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FIELD VALIDATION OF CABLE MONITORING AND RATING
SYSTEM (CMARS) LABORATORY MODEL

Semi-Annual Report, May 1—December 31, 1979

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January 1980

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Public Service Electric & Gas Research Corporation
Newark, New Jersey

U. S. DEPARTMENT OF ENERGY

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SEMI-ANNUAL REPORT

FOR THE PERIOD

1 MAY 1979 - 31 DECEMBER 1979

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INTRODUCTION AND SUMMARY

This annual report covers the time period from May 1, 1979 to December 31, 1979. The extended time period between reports was required to allow for installation of the Laser Temperature Monitoring System (LTMS) to be completed at all sites and fully cover all aspects of design, fabrication, and installation of the units.

Systems Control, Inc. (SCI) after a full factory test of the CMARS software in Palo Alto, California had the CMARS system and associated hardware shipped to PSE&G in New Jersey.

The Hinchmans-Hawthorne 230-kV pipe type cable circuit, which is the most extensively monitored circuit of the three pipe cable circuits associated with CMARS testing, was energized on May 1, 1979. All temperature sensing devices associated with this circuit were tested, placed in service, and are now providing data for CMARS computations.

SCI made several modifications to the software per PSE&G requests which include:

- A visual message appears on the screen whenever an alarm condition occurs.
- Modification of the tape dump program to speed execution. The program achieved a 22% increase in speed on a high-speed unit at SCI.

- Addition of ambient earth temperature measurement or calculations to the cross-sectional display of a cable.
- Modification of the Change Point Attributes and Display Point Attributes Tasks to permit the addition of linearization procedures for thermocouple inputs.

A two week training session was held for PSE&G and USI personnel by SCI in California.

After field installation it was discovered that the thermocouple transmitters were incorrectly calibrated by their manufacturer. The thermocouple transmitters had to be removed, recalibrated, and reinstalled.

Underground Systems, Inc. developed a Laser Temperature Monitoring System (LTMS) to relay data from the top of the 230 and 345-kV potheads to ground level receivers. This is the first installation of laser instrumentation for conductor temperature monitoring applications. Delivery delays of critical components required for assembly of the LTM Systems and numerous shop testing problems, which arose during fabrication, contributed to approximately a two month delay in their installation. At the present time all LTMS units have been installed and are operating reasonably well.

Public Service Electric and Gas Company along with its subcontractors Systems Control, Inc. and Underground Systems, Inc. have concentrated their efforts over the last nine months in the following project task areas:

- Task I - Installation of Sensing Devices
- Task II - Data Acquisition System Installation
- Task V - Software Installation and Development
- Task VII - CMARS Testing Program

The following report will describe the project goals and system description along with the progress to date within each task.

GOALS

The goal of this project is to quantitatively validate the CMARS software and associated hardware as applied to commercially operating underground transmission systems. In the course of the project, it is expected that improvements and refinements of the CMARS will occur resulting in improved accuracy, flexibility and predictive capability for CMARS. The circuits to be utilized are equipped with extensive monitoring facilities, which will allow the determination of CMARS accuracy. In addition, recommendations will be made regarding accuracy vs. cost trade-offs as a function of the amount and complexity of data which might be available on or retrofitted to existing systems, or considered for future systems. Information displays will be optimized by discussions with system operators, transmission planners and underground transmission engineering groups, not only within PSE&G but with other interested utilities as well. Finally, hardware installation problems for sensor equipment as well as data acquisition equipment will be readily identified. At the completion of the project, specifications for CMARS software and hardware, and all associated sensors, data acquisition and communications equipment will be available to the industry.

SYSTEM DESCRIPTION

The Hinchmans-Hawthorne, Waldwick-Hawthorne 230-kV and the Waldwick-South Mahwah 345-kV pipe type cable test circuits are in series located in the northern part of the state and are equipped with a temperature monitoring system designed specifically for CMARS research. The circuits can be selectively loaded utilizing remotely controlled phase angle regulators located at Waldwick Switching Station.

The Hinchmans-Hawthorne 230-kV HPOF pipe cable circuit is equipped with a temperature monitoring system designed specifically for CMARS application. This circuit is the primary line for the CMARS evaluation testing and is described in figure 1.

Two monitoring cross sections located 90 feet and 300 feet from manhole 1 are equipped with conductor, cable shield, pipe and earth temperature sensors. The monitoring cable section between manhole 1 and manhole 2 has a special Temperature Sensing Wire (TSW), manufactured by Underground Systems, Inc., installed in the center interstice of the cable.

Installation of the TSW during cabling operations had to be carefully coordinated with Okonite, the pipe cable manufacturer, to achieve the desired location of temperature sensing points, especially since three phases were manufactured in one length.

The TSW provides the average conductor temperature of the section along with spot conductor temperatures at the 90 foot and 300 foot cross sectional points for each phase. Thermistor sensors are also in the conductor at 500 and 900 feet for axial spot conductor temperatures, as well as sensors for splice connector temperatures in manhole 1, manhole 2 and manhole 3. All of these sensor facilities, in addition to oil probes and splice shield sensors in manhole 1 are instrumented for CMARS data transmission to the Newark Electric System Operation Center.

The conductor average and spot temperature data is transmitted from pothead mounted equipment to ground level receivers by a Laser Temperature Monitoring System, (LTMS) designed and fabricated by Underground Systems, Inc. Monitored temperatures are then sent via a telephone lease line to Newark with other sensor data, including current readings for each phase, potential readings for the line and pothead cable shield, stress cone and oil temperatures.

The transmitted data for CMARS will be supplemented by temperature data that will be read in the field. This includes the splice shield and oil temperatures available in manhole 2 and manhole 3. The Waldwick-South Mahwah 345-kV HPOF pipe cable, placed in service in 1973, was extensively equipped with thermocouples on the cable and splice shield with additional pipe and earth thermocouples installed especially for the CMARS project. The circuit is also equipped with a Temperature Sensing Wire in the center interstice of the cable which provides a means of measuring

average conductor temperature from the South Mahwah pothead to manhole 16. The monitored sections for this line are 100 ft. from manhole 1, 30 ft. from manhole 2 and 100 ft. from manhole 17.

Instrumentation has been installed for data acquisition from these three cross sections including the average conductor temperature from the South Mahwah pothead LTMS equipment, splice shield, oil and ambient air sensors. Temperature information is also available for the cable shield, stress cone and oil at the Waldwick potheads. Current for each phase and the circuit potential are included in the transmitted data.

The Waldwick-Hawthorne 230-kV HPOF pipe cable is equipped with Temperature Sensing Wires for monitoring average conductor temperature to manhole 2 at the Waldwick end. The Waldwick potheads are equipped with LTMS equipment for monitoring average conductor temperatures. Pipe and earth ambient sensors have been installed 100 feet from manhole 1. All of this sensor data together with the current from each phase and the circuit potential is transmitted to Newark. The Waldwick potheads are also equipped with oil, cable stress cone and cable shield thermocouples. Earth ambient and pipe surface sensors are also available along this line for longitudinal temperature profile surveys.

INSTALLATION OF SENSING DEVICES

The design, fabrication, and installation of the Temperature Monitoring Sensor cable and Thermocouple Bundle cable for the Hinchmans-Hawthorne 230-kV HPOF pipe cable was discussed in detail in the semi-annual project report for the period November 1, 1978, through April 30, 1979. This section of the report will concentrate on the development and installation of the Laser Temperature Monitoring System (LTMS).

The function of the LTMS is to measure conductor spot and average temperatures and transmit these measurements, via a laser beam, from a HV level to ground base where they can be retrieved.

LTMS Unit Description

The three phases of the Hinchmans-Hawthorne 230-kV HPOF pipe cable system contain special temperature sensors and leads in their conductors in the first two sections and terminal lengths at the Hinchmans end of the line. These provisions were incorporated into the cables during manufacturing and installation, as described in Dwg. HVA-771221. The LTMS equipment is used to monitor these sensors and provide this temperature data to a Cable Monitoring and Rating System (CMARS) via Remote Terminal Units (RTU's) and a leased telephone line. The LTMS equipment utilizes an open-air pulsed light beam communication link for each data point, incorporated into three TMS units installed on the potheads.

The Hinchmans LTMS equipment are six channel units consisting of transmitters mounted on top of the pothead, six laser detectors at the base of the pothead, and a receiver box mounted on the support structure, as shown on dwg. HVD-791110, and photograph #1.

The transmitter contains a CT-driven power supply, six RTD bridge circuits and six laser drivers and transmitters. The configuration is shown on Dwg. HVA-790810.

The receiver box contains six receivers, linearization and output circuitry and the 4-20 ma output connections to the RTU.

One receiver box also contains an air temperature detector and control relay for the heater controls. Each box has an adjustable heater voltage control for the laser detectors of that phase. The heaters in each laser detector melt ice and snow which may accumulate on the lens.

Photograph #2 illustrates the laser detectors of phase #1 on the Hinchmans pothead rack.

Two single channel units which monitor a #20 AWG pilot wire temperature (resistance) are installed on the Waldwick-Hawthorne 230-kV pipe cable, Waldwick pothead, and the Waldwick-So. Mahwah 345-kV pipe cable, So. Mahwah pothead. These units are similar to the Hinchmans-Hawthorne units except they were retrofitted to existing potheads and busswork and they are single channel units.

Power Supply

Each unit contains a 12-volt power supply which derives its power from a current transformer on the phase being monitored. The power supply provides a highly regulated 12-volt d.c. output voltage and switching capability to turn itself on and off, depending on the level of line current in that phase. The power supply switches on when the current exceeds approximately 250 amperes and switches off when the current decreases below about 150 amperes.

The power supply powers the RTD bridges and meters, the laser transmitters, and two 180-volt d.c./d.c. converters to supply the 180 V driving voltage for the laser diodes.

Spot Conductor Temperature Thermistor Bridge

Five of the six RTD's in each phase are Yellow Springs, Inc. #44011 Thermistors. These are 100 K-ohm at 25°C, NTC units approximately 95 mils in diameter with a 1% tolerance. Table I shows their resistance temperature characteristics.

TABLE I

YSI #44011 Thermistor Resistance

<u>Temp.°C</u>	<u>Res., K</u>	<u>Temp.°C</u>	<u>Res., K</u>
-10	565.5	50	34.78
0	331.1	60	23.65
10	201.7	70	16.37
20	125.5	80	11.54
25	100.0	90	8.261
30	80.0	100	6.005
40	52.19	110	4.427

The maximum lead resistance is 150 ohms at 0°C. Lead resistance is neglected in the calibration.

Average Temperature Resistance Bridge

The sixth RTD is a PTC copper resistance loop which responds to the average conductor temperature of the cable between manholes one and two. The average temperature resistance loop includes pair one in series for the first section length, and the conductor for the return in the terminal length.

The circuit operates by driving a constant current into the pilot wire resistance, producing a voltage which is directly proportional to that resistance. This voltage is amplified and buffered and then compared to a fixed voltage developed by a temperature compensated voltage reference. The output circuitry causes a current of 0 to 1 ma to flow through the load resistance (meter), which is linearly dependent on the pilot wire temperature.

A.C. and Surge Voltage Attenuation

Because of the nature and location of the RTD sensors and their leads, considerable a.c. voltages could appear at the bridge input terminals. Superimposed on each d.c. bridge is a fixed balance a.c. bridge designed to null the 60 Hz a.c. voltage appearing on the output of the d.c. bridge.

The a.c. bridge nulls 60 Hz voltage on the d.c. input but does not eliminate other frequency noise and leaves a significant common mode 60 Hz voltage on the instrument amplifier. For this reason, additional a.c. attenuation is provided by RC networks.

Detector and Display

The bridge output detector is an instrument amplifier that has the following characteristics:

Input - 0 - .5 volts

Output - 0 - 1 ma

Input impedance - greater than 100 K ohms

Output impedance - zero ohms to 1.2 K ohms load

Supply - + 10 V min.

Common mode voltage - $\pm$ 50 V peak

Temperature coefficient - .05%/°C

NOTE: Output carries common mode voltage

The pilot wire display (average conductor temperature) is a 0 - 1 ma meter calibrated according to the output characteristics with a 0-100°C scale.

The thermistor display (spot conductor temperature) is a 0 - 1 ma meter calibrated according to the output characteristics with a 10 - 130°C scale.

The single channel units have a six-inch 250° meter with a 0 - 100°C scale.

Laser Data Transmitter

Each bridge generates a floating output voltage of 0 - .5 volts which is fed to a laser data transmission link, as shown on the block diagram of Dwg. HVA-790504. The laser transmitting system consists of two components - a transmitter driver and the laser transmitter itself.

The driver converts the input voltage to a pulse train whose frequency is directly proportional to the input. Each pulse causes a 10-watt laser diode to emit monochromatic light in the infrared range for the short duration of about 100 ns. This energy is made available by discharging a 10 Uf capacitor at 100 volts into the diode via a transistor switch. A 180-volt d.c./d.c. converter and zener controlled regulator circuit provide the high voltage from the 12-volt supply. The light pulses are fed through a lens which focuses the light energy in a circle about 8 inches in diameter at a 10-ft. distance.

The frequency is a direct linear function of the input voltage and is equal to $10,000 \times V_{in}$. However, the frequency levels off at about 26 Hz at zero volts and below. The high voltage power required is directly proportional to frequency, since each pulse has the same energy content.

Laser Data Receiver

The laser pulses are detected by a photo diode sensitive only to the same infrared frequency characteristic of the transmitting laser diode. Each pulse is amplified and fed to a receiver which transforms the pulse repetition rate (frequency) to a d.c. voltage level, 1 volt per 1000 Hz.

The photo diode detector and pulse amplifier are mounted in an optical tube which is contained in a special housing at the base of the pothead. The detector is fitted with the same lens as the transmitter and must also be carefully aligned to insure that the transmitter is within its target area.

Linearization and Output Circuitry

The laser data receiver output voltage is not a linear function of RTD temperature. These signals are linearized by a voltage sensitive transfer network and then amplified and offset to provide a 4 to 20 ma current output.

Heater Control Circuits

The laser has sufficient power to penetrate clear water and some amount of ice or snow. However, to insure continuous operation, the detector housings are equipped with three 500-ohm 50-watt heater resistors connected in parallel, to be energized when ambient conditions could lead to snow or ice accumulation.

A temperature controller, sensing outside air temperature, activates a relay which provides 100 Vac to a voltage control (standard 600-watt dimmer) in each box. The output voltage is adjusted to about 70 V RMS to generate about 10 watts in each element.

Housings and Mechanical Components

Each six-channel laser temperature monitoring system transmitter is mounted on top of the pothead in a two-part housing, as illustrated in Dwg. HVB-791109. The main housing contains the current transformer, extension lug, holds the six laser transmitter drivers, and the laser modules. The electronic components and meter outputs are mounted in a transmitter housing unit, which plugs into the main housing on Dwg. HVC-791108.

The two 230 kV single channel units are shown in Dwg. HVB-790501.
The two 345 kV units are shown in Dwg. HVB-790502.

The laser detector is mounted in an aluminum pipe with a sloped acrylic top which can be adjusted to align with the transmitter. Three channels are fixed to a 4" x 4" aluminum angle, which spans the pothead support structure. Typically, two angles are mounted one on each side of the pothead.

The six detectors per phase feed their pulse outputs to receivers mounted in a weather-tight box on the pothead support structure. The six receivers feed their voltage outputs to a common linearization and output box.

Connections to the system include the sensor cable inputs via an amphenol plug, the 24-volt power and six current outputs via the terminal strip in the receiver box and the a.c. supply for the receiver heaters.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REV. PAIR 1 & 4 WAS # 30 AWG. ADD. PAIR 5 & THERMISTORS	6/28/78

PAIR 1, 4 & 5 # 28 AWG 7 STRAND TWISTED,
 PAIR 2 & 3 # 30 AWG 7 STRAND TWISTED AND
 JACKETED TFE CONSTRUCTION. ALL PAIRS BUNDLED PARALLEL
 WITH TWO INTERCULATED 3/4" X .001" MYLAR TAPES
 AND PAPER MARKER TAPE.

PAIR 1 WHITE AND YELLOW
 PAIR 2 WHITE JACKET
 PAIR 3 BLACK JACKET
 PAIR 4 WHITE AND GREEN
 PAIR 5 WHITE AND RED

NOTE - L
 PHASE A 500'
 B 700'
 C 900'

NOTE: ALL PHASES ARE IDENTICAL.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS: .X ± .05, .XX ± .01, .XXX ± .005 FRACTIONS: 1/64 TOLS: ANGLES 0° 30'	DRAWN <i>[Signature]</i>	DATE 12/77	UNDERGROUND SYSTEMS, INC. SENSOR CABLE WIRING P.S.E. & G. HAWTHORNE - HINCHMANS 230 KV PIPE CABLE		
	CHECKED	DATE			
	APPROVED	DATE	SIZE A	DRAWING NO. HVA 77 12 21	REV. A
	MATERIAL	JOB	SCALE	SHEET	OF

TOP VIEW
NO'S IDENTIFY CHANNEL

ELEVATION
TYP UNITS 1, 2 & 3

HAWTHORNE - HINCHMANS SUBSTATION

ITEM	REV	DESCRIPTION	DATE
CHARGE	E. H.	DATE	11/8/79
CHECKED	DATE	UNDERGROUND SYSTEMS, INC.	
APPROVED	DATE	TYPICAL ARRANGEMENT	
JOB	DATE	OPEN-AIR LASER T.M.S. COMMUNICATION SYSTEM	
SIZE	BRASSING NO.	HVD 79 11 10	REV
NETT ASSY	SCALE 1/8	SHEET 1 OF 1

TRANSMITTER CONFIGURATION
6 CHANNEL T.M.S.

HVA 79 08 10

-20-

DRAWN K. M.	DATE 11/79	UNDERGROUND SYSTEMS, INC.	
CHECKED	DATE	ASS'Y HOUSING	
APPROVED	DATE		
JOB	SIZE B	DRAWING NO. HVB 79 11 09	REV
NEXT ASSY	SCALE 1/4	SHEET OF

REAR VIEW

VIEW B-B

SECTION A-A

ITEM		REQ'D	DESCRIPTION	DWG NO.
LIST OF MATERIAL				
DRAWN		DATE	UNDERGROUND SYSTEMS, INC.	
CHECKED		DATE	ASS'Y TRANSMITTER HOUSING	
APPROVED		DATE		
MATERIAL		JOB	SIZE	DRAWING NO.
NO. REQ'D		NEXT ASSY	C	HVC 791108
		SCALE 1/4"	SHEET	OF

ITEM		REQ'D	DESCRIPTION		DWG NO.
LIST OF MATERIAL					
<small>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES</small> <small>DECIMALS FRACTIONS</small> <small>.XX ± .005 1/64</small> <small>XX ± .01 TOL. ANGLES</small> <small>XX ± .008 0° 30'</small>			<small>DRAWN</small> <i>[Signature]</i>	<small>DATE</small> 5/79	UNDERGROUND SYSTEMS, INC. 1 CHANNEL LASER T.M.S. ARRANGEM. WALDWICK 230KV POTHEADS
			<small>CHECKED</small>	<small>DATE</small>	
			<small>APPROVED</small>	<small>DATE</small>	
			<small>JOB</small> P.S.E. & G	<small>SIZE</small> B	
<small>MATERIAL</small>			<small>DRAWING NO.</small> HVB 79 0501		<small>REV.</small>
<small>NO REQ'D</small>			<small>NEXT ASSY</small>		<small>SCALE</small>
			<small>SHEET</small>		<small>OF</small>

ITEM		REQ'D	DESCRIPTION		DWG NO.	
LIST OF MATERIAL						
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES			DRAWN <i>E. L.</i> DATE 5.3.79	UNDERGROUND SYSTEMS, INC.		
DECIMALS .125 1/8 .250 1/4 .375 3/8 .500 1/2 .625 5/8 .750 3/4 .875 7/8 1.000 1			FRACTIONS 1/64 1/32 1/16 1/8 1/4 1/2 3/4 1	TOL .005 .010 .015 .020 .030 .040 .050 .060 .070 .080 .090 .100	ANGLES 0° 30' 0° 45' 0° 60' 0° 75' 0° 90' 0° 105' 0° 120' 0° 135' 0° 150' 0° 165' 0° 180'	1 CHANNEL LASER TMS ARRANGEMENT MAHWAH 34.5 KV POTHEADS
MATERIAL			APPROVED DATE	REV.		
JOB P.S.E. & G			SIZE B	DRAWING NO. HVB 790502		
NO REQ'D			NEXT ASSY	SCALE	SHEET	OF

DATA ACQUISITION SYSTEM INSTALLATION AND COMMUNICATION CIRCUIT PROVISIONS

This section describes the key elements of the CMARS data acquisition system and the progress to date in construction and installation of this system. The data acquisition system provides cable cross section temperatures, earth and weather data, and cable currents and voltage for use as required by the CMARS software. Figure 1 illustrates the key elements of the Data Acquisition System.

Surge Arresters: Surge arresters are required because of the possibility of inducing a high voltage surge in some of the thermocouple circuits during system fault conditions, due to the close proximity of these circuits to high voltage cables. These surges are capable of damaging thermocouple circuits. The arresters selected to prevent such damage are Model TII-317, 3 electrode, gas tube type, manufactured by TII Industries. Fast ionizing gas provides a conducting path to ground for any incoming surges. The breakdown voltage is 150-300 volts DC.

Thermocouple Transmitters: Thermocouple transmitters serve to condition incoming signals and provide cold junction compensation, open thermocouple indication, and input/output isolation (600 volts). The thermocouple transmitters selected for CMARS are manufactured by Action Instruments and are Type TP621. Their temperature span is 0-200°F with an accuracy of .1 percent and their output is 4-20 ma. A total of 100 thermocouple transmitters and surge arresters have been installed.

Remote Terminal Units: Remote terminal units (RTU's) collect all conditioned signals and transmit them to Newark on command of a host computer. The RTU's are Type 1801, manufactured by Systems Control Incorporated. Each unit utilizes a Motorola microcomputer and can accommodate up to 30 analog signals. Under control of the microcomputer, the analog signals are transformed to a parallel digital format by an A/D converter. A UART (universal asynchronous receiver transmitter) performs a parallel to serial conversion and the messages are then transmitted asynchronously at a rate of 1200 bits per second. The RTU contains an integral FSK modem for data communication. Security for transmitted data is assured by word and longitudinal parity checks. Eight RTU's with a total of 146 analog inputs are located at 4 field sites.

Photograph #3 illustrates two thermocouple transmitter and remote terminal units installed for data acquisition on the Hinchmans-Hawthorne pipe cable circuit.

Telephone Circuit: Arrangements have been made with New Jersey Bell to lease a type 3002 four wire full duplex multi-drop channel for transmission of data from the RTU's to the CMARS control center in Newark.

Current and Voltage Transmitters: Model 20.471 and 20.571 transmitters, manufactured by Kratos, were selected to provide voltage and current data for CMARS. These units have an accuracy of .25 percent and an output of 4-20ma to maintain compatibility with

the thermocouple transmitters. A total of twelve voltage and current signals at four field locations are required for CMARS.

Laser Temperature Monitoring System: Underground Systems, Inc., is providing a specially designed Laser Temperature Monitoring System (LTMS) to supply actual conductor average and conductor spot temperatures for correlation with CMARS software. The LTMS uses a modulated laser beam transmitter-receiver system to provide isolation between conductor potential and ground. A total of 22 conductor temperatures are monitored, each requiring a laser transmitter-receiver pair. Output from the receivers are 4-20ma.

Master Computer System: This equipment, purchased from Systems Control, includes a computer system manufactured by Digital Equipment Corporation, an ISC 8001 color CRT, and a 1200 baud Vadic modem, and is located at PSE&G headquarters in Newark, New Jersey. The computer system consists of a PDP 11/34 processor, two RL01 5 Mb disk drives for program and data storage, a TMB11 tape unit for long-term data storage, a LS120 high-speed hard copy terminal for printouts and a LA36 hard copy terminal for system control and alarm messages. The color CRT is used for CMARS graphic displays and man-machine interaction and the modem is used for communication with the RTU's.

System Installation

All of the equipment for the field data acquisition system has been delivered and installed. All yard trenching, cabling and control house wiring has been completed at each site.

Weather sensing equipment has been installed at Hinchman's Avenue Substation and is operating. Additional thermocouples for temperature data (earth, air and pipe jacket at several locations) not included in the original pipe cable installations have been fabricated and installed.

During testing of the field equipment, problems were detected in the telephone circuit, the RTU's, and the thermocouple transmitters. The telephone circuit problems were traced to improper RTU connections at one of the termination points and an incomplete installation by the telephone company. These problems have been resolved and the communication circuit is operating properly. Problems in the RTU's were corrected by SCI and PSE&G personnel and they are now in operation.

Several thermocouple transmitters were found to be defective and were returned to the manufacturer for repair. The remaining units have all been recalibrated.

The CMARS computer system was delivered on September 25th to Room 10332 in the Electric - Transmission and Distribution Department, Newark. A field service technician from Digital Equipment Corporation completed the installation, checkout, and start-up of the system.

SOFTWARE INSTALLATION AND DEVELOPMENT

Systems Control, Inc. has the responsibility to provide software which operates on a PDP 11/34 mini-computer in a real-time environment. The package incorporates three basic CMARS functions -- monitoring, rating, and prediction -- plus a set of comprehensive graphic color CRT displays. In addition, the software includes complete data acquisition, data conversion, and data storage capability. The supervisory software system -- the SCI Process Control System (SCI/PCS) -- performs these tasks and in addition incorporates the CMARS applications software.

This section describes the considerations involved in the software development and reports on the progress implementing the various software components within the integrated 11/34 mini-computer system.

Overall Software System Design

The design of the software system was discussed in detail in the semi-annual project report for the period November 1, 1978, through April 30, 1979. In this document a description was given of the software controller -- the SCI Process Control System (SCI/PCS). Its capabilities as a controller for input/output data logging and conversion, task scheduling, prioritization, user interface, etc. were also discussed. The task of

designing the overall software system was completed during the first six months of the project. This section therefore is descriptive in nature and will cover in much less detail some of the basic characteristics and uses of SCI/PCS as it pertains to this project. A person requiring more information about this software package is referred to the previous semi-annual report.

Figure 2 is a schematic of the software configuration. The SCI/PCS is a software package which governs the operation of all software developed for this project. It interrogates the Remote Terminal Units (RTUs) converts the incoming data into engineering units, and places this data into a computer memory common area called the Engineering Units Table (EUT). Other CMARS software may then have access to this data, but this access also is controlled by the SCI/PCS.

Each of the software tasks shown in Figure 2 is directly controlled by the SCI/PCS. Some are activated automatically; others require operator initiation.

The SCI/PCS controls these and other operator interactions via a color CRT. Software tasks can be activated by the light pen. In addition, full color displays of cable schematics can be generated.

CMARS/PCS Integration and Data Base Design

The Engineering Units Table (EUT) is the principal part of the data base. As seen in Figure 2, all measured data from the RTUs is stored in memory. In addition, much of the data calculated by the CMARS application software tasks also is stored in the EUT.

Only by storing data in the EUT can the full capability of the SCI/PCS be exploited.

The EUT is comprised of points and attributes. A point is a data value such as a temperature measurement, but there are four kinds of points represented in the EUT. These include:

- Analog points
- Virtual points
- Cable points
- Statistical points

A set of attributes is associated with each point. These include:

- Status
- Conversion parameters
- Alarm limits
- RTU indexing

A complete description of each point type and attribute can be found in the "Data Base Design, Version 3.1" design document included in the Appendix.

Design of System Scan and Engineering Unit Storage Procedures

The SCI/PCS has a capacity of 400 points. They may be a mixture of analog, virtual, statistical, or cable points as long as they number 400 or less.

The test hardware system has 146 analog measurements, each of which is included in the EUT. In addition, each of the 30 cable cross-sections being monitored requires 7 points - 5 cable points and 2 statistical points - totaling 210 points. There were therefore 44 spare points in the EUT ($400 - 146 - 210 = 44$). Several of these spares were used. Figures 3 to 3-5 are a complete list of the 146 analog measurement points.

Several virtual points have been added. For example phase current was initially stored in the EUT as an analog point whose units were kiloamperes. Since cable engineers prefer units of amps, appropriate virtual points were added to the EUT. The value of each such virtual point is the analog value in kA multiplied by 1000.

Cable cross-sections may be identified by a unique 8 character alpha-numeric name. PSE&G has chosen the following 2 character scheme. The first character is a number designating the location of a cross-section, and the second character is a letter which is a code for the set of measurements utilized by the particular cross-section. The complete list of cross-sections is given in Figure 4. These 30 configurations (out of a possible 100-200) were chosen by PSE&G as the most encompassing set of cross-sections and the set most likely to provide interesting test data.

Man-Machine Interface Design

The task on which the greatest effort was expended during the period covered by this report was the Man/Machine Interface Design task. This task, though part of the SCI/PCS, is the main link between operator and the various PCS and CMARS software tasks. This task provides the means to activate unscheduled, non-automatic software tasks and displays information to the user via color pictures, logs, graphics, etc.

The previous semi-annual report described the tentative design of the man/machine interface. Since that report was issued, the interface has been completely defined and implemented. This subsection describes the interface in substantial detail.

Graphic Displays

Photograph #4 is a color picture of the Display Index. The Display Index is a list of color graphical displays which can be projected on the screen of the color CRT terminal. By depressing a keyboard button enscribed "DISPLAY INDEX" the operator causes the graphic shown in Photo #4 to be displayed on the color CRT terminal screen. To select a color display for viewing, the operator "pokes" a blue square adjacent to the display name with the light pen. The Display Index will then be replaced by the appropriate color graphical display.

Photographs #5 - #10 illustrate displays which can be accessed from the Display Index. In addition, a feature of the SCI/PCS permits the user to have access to displays by means of poke points on other displays. Thus the operator may request a succession of displays without returning to the Display Index.

Photograph #5 is a schematic of the northern New Jersey area showing the PSE&G underground pipe cable system. The dark blue, green, and purple lines represent the Hinchman's-Hawthorne, Waldwick-Hawthorne, and Waldwick-South Mahwah cables, respectively. This graphical display was added to the system to facilitate demonstration of the CMARS system to interested visitors.

The light blue squares adjacent to these three lines are poke points by which the operator may request displays of the axial schematic of the respective cables.

Photographs #6, #7 and #8 are axial schematics of Hinchman's-Hawthorne, Waldwick-Hawthorne, and Waldwick-South Mahwah cables, respectively. The dark blue, green, and magenta color scheme has been maintained throughout all the displays. These three displays are static displays. The only time-varying portions of the displays are the yellow numbers. These represent points from the EUT, and consequently are updated whenever they change in the EUT.

The quantities displayed in Photographs #6, #7, and #8, are currents, voltages, and measured temperatures. Their values are zero because the photographs were taken in California, and, consequently, there were no actual inputs to the system.

The points shown in the photographs also happen to be within alarm limits, that is, within a normal range. When a point value is outside of this permissible range the immediate area surrounding the yellow number will change from black to red and the yellow number will blink. Simultaneously an alarm message will be written on the low-speed LA36 hard-copy console, and the word "ALARM" in yellow letters on a red background will blink in the upper right corner of the color CRT screen.

If more information is desired about one particular point on any graphic display, the operator may "poke" the yellow point value with the light pen. The point name, description, value and certain attributes will then appear above the horizontal white line at the top of the screen.

Photographs #9 and #10 are examples of cable cross-section displays at a splice and at 90 ft. from manhole #1 on the Hinchmans-Hawthorne line. Each of these displays can be requested from the Display Index or from a poke point on another display. For example, Photo #9, the Hinchmans-Hawthorne splice display, is requested by poking the blue square to the left of manhole #1 on Photo #6.

Functional Displays

Photograph #11 is a photograph of a display called the Function Index. It can be requested by the operator when he depresses a keyboard button enscribed "FUNCTION INDEX". The white letters are names and descriptions of software tasks that can be activated by poking the adjacent blue squares with the light pen. Certain software tasks are common to all SCI/PCS systems and have been grouped together under the heading (in green letters) "PCS TASKS". Other tasks pertain only to the CMARS application and are grouped under the heading "CMARS TASKS".

Figure 5 is a Cable Group Status Summary which is projected on the CRT when the operator pokes the blue square next to CSS on the Function Index. This display summarizes important operating data for all cable cross-sections in one convenient display. Different cable cross-sections may be grouped together in this multi-page display. The cross-section name and description are given along with the associated conductor temperature, loading, rating, etc.

The Cable Cross-Section Display, Photograph #12, gives more information about one particular cross-section. This display is generated when the "CSD" function is activated from the Function Index. All the calculated and measured temperatures associated with that particular cross-section are given. In addition all cable parameters, ratings, loadings also are displayed.

The operation of the Predictor task is illustrated in Photographs #13 and #14. When the operator activates "PRD" from the Function Index, a simple question/answer sequence ensues during which time the operator selects a study cross-section and enters a hypothetical future load shape. Photograph #13 is a graphical representation of one such loading for cross-section 1L.

Upon operator verification of the input, the Predictor task generates the display shown in Photo #14. This is the predicted conductor temperature at cross-section 1L for the hypothetical future load, given the present temperature distribution within the cross-section. Although conductor temperature is shown in Photo #4, shield, oil, and pipe temperatures may be displayed as well.

Photograph #15 is a rating curve for a cable cross-section. This display is generated from the "RAT" function, and reflects the rating at the present time. Since the purpose of the CMARS is to provide dynamic ratings, this figure will change over time, reflecting changing cable conditons; the display is not, however, dynamically updated. Although Photo #15 represents the normal (80°C) conductor ratings, the emergency (100°C) conductor rating and the 50°C and 55°C pipe ratings can also be displayed.

Figure 6 results from the Change Scan Status, or "SCN", task. Information pertaining to each of the 8 RTU's is summarized in this display. Furthermore the definition of the RTU's in terms of the number and type of inputs, frequency of scanning, etc. can be manipulated by means of this task and this display.

Many other tasks can be initiated from the Function Index, but with the exception of the Histogram task, their operation involves little display activity. Consequently their descriptions are not included in this section.

The Alarm Summary Task generates the display shown in Figure 7 and is activated by depressing the appropriate keyboard button. As previously described, a point in the EUT going into alarm precipitates a series of actions: point values flash in a red background on graphic displays, the word "ALARM" flashes in the upper right corner of the screen, and a message is logged on the low-speed, LA36 hard copy terminal. In addition, this alarm message is written to a computer file. When the Alarm Summary button is pressed, the contents of this file are displayed on the screen, providing a convenient summary of points in the alarm state. When an alarm message first appears on the color CRT screen, a blinking yellow square appears to the left of the message, indicating that the alarm has not been acknowledged by the operator. To acknowledge the existence of an alarm, the operator pokes the square which then changes from yellow to green and stops flashing. Simultaneously a message of acknowledgment is typed on the LA36 hard copy terminal. This serves as a record that the operator has duly noted an alarm. When a point leaves the alarm state and returns to a normal range, the message on the computer file is erased and a "return to normal" message is typed on the LA36.

Figure 8 is a display generated by the Log Index Task. This task is initiated by depressing the appropriate button on the keyboard. Points in the EUT can be associated by placing them in groups. If a number of points share certain characteristics (such as measurement location, for example) these points can then be placed into a group upon which SCI/PCS operations may be made. There is no limit on the number of points in a group, and one point may belong to any number of groups.

Figure 8 lists 30 groups. Each group contains the points associated with each of the 30 cable cross-sections.

Three SCI/PCS operations may be performed on these groups of points as part of the Log Index task. These include:

- Display
- Print
- Alarm

The operator pokes the blue box next to the group name he wishes to investigate and then pokes the blue box beside the chosen operation. If he pokes the "ALARM" box, a display similar to Figure 7 appears on the color CRT. The alarms pertain only to those points in the selected group.

All of the tables and displays shown in this report can be copied from the color CRT to the high speed LS-120 hard-copy terminal by sequentially depressing a "FREEZE CRT" button and a "COPY PAGE" button on the keyboard. In addition, several tasks automatically generate similar displays and tables

directly on the high-speed printer. For example a cross-section display for each of 30 cross-sections is currently printed on the high-speed LS-120 printer every twelve hours at noon and at midnight. The activation of this task is automatic.

Interactive Data Conversion Software

This task exists to input physical cable dimensions and parameters and convert this data into a form required by the CMARS. This task was described in the previous semi-annual report. The initiation of this task is accomplished by poking the "ENT square on the Function Index.

It is not anticipated that this task will be frequently run because it is required only when a new cable cross-section is added to the system. Once the parameters are entered in an interactive manner, software proceeds to "initialize" a cross-section. This initialization consists of calculating lumped thermal resistances and capacitances, Kalman estimate gains, and parameter identification gains which are then used by subsequent CMARS tasks.

A minor problem exists with this task in that the calculation of the estimation and identification gains involves the inversion of a 7x7 matrix, and this inversion may not possess a stable solution. The problem is due to the fact that the matrix entries

may vary by several orders of magnitude. During the process of matrix inversion a large number divided by a small number may approach an unacceptably large value, causing solution divergence. Of the 30 cross-sections chosen for this project by PSE&G, approximately 5 cross-sections would not initialize. The problem was pragmatically solved by increasing a certain small cable dimension by a few percent. This permitted the initialization task to generate identification and estimation gains which were within 1/2% of their true value. Later, the dimension and associated lumped parameters were changed to their true value.

CMARS Software Revision

Over the past six months earlier CMARS software programs were adapted and incorporated within the CMARS/PCS system. The three main tasks are the Minute, Hour, and Prediction Tasks. These were described in the previous semi-annual report.

The Minute Task monitors cable cross-sections by updating temperature calculations, identifying cable parameters, and calculating dynamic ratings. The task is currently operating automatically at 10 minute intervals; however, it may be operated on demand by the operator from the Function Index by poking the "MIN" square.

The Hour Task updates rating factors used in the rating calculations. This task automatically operates every hour, but may be externally initiated by poking the "HOR" square on the Function Index.

The Prediction Task is executed from the Function Index by poking the "PRD" square. This task is intended to predict future cable temperatures given the current cable temperature profile and is described in the previous Man/Machine Interface Design subsection.

Statistical Analysis Package

The statistical analysis effort was described in the previous semi-annual report. A description of the software may be found in that document and in the Data Base Design document included in the Appendix.

Historical Storage

This software task was designed to provide a means to store test data on a permanent medium such as a magnetic tape for subsequent retrieval and off-line processing in the impacts analysis effort. The last semi-annual report described two potential storage schemes, between which a choice was made during the past six months. The final version involves a two step process -- the automatic, continuous dumping of real-time data to disk and the arbitrary, operator initiated dump of the accumulated data from disk to tape. A schematic of this task and the associated files is shown in Figure 9.

The software task to dump real-time data to the disk is called HSTDMP and is currently activated automatically every ten minutes. This task writes the contents of the EUT (400 points) and the time of the dump onto two files, PTHIST.DAT and PTHSTP.DAT

respectively. A second software task is activated automatically every 24 hours. This task dumps the contents of the file of all cable cross-sectional data into a special disk file called CABDT.DAT and also writes the time of the dump into file CABTIM.DAT.

The disk storage files are limited in size to accomodate 720 copies of the EUT. This means that up to five days of data taken at 10-minute intervals (or ten days at 20-minute intervals) may be stored. When the file is within 24 hours of filling up, and every four hours thereafter, an alarm message is sent to both the LA-36 hard-copy terminal and to the alarm message file informing the operator that he must dump the disk file to tape and reporting how much time remains for him to do so. If the contents of the disk files are not dumped to tape before the file fills, an alarm is generated every two hours advising the operator of the amount of lost historical data.

The Magnetic Tape Dump task may be activated from Function Index by activating the "MTD" poke point. All of the previously mentioned alarming stops once "MTD" has sucessfully been completed.

When the system was delivered, the tape dump task required thirteen minutes to complete. This could have resulted in the loss of data from two 10-minute scans since the disk file would be unavailable to the automatic 10-minute EUT-to-disk dump program. Consequently

at PSE&G's request, SCI modified the disk-to-tape dump program to accelerate its operation. At the present time, the program operates in eight minutes so that with careful choice of a start time, the disk-to-tape dump program will not cause 10-minute data to be lost.

CMARS TEST PROGRAM

CMARS software permits the monitoring of up to thirty independent cable cross sections. For the purposes of this project several cable cross sections are physically located at the same place but utilize different sets of measurements. For example, 12 different cross sections can be found at one location of the primary 230 kV cable. Each utilizes a different combination of the five available temperature measurements - earth ambient, pipe, oil, shield and conductor. One cross section utilizes only an earth temperature; another uses all five. The remainder utilize different intermediate combinations. The set of cross sections was selected by PSE&G to provide the most encompassing set in order to make trade-off judgments regarding instrumentation requirements.

During the remaining months of this project PSE&G plans controlled load excursions to track the performance of CMARS. The on-line tests will encompass normal and controlled load excursion under various ambient conditions and operating modes for each circuit under test.

The test to be conducted under normal loading and operating conditions will cover an estimated aggregate time of 6 to 10 months embracing a variety of seasonal conditions. For these tests the cables will be allowed to operate in their usual way as part of the system.

Wide range controlled loading will be applied to test CMARS with variations of loading steps ranging from no-load up to full normal rating. The loading will be extended beyond the normal rating if, as expected, the maximum temperature is not reached at normal load.

Controlled emergency loading tests will be conducted in the emergency rating range for periods of 15 minutes up to 1 week or possibly more, depending on system conditions, to the extent necessary to accomplish the objectives of the program.

Desired controlled test loading levels on all cables will be achieved remotely from the PSE&G Electric System Operations Center in Newark, New Jersey. This will be accomplished by means of direct power flow control afforded by phase angle regulating transformers. Additional flow control is available through a multiplicity of parallel transmission paths in the PSE&G system and interconnections with other utilities.

The actual test loading schedule, including deenergization, will be determined by the PSE&G project team. Circuit loadings will be implemented as feasible consistent with maintaining adequate system security.

REFERENCES

1. "The Design and Testing for a System to Monitor Temperature in Underground Electric Power Transmission Cables," Final Report prepared for U.S. Department of Energy, HCP/T-2079, Systems Control, Inc., February, 1979.
2. "Field Validation of Cable Monitoring and Rating System (CMARS) Laboratory Model" Semi-Annual Report prepared for U.S. Department of Energy period 1 November, 1978 - 30 April, 1979

CMARS

FIGURE 1

202/203

PSE&G CMARS TASKS

FIGURE 2

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INDEX =====	NAME =====	DESCRIPTION =====	TYPE =====	LIMITS =====	
1	HHCNAVG1	H1 CONDUCTOR AVERAGE PH1	ANALOG	10.00	80.00
2	HHCN9M11	H1 CONDUCTOR 90'MH1 PH1	ANALOG	10.00	80.00
3	HHC30M11	H1 CONDUCTOR 300'MH1 PH1	ANALOG	10.00	80.00
4	HHTSPM31	H1 T&B SPLICE MH3 PH1	ANALOG	10.00	80.00
5	HHVSPM21	H1 VTLIT SPLICE MH2 PH1	ANALOG	10.00	80.00
6	HHC90M11	H1 CONDUCTOR 900'MH1 PH1	ANALOG	10.00	80.00
7	HHCNAVG2	H1 CONDUCTOR AVERAGE PH2	ANALOG	10.00	80.00
8	HHCN9M12	H1 CONDUCTOR 90'MH1 PH2	ANALOG	10.00	80.00
9	HHC30M12	H1 CONDUCTOR 300'MH1 PH2	ANALOG	10.00	80.00
10	HHTSPM32	H1 T&B SPLICE MH3 PH2	ANALOG	10.00	80.00
11	HHVSPM22	H1 VTLIT SPLICE MH2 PH2	ANALOG	10.00	80.00
12	HHVCNM12	H1 VTLIT CONNECT MH1 PH2	ANALOG	10.00	80.00
13	HHCNAVG3	H1 CONDUCTOR AVERAGE PH3	ANALOG	10.00	80.00
14	HHCN9M13	H1 CONDUCTOR 90'MH1 PH3	ANALOG	10.00	80.00
15	HHC30M13	H1 CONDUCTOR 300'MH1 PH3	ANALOG	10.00	80.00
16	HHTSPM33	H1 T&B SPLICE MH3 PH3	ANALOG	10.00	80.00
17	HHVSPM23	H1 VTLIT SPLICE MH2 PH3	ANALOG	10.00	80.00
18	HHC50M13	H1 CONDUCTOR 500'MH1 PH3	ANALOG	10.00	80.00
19	HHM1S00P	H1 MH1 SPL-T10 OIL PROBE	ANALOG T	0.00	80.00
20	HHM1S10P	H1 MH1 SPL-T11 OIL PROBE	ANALOG T	0.00	80.00
21	HHPHDOP3	H1 POTHEAD OIL PROBE PH3	ANALOG T	-10.00	80.00
22	HHPHDCS3	H1 PTHD CABLE SHIELD PH3	ANALOG T	-10.00	80.00
23	HHPHDSC3	H1 PTHD STRESS CONE PH3	ANALOG T	-10.00	80.00
24	HHPHDOP2	H1 POTHEAD OIL PROBE PH2	ANALOG T	-10.00	80.00
25	HHPHDCS2	H1 PTHD CABLE SHIELD PH2	ANALOG T	-10.00	80.00
26	HHPHDSC2	H1 PTHD STRESS CONE PH2	ANALOG T	-10.00	80.00

FIGURE 3

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FROZEN

INDEX =====	NAME =====	DESCRIPTION =====	TYPE =====	LIMITS =====
27	HHPHDOP1	H1 POTHEAD OIL PROBE PH1	ANALOG T	-10.00 80.00
28	HHPHDCS1	H1 PTHD CABLE SHIELD PH1	ANALOG T	-10.00 80.00
29	HHPHDSC1	H1 PTHD STRESS CONE PH1	ANALOG T	-10.00 80.00
30	HHM1SS12	H2 MH1 SPL SH-JTC T1 PH2	ANALOG T	0.00 80.00
31	HHM1SS22	H2 MH1 SPL SH-JTC T2 PH2	ANALOG T	0.00 80.00
32	HHM1SS33	H2 MH1 SPL SH-JTC T3 PH3	ANALOG T	0.00 80.00
33	HHM1SS43	H2 MH1 SPL SH-JTC T4 PH3	ANALOG T	0.00 80.00
34	HHM1SS51	H2 MH1 SPL SH-JTC T5 PH1	ANALOG T	0.00 80.00
35	HHM1SS61	H2 MH1 SPL SH-JTC T6 PH1	ANALOG T	0.00 80.00
36	HHM1SS72	H2 MH1 SPL SH-JTC T7 PH2	ANALOG T	0.00 80.00
37	HHM1SS82	H2 MH1 SPL SH-JTC T8 PH2	ANALOG T	0.00 80.00
38	HHM1SS92	H2 MH1 SPL SH-JTC T9 PH2	ANALOG T	0.00 80.00
39	HHS30M13	H2 CBL SHLD 300'MH1 PH3	ANALOG T	0.00 80.00
40	HHS30M11	H2 CBL SHLD 300'MH1 PH1	ANALOG T	0.00 80.00
41	HHS30M12	H2 CBL SHLD 300'MH1 PH2	ANALOG T	0.00 80.00
42	HHS9M153	H2 CBL SH 90'MH1 T15 PH3	ANALOG T	0.00 80.00
43	HHS9M161	H2 CBL SH 90'MH1 T16 PH1	ANALOG T	0.00 80.00
44	HHS9M172	H2 CBL SH 90'MH1 T17 PH2	ANALOG T	0.00 80.00
45	HHS9M183	H2 CBL SH 90'MH1 T18 PH3	ANALOG T	0.00 80.00
46	HHS9M191	H2 CBL SH 90'MH1 T19 PH1	ANALOG T	0.00 80.00
47	HHS9M192	H2 CBL SH 90'MH1 T20 PH2	ANALOG T	0.00 80.00
48	HH10M1FS	H2 PIPE SURFACE 100' MH1	ANALOG J	0.00 80.00
49	HH9M12PJ	H2 PIPE JACKET T2 90'MH1	ANALOG J	0.00 80.00
50	HH9M13PJ	H2 PIPE JACKET T3 90'MH1	ANALOG J	0.00 80.00
51	HH9M14PJ	H2 PIPE JACKET T4 90'MH1	ANALOG J	0.00 80.00
52	HH9M15PJ	H2 PIPE JACKET T5 90'MH1	ANALOG J	0.00 80.00

FIGURE 3-1

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INDEX =====	NAME =====	DESCRIPTION =====	TYPE =====	LIMITS =====
53	HH9M1EAM	H2 EARTH AMBIENT 90' MH1	ANALOG J	0.00 80.00
54	HH3M12PJ	H2 PIPE JACKT T2 300' MH1	ANALOG J	0.00 80.00
55	HH3M13PJ	H2 PIPE JACKT T3 300' MH1	ANALOG J	0.00 80.00
56	HH3M14PJ	H2 PIPE JACKT T4 300' MH1	ANALOG J	0.00 80.00
57	HH3M15PJ	H2 PIPE JACKT T5 300' MH1	ANALOG J	0.00 80.00
58	HH30M1EA	H2 EARTH AMBIENT 300' MH1	ANALOG J	0.00 80.00
59	HHCCRNT1	HC CURRENT HNCH-HWTH PH1	ANALOG	0.01 1.40
60	HHCCRNT2	HC CURRENT HNCH-HWTH PH2	ANALOG	0.01 1.40
61	HHCCRNT3	HC CURRENT HNCH-HWTH PH3	ANALOG	0.01 1.40
62	HHVLTGE2	HC VOLTAGE HNCH-HWTH PH2	ANALOG	210.00 250.00
63	HHOILFLO	HC OIL FLOW HNCH-HWTH	ANALOG	-20.00 20.00
64	HNEARRST	HC EARTH RSTVTY PMP-HSE	ANALOG	0.00 200.00
65	HNEKFRST	HC BKFILL RSTVTY PMP-HSE	ANALOG	0.00 200.00
66	HNSUNLOD	HC SUN LOADING CTL-HSE	ANALOG	0.00 20.00
67	HNRAINFL	HC RAIN FALL CTL-HSE	ANALOG	0.00 10.00
68	HNAIRAMB	HC AIR AMBIENT CTL-HSE	ANALOG T	-17.80 93.33
69	HNEAMB1F	HC EARTH AMB 1F CTL-HSE	ANALOG T	-17.80 93.33
70	HNEAMB8F	HC EARTH AMB 8F CTL-HSE	ANALOG T	-17.80 93.33
71	WHCNAVG2	WH CONDUCTOR AVERAGE PH2	ANALOG	10.00 80.00
72	WHCNAVG3	WH CONDUCTOR AVERAGE PH3	ANALOG	8.00 80.00
73	WHPHDOP1	WH POTHEAD OIL PROBE PH1	ANALOG T	0.00 80.00
74	WHPHDSC1	WH PTHD STRESS CONE PH1	ANALOG T	0.00 80.00
75	WHPHDCS1	WH PTHD CABLE SHIELD PH1	ANALOG T	0.00 80.00
76	WHPHDOP2	WH POTHEAD OIL PROBE PH2	ANALOG T	0.00 80.00
77	WHPHDSC2	WH PTHD STRESS CONE PH2	ANALOG T	0.00 80.00
78	WHPHDCS2	WH PTHD CABLE SHIELD PH2	ANALOG T	0.00 80.00

FIGURE 3-2

INDEX	NAME	DESCRIPTION	TYPE	LIMITS	09:26:44 30-JAN-80 FROZEN
=====	=====	=====	=====	=====	=====
79	WHPHDOP3	WH POTHEAD OIL PROBE PH3	ANALOG T	0.00	80.00
80	WHPHDSC3	WH PTHD STRESS CONE PH3	ANALOG T	0.00	80.00
81	WHPHDSC3	WH PTHD CABLE SHIELD PH3	ANALOG T	0.00	80.00
82	WHPHDAAM	WH POTHEAD AIR AMBIENT	ANALOG T	0.00	80.00
83	WHPDCOIL	WH PIPE DIFF CHAMBER OIL	ANALOG T	0.00	80.00
84	WH1M12PJ	WH PIPE JCKT T2 100' MH1	ANALOG T	0.00	80.00
85	WH1M13PJ	WH PIPE JCKT T3 100' MH1	ANALOG T	0.00	80.00
86	WH1M14PJ	WH PIPE JCKT T4 100' MH1	ANALOG T	0.00	80.00
87	WH1M15PJ	WH PIPE JCKT T5 100' MH1	ANALOG T	0.00	80.00
88	WH1M11EA	WH EARTH AMB 1F 100' MH1	ANALOG T	0.00	80.00
89	WH1M1FEA	WH EARTH AMB FC 100' MH1	ANALOG T	0.00	80.00
90	WH1M18EA	WH EARTH AMB BF 100' MH1	ANALOG T	0.00	80.00
91	WSCRNT1	WC CURRENT WLDK-SMWH PH1	ANALOG	0.02	1.40
92	WSCRNT2	WC CURRENT WLDK-SMWH PH2	ANALOG	0.02	1.40
93	WSCRNT3	WC CURRENT WLDK-SMWH PH3	ANALOG	0.02	1.40
94	WSVLTGE2	WC VOLTAGE WLDK-SMWH PH2	ANALOG	315.00	375.00
95	WSOILFLO	WC OIL FLOW WLDK-SMWH	ANALOG	-20.00	20.00
96	WHCRNT1	WC CURRENT WLDK-HWTH PH1	ANALOG	0.01	1.40
97	WHCRNT2	WC CURRENT WLDK-HWTH PH2	ANALOG	0.01	1.40
98	WHCRNT3	WC CURRENT WLDK-HWTH PH3	ANALOG	0.01	1.40
99	WHVLTGE2	WC VOLTAGE WLDK-HWTH PH2	ANALOG	210.00	250.00
100	WHOILFLO	WC OIL FLOW WLDK-HWTH	ANALOG	-20.00	20.00
101	WSPHDOP3	WS POTHEAD OIL PROBE PH3	ANALOG T	-10.00	80.00
102	WSPHDSC3	WS PTHD STRESS CONE PH3	ANALOG T	-10.00	80.00
103	WSPHDSC3	WS PTHD CABLE SHIELD PH3	ANALOG T	-10.00	80.00
104	WSPHDSC2	WS PTHD STRESS CONE PH2	ANALOG T	-10.00	80.00

FIGURE 3-3

09:28:24
30-JAN-80
FROZEN

INDEX =====	NAME =====	DESCRIPTION =====	TYPE =====	LIMITS =====	
105	WSPHDCS2	WS PTHD CABLE SHIELD PH2	ANALOG T	-10.00	80.00
106	WSPHDCS1	WS PTHD CABLE SHIELD PH1	ANALOG T	-10.00	80.00
107	WSPHDAAM	WS POTHEAD AIR AMBIENT	ANALOG T	-17.80	93.33
108	WSM1SFS1	WS MH1 SPL SHLD-JTCL PH1	ANALOG T	0.00	80.00
109	WSM1SFS2	WS MH1 SPL SHLD-JTCL PH2	ANALOG T	0.00	80.00
110	WSM1SFS3	WS MH1 SPL SHLD-JTCL PH3	ANALOG T	0.00	80.00
111	WSM1SFOP	WS MH1 SPLICE OIL PROBE	ANALOG T	0.00	80.00
112	WSCS9M12	WS COND SHLD 94' MH1 PH2	ANALOG T	0.00	80.00
113	WS9M12PJ	WS PIPE JACKET T2 94' MH1	ANALOG T	0.00	80.00
114	WS9M13PJ	WS PIPE JACKET T3 94' MH1	ANALOG T	0.00	80.00
115	WS9M14PJ	WS PIPE JACKET T4 94' MH1	ANALOG T	0.00	80.00
116	WS9M15PJ	WS PIPE JACKET T5 94' MH1	ANALOG T	0.00	80.00
117	WS9M11EA	WS EARTH AMB 1F 94' MH1	ANALOG T	-10.00	80.00
118	WS9M1PEA	WS EARTH AMB PC 94' MH1	ANALOG T	0.00	80.00
119	WS9M18EA	WS EARTH AMB 8F 94' MH1	ANALOG T	0.00	80.00
120	WS9M1ERS	WS EARTH RSTVTY 94' MH1	ANALOG	10.00	200.00
121	WSM2SFS1	WM MH2 SPL SHLD-JTCL PH1	ANALOG T	0.00	80.00
122	WSM2SFS2	WM MH2 SPL SHLD-JTCL PH2	ANALOG T	0.00	80.00
123	WSM2SFS3	WM MH2 SPL SHLD-JTCL PH3	ANALOG T	0.00	80.00
124	WSM2SFOP	WM MH2 SPLICE OIL PROBE	ANALOG T	0.00	80.00
125	WSCS3M22	WM COND SHLD 30' MH2 PH2	ANALOG T	0.00	80.00
126	WSCS3M23	WM COND SHLD 30' MH2 PH3	ANALOG T	0.00	80.00
127	WS3M22PJ	WM PIPE JACKET T2 30' MH2	ANALOG T	0.00	80.00
128	WS3M23PJ	WM PIPE JACKET T3 30' MH2	ANALOG T	0.00	80.00
129	WS3M24PJ	WM PIPE JACKET T4 30' MH2	ANALOG T	0.00	80.00
130	WS3M25PJ	WM PIPE JACKET T5 30' MH2	ANALOG T	0.00	80.00
131	WS3M21EA	WM EARTH AMB 1F 30' MH2	ANALOG T	0.00	80.00

FIGURE 3-4

INDEX	NAME	DESCRIPTION	TYPE	LIMITS	09:29:29 30-JAN-80 FROZEN
=====	=====	=====	=====	=====	
132	WS3M2FEA	WM EARTH AMB PC 30' MH2	ANALOG T	0.00 80.00	
133	WS3M28EA	WM EARTH AMB 8F 30' MH2	ANALOG T	0.00 80.00	
134	SWCRRNT1	SM CURRENT SMWH-WLDK PH1	ANALOG	0.01 1.40	
135	SWCRRNT2	SM CURRENT SMWH-WLDK PH2	ANALOG	0.01 1.40	
136	SWCRRNT3	SM CURRENT SMWH-WLDK PH3	ANALOG	0.01 1.40	
137	SWVLTGE2	SM VOLTAGE SMWH-WLDK PH2	ANALOG	315.00 375.00	
138	SWCNAV61	SM CONDUCTOR AVERAGE PH1	ANALOG	10.00 80.00	
139	SWCNAV62	SM CONDUCTOR AVERAGE PH2	ANALOG	10.00 80.00	
140	SWM172PJ	SM PIPE JCKT T2 100'MH17	ANALOG T	0.00 80.00	
141	SWM173PJ	SM PIPE JCKT T3 100'MH17	ANALOG T	0.00 80.00	
142	SWM174PJ	SM PIPE JCKT T4 100'MH17	ANALOG T	0.00 80.00	
143	SWM175PJ	SM PIPE JCKT T5 100'MH17	ANALOG T	0.00 80.00	
144	SWM171EA	SM EARTH AMB 1F 100'MH17	ANALOG T	0.00 80.00	
145	SWM17FEA	SM EARTH AMB PC 100'MH17	ANALOG T	0.00 80.00	
146	SWM178EA	SM EARTH AMB 8F 100'MH17	ANALOG T	0.00 80.00	

FIGURE 3-5

CABLE CROSS-SECTION DATA DIRECTORY

09:24:00
30-JAN-80
FROZEN

.....

RECORD #	CROSS-SECTION NAME	DESCRIPTION
1	1A	HH 90' MH #1 ZERO MEAS
2	1B	HH 90' MH #1 S MEAS
3	1C	HH 90' MH #1 O MEAS
4	1D	HH 90' MH #1 P MEAS
5	1E	HH 90' MH #1 E MEAS
6	1F	HH 90' MH #1 C,P MEAS
7	1G	HH 90' MH #1 S,O MEAS
8	1H	HH 90' MH #1 S,P MEAS
9	1I	HH 90' MH #1 P,E MEAS
10	1J	HH 90' MH #1 O,P,E MEAS
11	1K	HH 90' MH #1 S,O,P,E ME
12	1L	HH 90' MH #1 C,S,O,P,E
13	2A	HH 300' MH #1 P MEAS
14	2B	HH 300' MH #1 E MEAS
15	2C	HH 300' MH #1 S,E MEAS
16	2D	HH 300' MH #1 O,P MEAS
17	2E	HH 300' MH #1 P,E MEAS
18	2F	HH 300' MH #1 S,O,P MEA
19	2G	HH 300' MH #1 S,O,E MEA
20	2H	HH 300' MH #1 S,P,E MEA
21	5A	WH 100' MH #1 P MEAS
22	5B	WH 100' MH #1 E MEAS
23	5C	WH 100' MH #1 C,E MEAS
24	5D	WH 100' MH #1 P,E MEAS
25	6A	WS 100' MH #1 P MEAS
26	6B	WS 100' MH #1 O,E MEAS
27	7A	WS 30' MH #2 P,E MEAS
28	8A	WS 100' MH #17 P MEAS
29	8B	WS 100' MH #17 E MEAS
30	8C	WS 100' MH #17 P,E MEAS

PRESS [RETURN] FOR PCS MENU

FIGURE 4

09:19:28
30-JAN-80
FROZEN

TIME= 09:19:09
DATE= 30-JAN-80

CMARS CABLE STATUS SUMMARY

CROSS SECTION	DESCRIPTION	COND TEMP DEG C	NORM LIMIT DEG C	VOLT KV	LOAD AMPS	PCNT CONT RTNG	CONT RTNG
HINCHMAN-HAWTHORNE 90 FT							
1A	HH 90' MH #1 ZERO MEAS	26	80	239	219	20	1044
1B	HH 90' MH #1 S MEAS	18	80	239	219	20	1067
1C	HH 90' MH #1 O MEAS	15	80	239	219	20	1073
1D	HH 90' MH #1 P MEAS	19	80	239	214	16	1293
1E	HH 90' MH #1 E MEAS	22	80	239	214	19	1098
1F	HH 90' MH #1 C,P MEAS	17	80	239	214	23	900
1G	HH 90' MH #1 S,O MEAS	18	80	239	214	15	1353
1H	HH 90' MH #1 S,P MEAS	18	80	239	214	19	1115
1I	HH 90' MH #1 P,E MEAS	19	80	239	217	18	1162
1J	HH 90' MH #1 O,P,E MEAS	15	80	239	217	17	1215
1K	HH 90' MH #1 S,O,P,E ME	18	80	239	217	22	983
1L	HH 90' MH #1 C,S,O,P,E	17	80	239	217	19	1101
HINCHMAN-HAWTHORNE 300 F							
2A	HH 300' MH #1 P MEAS	14	80	239	217	13	1636
2B	HH 300' MH #1 E MEAS	22	80	239	217	18	1160
2C	HH 300' MH #1 S,E MEAS	15	80	239	219	15	1431
2D	HH 300' MH #1 O,P MEAS	17	80	239	219	16	1337
2E	HH 300' MH #1 P,E MEAS	15	80	239	219	14	1499
2F	HH 300' MH #1 S,O,P MEA	15	80	239	219	13	1570
2G	HH 300' MH #1 S,O,E MEA	15	80	239	219	15	1428
2H	HH 300' MH #1 S,P,E MEA	15	80	238	219	16	1367
VALDWICK-HAWTHORNE 100 F							
5A	WH 100' MH #1 P MEAS	13	75	242	191	13	1458
5B	WH 100' MH #1 E MEAS	24	75	242	191	18	1057
5C	WH 100' MH #1 C,E MEAS	12	75	242	191	17	1117
5D	WH 100' MH #1 P,E MEAS	13	75	242	191	12	1550

FIGURE 5
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09:20:10
30-JAN-80
FROZEN

TIME= 09:19:09
DATE= 30-JAN-80

CMARS CABLE STATUS SUMMARY

CROSS SECTION	DESCRIPTION	COND TEMP DEG C	NORM LIMIT DEG C	VOLT KV	LOAD AMPS	PCNT CONT RTNG	CONT RTNG
WALDWICK-SMAHWAH 100' MH							
6A	WS 100' MH #1 P MEAS	21	75	354	297	18	1569
6B	WS 100' MH #1 O,E MEAS	20	75	354	297	18	1570
WALDWICK-SMAHWAH 30' MH2							
7A	WS 30' MH #2 P,E MEAS	22	75	354	302	20	1506
WALDWICK-SMAHWAH 100MH17							
8A	WS 100' MH #17 P MEAS	21	75	335	366	23	1566
8B	WS 100' MH #17 E MEAS	44	75	335	366	41	883
8C	WS 100' MH #17 P,E MEAS	21	75	335	366	23	1548

FIGURE 5-1

ID	SCAN HOLD	MESSAGE LENGTH	RETRY LIMIT	HARD ERRORS	TOTAL ERRORS	WEIGHTED AVERAGE	SCAN TIME = OVERRUNS =	15 0	09:20:55 30-JAN-80 FROZEN
1		60	1	0	0	100.00			
2		60	1	0	0	100.00			
3		40	1	0	0	100.00			
4		40	1	0	0	100.00			
5		20	1	0	0	100.00			
6		40	1	0	0	100.00			
7		40	1	0	0	100.00			
8		40	1	0	0	100.00			

HOLD, TIME, ADD, MODIFY, ZERO, OR DELETE CH/T/A/M/Z/DJ:

FIGURE 6

A L A R M S U M M A R Y

09:21:33
30-JAN-80
FROZEN
PAGE 1

```

.....
07:40:02 30-JAN ALARM [WARNING] YOU HAVE      8 HOURS TO RUN 'MTD' OR LOSE
          HISTORICAL DATA

06:24:02 30-JAN ALARM *POINT HHC50M13  H1 CONDUCTOR 500'MH1 PH3 - BELOW
          LIMIT:  VALUE=    0.00   LIMIT=   10.00

06:23:56 30-JAN ALARM *POINT HHVSPM23  H1 VTLIT SPLICE MH2   PH3 - BELOW
          LIMIT:  VALUE=    0.00   LIMIT=   10.00

06:23:50 30-JAN ALARM *POINT HHTSPM33  H1 T&B SPLICE MH3     PH3 - BELOW
          LIMIT:  VALUE=    0.00   LIMIT=   10.00

06:23:44 30-JAN ALARM *POINT HHCN9M13  H1 CONDUCTOR 90'MH1   PH3 - BELOW
          LIMIT:  VALUE=    0.00   LIMIT=   10.00

06:23:38 30-JAN ALARM *POINT HHCNAVG3   H1 CONDUCTOR AVERAGE PH3 - BELOW
          LIMIT:  VALUE=    2.12   LIMIT=   10.00

05:57:23 30-JAN ALARM *POINT HHCNAVG1   H1 CONDUCTOR AVERAGE PH1 - BELOW
          LIMIT:  VALUE=    9.23   LIMIT=   10.00

04:19:29 30-JAN ALARM *POINT SWCNAVG2   SM CONDUCTOR AVERAGE PH2 - BELOW
          LIMIT:  VALUE=    1.73   LIMIT=   10.00

03:40:02 30-JAN ALARM [WARNING] YOU HAVE     12 HOURS TO RUN 'MTD' OR LOSE
          HISTORICAL DATA

23:56:06 29-JAN ALARM *POINT HHC30M13  H1 CONDUCTOR 300'MH1 PH3 - BELOW
          LIMIT:  VALUE=    9.94   LIMIT=   10.00

23:40:02 29-JAN ALARM [WARNING] YOU HAVE     16 HOURS TO RUN 'MTD' OR LOSE
          HISTORICAL DATA

19:40:02 29-JAN ALARM [WARNING] YOU HAVE     20 HOURS TO RUN 'MTD' OR LOSE
          HISTORICAL DATA

15:40:02 29-JAN ALARM [WARNING] YOU HAVE     24 HOURS TO RUN 'MTD' OR LOSE
          HISTORICAL DATA

16:23:34 28-JAN ALARM *POINT HHC90M11  H1 CONDUCTOR 900'MH1 PH1 - BELOW
          LIMIT:  VALUE=    6.28   LIMIT=   10.00

```

FIGURE 7

LOG INDEX

09:22:34
30-JAN-80
FROZEN
PAGE 1

PSE&G RTU POINT LIST

1A HH 90' MH #1 ZERO MEAS

1B HH 90' MH #1 S MEAS

1C HH 90' MH #1 O MEAS

1D HH 90' MH #1 P MEAS

1E HH 90' MH #1 E MEAS

1F HH 90' MH #1 C,P MEAS

1G HH 90' MH #1 S,O MEAS

1H HH 90' MH #1 S,P MEAS

1I HH 90' MH #1 P,E MEAS

1J HH 90' MH #1 O,P,E MEAS

1K HH 90' MH #1 S,O,P,E MEAS

1L HH 90' MH #1 C,S,O,P,E MEAS

2A HH 300' MH #1 P MEAS

2B HH 300' MH #1 E MEAS

2C HH 300' MH #1 S,E MEAS

2D HH 300' MH #1 O,P MEAS

2E HH 300' MH #1 P,E MEAS

2F HH 300' MH #1 S,O,P MEAS

2G HH 300' MH #1 S,O,E MEAS

2H HH 300' MH #1 S,P,E MEAS

5A WH 100' MH #1 P MEAS

5B WH 100' MH #1 E MEAS

5C WH 100' MH #1 C,E MEAS

5D WH 100' MH #1 P,E MEAS

6A WS 100' MH #1 P MEAS

6B WS 100' MH #1 O,E MEAS

7A WS 30' MH #1 P,E MEAS

8A SW 100' MH #17 P MEAS

8B SW 100' MH #17 E MEAS

8C SW 100' MH #17 P,E MEAS

FIGURE 8

DISK 1

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SIX CHANNEL LASER TEMPERATURE
MONITORING SYSTEM

PHOTO #1

SIX CHANNEL LASER DETECTORS

PHOTO #2

REMOTE TERMINAL UNITS & PHOTO #3
THERMOCOUPLE TRANSMITTER CABINETS

DISPLAY INDEX

PHOTO #4

SCHEMATIC OF NORTHERN PSE&G UNDERGROUND SYSTEM

PHOTO #5

WALDWICK-HAWTHORNE
AXIAL SCHEMATIC

PHOTO #7

WALDWICK-SOUTH MAHWAH
AXIAL SCHEMATIC

PHOTO #8

HINCHMANS—HAWTHORNE
AXIAL SCHEMATIC

PHOTO #6

PHOTO #9

SCI/PCS PROCESS CONTROL SYSTEM

13-22-89
23-NOV-79
PAGE 1

- PCS TASKS
- CLS - CLEAR CRT SCREEN
 - CPA - CHANGE POINT ATTRIBUTES
 - CVL - CHANGE POINT VALUE
 - DPA - DISPLAY POINT ATTRIBUTES
 - DVL - DISPLAY POINT VALUE
 - DPH - DISPLAY POINT NAMES
 - EPN - EVENT FLAG SET SERVICE
 - GPE - GRAPHIC PICTURE EDITOR
 - HTD - HISTORICAL FILE TAPE DUMP
 - PWD - OPERATOR PASSWORD SERVICE
 - SCH - CHANGE SCHED STATUS
 - RDS - RTU DATA DUMP
 - REN - REMOVE THIS CRT
 - HCR - DEMAND - HOUR TASK
 - HST - HISTOGRAM TASK
 - INI - DEMAND - INITIALIZATION TASK
 - MIN - DEMAND - MINUTE TASK
 - PRD - CHARS PREDICTOR
 - RAT - RATING DURATION CURVE
- CHARS TASKS
- CSD - CHARS CROSS SECTION DISPLAY
 - CSS - CABLE GROUP STATUS SUMMARY
 - DIR - CROSS SECTION DIRECTORY
 - DMP - CABLE DATA DUMP
 - ENT - CHARS DATA ENTRY

FUNCTION INDEX

PHOTO #11

PHOTO #12

**HINCHMANS-HAWTHORNE
90 FT. CROSS-SECTION**

PHOTO #10

**GRAPHICAL REPRESENTATION
OF PREDICTOR INPUT**

PHOTO #13

**GRAPHICAL REPRESENTATION
OF PREDICTOR OUTPUT**

PHOTO #14

RATING DURATION CURVE

PHOTO #15

APPENDIX I

SOFTWARE DESIGN DESCRIPTIONS

CABLE MONITORING AND RATING SYSTEM

REAL-TIME PDP 11/34 VERSION

DATA BASE ORGANIZATION

DATA BASE ORGANIZATION

The primary part of the data base is the engineering units table (EUT) of the SCI/PCS software package. The EUT contains all the information for analog points, virtual points, and statistical points. For cable cross section points, the EUT's main purpose is to hold a calculated conductor temperature for the cross section which can be displayed by SCI/PCS output tasks.

EUT STRUCTURE

The basic EUT structure within the old version of SCI/PCS contained two types of points, analog and digital. These points are primarily repositories for incoming data from the RTUs. In addition, "virtual" points may be set up which are identical to the "real" analog and digital points except that virtual points do not represent measured data from the RTUs.

For CMARS, two new types of points have been created -- cable cross section and statistical. These two types are special versions of analog virtual points in which some of the point attributes take on different meanings than the regular analog attributes. This change required changes in the SCI/PCS tasks, Change Point Attributes (CPA) and Display Point Attributes (DPA), to allow proper presentation of the new point types.

There are two kinds of cable cross section points -- a monitored cable cross section point and a predicted cable cross section point -- each with identical structure. The former will be used for minute task monitoring. The latter is used for gauging the performance of the predictor. See the description of the minute task for details regarding their usage.

In essence, the new points have the following use.

Monitored Cable Cross Section Point -- The principle purpose is to hold a calculated conductor temperature for the monitored cross section on disk to permit display by SCI/PCS output tasks.

Attributes for this point will include:

- Eight character identifier; 2 characters temperature type followed by 6 character x-section name
- 24 character description
- Monitored cable cross section temperature

Predicted Cable Cross Section Point -- The principle purpose of this point is to hold a value for the predicted conductor temperature for a cable cross section data file on disk. This value is then displayed by SCI/PCS output tasks. Attributes for this point include:

- Eight character identifier; 'PR' followed by 6 character x-section name
- 24 character description
- Predicted cable cross section temperature

Statistical Point -- These points represent results of recursive calculations that produce a mean and variance of some user defined value over a midnight-to-midnight 24 hour period. Attributes for this point include:

- Eight character identifier; 'ST' or 'S2' followed by 6 character x-section name
- Mean value
- Variance
- Time the last increment to the statistic was calculated

The equations for some of the statistical point attributes are given below.

$$a_i = \frac{a_{i-1} t_{i-1} + v_i \delta t}{t_{i-1} + \delta t}$$

$$\sigma_i^2 = \frac{\sigma_{i-1}^2 t_{i-1} + (v_i - a_i)^2 \delta t}{t_{i-1} + \delta t}$$

$$t_i = t_{i-1} + \delta t$$

Variables are defined as follows:

- a_i = mean value including the present sample
- a_{i-1} = mean value at the last sample
- v_i = present value sample
- t_{i-1} = total time from the beginning of the calculation period up to the last sample
- t_i = total time up to the present sample
- δt = $t_i - t_{i-1}$ = time increment since the last sample
- σ_i^2 = variance including the present sample
- σ_{i-1}^2 = variance at the last sample interval

Table 1 provides a definition of the use of various values in the Engineering Units Table for the four types of points. The structure of both types of cable points is the same. Note that the cable and statistical type points are most similar to analog points.

CABLE FILE STRUCTURE

The cable type points require a large amount of auxilliary data that are stored on disk file. One file exists for all monitored cable points

where a given cable's data string occupies one record (see Table 2 for details of a record). A second file exists for all predicted cable points.

Another disk file required is a directory for the monitored cable disk file. The directory has two byte logical variables for each possible cable record. The logical variable is set .TRUE. whenever a cable record is in use. The directory thus allows tasks that access the cable file to skip over unused records. The directory file structure is:

NCROSS, ICROSS(NCROSS)	NCROSS = INTEGER - UNUSED
	ICROSS = (LOGICAL*2)*NCROSS

where NCROSS = the number of monitored cable cross sections (up to 30)
and ICROSS = .TRUE. for all monitored cables

TABLE 1
ENGINEERING UNITS TABLE STRUCTURE FOR VARIOUS TYPES OF POINTS

n = number of points

<u>EUTCOM</u>	CONTENTS				
	# BYTES	ANALOG	DIGITAL	STATISTICAL ²	CABLE ¹
EUSIZE	2	Maximum number of points in system			
EUTBL	4*n	Value (floating point)	State Name (6 character Radix - 50)	Variance (floating point)	Conductor Temp (floating Point)
EUSTAT	2*n				
<u>bit</u>					
15		Error →			
14		Error message print flag →			
13		Point in use →			
12		1 → Auto, 0 → Manual			
11		1 → Remote, 0 → Master			
10		Linearize (Analog Only)			
9		Alarm acknowledged →			
8		1→J, 0→T Thermocouple (Analog Only)			
7		Changing value →			
6		{ Error hold off, error type: 0 - unknown state, 1 - input/output mismatch, 2 - alarm state			
5					
4		Alarm limits active →			
3		Point RTU I/O		0	0
2		1 Analog output 0		0	0
		0 Analog input			
ANALOG=0	{	1	0	1	1
DIGITAL=1		0	1	0	1
STAT=2					
CABLE=3					

¹ Both monitored and predicted cable points have same structure
TC, TS, TO, TP, PR - contain calculated temperature measurements

² ST, S2 - statistical points for cable & hist. pred. cable, respectively

TABLE 1 CONTINUED

CONTENTS					
	# BYTES	ANALOG	DIGITAL	STATISTICAL	CABLE
EUCKLO	4*n	Lower alarm limit	Input buffer indices	Not Used	Not Used
EUCKHI	4*n	Upper alarm limit	Previous state name	Not Used	Not Used
<u>EUSCOM</u>					
EUALTD	4*n		Input bit #'s	Not Used	Not Used
Byte 0		Storage deviation (0→100%)	↓	↓	↓
Byte 1		Alarm limit deadband (0→100%)			
Byte 2		Alarm time limit			
Byte 3		Alarm time counter			
EUCP1	4*n	Slope conversion Constant	Output point id's	Mean value	Not used
EUCP2	2*n	Count off-set conversion constang	State list index	Time of last calculation in minutes from midnight	Not used
EUIOP	2*n				
Byte 0		RTU ID	RTU ID	0	0
Byte 1		Input: Buffer index Output: Point ID	#Inputs & # Outputs	0	0

CONSIDERATIONS FOR INTERFACE TO SCI/PCS

The addition of two new point types means that the SCI/PCS task Display Point Attributes (DPA) and Change Point Attributes (CPA) must now accommodate the new point types. The changes involve relatively minor modifications to DPA and CPA as those two tasks already route processing to tasks dedicated to analog or digital points, respectively.

New tasks required for cable and statistical points should very closely parallel the existing analog point tasks, except for a few details of setting attributes.

<u>EXISTING ANALOG TASKS</u>	<u>REQUIRED TASKS FOR STATISTICAL</u>	<u>CABLE</u>	<u>DESCRIPTION</u>
DPAANA	DPASTA	DPACAB	Displays attributes for a particular point type
UPDANA	UPDSTA	UPDCAB	Provides update service for a particular point type

Figure 1 presents an overview of the SCI/PCS structure regarding the EUT and point dependent operations on the EUT. Solid lines show the present SCI/PCS structure and dotted lines indicate additions that are required.

FIGURE 1

DATA BASE STRUCTURE AND POINT TYPE
DEPENDENT OPERATIONS

CROSS REFERENCE TABLE
SHOWING THE TASKS ACCESS TO THE CABLE CROSS SECTION DATA BASE

	<u>VARIABLE</u>	<u>SET - UP</u>		<u>MINUTE</u>		<u>TASK HOUR</u>		<u>PREDICTION</u>		<u>DISPLAY</u>		<u>STATISTIC</u>	
		I	O	I	O	I	O	I	O	I	O	I	O
	IDCABL(6)	X	X	X									
	XTRA(2)							X					
	ICREFY(168)	X	X	X									
One group for each of 30 cable cross- section storage areas	TEMPC(30)			X	X			X		X		X	
	THETAC(30)	X	X	X	X	X		X		X		X	
	RLAMDA(30)	X	X	X	X					X		X	
	RLIML(30)	X	X	X									
	RLIMU(30)	X	X	X									
	U1				X			X		X		X	
	Y(4)				X			X		X		X	
	U2				X			X		X		X	
	U3				X			X		X		X	
	USAVE(5)			X	X								
	TIMEP(3)	X	X	X	X	X		X		X			
	GAIN(40)	X	X	X									
	PCAIN(40)	X	X	X									
	FIXU(4)	X	X	X		X		X					
	Z(5)		X	X				X					
	DIM(16)	X	X										
	THERM(19)	X	X										
	TMAX(4)	X	X	X		X				X			
	DURATN(6)	X	X			X				X			
	RATFAC(176)			X			X						
	IRATNG(28)				X					X			
	MDIM(4)	X	X	X		X		X		X			
	ICREFY(168)	X	X	X									
	NCREFY(21)		X	X	X								
	INDXP(30)	X	X	X									
	IFLAG(16)	X	X	X									

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
TEMPC(30)	TCOND	Conductor temperature, °C	Real	4
	TINSL	Insulation temperature, °C	"	4
	TSHLD	Shield temperature, °C	"	4
	TOIL	Oil temperature, °C	"	4
	TPIPE	Pipe temperature, °C	"	4
	TETH1-TETH5	Earth shell temperature, °C	"	20
	TEMPC01-30)	Spare	"	80
THETAC(30)	RINSL	Insulation thermal resistance, °C/watt/ft	"	4
	ROIL	Oil thermal resistance, °C/watt/ft	"	4
	ROFACT	Multiplicative factor on ROIL (i.e., ROIL - ROIL * ROFACT)	"	4
	RPCVR	Pipe cover thermal resistance, °C/watt/ft	"	4
	RETHP	Earth thermal resistance and pipe cover thermal resistance, °C/watt/ft	"	4
	CCOND	Conductor thermal capacitance, watt·hr/ft/°C	"	4
	CINSP	Insulation + shield + skid wire thermal capacitance, watt·hr/ft/°C	"	4
	CSHLD	Shield + skid wire thermal capa- cittance, watt·hr/ft/°C	"	4
	COIL	Oil thermal capacitance, watt·hr/ft/°C	"	4
	CPIPP	Pipe + pipe cover thermal capa- cittance, watt·hr/ft/°C	"	4
	CPCVR	Pipe cover thermal capacitance, watt·hr/ft/°C	"	4
	CERTH	Earth thermal capacitance, watt·hr/ft/°C	"	4
	HCON1	AC electrical resistivity of the conductor, watts/KA ² ·ft	"	4
	HCONP1	Temperature sensitivity of HCON1, watts/KA ² ·°C·ft	"	4

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
	HCON2	Voltage induced loss rate for the insulation, watts/kV ² ·ft	Real	4
	HCONP2	Temperature sensitivity of HCON2, watta/kV ² ·ft	"	4
	HCON3	AC electrical loss of the shield watts/KA ² ·ft	"	4
	HCONP3	Temperature sensitivity of HCON3, watts/KA ² ·ft	"	4
	HCONS	AC electrical loss of the pipe, watts/KA ² ·ft	"	4
	HCONP5	Temperature sensitivity of HCONS, watts/KA ² ·°C·ft	"	4
	BIAS 1	Bias for measurement estimate 1, °C	"	4
	BIAS 2	Bias for measurement estimate 2, °C	"	4
	BIAS 3	Bias for measurement estimate 3, °C	"	4
	BIAS 4	Bias for measurement estimate 4, °C	"	4
	spare		"	4
	spare		"	4
	spare		"	4
	spare		"	4
	spare		"	4
	spare		"	4
RLAMDA(30)	RLAMDA(30)	Information content for the parameters (Variable used in parameter identification)	"	120
RLIML(30)	RLIML(30)	Lower limit on parameter variations for the identification process	"	120
RLIMU(30)	RLIMU(30)	Upper limit on parameter variations for re-identification process	"	120
U1	AMPS	current, KA	"	4
Y(4)	TOIL	measured oil temperature, °C	"	4
	TPIPE	measured pipe temperature, °C	"	4
	TSHLD	measured shield temperature, °C	"	4
	TCOND	measured conductor temperature, °C	"	4
U2	VOLTS	voltage, KV	"	4
U3	TERTH	ambient earth temperature, °C	"	4

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
USAVE(5)	AMPSV	Saved value of current, in KA	Real	4
	VOLTSV	Saved value of voltage, in KV	"	4
	TAMBSV	Saved value of ambient earth temperatures, °C	"	4
	spare		"	4
	spare		"	4
TIMEP(3)	TIMESV	Time of the last estimation update	"	4
	TINT	Integration step size, hrs	"	4
	ALPHA	Identification time constant, hrs	"	4
GAIN(40)	GAIN(10,4)	Estimator gains	"	160
PGAIN(40)	PGAIN(4,20)	Identifier gains	"	160
FIXU(4)	FVOLT	Fixed value for voltage, KV	"	4
	FTAMB1	Fixed value for average am- bient earth temperature, °C	"	4
	FTAMB2	Fixed value for amplitude of ambient earth temperature, °C	"	4
	FTAMB3	Time from Jan 1 when peak temperature occurs, days	"	4
Z(5)	Z(5)	Factors for splitting up the earth thermal capacitance, dimensionless	"	20
DIM(16)	CIR	Conductor cross section, MCM	"	4
	DC	Conductor diameter, inches	"	4
	DI	Outside Insulation diameter, inches	"	4
	DP	Pipe inside diameter, inches	"	4
	S	Cable separation, inches	"	4
	XL	Burial depth, inches	"	4

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
DIM(16)	TKS	Shield thickness, inches	Real	4
	TKT	Shield tape thickness, inches	"	4
	XLAYT	Lay length of shield tape	"	4
	AW	Cross sectional area of skid wire, inches ²	"	4
	XLAYW	Lay length of skid wire	"	4
	WIRES	Number of skid wires	"	4
	TKP	Pipe thickness, inches	"	4
	TKPC	Pipe cover thickness, inches	"	4
	* AMPB	Average value linearized amps	"	4
	spare		"	4
THERM(19)	RHOI	Insulation resistivity, watt/°C cm	"	4
	RHOT	Shield resistivity, watt/°C cm	"	4
	RHOW	Skid wire resistivity, watt/°C cm	"	4
	RHOPC	Pipe cover resistivity, watt/°C cm	"	4
	RHOE	Earth resistivity, watt/°C cm	"	4
	CAPC	Conductor specific capacitance, watt·hr/°C·cm ³	"	4
	CAPI	Insulation specific capacitance, watt·hr/°C·cm ³	"	4
	CAPS	Shield specific capacitance, watt·hr/°C·cm ³	"	4
	CAPW	Skid wire specific capacitance, watt·hr/°C·cm ³	"	4
	CAPO	Oil specific capacitance, watt·hr/°C·cm ³	"	4
	CAPP	Pipe specific capacitance, watt·hr/°C·cm ³	"	4
	CAPPC	Pipe cover specific capacitance, watt·hr/°C·cm ³	"	4
	CAPE	Earth specific capacitance, watt·hr/°C·cm ³	"	4
	SIC	Specific inductive capacitance of insulation	"	4

* Not User Enterable

VARIABLE GROUP	(6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
	OILFL	Oil flow, gpm	Real	4
	FZERO	Kalman gain scale factor	"	4
	spare		"	4
	spare		"	4
	spare		"	4
TMAX(4)	TMAX(4)	Cable temperature limits, °C 1 & 2 for the conductor 3 & 4 for pipe/earth interface	"	16
DURATN(6)	DURATN(6)	Six short periods for cable ratings, hrs	"	24
RATFAC(176)	RLC(4)	Rating factors	"	16
	RVC(2)	Rating factors	"	8
	RTAC(2)	Rating factors	"	8
	RL(4,6)	Rating factors	"	96
	RV(2,6)	Rating factors	"	48
	RTA(2,6)	Rating factors	"	48
	RT(2,6,10)	Rating factors	"	480
IRATNG(28)	IRATNG(4,7)	Cable ratings, in amps Row 1 are the continuous ratings for each of the four temperature limits, TMAX(4) Rows 2-7 are the 6 short period ratings for the times in DURATN(6)	Integer	36
MDIM(4)	N	Number of temperature states	"	2
	M	Number of measured temperatures	"	2
	NQ	Number of measured inputs	"	2
	NP	Number of parameters	"	2

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
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NCREFY(21)	NCREFY(7,3)	Sequence numbers for referencing the analog points specified by ICREFY in the engineering units table	Integer	42
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INDXP(30)	INDXP(30)	Flags for parameter identification. If INDXP(I) = .TRUE., identify parameter I	Logical	60
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IFLAG(16)	IFLAG	General purpose flags Flag Number	Logical*2	32
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1 = .TRUE. restart cross-section monitoring using the initialization routine to reset temperature estimates, parameters, and lambdas

2 = .TRUE. use linearized parameters for ROIL, HCON1, and HCON3

3 = .TRUE. use the Neher-McGrath oil resistance model. Otherwise, the Chato model

4 = .TRUE. Triangular cable configuration. Otherwise, cradled.

5 = .TRUE. calculate Kalman gains. Otherwise user input

Not user enterable.
Set automatically, however,
can be changed in modify
mode of "ENT" program

6 = .TRUE. if at least 1 oil measurement
7 = .TRUE. if at least 1 pipe measurement
8 = .TRUE. if at least 1 shield measurement
9 = .TRUE. if at least 1 conductor measurement

10-16 = spare

6/1/79

MINUTE TASK DESCRIPTIONPURPOSE

Calculates updates to temperature estimates, parameters, and cable ratings.
Calculates predicted temperatures over midnight-to-midnight time period.

EXECUTION CRITERIA

The minute task runs synchronously off the real-time clock at least every ten (10) minutes, but can also be executed asynchronously on operator demand from the SCI/PCS task index table. In addition the minute task can be executed off the real-time clock by a "RUN" command. This option permits the operator to schedule the minute task at any time and repeat at pre-specified intervals. The task priority is moderately high.

INPUTSNAMEDESCRIPTION

EUT

Measurement values of analog points as specified by a cross reference table associated with each cable (ICREFY/NCREFY as described in the data base).

Disk

Data bases for the monitored and predicted cable cross sections plus a list of the cross sections that are in use for each function.

OUTPUTSNAMEDESCRIPTION

Event Logger

Notation of the following changes in status:

1. Cross-section out-of-service
2. Cross-section restored to service or started up.

Disk File

New values for temperatures, parameters and ratings.

COMMON BLOCKS

<u>NAME</u>	<u>DESCRIPTION</u>
Global	EUTCOM, EUSCOM, CRTCOM (CABLE, COM)
Local	CABLE, CABLE2, CNAME\$, CNTRL, MAIN1, INOU

SUBROUTINES USED

CLRCRT, CRTASN, CRTXIT, EXIT, GETDAT, INIT, INT, INTP, IRAD50, LIMIT, MEAS, POSCUR,
PTLOOK, RATNG, RECEIV, RECOEX, SEND, STATE

COMPUTATION PROCEDURES

See attached flow chart

FLOW CHART FOR THE MINUTE TASK

FLOW CHART FOR GETDATA

HOUR TASK DESCRIPTION

PURPOSE

Calculates factors used in the rating computations performed by the Minute task.

EXECUTION CRITERIA

The hour task runs synchronously off the real-time clock once a day at midnight, but can also run asynchronously on operator demand from the SCI/PCS task index table. In addition the hour task can be executed by a "RUN" command. This option permits the hour task to be executed at any desired time and to be repeated at pre-specified time intervals. Priority should be low since rating factors will not change much from day to day, but only over a long period of time.

INPUTS

<u>NAME</u>	<u>DESCRIPTION</u>
Disk	Data base for the cable cross sections plus a directory for the cross section data base

OUTPUTS

<u>NAME</u>	<u>DESCRIPTION</u>
Disk	New values for the rating factors (see RATFAC variables in the cable cross section description)

COMMON BLOCKS

<u>NAME</u>	<u>DESCRIPTION</u>
	CABLE.COM
Local	<u>CABLE, CABLE2, CNAMES, MAIN1, INOU</u>

SUBROUTINES USED

RATFAC, MTINV, RCNET, MEXP, XNORM, MMUL

COMPUTATIONAL PROCEDURE

See the attached flow chart.

FLOW CHART FOR THE
HOUR TASK

STRUCTURE FOR THE CABLE CROSS SECTION PART OF THE ENGINEERING UNIT TABLE

(The following data are repeated for each cable cross section
storage area)

VARIABLE GROUP	NAME (6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
IDCABL(6)	IDCABL(6)	Cable cross section eight character identifier	Byte	6
XTRA(2)		Unused	Byte	2
ICREFY(168)	ICREFY(7,3,8)	Measurement/input cross reference table (elements contain the point identifier of analog values used by the model for the various measure- ments and inputs where each identifier is 8 characters)	Byte	168

The structure of ICREF is

ROW	COLUMN	1	2	3
1	CURRENT			
2	OIL TEMPERATURE			
3	PIPE TEMPERATURE			
4	SHIELD TEMPERATURE			
5	COND TEMPERATURE			
6	VOLTAGE TEMPERATURE			
7	AMBIENT EARTH TEMP.			

Each row contains the identifier of up to 3 analog points
which will be averaged to give the single measured value
used by the CMARS algorithm. Measured values are stored
in VMEAS(7).