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Accession #: D196071832

Document #: SD-WM-TI-671

Title/Desc:

TANK MONITOR & CONTROL SYSTEM DESCRIPTION

40
OCT 17 1995

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 160771

2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) Instrument Systems Integration		4. Related EDT No.: N/A	
5. Proj./Prog./Dept./Div.: TWRS/DBI/ISI 74770		6. Cog. Engr.: C.C. Scaief III		7. Purchase Order No.: N/A	
8. Originator Remarks: This EDT is for release of WHC-SD-WM-TI-671, Rev 0				9. Equip./Component No.: N/A	
				10. System/Bldg./Facility: TMACS/241G	
11. Receiver Remarks:				12. Major Assm. Dwg. No.: H-2-81761	
				13. Permit/Permit Application No.: N/A	
				14. Required Response Date: N/A	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-WM-TI-671		0	TMACS SYSTEM DESCRIPTION	N/A	1,2		

16. KEY									
Approval Designator (F)		Reason for Transmittal (G)				Disposition (H) & (I)			
E, S, Q, D or N/A (see WHC-CM-3-5, Sec. 12.7)		1. Approval 2. Release 3. Information		4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)		1. Approved 2. Approved w/comment 3. Disapproved w/comment		4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged	
(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)						(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN
1,2	1	Cog. Eng. CC Scaief III	<i>CC Scaief</i>	10/11/95	1440/82493				
1,2	1	Cog. Mgr. T.L. Moore	<i>T.L. Moore</i>	10/12/95	115-09				
		QA							
		Safety							
		Env.							
18. <i>CC Scaief III</i> Signature of EDT Originator		19. Authorized Representative for Receiving Organization		20. <i>T.L. Moore</i> Cognizant Manager		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments			

RELEASE AUTHORIZATION

Document Number: WHC-SD-WM-TI-671, REV 0

Document Title: TMACS System Description

Release Date: 10/17/95

**This document was reviewed following the
procedures described in WHC-CM-3-4 and is:**

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

Kara Broz

10/17/95

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SUPPORTING DOCUMENT

1. Total Pages 36

2. Title

TMACS System Description

3. Number

WHC-SD-WM-TI-671

4. Rev No.

0

5. Key Words

TMACS, hardware, software, data acquisition, monitoring

6. Author

Name: C. C. Scaief III

C. C. Scaief III

Signature

Organization/Charge Code 74770/N3027

7. Abstract

This document provides a description of the Tank Monitor and Control System (TMACS). It is intended as an introduction for those persons unfamiliar with the system as well as a reference document for the users, maintenance personnel, and system designers. In addition to describing the system, the document outlines the associated drawing documentation, provides maintenance and spare parts information, and discusses other TMACS documents that provide additional detail.

8. RELEASE STAMP

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1.0 INTRODUCTION

This document provides a description of the Tank Monitor and Control System (TMACS). It is intended as an introduction for those persons unfamiliar with the system as well as a reference document for the users, maintenance personnel, and system designers. In addition to describing the system, the document outlines the associated drawing documentation, provides maintenance and spare parts information, and discusses other TMACS documents that provide additional detail. The level of detail found in this document varies from general functional information to somewhat detailed information. As a result, the reader interested in an overview of capabilities may wish to first read Sections 2.0, 3.1, 3.2, 4.1, and 4.4 before proceeding to more detailed sections.

2.0 OVERVIEW

The TMACS was originally designed in response to recommendations from the Defense Nuclear Facilities Safety Board for improved monitoring of waste tank temperatures. It has since been expanded for monitoring of other parameters and it will eventually replace the aging Computer Automated Surveillance System (CASS). It has the capability to monitor most standard instrument and sensor types using commercially available local signal conditioning hardware. The hardware is also capable of providing outputs for control of discrete or continuous devices, although to date no control has been implemented. In addition to the signal conditioners, special instrumentation types such as the Enraf level gauges and the Panalarm Series 90 annunciators are connected to the TMACS computers via serial ports. Other device types can be connected in the future by developing a device specific software driver. Plans for system expansion are described in WHC 1993b.

The system monitors analog (continuous) values for temperature, level, tank pressure, ventilation flow, and hydrogen gas concentration. The actual parameters monitored vary from tank farm to tank farm, however, plans are to maximize parameter monitoring in all farms. Discrete parameters of various types are also monitored.

The signal conditioners are generally located within the tank farms and associated facilities. These communicate with the TMACS main computer system located in Building 2750E via modems operating over dedicated telephone lines. The Operator interface consists of two workstations in Room B-105 of Building 2750E and two remote workstations ("view only" capability) located in the 272AW (East) and 278WA (West) Shift Offices. The workstations provide real time dynamic graphics depicting the status of all parameters associated with the system (see Figure 2.1). Features include alarm management, data storage, data trending, reporting, event logging, failure status, and graphical presentation using a hierarchy of displays that allows progression from the general to the specific. Data are periodically and automatically sent to the Surveillance Analysis Computer System (SACS) for archiving and for access by engineers and scientist via the Hanford Local Area Network (HLAN). A more detailed discussion of the hardware and software can be found in Sections 3.0 and 4.0.

FIGURE 2.1 TMACS OPERATOR INTERFACE

3.0 HARDWARE DESCRIPTION

3.1 GENERAL

A block diagram of the TMACS is illustrated in Figure 3.1. A more detailed system block diagram is illustrated on Drawing H-2-81761. The master drawing list is contained on H-2-81778. The drawing block diagram illustrates the various facilities that are connected to TMACS, however, it may not reflect the most current status due to outstanding design changes that have yet to be incorporated. The TMACS Input/Output (I/O) Termination Point Listing (WHC 1994b) provides a more comprehensive listing of instruments and sensors connected to the system and is probably more current than the block diagram. It also lists sensors that are scheduled for connection in the immediate future. The actual connection status is indicated so that one may discern which sensors are presently being monitored.

Local signal conditioning for I/O signals is primarily performed by the Acromag 4000 Series I/O Processor (Acromag 1990a). Various configurations are available, however, TMACS is using the Model 4366 which has capability for 16 analog and 16 discrete inputs or outputs. For tank level monitoring, the Enraf 854 Automated Tank Gauge (ATG) is connected to TMACS via an analog 4-20 ma input, however, designs are in progress to interface the gauge via serial communication using the Enraf 858 Computer Interface Unit (CIU). This will allow reading the level with full precision over the entire operating span. An interface is also being developed for connection of Panalarm Series 90 annunciator panels. This will allow reading of all signals connected to these annunciators.

3.2 COMPUTERS AND COMMUNICATIONS AT 2750E

Drawing H-2-81762 illustrates the TMACS computers and communications equipment located in 2750E, Rooms B-105 and B-107. The TMACS computers are on an ethernet sub network along with the SACS computers. The computers are Sun Sparc¹ workstations running under a UNIX operating system. One of the workstations is designated the Master and runs a software package called G2 developed by Gensym, Inc. The Slave workstation runs the communications software drivers and has an eight port serial interface used to communicate with the field hardware via modems. The East and West Shift Offices each have a "view only" workstation connected to the 2750E sub network via the HLAN.

The telephone modems and interconnections are illustrated on the drawing for clarity, however, the telephone system configuration is controlled by Boeing Computer Services Richland (BCSR) Telecommunications. The portion marked "telephone system" is configured and maintained by US West under contract to Westinghouse Hanford Company (WHC). Additional details showing the RS-485 networks used to achieve modem sharing are illustrated on drawing H-2-81782.

The Acromag 4000 Processors, the Enraf CIUs, and the Panalarm annunciators all communicate with the main TMACS computers using a serial interface. Each device has its

¹Sparc is a registered trade mark of Sun Microsystems, Inc.

FIGURE 3.1 TMACS BLOCK DIAGRAM

own communication protocol and a special software driver for performing the communication has been developed for each. The TMACS computer, acting as the master or host, sends requests for information via the communication line to the devices. Each of the three types of devices has an address scheme allowing only the addressed unit to respond. The data request rate is a function of the device type as well as address. For example, one Acromag unit can be polled at a fast rate while another is polled at a slower rate (see Section 4.2.1). This allows the data rate to be adjusted to the importance and/or the response time of the parameter being measured. The following is a discussion of the general methods employed to communicate with the different device types. Additional device specific communication detail can be found in the Sections 3.4 through 3.6.

Drawing H-2-81762, Sheet 3 illustrates the communications connections in more detail than the main block diagram. Note that Ports 0 through 5 of the Sparc workstation are used for communication to the Acromag I/O Processors in the various farms. Two small RS-485 networks are used so that multiple modems can share a serial port (Ports 2 and 3). Note that A/AX, AW, and AP share Port 2 and that SY and U share Port 3. The use of different serial ports allows the thruput to increase since the Sparc station can serve all eight ports simultaneously with each operating at near maximum speed (9600 baud). It also allows the connection of more than 253 (maximum address) Acromag I/O Processors since addresses must only be unique if they are on the same port.

The Gandalf LDS 140 modems can be used within the 200E or 200W Area but they are not compatible with the telephone system for use between areas. They are essentially bit repeaters and operate without buffering of data or communications protocol overhead. The AT&T ISDN 7500 will operate with minimum communications delays in the synchronous mode but has delays of several hundred milliseconds when operated asynchronously. Since typical communications consist of short command/response messages at close intervals, this delay would seriously degrade the communications thruput. To avoid this, inter-area (East/West) communications use a Supermux 380 which multiplexes up to eight asynchronous serial ports and then communicates inter-area via an ISDN 7500 operating synchronously. The Supermux 380 backbone synchronous circuit operates at 19.2k baud, however, if all eight ports are used and traffic is high, thruput will be degraded because of the need to multiplex eight 9600 baud circuits through one 19.2k baud backbone circuit. Solutions to this problem are being pursued with BCSR Telecommunications and the telephone maintenance contractor (US West).

Port 6 has been dedicated for communication to the Enraf level gauges. Special characters are sent by the communications driver for the Enraf CIUs to control a Code Operated Switch (COS) to multiplex up to eight modems into one serial port. The CIU reads one gauge at a time on request from the computer at a data rate of 2400 baud. The thruput with multiplexing will still be sufficiently high to provide the response times required.

Port 7, in a similar fashion to Port 6, is dedicated for communication to the Panalarm Series 90 annunciator panels and also uses a COS. Unlike the Enraf CIU, the Panalarm can send all alarm data for an annunciator panel in one message. The average scan rate is about 100 points per second as discussed in Section 3.6.

3.3 FARM INSTALLATION DESIGN

The installation design of TMACS has a top level drawing for each tank farm. This drawing illustrates the plan view and associated installation parts list, general notes, wire and conduit lists, and any miscellaneous details. Drawing H-2-820792 (AW Farm) is typical except the wire runs are shown on the farm master wire run (Drawing H-2-70333). In AW, as well as several other farms, a general purpose conduit system has been designed which is then used by TMACS and is available for other uses. Drawing H-2-70330 illustrates this conduit system for AW Farm. The conduit routing is repeated on the AW Farm TMACS plan view (H-2-820792) along with conduits added specifically for TMACS. Sheet 4 of H-2-820792 illustrates the communication and power wiring for the Acromag enclosures.

Each major farm area also has a drawing depicting the modem used for communication. Drawing H-2-820793 shows the modem installation for AW Farm. The modems are supplied by BCSR Telecommunications and are mounted inside the enclosure. Installations vary from farm to farm depending on the location and number of farms served by one modem. The AW installation includes a modem for the Enraf CIU.

Presently two different labeling conventions are employed for the Acromag I/O Processors and the associated terminal boxes. New designs started in FY94 conform to the labeling standards contained in WHC-SD-WM-PLN-042 (WHC 1993d) and 6-TF-100 (WHC 1994a). For installations designed prior to adoption of the labeling standard, terminal boxes for the Acromag units are labeled as follows:

TBX-TMACS-TTTTT-N

where: **TTTTT** is the tank or building number and **N** is a sequence number beginning with 1

Within a terminal box the lower Acromag is designated by the tank number followed by **-UX** where **X** is a sequence number. **U1** and **U2** are in **TBX-TMACS-TTTTT-1**. **U3** and **U4** are in **TBX-TMACS-TTTTT-2**. A typical Acromag label is:

BY101-U1

This is also the name of the DOS ASCII file that contains the configuration data for the Acromag (see WHC 1995). Farms using this convention are AN, BX, BY, C, SY, T, and TY. Design modifications that affect these farms continue to use the same convention to avoid confusion.

For designs started in FY94, terminal boxes are labeled as follows:

TMAC-TBX-XXYY

where: **XX** is a one or two digit number representing the farm (WHC 1994a)
YY is a sequence number for the terminal boxes within the farm

For example, a terminal box in S Farm would be labeled:

TMAC-TBX-3301

where: **33** is the designated number for S Farm
 01 is the terminal box sequence number

The lower and upper Acromag units in the terminal box would be designated:

RTU3301A (lower) and **RTU3301B** (upper)

This is also the name of the DOS ASCII file that contains the configuration data for the Acromag. RTU is an acronym for Remote Terminal Unit.

3.4 ACROMAG 4000 I/O PROCESSORS

The Acromag units can perform a variety of functions in addition to signal conditioning and conversion to engineering units. This includes triggering outputs locally on occurrence of events or alarms, storing of maximum, minimum, and average values, continuous logging, and waveform generation. A complete description of functions and capabilities can be found in the User's manuals (Acromag 1990a and 1990b).

3.4.1 Acromag Communication

The Acromag 4000 units share a common communications cable using a multi-drop configuration. This communication is also serial and it conforms electrically to the Electronic Industries Association (EIA) RS-485 Standard. This signal is converted to an EIA RS-232 signal before connection to the telephone modem. The RS-485, for optimum performance, requires a linear (no branching) cabling configuration between the RS-232-to-RS-485 converter and the last Acromag I/O Processor. The converter and the last device each have an impedance matching (120 ohm) End of Line Resistor (EOLR) to minimize reflections. Up to 32 unit loads can be placed on a line and the RS-485 standard specifies a transmission distance of up to 4000 feet. This is illustrated in Figure 3.4A. Branching can be accommodated by placing an isolating repeater at the branch point. The repeater simply looks like another load to the devices on the first line. The repeater provides an isolated output that can then have an additional 32 loads distributed in a linear fashion. The repeater and the last I/O Processor each have an EOLR.

The RS-485 transmitters/receivers use a balanced, two wire, bi-directional data line with a third wire for common reference. The third wire is not required where units share a common power ground. Each Acromag 4000 has a 100 ohm resistor between the signal common terminal and power ground. When the power ground is used for common reference, each converter and repeater must have a 100 ohm resistor added from the common terminal to ground. More recent TMACS installation designs (AW Farm) use the power ground for reference (see H-2-820792 Sht. 4). This was done to free the second pair in the Belden 9842 cable for the Enraf level communications. It is expected that other farms will

FIGURE 3.4A ACROMAG COMMUNICATIONS CONFIGURATION

be retrofitted to use the power ground as a reference when the cable is required for Enraf digital communication.

3.4.2 Inputs and Outputs

Each Acromag unit contains plug-in modules that perform signal conditioning for all standard instrument and electrical signals. The type of module must be matched to the signal type, however, any analog module can be plugged into any of the 16 positions and likewise any discrete module can be plugged into any discrete position. The 4000 Processor continually scans each input and performs conversion to engineering units. The value is stored for transmission to the host on request. The I/O modules electrically isolate all inputs (250 VRMS) and the analog modules have internal zero and span correction using a voltage reference. These parameters are checked every 30 seconds and corrected as required.

Each 4000 unit has a reference junction temperature sensor associated with each of the two signal termination strips. The sensor is a semiconductor that provides a linear signal proportional to absolute temperature and is calibrated at the factory. The temperature of the sensor is used as the reference junction temperature when thermocouples are read. The sensors are centrally located on an isothermal bar mounted parallel to the termination strips. The isothermal bar ensures that the sensor sees the average temperature along the termination strip. The isothermal bar does not, however, even out the actual reference junction temperatures.

When the units are mounted in dead air inside an enclosure, a temperature gradient exists vertically within the cabinet. This can cause errors in sensing the correct reference junction temperature of the terminations. The error increases linearly with vertical distance from the center of the termination bar. The additional worst case error in the measured value of the thermocouple due to this effect has been estimated from data to be about -2

°F (Inputs 1 or 9) and +2

°F (Inputs 8 or 16). This effect can be

significantly reduced by running the internal circulating fan (see Section 3.4.3). For applications requiring more precise thermocouple (TC) measurements, the 4000 units should be mounted in free air or with the termination strips in a horizontal position.

The 4-20 ma input module (4M00-240) contains an internal DC supply that can be used to provide power to two wire transmitters. The excitation supply provides 16 VDC minimum at 20 ma. The output is current limited for short circuit protection. Refer to the manual (Acromag 1990a) for connection details.

The 4000 Processor can perform limited control and interlock functions independently of the host computer. Discrete outputs can be made to change state based on the condition of other discrete I/O or on the value of an analog input. More advanced direct computer control can be exercised from the host computer via commands to turn outputs on or off. This type of control is of course dependent on the communications link between the host and the field I/O Processor.

3.4.3 Installation

For installations within the farm, the Acromag 4000 units are housed in a Nema Type 4X enclosure with a sun shield for limiting internal heating from solar radiation. The basic design for the I/O Processor enclosure is contained on Drawings H-2-815301 and H-2-820820. Earlier designs did not use these assemblies since the design has evolved over time. In fact, H-2-815301 and H-2-820820 are very similar but H-2-820820 is the latest version. Whenever the basic design is changed a new drawing is created since existing installations use the old design. This drawing (H-2-820820) provides a generic design which is called out on other drawings which are location specific. Each installation of the I/O Processors has a separate drawing that adds location specific details, primarily differences in termination wiring. Figure 3.4B illustrates a typical installation.

As shown on H-2-820820, the basic design can accommodate up to two Acromag 4366 I/O Processors (Item 6 on the parts list). Sheet 2 of this drawing illustrates the basic power and communication wiring. Drawing H-2-820820 eliminated the third (common) wire in the Acromag communication. The common power ground makes the third wire unnecessary (see 3.4.1). This frees the other pair in the cable to be used for the Enraf CIU communications. Adding additional 4000 units can be accomplished by connecting them to the communications cable. The enclosures have local 115 VAC switched power for the Acromags. An optional 24 VDC power supply assembly can be added (H-2-81764-030) if needed to supply source voltage for transmitter loops or discrete I/O.

For those units that interface to TC trees, up to two selector switches can be added on the side of the enclosure for manual monitoring of the TCs. New temperature trees have the selector switch at the riser and do not require the switch in the TMACS enclosure. All enclosures installed outdoors have a small fan for internal circulation of the air to even out hot spots and increase the thermal conductivity to the enclosure walls. The operation of the fan is controlled locally by the lower Acromag unit based on internal temperature. Enclosures containing Acromags used for monitoring the Multifunctional Instrument Tree (MIT) in Hydrogen Watch List tanks have fans that run continuously. This was accomplished by changing the configuration in the Acromag. This has been done to make the reference junction temperatures more isothermal (see Section 3.4.2). Figure 3.4C illustrates the inside of a typical enclosure.

Most of the 4000 I/O Processors have been installed near the sensor or instrument to be monitored. For the tank farms, this has resulted in the enclosures being located within the farm or Radiologically Controlled Area (RCA). This has both advantages and disadvantages. It requires that maintenance on the I/O Processor be performed within the RCA. Thus maintenance costs will be higher due to access restrictions and the work environment. Recent efforts to clean up the farms and remove the RCA designations for all or portions of the farms will improve access. Locating the processor near the sensor does, however, significantly reduce the amount of conduit and wiring that must exit the farm. Connection of new instruments and sensors only impacts the sizing of the conduit from the sensor to the processor. To date, maintenance on the 4000 Processor and I/O modules has been minimal.

FIGURE 3.4B TYPICAL ENCLOSURE INSTALLATION

FIGURE 3.4C TYPICAL ENCLOSURE INTERNAL COMPONENTS

Drawings H-2-81769 and H-2-815302 provide the field mounting stand and the concrete footings that hold the stand in place. H-2-815300 shows a typical installation of the stand and footings. This installation has been analyzed for seismic and wind loading (WHC 1993c). Note that the front of the enclosure must face north for the sun shield to have maximum effectiveness. This is important to ensure that during hot summer days the maximum temperature (140 °F) of the I/O Processor is not exceeded.

3.4.4 Processor Configuration

Each 4000 unit must have the firmware configured to the selected I/O complement, unit address, and operating parameters. These configuration values are stored in Electrically Erasable Programmable Read Only Memory (EEPROM) and therefore are not lost when power fails. The configuration can be sent to the unit via an RS-232 serial port local to the unit using a Personal Computer (PC). This is how the initial configuration is established prior to installation. Once a unit is installed, a portable computer can be used to reconfigure in the field if changes are necessary or it can be performed remotely via the RS-485 communication line.

Presently, remote configuration requires taking the host-to-processor communications off-line while the target unit is reconfigured using a PC. Generally this only takes a few minutes. In the future this process will be accomplished from the Operator workstation at 2750E using the G2 software package. The system manager will be allowed to perform the configuration from a screen menu. This change request is pending and the functional capability is contained in the initial software requirements (WHC 1992a). Configuration of the I/O Processors is presently performed and maintained by Tank Waste Remediation System (TWRS) Instrument Systems Integration (ISI).

3.5 ENRAF LEVEL GAUGES

The Enraf level gauges have a 4-20 ma analog output representing the measured level. To date this signal has been used to read the gauge level with the TMACS I/O Processor. Since it is an analog signal its accuracy is limited to about 0.1 % of span. As a result, the analog output is presently set to cover a span of 50 inches so that acceptable accuracy can be obtained via the TMACS. This places the maximum error contributed by the electronic signal conditioning at about .05 inches. Since the range is limited to 50 inches, this practice may prove unacceptable for active double shell tanks. This limitation does not exist when using the digital communication output from the gauge. In addition, many other features are available via the digital interface such as diagnostics and commands that control the operation of the gauge. Figure 3.5 illustrates a typical gauge installation.

Designs are in progress to implement this digital communication and each local farm complex will have at least one CIU that provides the communication interface between the local Enraf level gauges and the host computer. Drawing H-2-820801 shows the generic installation of a CIU to include all jumper and switch settings for proper operation. The CIU communicates with the host computer via an RS-232C serial link. Each CIU has an address, however, the addresses only need to be unique when the units share common communications channels.

FIGURE 3.5 TYPICAL ENRAF LEVEL GAUGE INSTALLATION

The CIU communicates to the field level gauges using a proprietary bi-phase mark signal. This is an AC signal that changes state at the start of each bit and also in the middle of a "one" bit. It does not change state in the middle of a "zero" bit. Because the receiver looks only at changes in level regardless of direction, the signal has no polarity. The signal is transformer isolated at each device. The CIU instruction manual (Enraf 1994) provides installation and operating guides. It should be noted that the manual also directs that field devices should not be arranged in a linear pattern (daisy chained). They state that all devices should be connected in a "star" pattern with a centrally located junction box. The junction box is then connected to the CIU. It cautions that if a linear pattern is used the device nearest the CIU will "dampen" (load) the signal.

This recommendation has largely been ignored in the installation design. It was assumed that the recommendation was based on some minimum distance from the CIU to the junction box and from the junction box to the devices. Attempts were made to gain a more technical rationale from the manufacturer (Enraf) for the requirement, however, no detailed information was forthcoming. The existing Acromag communications were designed for daisy chaining and it is most cost effective to utilize the existing conduit routing as well as cable if possible. As a result, ISI did some testing and modeling of the various network configurations to determine how the topology contributes to the loading of the signal. The impedance of a gauge was measured to determine the load it presents to a transmitted signal. At a transmission speed of 2400 baud this impedance was estimated to be about 115 ohms.

Using this information a "linear" network was built in the laboratory using an Enraf CIU, two Enraf 854 level gauges, and numerous dummy loads of 115 ohms. One ATG was placed near the CIU and one at the end of the linear network. The gauges and dummy loads were separated by 500 feet of cable (4000 feet total) using a large roll of multi-pair cable. The CIU communicated with both ATGs and additional loading was added until communication failed. The results of the test and subsequent network modeling confirmed that loading will not become a problem until the distance between the linear devices becomes quite large (thousands of feet). In the tank farms these distances are typically between 100 and 200 feet. Enraf's customers have mostly been in the oil industry where the tanks and farms are separated by large distances.

Each level gauge has an address for digital communication. The numbers available for addressing depend on which "transmission line" (TL) serves the gauge. The CIU has three lines (TL1, TL2, and TL3) and a total of 100 device addresses are available. The distribution of addresses is as follows:

<u>Xmt Line</u>	<u>Address</u>
TL1	00 - 29
TL2	30 - 59
TL3	60 - 99

Enraf also recommends that no more than 10 devices be placed on one TL, however, in the testing discussed above it was determined that this number can probably be exceeded when the distances are not long. The CIU will not respond to a gauge with an address other than as shown above for the TL in question.

The turn around time for reading a gauge is less than 200 ms. This means that the sampling rate is approximately five gauges per second. Thus about 300 gauges can be read in a minute. In addition, the sampling (polling) rate can be set for each gauge allowing selected gauges to be read even more frequently than once per minute (see 4.2.2).

3.6 PANALARM ANNUNCIATORS

Designs are in place to connect the TMACS to Panalarm Series 90 annunciators using serial communication (see Section 3.2). This connection allows TMACS to read any of the "windows" on the Panalarm annunciators via a serial port. Locally, multiple annunciators can be daisy chained together using an RS-422 compatible communication. The RS-422 signal is converted to RS-232 for connection to a modem. The modem transmits the signal to the host computer at 2750E. Drawing H-2-820813 (241-A-271) Sheet 3 shows an example of this connection. Drawing H-2-820812 illustrates the modem and converter connections.

One of the annunciator panels contains a 90CPC card that acts as the main processor and communicates with the host computer via the serial link. The Panalarm uses eight bit binary rather than ASCII characters. Each panel contains a 90CPX card which communicates with the 90CPC card. Setup, operation, and connection of the various cards are described in the Instruction and Operating Manual (Ametek 1991).

The annunciator windows are addressed using a row x column designator. The maximum annunciator size is 10 x 10. The sizes in the field will vary depending on the number of alarms. The processor software in the annunciator responds to data requests by the host via the serial interface. Data are returned in the format rows x 10. In other words, regardless of the actual number of columns in the annunciator, the processor always sends 10 and fills unused column data positions with zeros. Thus if the annunciator is 5 x 5, the data are returned as 5 x 10 with the last five columns filled with zeros. This, of course, increases the communications overhead. In addition, four bytes of data are returned for each window even though only the first byte is used for digital information. It is assumed that this was done to accommodate analog data. Given this information, the following timing (times in ms) information applies to the data request at 9600 baud:

PANALARM MESSAGE COMMUNICATION OVERHEAD TIMES (ms)

<u>Time</u>	<u>Description</u>
05	Data request command
55	Maximum communication turnaround delay (Supermux 380)
05	Panalarm processor delay
05	Communication overhead - header, checksum, etc.
70	Total maximum communication overhead
15	Total minimum communication overhead (no modem delay)

The actual byte transmission time for one row (10 columns) is 40 ms (4 ms per column). This results in the following total transmission time for multiple rows:

(rows x 40) + 70	Total maximum transmission time (Supermux 380)
(rows x 40) + 15	Total minimum transmission time (Gandalf LDS 140)

For a typical annunciator panel that is 5 x 5, the maximum and minimum times to acquire the data are 270 ms and 215 ms. This amounts to 10.8 ms and 8.6 ms per point. Using an average value of 10 ms per point, the sample rate is 100 points per second.

3.7 TESTING

Whenever new points are added to TMACS an Acceptance Test Procedure (ATP) is performed in accordance with WHC-SD-WM-ATP-023 (WHC 1991b). This test procedure is generic in nature. The data sheets are designed for the different instrument and sensor types connected. Actual job specific information is added to the data sheets by the Test Coordinator. In this way the ATP does not need to be revised for each job. Completed data sheets are collected by TWRS ISI for subsequent release as an Acceptance Test Report (ATR). The ATP is periodically revised to add new sensor types as required by the ongoing system expansion.

In addition to the formal ATP, much informal testing is performed at various stages of construction. TWRS ISI has developed an inspection and test check list that is performed on the field Acromag I/O processor enclosure assemblies prior to installation in the field. This includes a dynamic test of the I/O processor using a portable PC. This check out verifies the operation of the I/O Processor and associated hardware. This reduces the chances of having to trouble shoot and repair after they are installed in the field. After field installation, measurements are made of the loop resistance on the communication wiring. The expected resistance can be estimated from the number of processor units and the wiring distance. Also, the power wiring is checked for faults and open circuits.

After the field units are powered, local communication is established with each processor using a portable notebook PC with a serial port and communication software. The modems between 2750E and the field are also tested using the PC. Finally, a PC based data acquisition system is connected to the field units and the instruments and sensors are monitored and trended for several days. The trends have been helpful in finding wiring problems with TCs as well as problems with input modules and reference junction sensing. Upon completion of the above informal testing, the hardware is connected to the operational TMACS and the formal ATP is performed.

4.0 SOFTWARE DESCRIPTION

4.1 GENERAL

The first implementation of TMACS, in 1991, was designed to monitor temperature in ferrocyanide tanks. Its success made it the selection for expanding automatic data collection to other tank farms. Although the I/O processors in TMACS could be scaled for this new role, the application package used for the data collection and monitoring in TMACS was

insufficient. The original DOS-based application had several limitations that did not make it conducive to expanding TMACS from 14 tanks to possibly all 177 tanks.

In FY92 a new version of the TMACS software was developed by configuring a commercial, real-time, expert system, software package to the specific needs of the project. The software package is a product of Gensym, Inc. and is referred to as G2. The software runs on Sun Sparc workstations using a UNIX operating system. These workstations are on an ethernet network along with the SACS Sun workstations (Figure 3.1, Page 4). TMACS software has the capability to process several thousand sensors, over multiple communication lines, and can serve more than one type of I/O processor. In addition, it communicates with the SACS and sends data for long term storage on a daily basis.

The Sparc stations use the UNIX operating system which is multi-tasking and the G2 software is executed by the TMACS Master terminal as an application. Other applications can also be executed under the multi-tasking environment. The TMACS Slave terminal operates as a window to the G2 software on the Master terminal. The software that controls the serial communication to the I/O is referred to as a bridge and is executed by the processor on the TMACS Slave terminal. The two computers communicate via an ethernet network using TCP/IP which is a standard network protocol.

The TMACS/SACS ethernet can be expanded to other facilities via the HLAN. This allows a workstation to operate as a remote window to the TMACS. This has been done for the 272-AW (East) Shift Office and the 278-WA (West) Shift Office.

4.2 BRIDGE COMMUNICATION SOFTWARE

The Slave terminal has a serial port expansion card that provides eight ports (numbered 0-7) for serial communication. The bridge uses this card for communication with the various field devices. Bridges have been developed for the Acromag 4000, the Enraf CIU, and the Panalarm Series 90 annunciators. Drawing H-2-81762, Sheet 3 illustrates the connection of Ports 0-7 to the field hardware. There is a one-to-one correspondence between each port and a bridge. For the Acromag 4000 ports, the bridges are identical except for the addresses and configuration of remote units that they communicate with. Since UNIX is multi-tasking, the bridges share processor CPU time. This allows the low speed serial ports to operate simultaneously. This increases thruput and improves the efficiency of communication.

4.2.1 Acromag Bridge Communication

The bridges for the Acromag 4000 units have a 5 x 600 array of polling slots that can be used to schedule polling of remote units. This is based on an assumed polling thruput of five command/responses per second with the array being repeated every 600 seconds. The polling rates available have periods of 1, 10, 60, and 600 seconds. For each second in the polling array there are five polling slots available. Each different polling period has one slot with the exception of the 60 second period which has been assigned two slots. The following is a summary of the available polling periods. An example of a polling array is also provided.

<u>Polling Period (sec)</u>	<u>Slots Available</u>
1	1
10	1
60	2
600	1

POLLING ARRAY EXAMPLE

Polling Second	One Second Slot	Ten Second Slot	60 Second Slot	60 Second Slot	600 Second Slot
0	A1	A2	A3	B1	C1
1	A1	B2	D1	E1	-
.	.	.	.	.	.
.	.	.	.	.	.
10	A1	A2	-	-	-
11	A1	B2	-	-	-
.	.	.	.	.	.
.	.	.	.	.	.
60	A1	A2	A3	B1	-
61	A1	B2	D1	E1	-
.	.	.	.	.	.
.	.	.	.	.	.
599	A1	-	-	-	-
600	A1	A2	A3	B1	C1
601	A1	B2	D1	E1	-
.	.	.	.	.	.
etc	.	.	.	.	.

A, B, C, .. etc = Units A, B, C, .. etc 1 = Pts 1-16 2 = Pts 17-32 3 = Pts 33-34 Shaded = Unused Slots

Note that on any port, only one remote Acromag can be polled at the 1 second period. Up to 10 units can be polled at the 10 second period. Likewise 120 units can be polled at the one minute period, and 600 units at the ten minute period. If all polling slots were utilized this would represent a total of 731 units which is greater than the maximum of 253 addresses

available for the Acromags. It must be remembered, however, that three polls are required to obtain all possible data from a unit. Each Acromag has up to 16 analog I/O, 16 discrete I/O, and two reference junction temperatures. Since a maximum of 16 channels can be scanned in one request, it requires three separate polls to scan the analogs, discretes, and the temperature references. Thus each unit may appear in up to three polling slots depending on the data required (i. e. analog, discrete, and reference temperature).

At the end of 600 seconds the array has been completed and the bridge begins again at the beginning of the array. When the TMACS is started, or after a reset of the bridge, the G2 software loads the array for each bridge to establish the polling. This polling array contains internal bridge object indices corresponding to Acromag stations in the TMACS G2 software.

The discrete inputs are presently scanned at 10 second intervals and the temperature reference junctions are scanned at 600 second (ten minute) intervals. The remaining analog channels are scanned at either 60 or 600 second intervals depending on the type and the tank of interest. Most Single Shell Tank (SST) temperatures are polled at the 600 second interval. The Double Shell Tank (DST) temperatures are polled at the 60 second rate. The polling rates are adjusted periodically based on data collection needs. This requires a reset of the bridge.

The bridge implements a command response type of communication protocol with the bridge acting as the master. After sending a command, the code expects a response within a specified time period. If no response is forthcoming before the time expires, the command is repeated once. If no response is received after the repeated command, repeated tries are suspended for that unit until a command is successfully completed at one of the next scheduled polls. Communication delays and remote hardware response times establish the typical expected delay. The total time for a 16 point analog poll is about 150 ms for an Acromag in East Area and about 200 ms for West Area. The longer times for West Area are due to the use of the Supermux 380 multiplexer operating over a synchronous backbone circuit. Delays are caused primarily by the multiplexing and possibly by the asynchronous to synchronous conversion. East Area uses Gandalf limited distance modems operating asynchronously without a multiplexer.

The performance goal of five polling slots per second (per port) can not be achieved with a total message communications time (start of command to end of response) of 200 ms since it leaves no time for processing and multi-tasking overhead. This time can be reduced by using a point to point synchronous modem with an asynchronous to synchronous converter at each end. Testing of this configuration revealed a total modem delay (out and back) of 15 ms.

The timer is set for each bridge to exceed the worst case delays. Due to delays caused by the multi-tasking process as well as limited precision in the UNIX timers, the timeout delay must be set large enough to accommodate these uncertainties. As a result, whenever a remote Acromag unit does not respond, the communication polling rate can be degraded. The amount of degradation is dependent on the number of units not responding and the distribution in the polling array. Whenever the scheduled polling for a particular second in the array can not be completed in the allotted time, the start of the next time slot is delayed until the current one is completed. In this way points are never skipped. Whenever a unit

does not respond to the command or to the retry, an indication of this failure is passed to the G2 processing software.

The polling rates and number of slots were selected based on a projected target performance specification rather than on current needs. This performance is dependent on processor speed, communication delays, and processor overhead and workload (i. e. other tasks that may be running). Presently the performance is only about three polls per second rather than the specified five, however, the performance greatly exceeds the current demand. The performance is expected to improve with future upgrades in hardware and software.

In addition to the scheduled polling, the TMACS software allows an Interactive command mode whereby the Operator can request an immediate update on a particular point. Other types of commands can also be sent via the interactive mode but are presently only available to the System Administrator under password protection. Whenever a command is sent in the Interactive mode, the scheduled polling is suspended until the Interactive command is completed (or times out).

4.2.2 Enraf Bridge Communication

The bridge for the Enraf level gauges is similar to the bridge for the Acromag in that it also uses an array driven polling schedule. The polling rate is about five gauges per second (see Section 3.5). The array is 5 x 60 as it is presently designed, however, it is easily changed as needed. Currently the slots available each second are:

<u>Polling Period (sec)</u>	<u>Slots Available</u>
10	1
60	4

This polling array allows a total of 250 gauges (240 at 60 seconds and 10 at 10 seconds) to be assigned polling slots. The level gauge bridge presently uses only one port (Port 6) in conjunction with a COS. The switch allows the one port to be expanded to up to eight modems. The bridge provides the required switching code as well.

4.2.3 Panalarm Bridge Communication

The Panalarm bridge also uses a COS on Port 7, however, it does not use an array driven polling schedule. All annunciators that are active are polled in sequence as rapidly as possible. Section 3.6 provides information on the polling rate.

4.3 G2 POINT PROCESSING

The bridge passes data acquired from the field hardware to the G2 software for processing, storing, alarming, and displaying. The discrete input points are checked by the bridge for change of state and only points that have changed are sent to the G2 application software. No checking of analog points is performed by the bridge. The G2 software performs filtering on all analog points prior to processing. The filter is simply a comparison of the

difference between the new value and the old value. For each point a delta band is specified such that if the absolute value of the difference meets or exceeds the delta, then the point is processed and the old value is updated.

Both exception reporting (communication) and exception processing are methods traditionally used to increase system performance. Note that TMACS only employs the latter. These techniques can in some cases have negative effects as they may mask the inability of the system to handle high data activity that may occur during process upsets. This is of little concern for TMACS since the monitored facilities are geographically diverse and either process independent or otherwise very loosely coupled. If a point passes the filter (i. e. exceeds the delta), then various processing rules are invoked such as alarm checking, trending, logging, and any special rules which may be in effect for the point. This processing continues on a point by point basis until all points are processed.

4.4 GRAPHICAL INTERFACE

The G2 software has a windows type graphical user interface that employs a mouse with "point and click" for navigating through the various screens. The displays are designed in a hierarchical structure that allows advancing from the general to the specific. Figure 4.4A depicts the most general (overview) display. This display illustrates the various tank farms and associated facilities. The graphic provides an overview of the total facility status by use of color icons. Tanks (or facilities) that have no monitored points are shown in gray shade. Those facilities that have monitored points that are currently being scanned and have no alarms are shown in green. Those in alarm are illustrated in red (highest priority), yellow (medium priority). White indicates that at least one monitored parameter associated with the tank or facility is not available or is out of range. White is technically not an indicator of an alarm but rather indicates equipment status and is not processed as an alarm.

Red and yellow alarms in the graphic (i. e. tank color) will flash until acknowledged. If the alarm clears (returns to normal) before being acknowledged, it will continue flashing in green. The lower right corner of the screen has an area that shows the most recent alarm. This area does not flash, however, the text indicates the unacknowledged/acknowledged status. This alarm will disappear from the overview whenever the current alarm list screen is selected. The current alarm button (upper right) will provide the list of all current alarms (Figure 4.4B). Once an alarm has cleared (back to normal) it will disappear from the list provided it has been acknowledged. If it clears and is unacknowledged, it will turn green but remain on the list until acknowledged.

The button labeled "PANALARM DIRECTORY" is used to get to the appropriate Panalarm annunciator display (Figure 4.4C). The display is a replica of the remote annunciator.

The mouse pointer can be moved to a facility or tank of interest and by "clicking" the mouse a more detailed display will appear. Clicking on Tank C-106 would produce Figure 4.4D which illustrates the tank in detail. The tank level is obtained from the Enraf gauge and the horizontal line's height above tank bottom is proportional to tank level. The position of this line also changes dynamically as the level changes. Temperature trees are illustrated with current temperature values displayed with the height of the numerical value scaled to the

FIGURE 4.4A OVERVIEW DISPLAY

0

TOP OF CURRENT ALARM LIST.
CURRENT ALARM LIST INITIALIZED AT:
10 Oct 95 10:44:52 a.m.

CURRENT ALARMS

Number of Current Alarms: 1

UP ONE ALARM

UP ONE PAGE

REFRESH ALARMS

DOWN ONE PAGE

DOWN ONE ALARM

GO TO TOP of LIST

GO TO END of LIST

Acknowledge
All White Alarms

Acknowledge
All Blue Messages

PANEL

DISPLAY

ALARMS

Alarms: 1

SY-101

0.3 CFM

0.4

DIRECTORY

10:15 am

Alarms: 1

10 Oct 95 10:45:00 a.m. TAG NAME: SY101-FI-R07A-3101B
ALARM LOW: SY-101 Reading: 0.3 CFM Limit: 0.4
NOT ACKNOWLEDGED

FIGURE 4.4B CURRENT ALARM LIST DISPLAY

FIGURE 4.4C PANALARM ANNUNCIATOR DISPLAY

FIGURE 4.4D TANK C-106 DISPLAY

approximate sensor height within the tank. The location of the riser is illustrated on the plan view in the upper right corner of the screen. Tank pressure values (both low and high ranges) are displayed adjacent to Riser-007. By clicking on the jagged line symbol next to a sensor numeric value, a single sensor trend is made available. This trend for TC-01, Riser-014 is illustrated in the lower left area of the screen. Figure 4.4E shows the same type of display for Tank SY-101. This tank has a Standard Hydrogen Monitoring System (SHMS) connected and the associated % H₂, sample flow, and discrete alarm signals are provided on the graphic.

As discussed for Figure 4.4D, dynamic trend graphs can be obtained by clicking on the trend symbol next to a sensor value. A more detailed historical trend for temperature can be obtained by clicking on the trend button at the bottom of the screen as illustrated by Figure 4.4F. This trend graph allows the Operator to select temperature sensors of interest as well as select the period of interest (1 hr, 8 hr, etc.). The current, low, and high numeric values over the selected period are displayed next to the sensor number.

The trend displays do not presently allow selecting a window of interest and then expanding the time scale to improve the resolution. This enhancement would allow the selection of a one, eight, or 24 hour period anywhere within the 31 days of data. This feature is expected to be available soon within the G2 software.

4.5 TESTING

All major releases of the software are tested prior to installation to verify the correct functioning of new features. The associated test plan (WHC 1992b) describes the testing requirements and lists the associated test case documents. In addition to the formal testing, much informal testing is done continually. Software has been developed that emulates the various hardware devices via a PC using a serial port. These software simulators allow the testing of error conditions as well as limiting conditions that do not normally occur with the operational system.

5.0 MAINTENANCE AND SPARE PARTS

Initial training of Tank Farm Maintenance instrument crafts personnel was conducted on site by Acromag, Inc. and focused primarily on the Acromag 4000 and associated communications equipment. A more comprehensive training program is being developed by TWRS Maintenance and Technical Training. This training program will encompass all aspects of TMACS.

The manuals provided by Acromag for the 4000 Series equipment (Acromag 1989 and 1990a) contain excellent documentation as well as information on troubleshooting. Acromag also has a repair service for all equipment returned. For most parts they have a flat rate for repair. Because of this it is not recommended that repair at the electronic component level be attempted. Repair by module and board replacement should be sufficient. Contact Acromag at 810-624-1541 for information on how to obtain parts and service.

FIGURE 4.4E TANK SY-101 DISPLAY

FIGURE 4.4F TANK C-106 TREND DISPLAY

The Acromag I/O Processor performs an internal calibration check for zero and span every 30 seconds for each analog input module. This check uses a processor controlled analog switch to short the input (zero check) and to select a reference voltage (span check). The analog to digital (A/D) conversion is accomplished within each module. The zero and span check allow the processor to provide a dynamic correction to the A/D conversion to adjust for temperature drift and component aging. As an additional check on the effectiveness of this correction, a periodic calibration check of analog input modules is recommended. The initial recommended period is two years.

Since TC input and Resistance Temperature Detector (RTD) modules generally monitor a sensor that is inaccessible for calibration check, a loop calibration in the field is either not possible or not practical. It is recommended therefore that these modules not be calibrated in the field but rather simply be replaced with modules that have been verified. This reduces the time the instrument technician must spend in the field. For other input modules such as 4-20 ma, it may be possible to perform a loop calibration with the associated instrument in the field.

Two calibration procedures have been written for calibration check of the Acromag I/O Processor. Procedure PSCP-4-287 governs the shop check of the TC I/O modules using a PC based computer program to guide the calibration. Procedure PSCP-4-301 controls the field replacement of the tested modules and check of the local reference junction temperature sensors in the I/O Processor. These procedures are presently being converted to "TF" procedures.

Spare parts have been established for TMACS under stock number 6118-0004. This is the TMACS system level number. Presently this contains items for the Acromag I/O signal conditioner and associated communications equipment. Spare parts for the Enraf level gauge are under stock number 6118-3448-2070.

Vendor information for TMACS Acromag I/O Processor is contained in VI file number 22138. Supplement 1 of this file contains information on the converters and repeaters used for the RS-485 communications. Vendor information number 31560 contains information on the Enraf level gauge and the CIU. The vendor information number for the Panalarm Series 90 annunciator equipment is 22260.

6.0 ACRONYMS

A/D	Analog-to-Digital
ATG	Automated Tank Gauge
ATP	Acceptance Test Procedure
ATR	Acceptance Test Report
BCSR	Boeing Computer Services Richland

CASS	Computer Automated Surveillance System
CIU	Communications Interface Unit
COS	Code Operated Switch
DST	Double Shell Tank
EEPROM	Electrically Erasable Programmable Read Only Memory
EIA	Electronic Industries Association
EOLR	End of Line Resistor
HLAN	Hanford Local Area Network
I/O	Input/Output
ISI	Instrument Systems Integration
MIT	Multifunctional Instrument Tree
PC	Personal Computer
RCA	Radiologically Controlled Area
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit
SACS	Surveillance Analysis Computer System
SHMS	Standard Hydrogen Monitoring System
SST	Single Shell Tank
TC	Thermocouple
TL	Transmission Line
TMACS	Tank Monitor and Control System
TWRS	Tank Waste Remediation System
WHC	Westinghouse Hanford Company
UNIX	An open standard computer operating system originally developed by AT&T.

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