abnormal or potentially dangerous conditions. Some of the alarms relate to current conditions and some relate to conditions found in the tank during a profile run.

3.7.1 LEVEL ALARMS

Probably the most important alarmed parameter relating to current conditions is level. There are several different level alarms: a low level alarm, a low, low level alarm, a high level alarm, and a high, high level alarm. Each alarm level setting should be determined by operations personnel and programmed using the HHPC.

3.7.2 TEMPERATURE AND DENSITY ALARMS

The other alarms relating to current conditions are the high and low temperature alarms and the high and low density alarms. In most environments, these alarms are not as critical, since it is the deviation alarms that are normally used to detect abnormal variations of temperature and density in the profile of the tank, not the high and low alarms.

3.7.3 DEVIATION ALARMS

During a profile run, temperature and density data are collected at each programmed stop point. At the end of the run, the data points are analyzed. If the temperature deviation between one point and the next point is greater than the programmed alarm value, the temperature deviation alarm is set. Similarly, if the density variation from one point to the next is greater than the alarm threshold value, the density deviation alarm is set. These alarms are not cleared until another profile run is made and the condition ceases to exist.

The deviation alarms are very important, since a variation in density or temperature could indicate layering or stratification, which if left unchecked could lead to a potential rollover condition.

It is very important to understand that when the system is in its Manual mode of operation, no alarms will be reported, even if alarm conditions exist. For the system to report alarms, it must be in the Auto mode.