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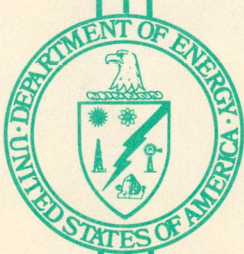
FIELD VALIDATION OF CABLE MONITORING AND RATING SYSTEM (CMARS) LABORATORY MODEL

First Semi-Annual Report, November 1, 1978—April 30, 1979

By
John Englehardt
David O'Neill
Dominic Orifice
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Work Performed Under Contract No. ET-78-C-01-3122

Public Service Electric & Gas Research Corporation
Newark, New Jersey



U. S. DEPARTMENT OF ENERGY

Division of Electric Energy Systems

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FIRST SEMI-ANNUAL REPORT

FOR THE PERIOD

1 NOVEMBER 1978 - 30 APRIL 1979

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U.S. DEPARTMENT OF ENERGY

ELECTRIC ENERGY SYSTEMS

UNDER CONTRACT ET-78-C-01-3122

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Introduction and Summary

This first semi-annual report covers a period from November 1, 1978 to April 30, 1979. During this period Public Service has subcontracted the services of Systems Control, Inc., to provide hardware and software, and Underground Systems, Inc., an underground pipe cable consultant. Public Service, along with our subcontractors have concentrated its efforts in the past six months in the following project task areas.

Task 1 - Installation of Sensing Devices

Task 2 - Data Acquisition System Installation

Task 4 - Communication Circuit Provisions

Task 5 - Software Installation & Development

The following report will again 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 which are representative of the bulk of this type of system used in the USA. 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 proposed work, specifications for CMARS software and hardware, and all associated sensor, data acquisition and communications equipment will be available to the industry.

System Description

Public Service will conduct the test program on the Hinchmans-Hawthorne 230-kV, Waldwick - South Mahwah 345-kV and Waldwick - Hawthorne 230-kV pipe type cable circuits.

The test circuits are located continuously in the northern part of the state and are being equipped with remote terminal units for transmission of the sensor data via telephone lines to the data processing and display equipment. This equipment will be installed in the Load Dispatch Center in Newark, providing a conveniently accessible location for conducting the CMARS validation program.

Hinchmans-Hawthorne 230-kV HPOF circuit, is being equipped with a temperature monitoring system designed specifically for CMARS research. This will be the primary line for the CMARS evaluation tests. Two monitoring cross sections located 90 feet and 300 feet from Manhole 1 are equipped with conductor, shield, pipe and earth temperature sensors. The monitoring cable section between Manhole 1 and Manhole 2 has a sensor wire for average conductor temperature in 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 internal temperatures in Manhole 1, Manhole 2 and Manhole 3. All of these sensor facilities, in addition to oil temperature and splice shield sensors in Manhole 1 will be instrumented for CMARS data transmission to the Newark Electric System Operation Center.

Additional facilities such as earth moisture and earth resistivity are planned. The conductor average and spot temperature data will be transmitted from pothead mounted equipment to ground level receivers by laser beam and sent via telephone communications to Newark with the other sensor data, including current readings for each phase and potential readings for the line. 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. Pothead temperature information is also available from pothead sensors.

The secondary test circuit is the Waldwick-South Mahwah 345-kV HPOF cable placed in service in 1973. This line is extensively equipped with thermocouples on the cable and splice shields, potheads and pipe, in the oil and at many locations in the earth. A pilot wire for average conductor temperature monitoring was also installed in the center interstice of the cable from the South Mahwah pothead to manhole 16. The monitored sections for this line will be 100 ft. from manhole 1, 30 ft. from manhole 2 and 100 ft. from manhole 17.

Instrumentation will be installed for data acquisition from these three cross sections including the average conductor temperature from the South Mahwah pothead transmitter/receiver equipment, splice shield, oil and ambient air sensors. Temperature

information is also available for the pothead cable, stress cone and oil at the Waldwick pothead. Current for each phase and the circuit potential will be included in the transmitted data.

The Waldwick-Hawthorne 230-kV HPOF cable is equipped with pilot wires for average conductor temperature to Manhole 2 at the Waldwick end. The Waldwick potheads will be equipped with transmitter/receiver equipment for the conductor temperatures. Pipe and earth ambient sensors will be installed 100 feet from Manhole 1. This will be an additional cross section for monitoring with average conductor temperature. All of this sensor data together with the current from each phase and the circuit potential will be transmitted to Newark. The Waldwick potheads are also equipped with oil, stress cone, and shield thermocouples. Earth ambient and pipe surface sensors are also available along this line for longitudinal temperature profile surveys.

Installation of Sensing Devices

CONDUCTOR SENSORS HINCHMANS-HAWTHORNE 230-KV PIPE CABLE

Each phase of the section between Manhole 1 and Manhole 2 is equipped with a specially made Temperature Monitoring Sensor (TMS) cable which was placed in the center of the segmental conductor during the manufacture of the pipe cable, as shown in photo #1. The TMS cable contains up to five twisted pairs, thermistors and paper fillers, as shown on U.S.I. Dwg. HVA-771221, Rev. A.

Each phase of the riser section contains a five-pair sensor lead, also in the center of the segmental conductor. This lead provides access to the TMS cable from the top of the pothead via connections within the splice in Manhole 1.

Each phase of the section from Manhole 2 to Manhole 3 contains a conventional single conductor pilot wire which is utilized as a lead to a thermistor placed on the connectors of the splice in Manhole 3. This pilot wire is spliced to one leg of a pair within the splice at Manhole 2, while the other leg of that pair is connected to a thermistor placed on the connectors of the splice in Manhole 2.

Eighteen pieces of data are available from three phases.

These are summarized as follows:

- 1) The average conductor temperature of each phase between Manhole 1 and Manhole 2.
- 2) The spot conductor temperature of each phase at points 90 ft. and 300 ft. from the Manhole 1 wall.
- 3) The connector temperature of each phase in the splices at Manhole 3 (a creped paper splice) and Manhole 2 (a Voltalit splice).
- 4) The spot temperature at 500 ft. in phase 3, and 900 ft. in phase 1.
- 5) The connector temperature in phase 2 in the Voltalit reducing splice in Manhole 1.

The TMS cable construction had to be carefully coordinated with Okonite, the pipe cable manufacturer, to achieve the desired location of sensors at the 90 ft. and 300 ft. points, especially since the three phases were to be manufactured in one length. The TMS cable manufacturing schedule shown on U.S.I. Dwg. HVA-780901A was generated, with four marks that had to be carried through all operations to position the proper cutting points after the skid wire operation. A marked cutting point is shown in photo #2.

The TMS cable was then constructed, using a two-pad taping head with parallel bunching of the twisted pairs. One 3/4" x .001" mylar tape was applied half-lapped to hold the construction together. A mylar marker tape was included and periodically checked by direct measurement of 100' sections. The thermistors used were Yellow Springs No. 44011 (100 K ohm at 25 C with NTC), which are .90" in diameter. After termination of a pair with a thermistor, a .040" x .070" paper filler was used in place of the pair until the next leg began.

The mylar marker tape was found to be in error by about 1.5% due to a slight wrinkling of the marker tape during the cover tape operation. Thus, the length indicated by marker tape was greater than the actual length by 1.5%.

The final location of cutting points was corrected for this observation, but the true thermistor locations were slightly off the mark, as seen in the following chart of actual distance to the pulling bolt mark. The design called for the pulling bolt to end 16 ft. from the outside manhole wall.

<u>Phase</u>	<u>TM 1</u>	<u>TM 2</u>	<u>TM 3</u>
1	104'-7"	318'-6"	948'
2	104'-9"	318'-2"	N.A.
3	104'-10-1/2"	318'-8-1/2"	520'

The normal segmental conductor for pipe cable has a central interstice of approximately 120 mils. The TMS cable and 5-pair lead have an O.D. of approximately 170 mils. It was therefore necessary to redesign the 2000 kcmil and 2500 kcmil conductors for a central opening of roughly 160 mils, which required minor retooling by Okonite. The resulting increase in conductor diameter was less than 10 mils, which is generally within the expected range of variation in normal production.

Only minor delays were experienced during the cabling operation. Carrying the four marks on the TMS cable through the cabling, taping and skid wire operations was no problem. No precautions were necessary during the impregnation cycle. The success of aligning the TMS cable pulling bolt marks with the actual pulling bolt is summarized below:

Phase	Marker Tape No.		
	at Pulling Bolt	Intended	Difference
1	5707	5707	0
2	4386	4385	1
3	3064	3063	1

The overall accuracy of locating the sensors at specific points is shown on the following table:

Phase	Actual Distance from Manhole Wall		
	TM 1 (90')	TM 2 (300')	TM 3
1	87'-7"	301'-6"	931
2	86'-9"	300'-2"	N.A.
3	86-10-1/2"	300'-8-1/2"	502'

The cables were about 1 ft. further into the manhole than anticipated, accounting for the unequal offset.

One of the nine thermistors (the 700-ft. location) was found to be open upon final test at the Okonite factory. This point was reassigned to a thermistor located on the connector in Manhole 1 splice for phase 2.

Because of the tendency for segmental conductors to extend from .1 to .2% before transmitting a tensile load, precautions were taken to avoid "spring-back" of the TMS cable after cutting of the conductor. At the pulling end of each section between Manholes 1, 2 & 3, the conductor was opened for 1 ft. before cutting, by stripping the insulation and binder. The TMS cable end was then pulled from between the segments. The conductor was then cut, and the excess TMS cable coiled and taped to the cable end, leaving a slack loop to allow for shrink-back. Similar precautions were taken at the trailing ends and at the Hinchmans potheads.

The procedures used for locating connector thermistors and splicing the pilot wire, TMS cable and 5-pair lead are shown in U.S.I. Dwgs. HVA-781107 (Manhole 1), HVA-781108 (Manhole 2) and HVB-790319 (Manhole 3). The technique for bringing the 5-pair lead out of the pothead via a Conax fitting in the stem is illustrated in U.S.I. Dwg. HVA-781115A.

SHIELD SENSORS - HINCHMANS-HAWTHORNE 230-KV PIPE CABLE

Type T (copper-constantan) thermocouples were installed on the cable and splice shields and in the oil volumes of the splices in Manholes 1, 2 and 3. Twenty thermocouples were brought out of the splice in a thermocouple access port at Manhole 1 and ten each from Manholes 2 and 3.

Three TFE-insulated and jacketed three-pair twisted #16 Awg extension grade thermocouple cables were pulled into the pipe with the cable on the Manhole 2 to Manhole 1 pull, illustrated in photo #3. Six prefabricated thermocouples were attached to the cable shields 106 ft. and the remaining three were attached 316 ft. from the pulling bolt. The pulling setup is depicted in photo #4. The thermocouple attachment resembles that shown on U.S.I. Dwg. HVA-781106. The thermocouple placement on the cable shield at the 106 ft. point is shown in photo #5.

The final position of these thermocouples is one foot short of their intended location, i.e., at 89 ft. and 299 ft. from the manhole wall, due to a one-ft. overpull into manhole 1. As a result, the shield thermocouples "miss" the conductor thermistor sensors by 1'-2" to 2'-6".

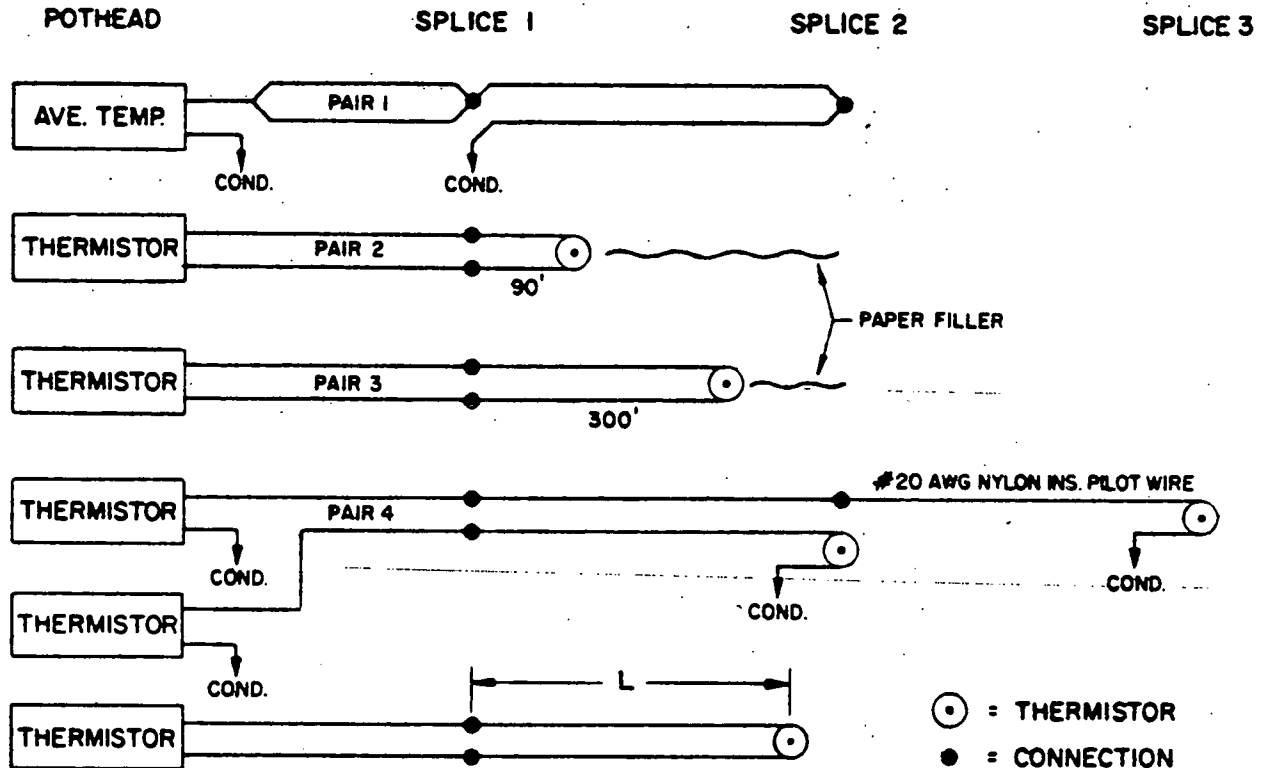
Nine thermocouples were placed on the shields of the splices, as shown on U.S.I. Dwgs. HVC-781008, HVC-781111 and HVC-781112 for Manholes 1, 2 and 3 respectively. Also shown are the oil probe

locations and terminal strips used to simplify the connections to the prewired thermocouple access ports. U.S.I. Dwg. HVB-781018A shows the terminal strip connections at Manhole 1 and HVA-781019 shows these connections in Manholes 2 and 3. The thermocouple terminal assembly of the Votlalit splice of manhole 2 is shown in photo #6.

Three Type T (copper-constantan) thermocouples were installed in each pothead spool piece at Hinchman's substation. These thermocouples are located on the stress cone shield about midway up the slope on the cable shield, just above the semi-stop gland and in the oil volume as shown on U.S.I. Dwg. HVA-790320. These are brought out of the system in a thermocouple access port mounted on the spool piece of each pothead.

REVISIONS

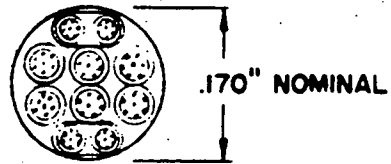
LTR	DESCRIPTION	DATE	APPROVED
A	REV. PAIR 1 & 4 WAS # 30 AWG, ADD. PAIR 5 & THERMISTORS	6/28/78	



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 INTERCALATED 3/4" X .001" MYLAR TAPES
 AND PAPER MARKER TAPE.

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

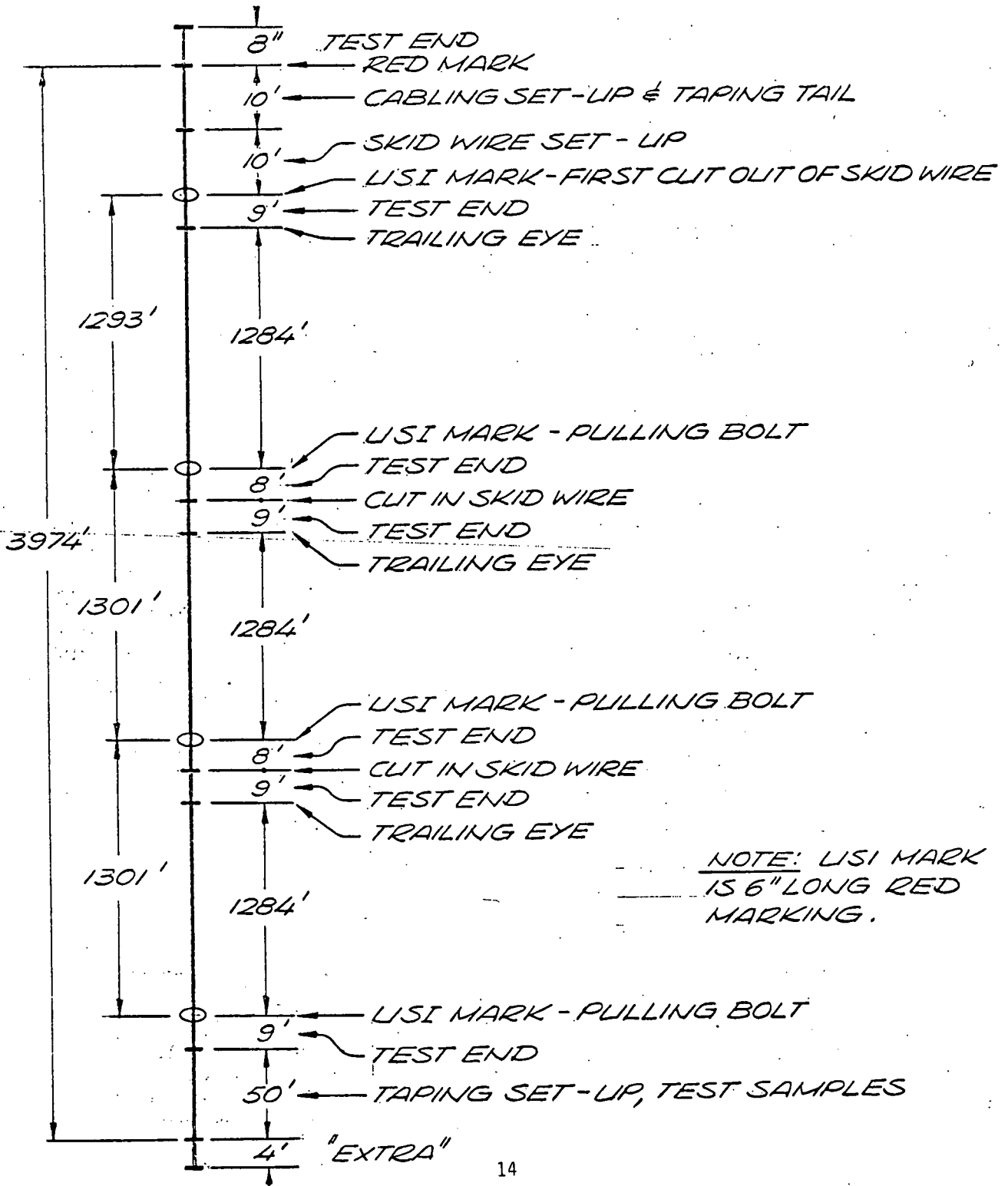
- PAIR 1 WHITE AND YELLOW
- PAIR 2 WHITE JACKET
- PAIR 3 BLACK JACKET
- PAIR 4 WHITE AND GREEN
- PAIR 5 WHITE AND RED



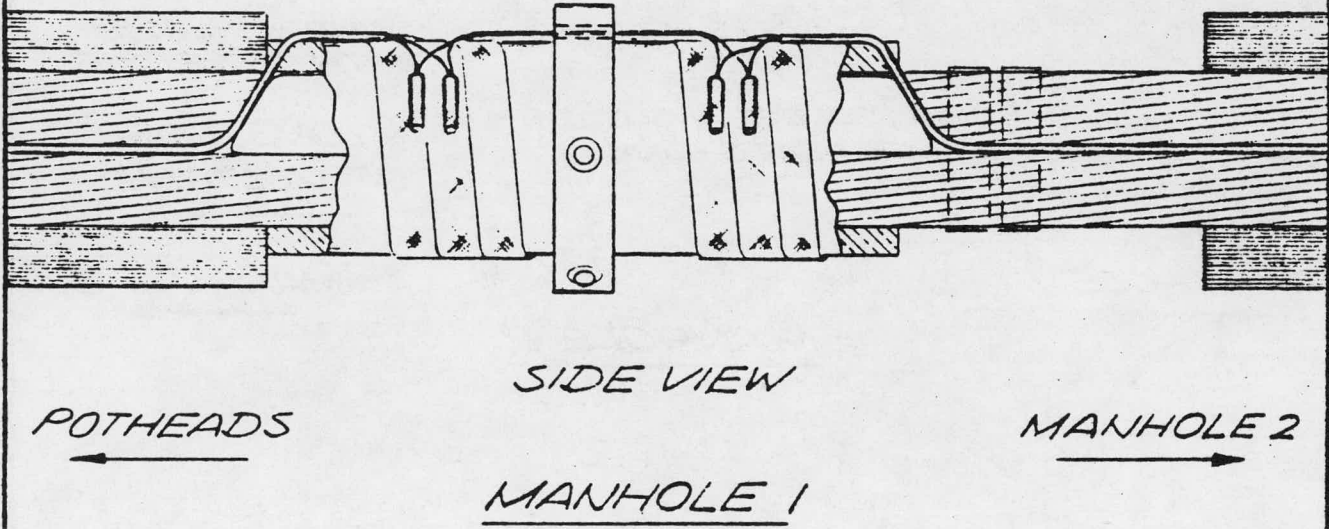
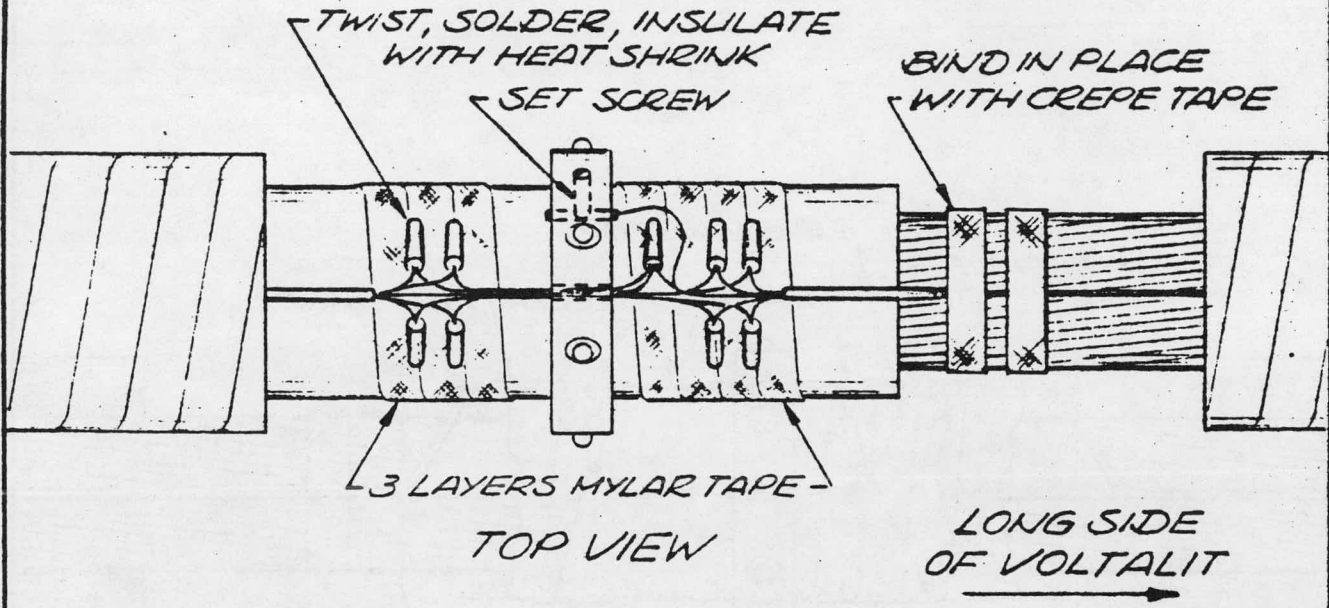
NOTE: ALL PHASES ARE IDENTICAL.

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

MANUFACTURING SCHEDULE - MANHOLE 1 - MANHOLE 2
 HAWTHORNE - HINCHMANS - 230 KV - P.S.E. & G WITH LSI
 TEMPERATURE SENSING CABLE



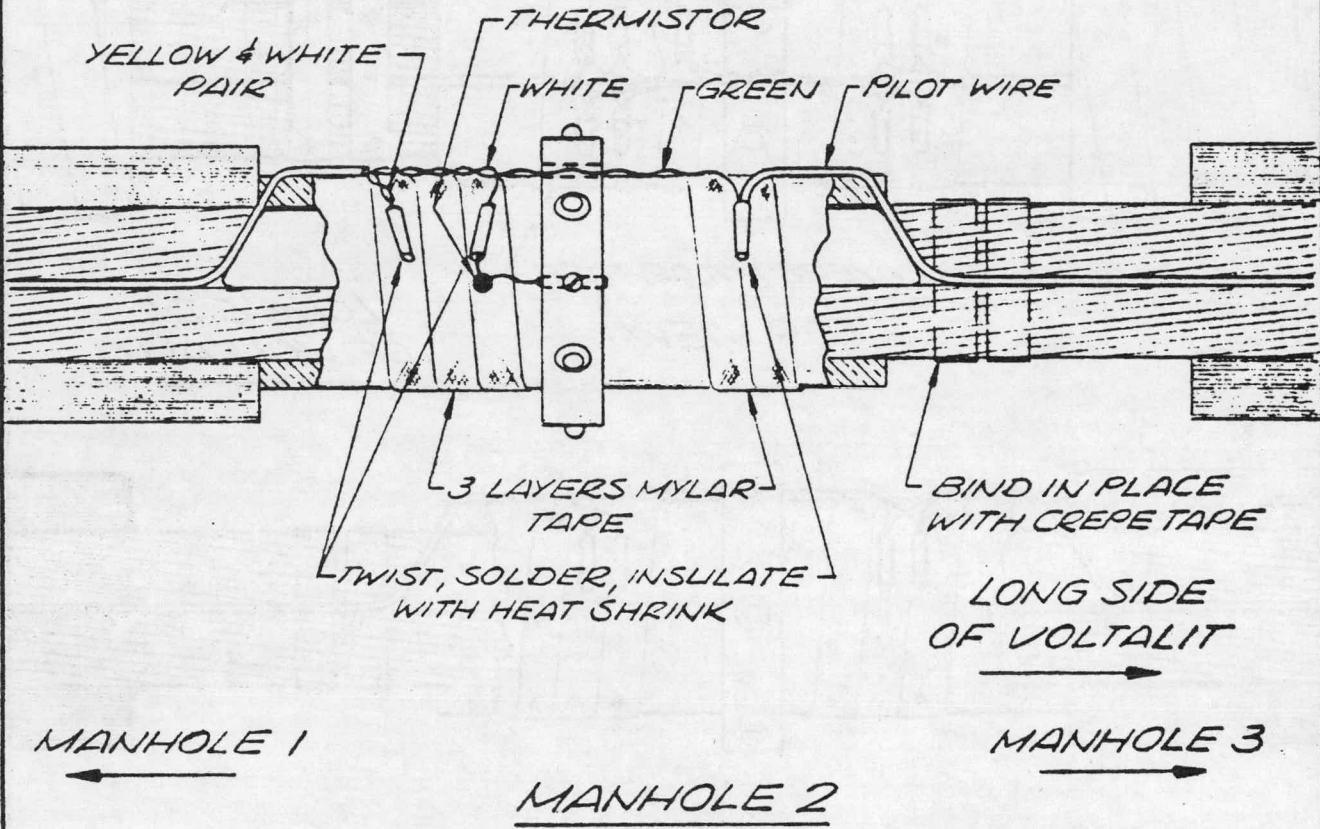
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LTR	DESCRIPTION	DATE	APPROVED




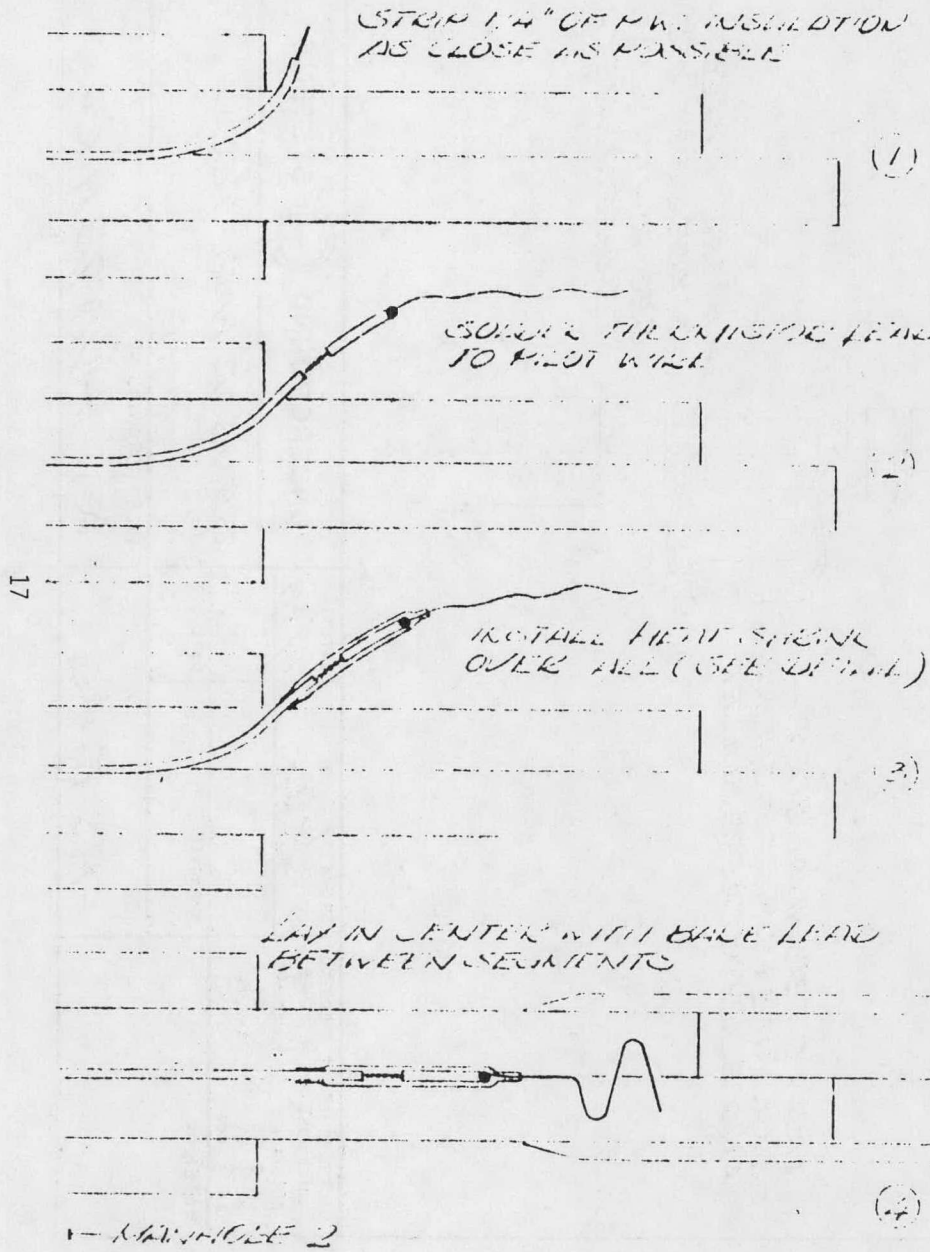
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS FRACTIONS .X ± .05 TOLS 1/64 .XX ± .01 ANGLES .XXX ± .005 0° 30'	DRAWN <i>J.H.</i>	DATE 11/78	UNDERGROUND SYSTEMS, INC.	
	CHECKED	DATE	SENSOR WIRE SPLICE VOLTALIT CONNECT. M.H. 1	
MATERIAL	APPROVED	DATE	SIZE A	DRAWING NO. HVA 781107
JOB P.S.E. & G				REV.

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED
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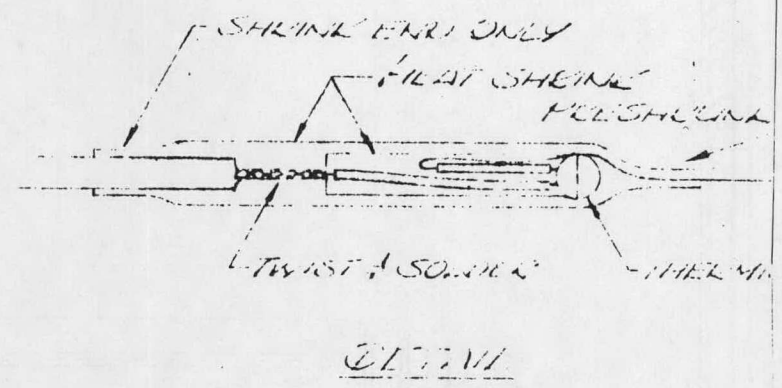


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS FRACTIONS .X ± .05 TOLS 1/64 .XX ± .01 ANGLES .XXX ± .005 0° 30'	DRAWN <i>J. H.</i>	DATE 11/78	UNDERGROUND  SYSTEMS, INC.	
MATERIAL	CHECKED	DATE	SENSOR WIRE SPLICE VOLTALIT CONNECT. M.H. 2	
	APPROVED	DATE	SIZE A	DRAWING NO. HVA 781108
NO. REQ'D	NEXT ASSY	SCALE	SHEET	OF
K&E CO 3397	16			



17

REVISIONS		
LTR	DESCRIPTION	DATE

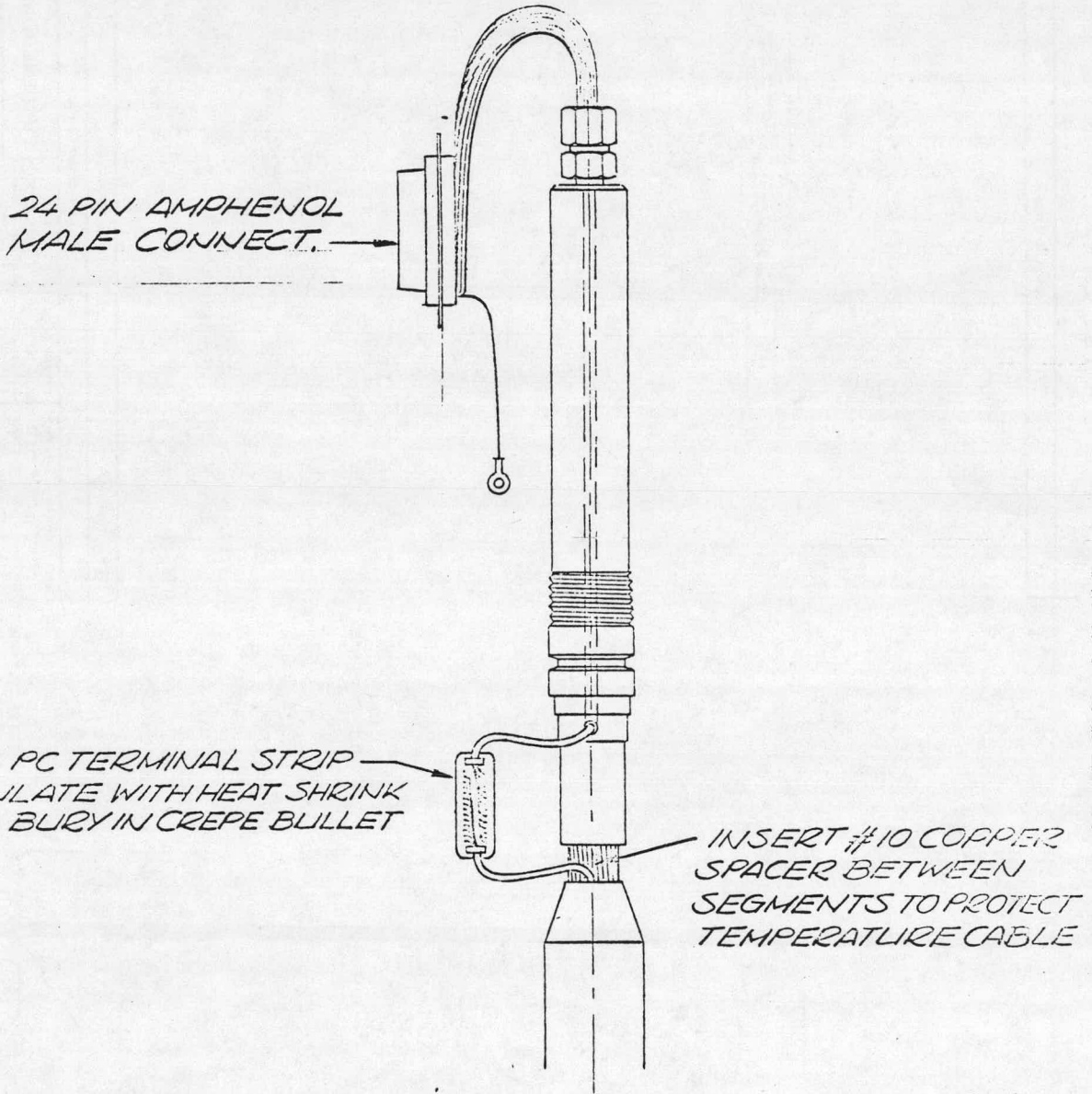


ITEM	REQ'D	DESCRIPTION	DWG.
LIST OF MATERIAL			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		DRAWN <i>[Signature]</i>	DATE 3/7/71
DECIMALS X 08	FRACTIONS 1/64	CHECKED	DATE
XX 01	TOLS ANGLES	APPROVED	DATE
XXX 005	0° 30'	JOB <i>[Signature]</i>	SIZE B
MATERIAL		NEAT ASSY	DRAWING NO. 1MB 1031R
NO REQ'D		SCALE	SHEET

UNDERGROUND SYSTEMS

THERMISTOR INSTALL
TEMP COMP. P.T. MANHOLE

LTR	DESCRIPTION	DATE	APPROVED
A	ADD. AMPH. CONNECT.	3/22/79	



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS .X ± .05 .XX ± .01 .XXX ± .005 FRACTIONS 1/64 ANGLES 0° 30'	DRAWN <i>K.H.</i>	DATE 11/78	UNDERGROUND SYSTEMS, INC.
	CHECKED	DATE	
MATERIAL	APPROVED	DATE	
JOB <i>P.S.E. & G</i>	SIZE A	DRAWING NO. <i>HVA 78 11 15</i>	REV. A

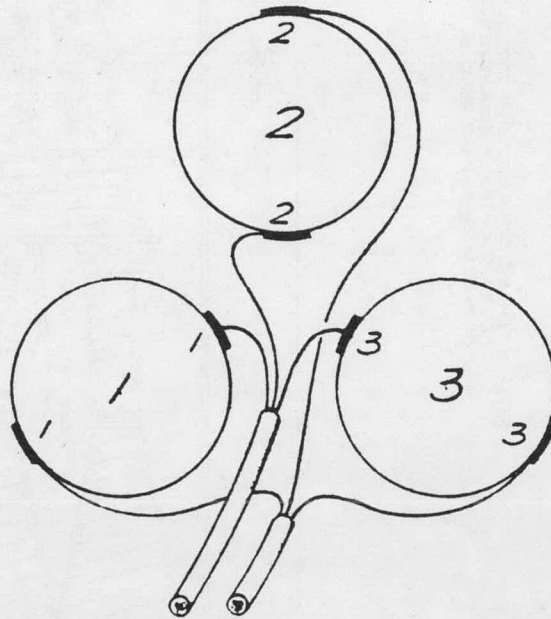
REVISIONS

LTR

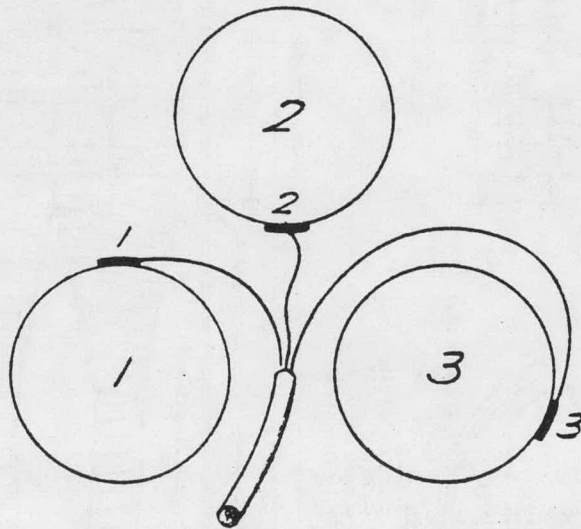
DESCRIPTION

DATE


APPROVED



T.C. PLACEMENT AT 90 FEET

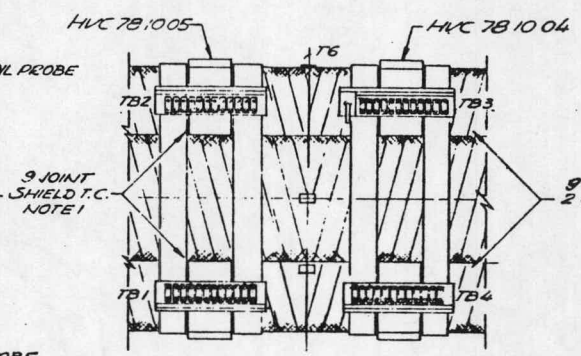
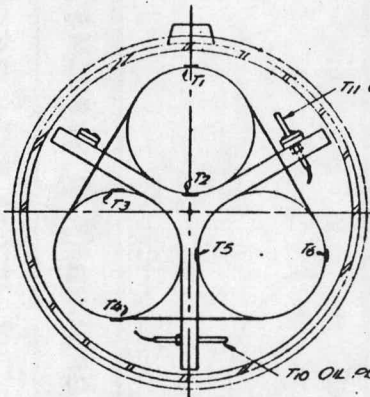


T.C. PLACEMENT AT 300 FEET

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	CHECKED	DATE	CABLE SHIELD T.C. LOCATIONS HAWTHORNE-HINCHMANS 230KV LINE	
MATERIAL	APPROVED	DATE	SIZE <i>A</i>	DRAWING NO. <i>HVA 781106</i>
	JOB <i>P.S.E. & G</i>	SCALE	SHEET	OF
NO. REQ'D	NEXT ASSY	NO. REV.	NO. REV.	NO. REV.

K&E CO 3397

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

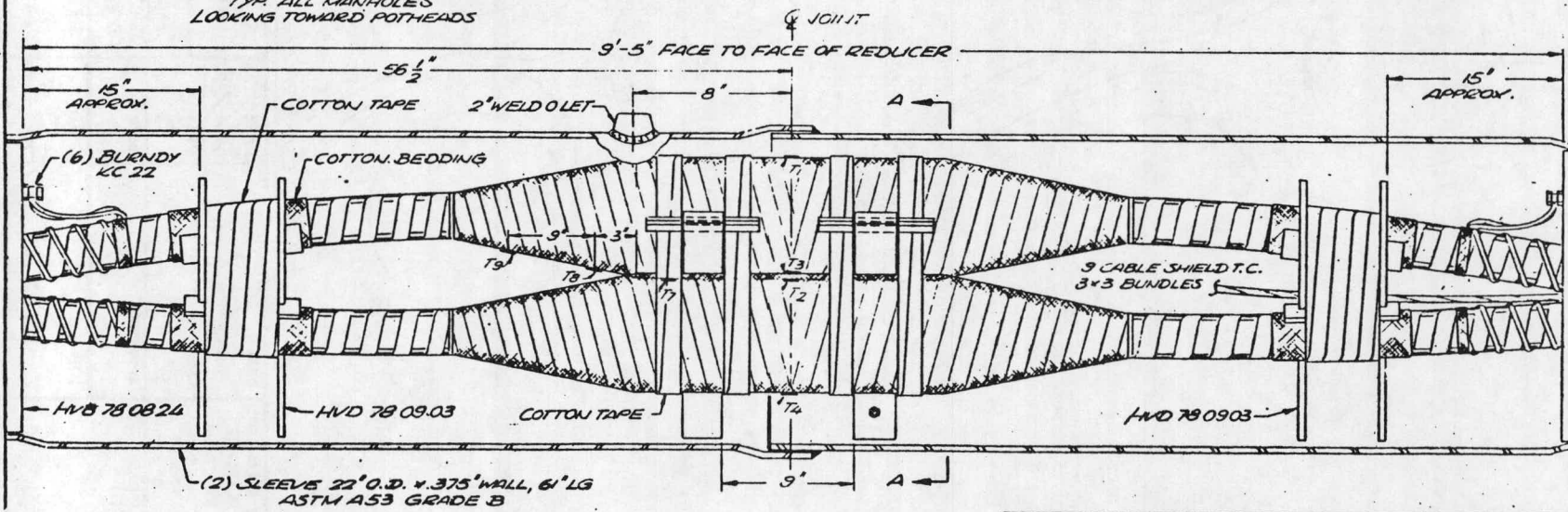


NOTES 1. FOR T.C. CONNECTIONS TO TERM. STEMS REF. CONNECTION DIAGRAM DWG HVB 78 10 18

SECTION A-A
JOINT SHIELD T.C. LOCATION
AT CENTERLINE
TYP. ALL MANHOLES
LOOKING TOWARD POTHEADS

TOP VIEW

20

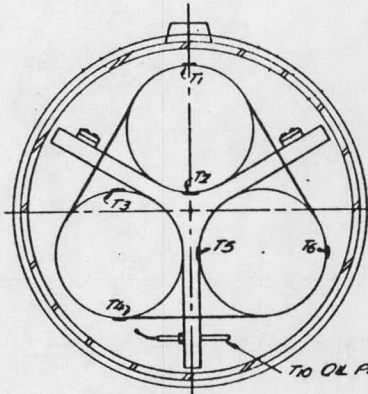


ITEM	REQ'D	DESCRIPTION	DWG NO.
LIST OF MATERIAL			
UNDERGROUND SYSTEMS, INC.			
INSTALLATION DWG			
VOLTALIT JOINT-MANHOLE 1			
JOB		SIZE	DRAWING NO.
P.S.E. #G		C	HVC 78 10 08
NO REQ'D	NEXT ASSY	SCALE	SHEET OF

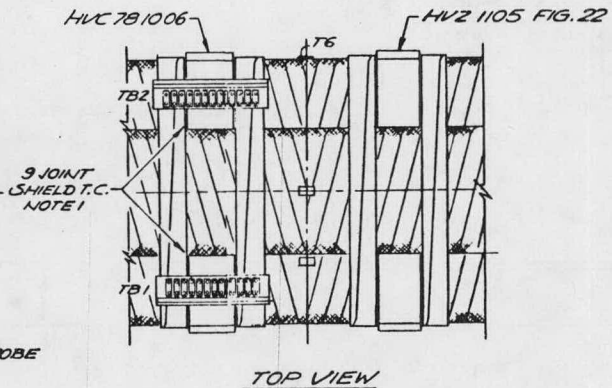
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS FRACTIONS
.125 ± .06 ± 1/64
.125 ± .01 ANGLES
.125 ± .006 ± 0° 30'

DRAWN: J.L. DATE: 10/79
CHECKED: DATE:
APPROVED: DATE:

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

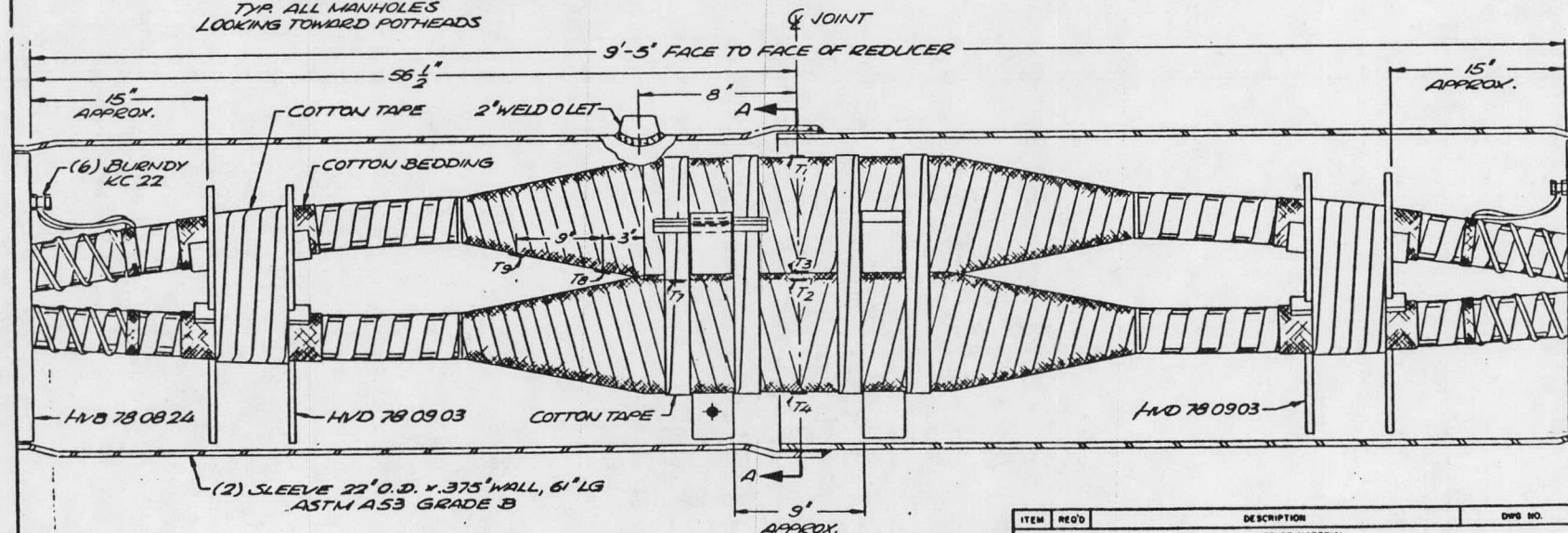


SECTION A-A
JOINT SHIELD T.C. LOCATION
AT CENTERLINE
TYP. ALL MANHOLES
LOOKING TOWARD POTHEADS



TOP VIEW

NOTES 1. FOR T.C. CONNECTIONS TO
TEAM STRIPAS REF CONNECTION
DIAGRAM DWG HVA 781019

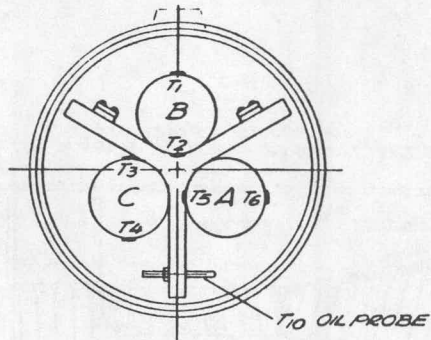


21

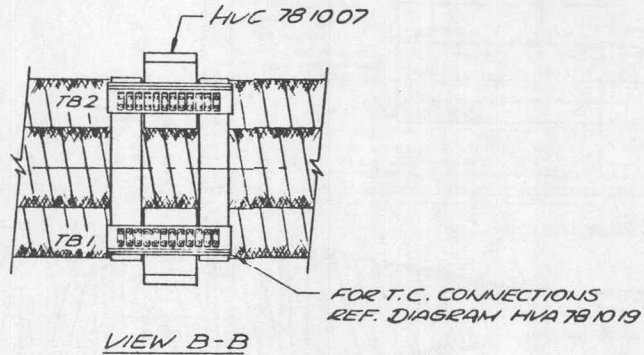
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS FRACTIONS
.X ± .05 ± 1/32
.XX ± .01 ± 1/64
.XXX ± .005 ± 0° 30'

ITEM	REQ'D	DESCRIPTION	DWG NO.
LIST OF MATERIAL			
DRAWN	K.H.	DATE 10/78	UNDERGROUND SYSTEMS, INC. INSTALLATION DWG VOLTALIT JOINT-MANHOLE 2
CHECKED		DATE	
APPROVED		DATE	
MATERIAL	P.S.E. #G	SIZE C	DRAWING NO. HVC 781111

D
T

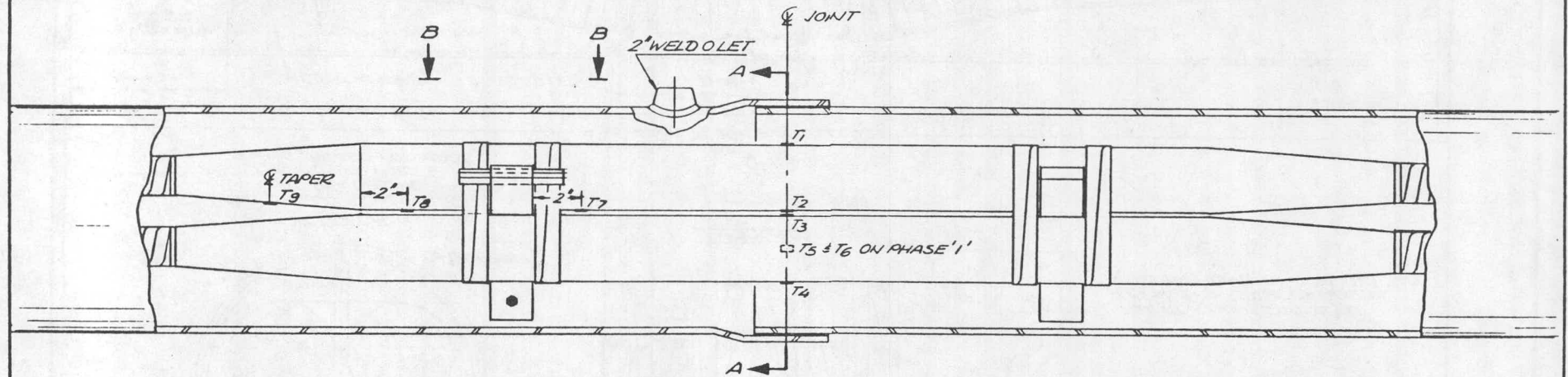


SECTION A-A
 JOINT SHIELD T.C. LOCATION
 AT CENTERLINE
 LOOKING TOWARD POTHEADS



FOR T.C. CONNECTIONS
 REF. DIAGRAM HVA 78 10 19

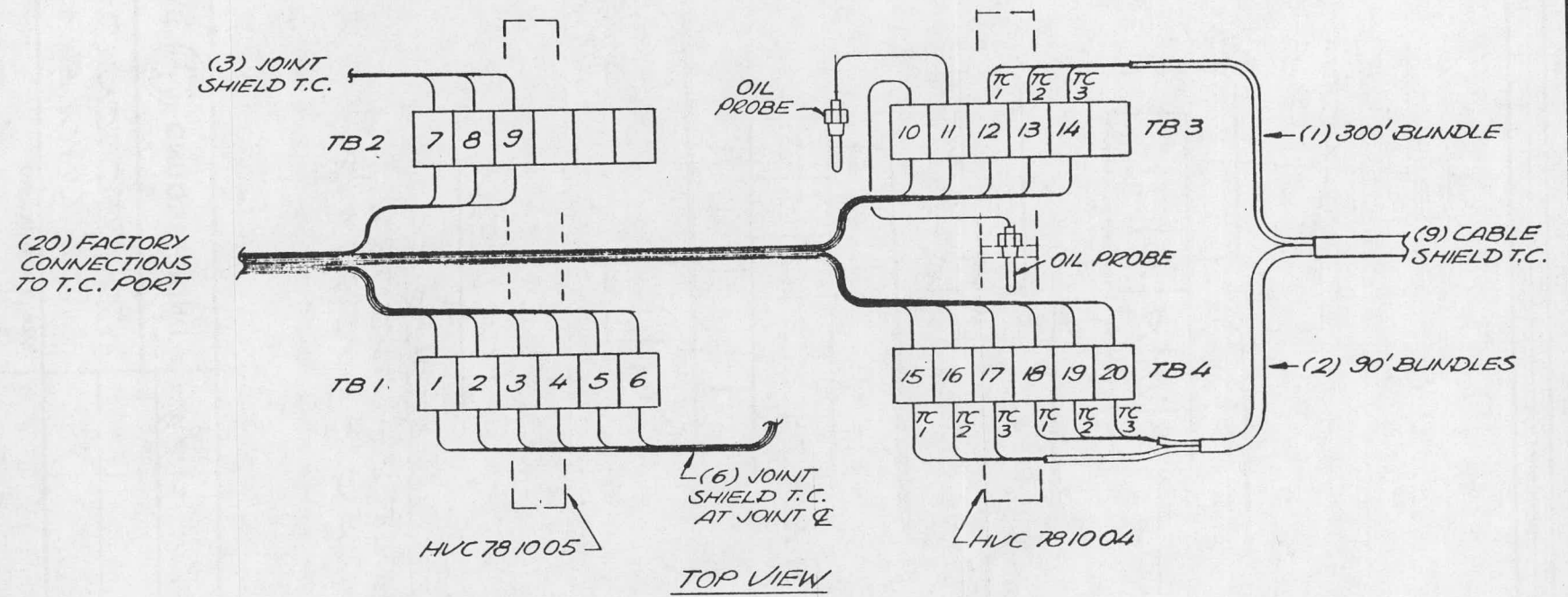
22



ITEM	REQ'D	DESCRIPTION	DWG NO.
LIST OF MATERIAL			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON DECIMALS FRACTIONS .X ± .05 ± 1/64 .XX ± .01 ± ANGLES .XXX ± .005 ± 0° 30'		DRAWN <i>F. L.</i> DATE 11/14/78 CHECKED DATE APPROVED DATE	UNDERGROUND SYSTEMS, INC. INSTALLATION DWG T & B JOINT-MANHOLE 3
MATERIAL	JOB	SIZE	DRAWING NO. REV
	<i>PSE & G</i>	<i>C</i>	<i>HVC 78 11 12</i>

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED
A	ADD. TC NO'S	3/15/79	



TOP VIEW

NOTE: FOR JOINT SHIELD T.C. LOCATIONS
REF. DWG HVC 78 10 08

23

ITEM	REQ'D	DESCRIPTION	DWG NO.
LIST OF MATERIAL			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		DRAWN <i>J.H.</i>	DATE <i>10/20/78</i>
DECIMALS X ± .08	FRACTIONS 1/64	CHECKED	DATE
.XX ± .01	TOLS ANGLES	APPROVED	DATE
.XXX ± .008	0° 30'	JOB <i>P.S.E & G</i>	SIZE B
MATERIAL		DRAWING NO. <i>HVB 78 10 18</i>	REV. A
NO REQ'D	NEXT ASSY	SCALE	SHEET OF

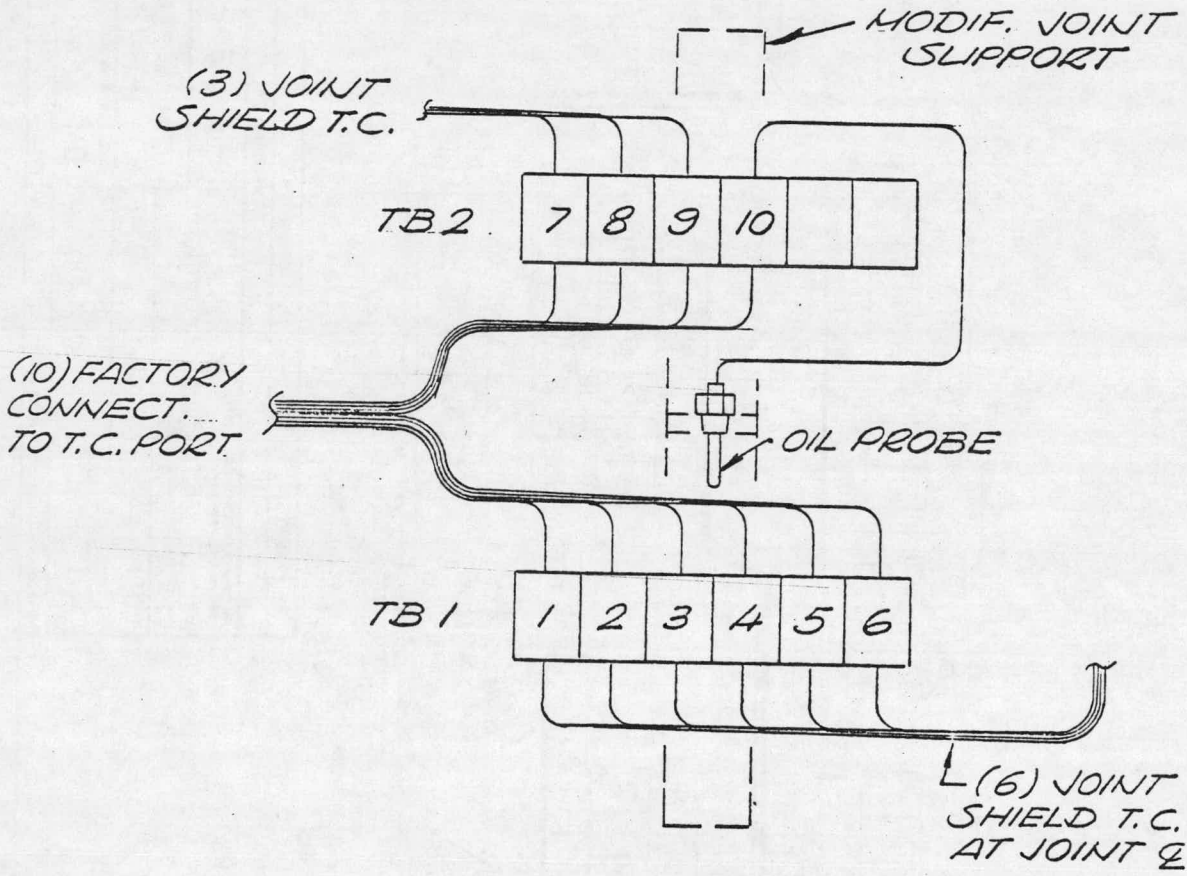
UNDERGROUND SYSTEMS, INC.
**CONNECTION DIAGRAM
MANHOLE 1**

LTR

DESCRIPTION


DATE

APPROVED

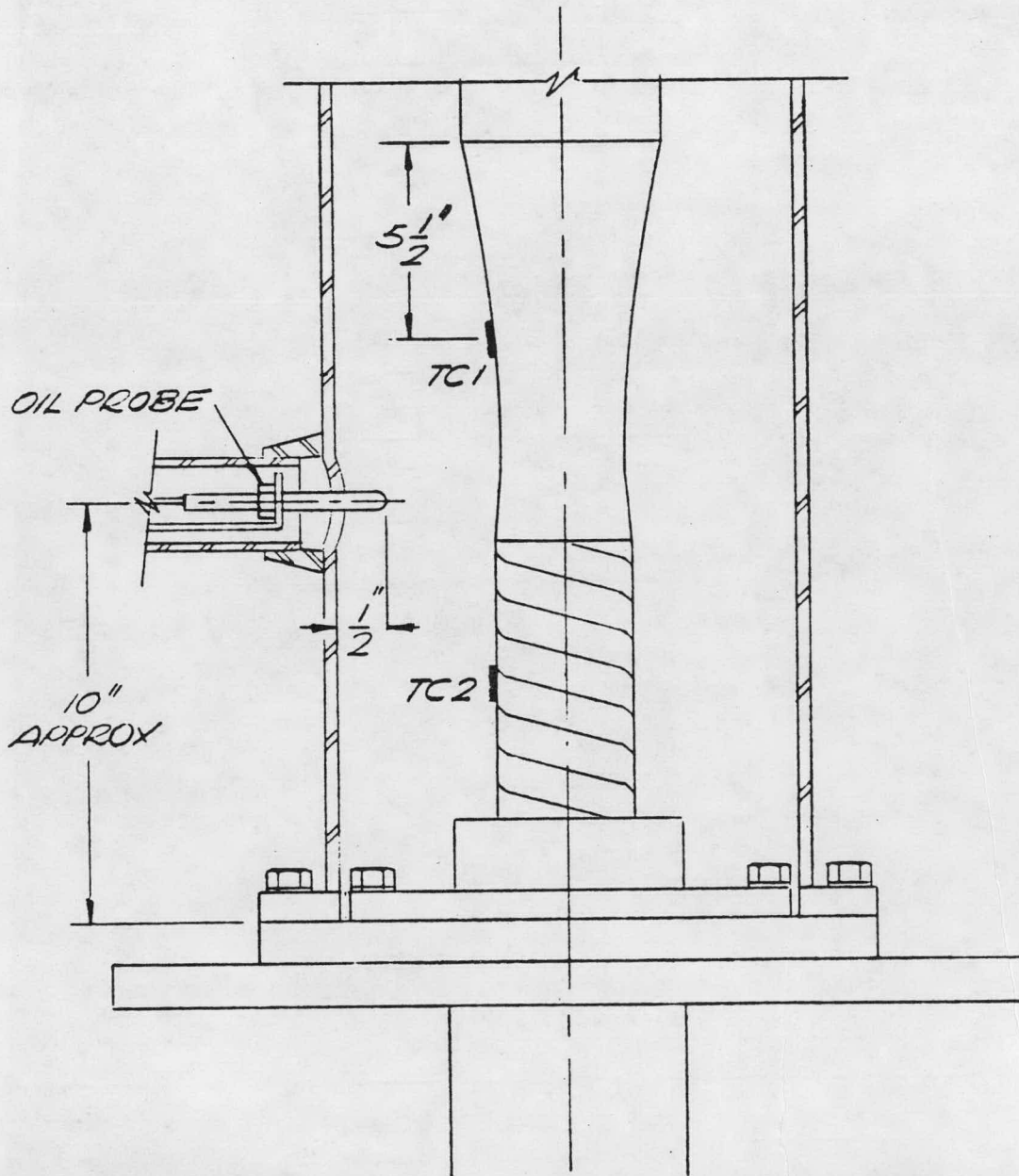



TOP VIEW

NOTE: FOR T.C. LOCATION REF.
 MANHOLE 2 - HVC 78 11 11
 MANHOLE 3 - HVC 78 11 12

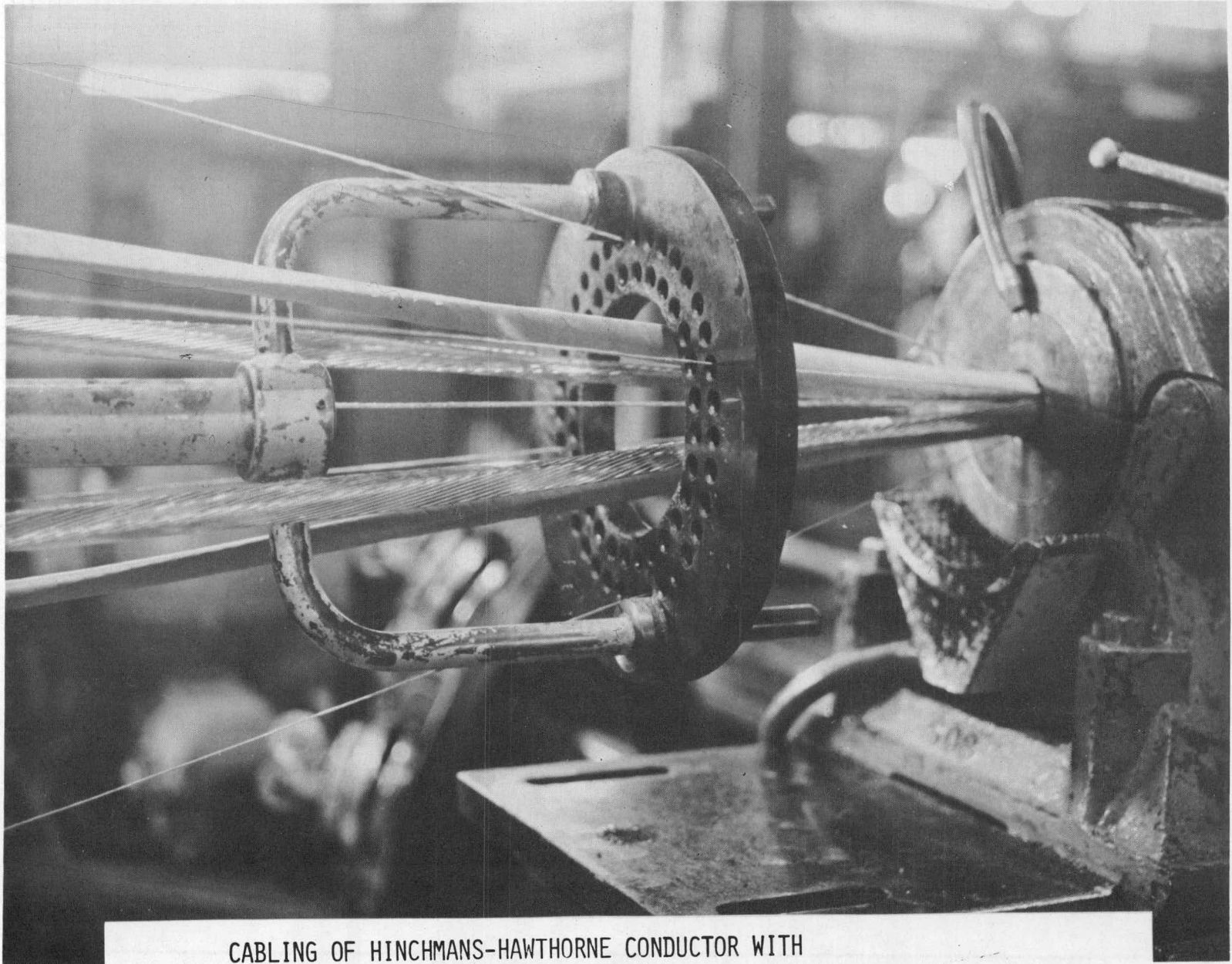
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS FRACTIONS .X ± .05 TOLS 1/64 .XX ± .01 ANGLES .XXX ± .005 0° 30'	DRAWN <i>J.H.</i> DATE <i>10/20/78</i>	UNDERGROUND  SYSTEMS, INC.			
	CHECKED			DATE	
	APPROVED	DATE	CONNECTION DIAGRAM MANHOLE 2 & 3		
	JOB <i>P.S.E. & G.</i>	SIZE <i>A</i>			DRAWING NO. <i>HVA 78 10 19</i>
MATERIAL	NO. REQ'D	NEXT ASSY	SCALE	SHEET	OF

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS FRACTIONS .X ± .05 TOLS 1/64 .XX ± .01 ANGLES .XXX ± .005 0° 30'	DRAWN <i>[Signature]</i>	DATE 3/79	UNDERGROUND  SYSTEMS, INC.	
	CHECKED	DATE	T.C. LOCATION - P.H. SPOOL PIECE HINCHMANS AVE POTHEADS	
MATERIAL	APPROVED	DATE	SIZE	REV.
	JOB P.S.E & G		A	HVA 790320

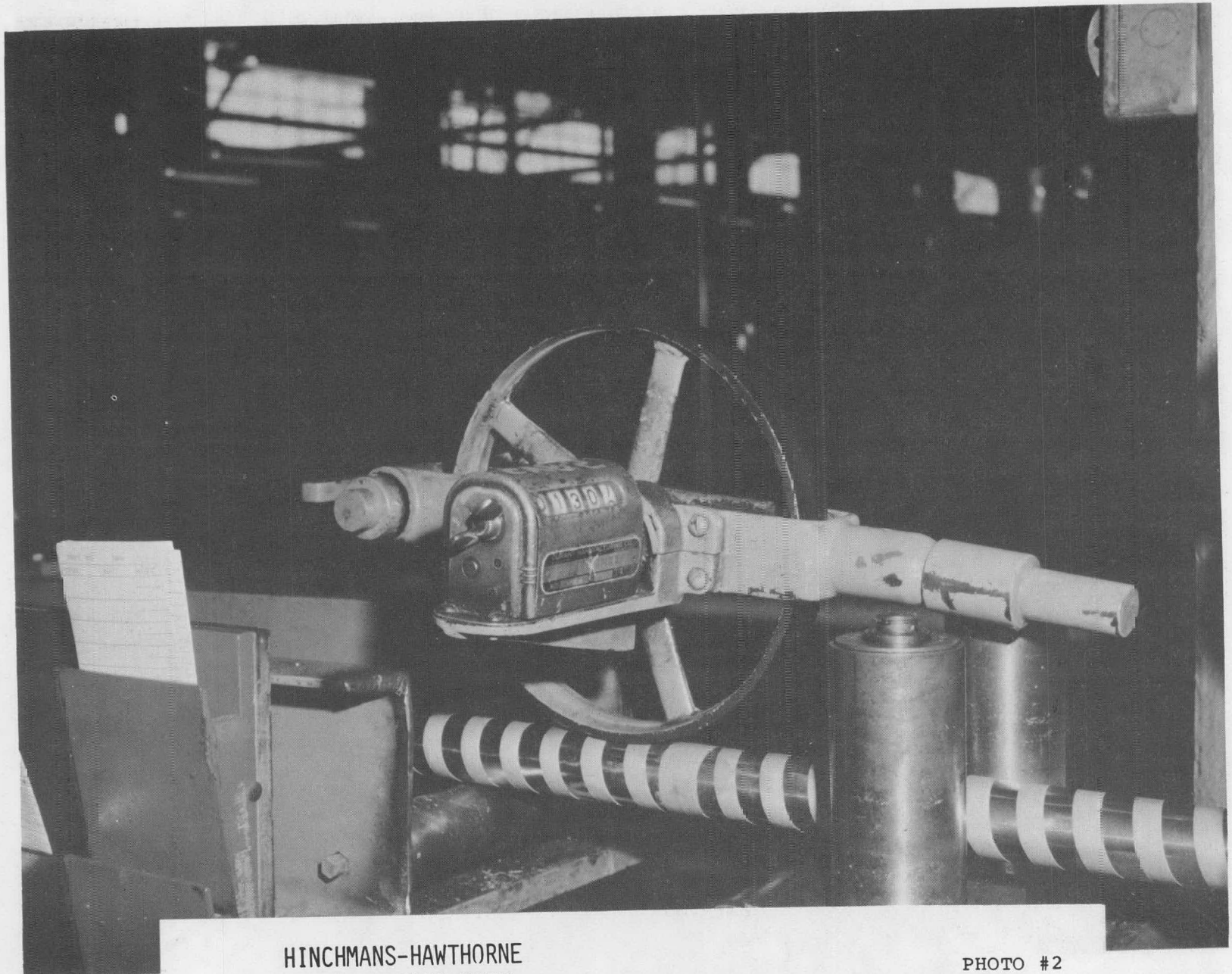
25a



CABLING OF HINCHMANS-HAWTHORNE CONDUCTOR WITH
TEMPERATURE MONITORING WIRE

PHOTO #1

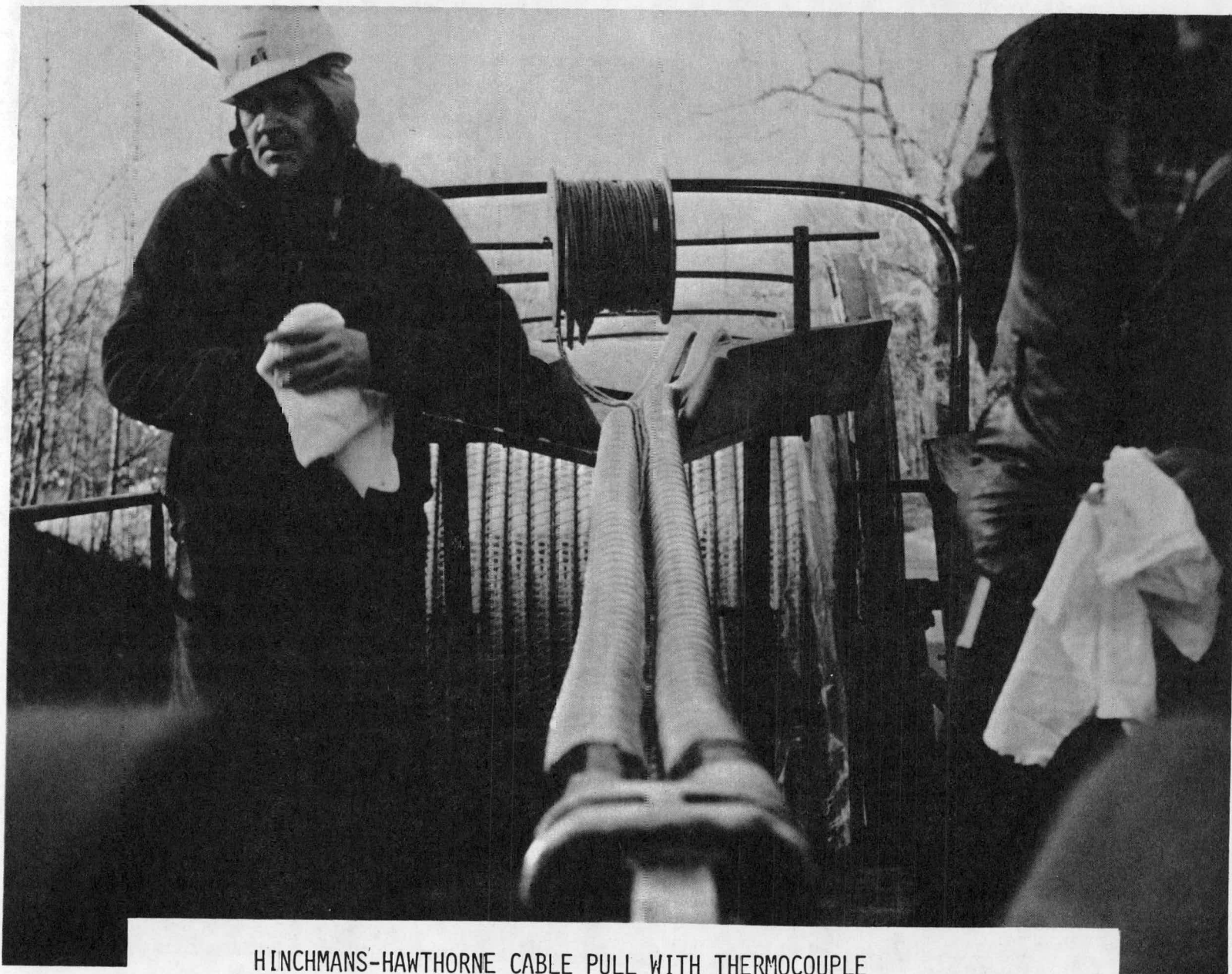
25b



HINCHMANS-HAWTHORNE
CABLE CUTTING MARK

PHOTO #2

25c



HINCHMANS-HAWTHORNE CABLE PULL WITH THERMOCOUPLE
BUNDLE WIRE

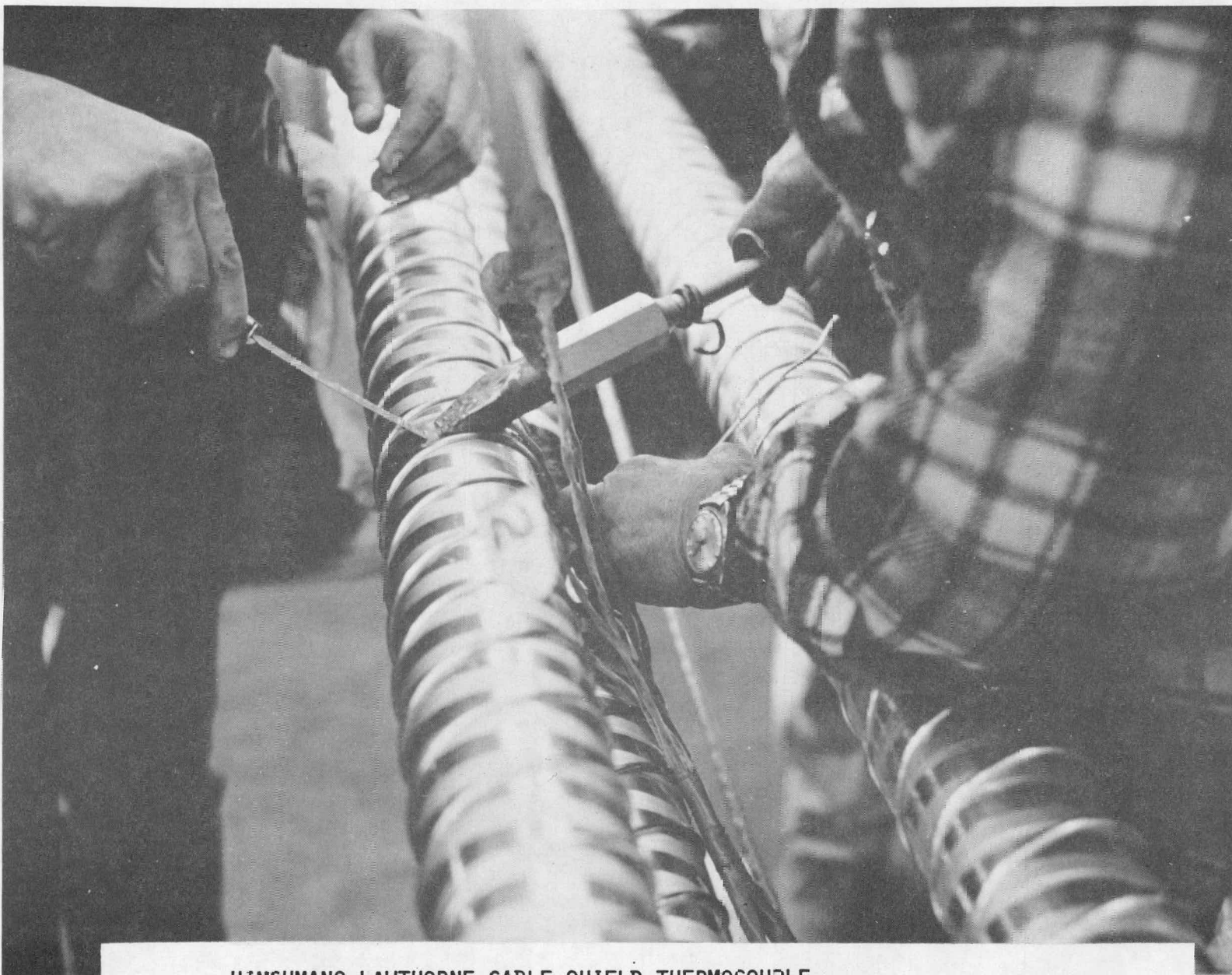
PHOTO #3

25d



HINCHMANS-HAWTHORNE
CABLE PULLING SET-UP

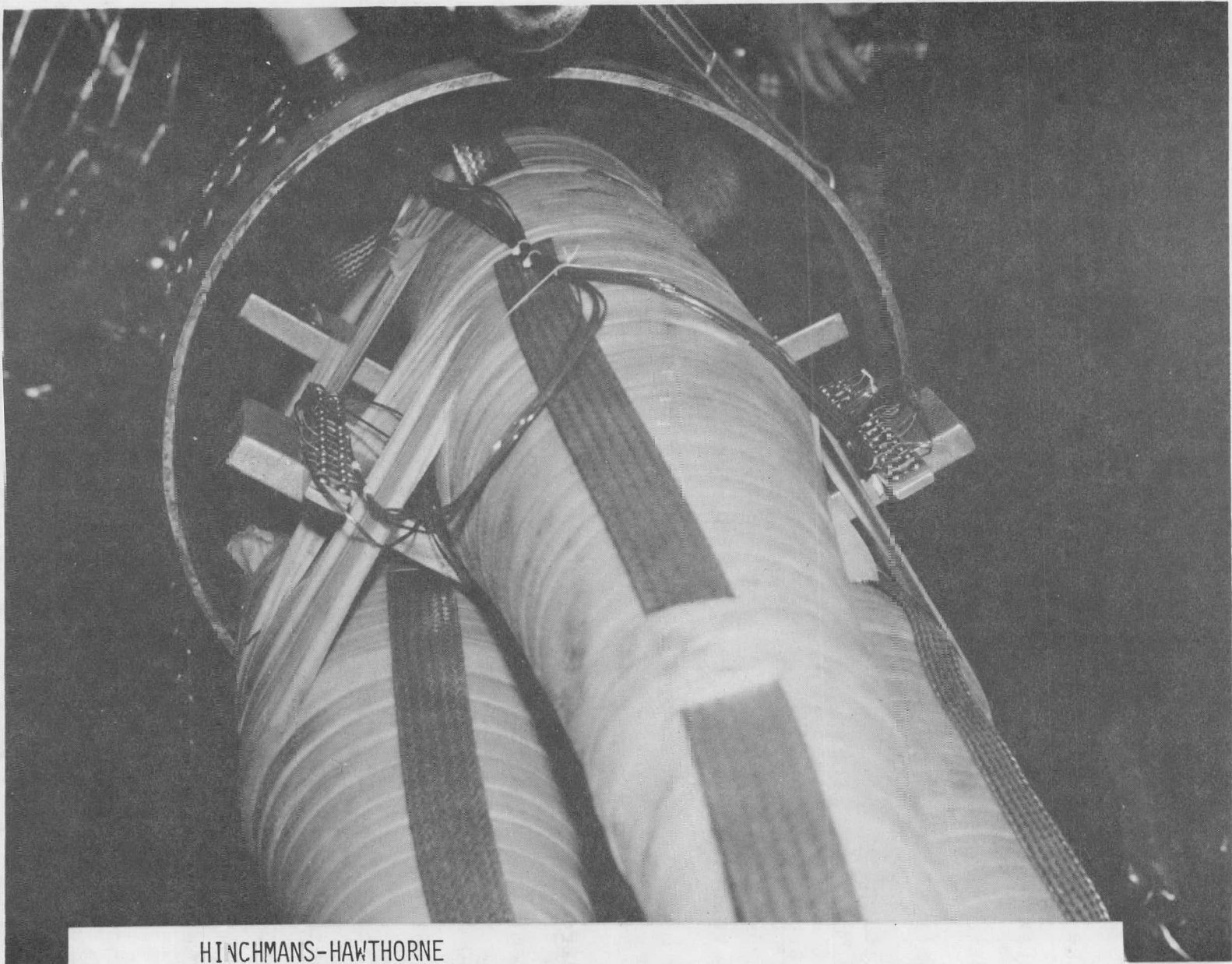
PHOTO #4



HINCHMANS-FAWTHORNE CABLE SHIELD THERMOCOUPLE
PLACEMENT AT 106 FT. POINT

PHOTO #5

25f



HINCHMANS-HAWTHORNE
VO_TALIT SPLICE - MANHOLE #2

PHOTO #6

DATA ACQUISITION SYSTEM INSTALLATION AND COMMUNICATION CIRCUIT PROVISIONS

Description

The following section is a technical description and the construction status of the data acquisition system. This system provides up-to-date cable cross section temperatures, cable loading and weather data to the CMARS system. The various elements of the data acquisition system, shown on Figure A, are described as follows:

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 their close proximity of these circuits to high voltage cables. These surges are capable of damaging thermocouple transmitters which are directly connected to the 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, burnout protection and input/output isolation (600 volts). The thermocouple transmitters selected

for CMARS were 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 4-20MA. A total of 100 thermocouple transmitters and surge arresters are being installed for CMARS.

Remote Terminal Unit

Remote terminal units (RTU's) collect all conditioned signals and transmit 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 the microcomputer, the analog signals are transformed to a parallel digital format by an A/D converter. A U/ART (universal asynchronous receiver transmitter) performs a parallel serial conversion and the messages are then transmitted asynchronously at a rate of 1200 bits per second. A nine bit format is used consisting of 1 start bit, 6 data bits, 1 parity bit and 1 stop bit. The RTU contains an integral FSK modem for data communication. Security for transmitted data is assured by word and longitudinal parity checks.

Telephone Circuit

Arrangements have been made with New Jersey Bell to lease a dedicated full duplex channel.

Status

Most of the equipment for the data acquisition system is on site and construction is progressing as follows:

Hinchmans Avenue

Two thermocouple transmitter cabinets and two RTU cabinets have been installed near the cable pothead and wiring is in progress.

All yard trenching and cabling is complete with the exception of the AC power supply cable. This cable is available and will be installed shortly.

The control house equipment (RTU, thermocouple transmitters and current and potential transducers) has been installed and wiring is in progress. Special weather sensors have been installed on the roof and their wiring is also in progress.

Wiring of the thermocouple circuits in Manhole No. 1 is complete.

Waldwick

All material with the exception of the internals of the RTU's, is on site. Trenching is in progress.

South Mahwah

All materials, with the exception of the internals of the RTU's is on site. Construction will start in the near future.

Computer Graphic System

The wiring diagrams used for the installation of the data acquisition system were created on PSE&G's computer graphic system. Use of this system lowered the drafting labor requirements from 240 mandays to 80 mandays. Enclosed are reduced copies of the Hinchmans Avenue Substation layout and wiring diagrams, Public Service drawings 247475, 76, 77, 78, 79 and 80.

CMARS HARDWARE CONFIGURATION

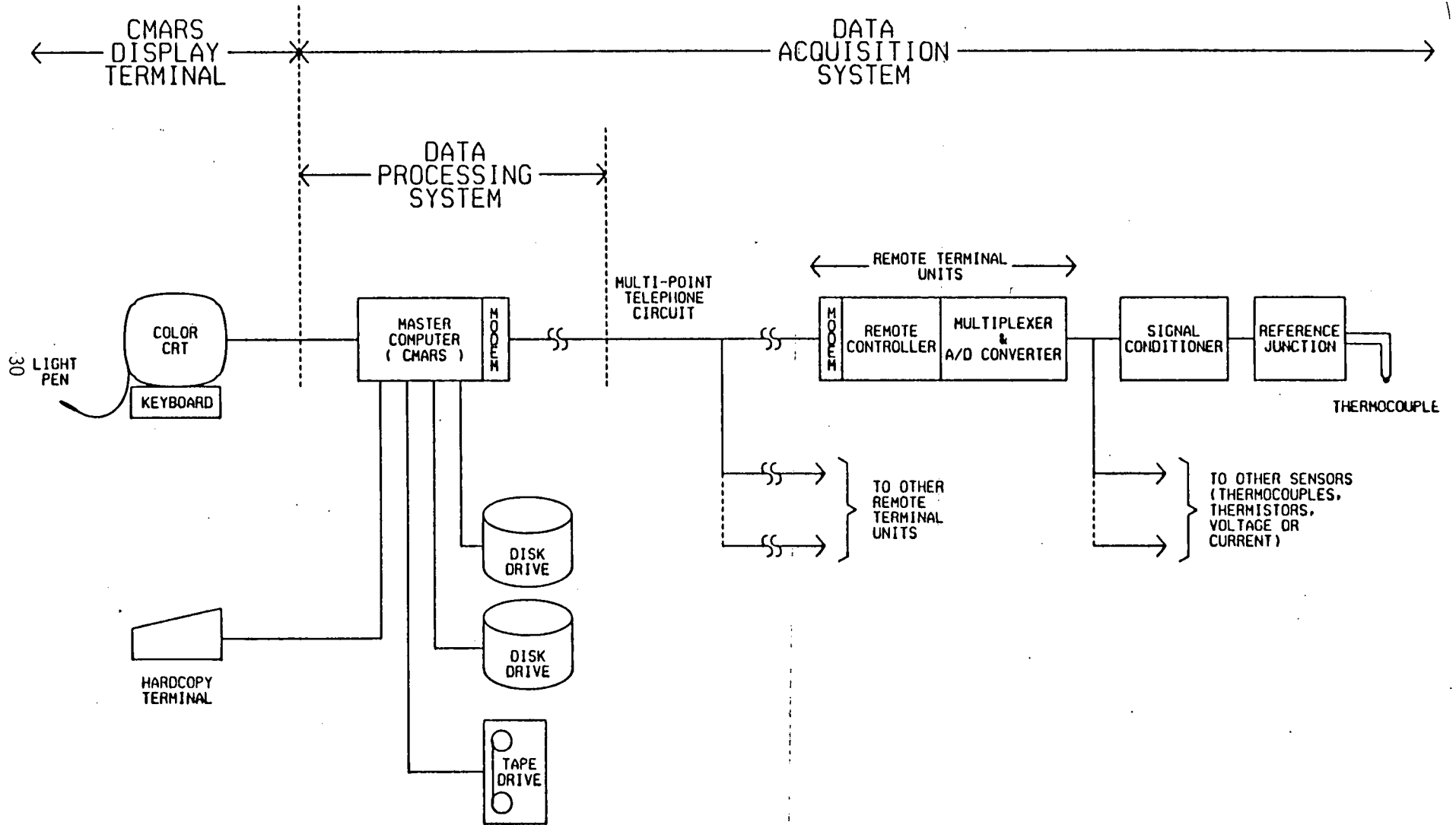
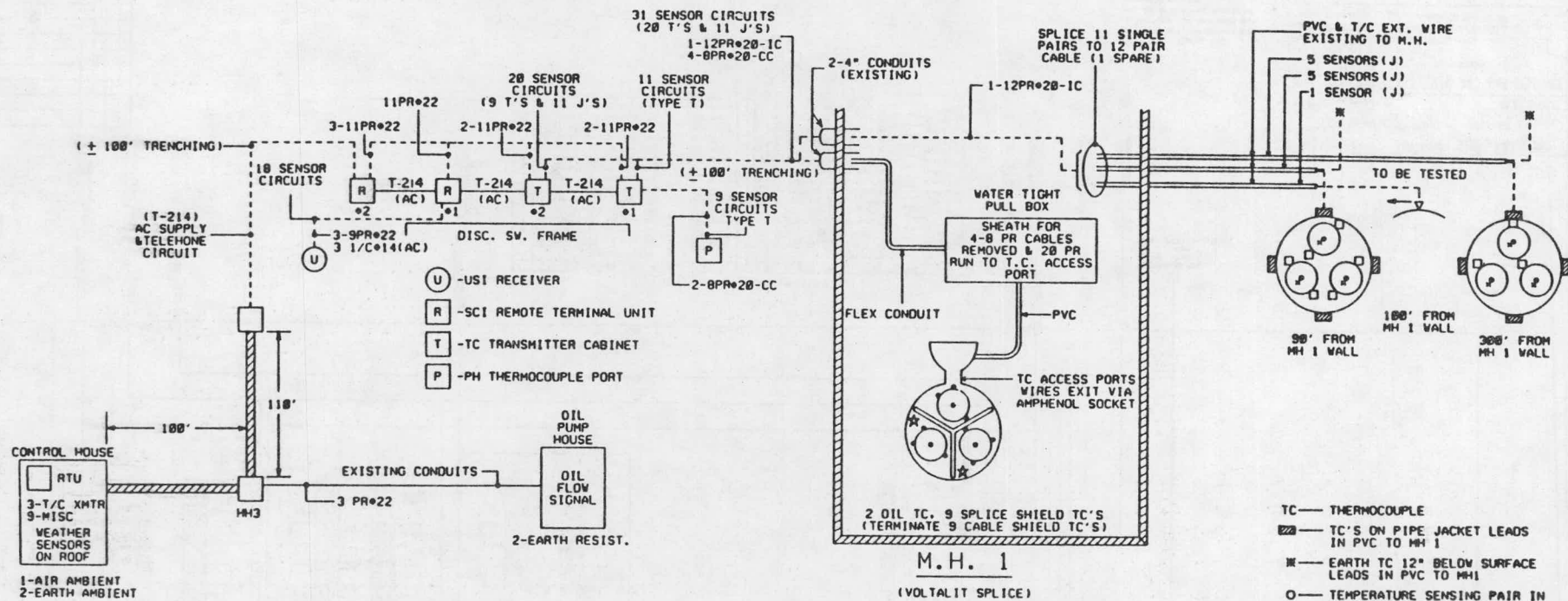


FIGURE 4

31



- U - USI RECEIVER
- R - SCI REMOTE TERMINAL UNIT
- T - TC TRANSMITTER CABINET
- P - PH THERMOCOUPLE PORT

- TC - THERMOCOUPLE
- ▨ - TC'S ON PIPE JACKET LEADS IN PVC TO MH 1
- ⊞ - EARTH TC 12" BELOW SURFACE LEADS IN PVC TO MH1
- - TEMPERATURE SENSING PAIR IN CONDUCTOR CORE BETWEEN MH 1 & MH 2 LEADS TO TM DEVICES ON PH'S
- - CABLE SHIELD TC'S LEADS TO MH 1 TM PORT
- ✕ - THERMISTOR IN CONDUCTOR CORE LEADS TO TM DEVICES ON PH'S
- ▽ - TC ON PIPE SURFACE LEADS TO MH 1
- ★ - OIL TC LEADS TO TM PORT
- - SPLICE SHIELD TC'S LEADS TO TM PORT ON SLEEVE

REFERENCE DRAWINGS:

REMOTE TERMINAL UNIT NO.1	WD DWG#247476-B-9742
REMOTE TERMINAL UNIT NO.2	WD DWG#247477-B-9742
REMOTE TERMINAL UNIT NO.3	WD DWG#247478-B-9742
T/C TRANSMITTER CABINETS	WD DWG#247479-B-9742
POTHEAD AND MANHOLE#1	WD DWG#247480-B-9742

NO	DATE	DESCRIPTION	BY	CHK	APP
REVISION					

GENERAL NOTES
 USE PRINTS OF LATEST REVISION ONLY.
 DO NOT SCALE - USE DIMENSIONS ONLY.
 FOR LIST OF REFERENCE DRAWINGS SEE DRAWING NO. 3118.020.
 THIS DRAWING SUPERSEDES NONE.....
 THIS DRAWING IS SHEET NO. 1. OF 1. SHEETS.

HINCHMANS AVENUE SUBSTATION
 CABLE MONITORING AND RATING SYSTEM

DIAGRAM ELECTRICAL

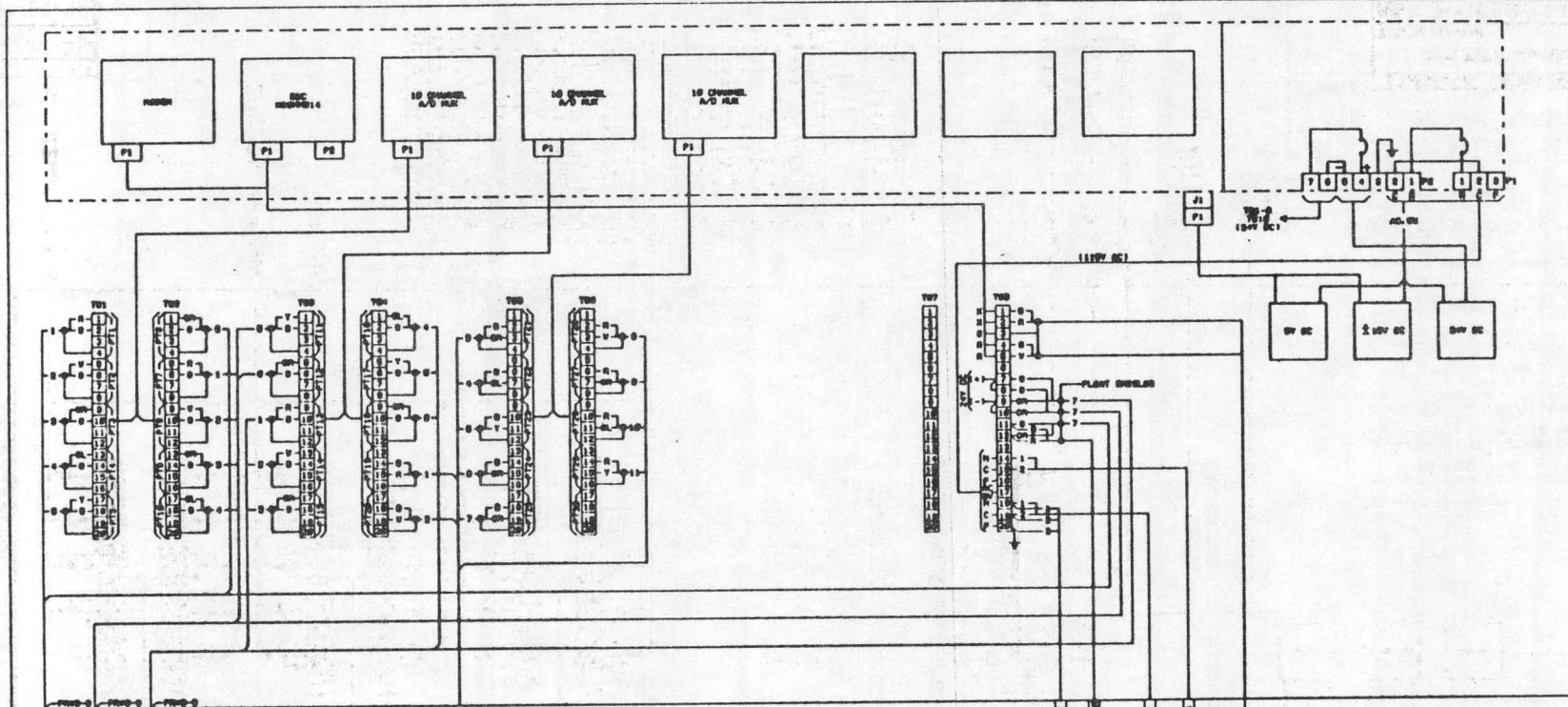
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
 ENGINEERING DEPARTMENT
 NEWARK, N. J. 07102

DRAWN *W. J. J.* CHECKED *S. J. J.* SCALE *1" = 100'*
 DATE *5/11/77* EXAMINED *J. J. J.*
 AUTH. *SCJ* APPROVED *W. J. J.*

247475

247476

REMOTE TERMINAL UNIT NO. 1



RTU POINT DESCRIPTIONS

RTU ANALOG INPUT POINTS			RTU ANALOG INPUT POINTS		
NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	CONDUCTOR AVERAGE PHS	16	CONDUCTOR 300 #441 PHS	31	CONDUCTOR 300 #441 PHS
2	CONDUCTOR 80 #441 PHS	17	CONDUCTOR 300 #441 PHS	32	CONDUCTOR 300 #441 PHS
3	CONDUCTOR 300 #441 PHS	18	CONDUCTOR 300 #441 PHS	33	CONDUCTOR 300 #441 PHS
4	CONDUCTOR 300 #441 PHS	19	CONDUCTOR 300 #441 PHS	34	CONDUCTOR 300 #441 PHS
5	CONDUCTOR 300 #441 PHS	20	CONDUCTOR 300 #441 PHS	35	CONDUCTOR 300 #441 PHS
6	CONDUCTOR 300 #441 PHS	21	CONDUCTOR 300 #441 PHS	36	CONDUCTOR 300 #441 PHS
7	CONDUCTOR 300 #441 PHS	22	CONDUCTOR 300 #441 PHS	37	CONDUCTOR 300 #441 PHS
8	CONDUCTOR 300 #441 PHS	23	CONDUCTOR 300 #441 PHS	38	CONDUCTOR 300 #441 PHS
9	CONDUCTOR 300 #441 PHS	24	CONDUCTOR 300 #441 PHS	39	CONDUCTOR 300 #441 PHS
10	CONDUCTOR 300 #441 PHS	25	CONDUCTOR 300 #441 PHS	40	CONDUCTOR 300 #441 PHS
11	CONDUCTOR 300 #441 PHS	26	CONDUCTOR 300 #441 PHS	41	CONDUCTOR 300 #441 PHS
12	CONDUCTOR 300 #441 PHS	27	CONDUCTOR 300 #441 PHS	42	CONDUCTOR 300 #441 PHS
13	CONDUCTOR 300 #441 PHS	28	CONDUCTOR 300 #441 PHS	43	CONDUCTOR 300 #441 PHS
14	CONDUCTOR 300 #441 PHS	29	CONDUCTOR 300 #441 PHS	44	CONDUCTOR 300 #441 PHS
15	CONDUCTOR 300 #441 PHS	30	CONDUCTOR 300 #441 PHS	45	CONDUCTOR 300 #441 PHS

32

NO.	REVISION
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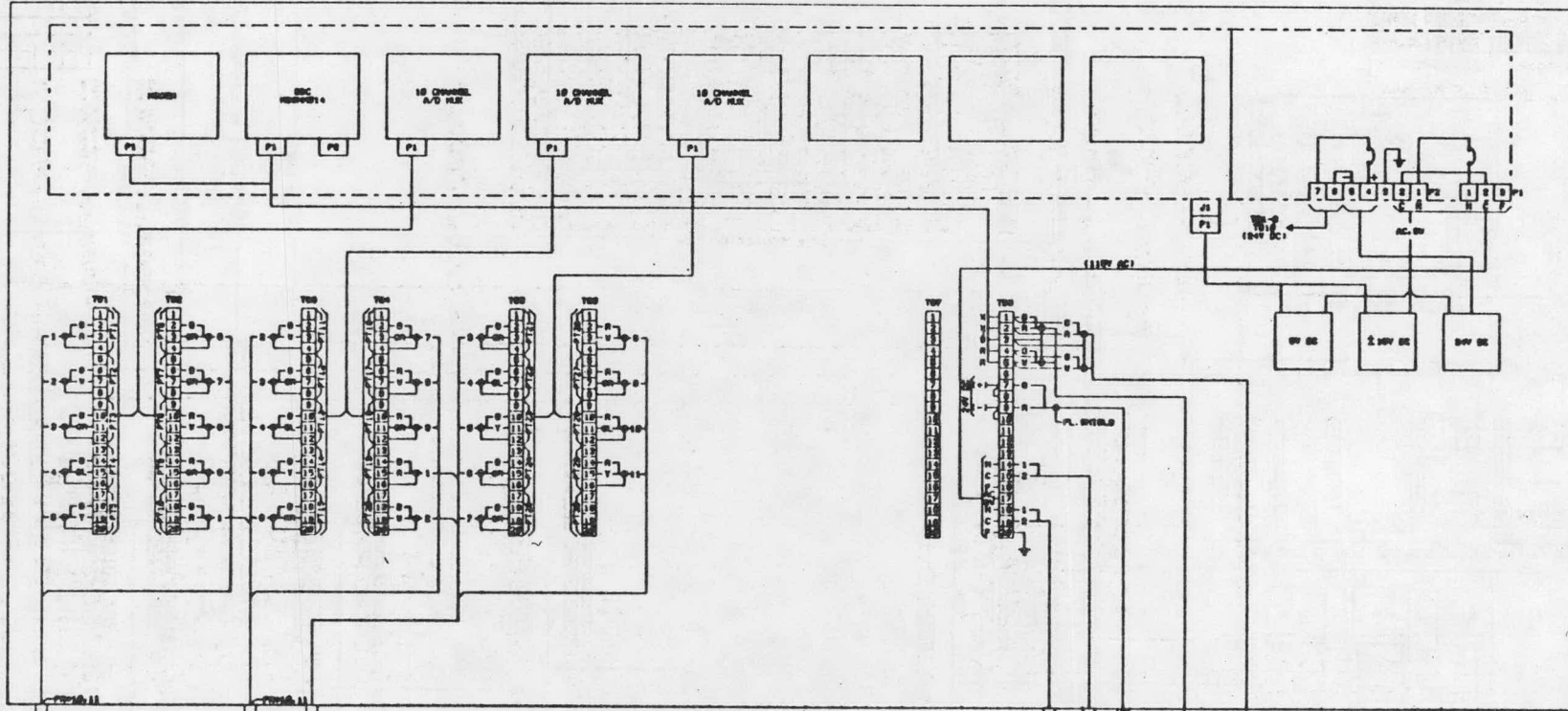
HINCHMANS AVENUE SUBSTATION
 CHMRS REMOTE TERMINAL UNIT NO. 1
 WIRING DIAGRAM ELECTRICAL
 PUBLIC SERVICE ELECTRIC AND GAS COMPANY
 ENGINEERING DEPARTMENT
 NEWARK, N. J.

DESIGNED BY: [Signature]
 CHECKED BY: [Signature]
 DATE: 3-18-73
 DRAWN BY: [Signature]
 APPROVED BY: [Signature]

247476

247477

REMOTE TERMINAL UNIT NO.2



33

RTU POINT DESCRIPTIONS

RTU ANALOG INPUT POINTS (CONTINUED)			RTU ANALOG INPUT POINTS (CONTINUED)		
NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
1	HQ CBL SH 80' #41 11 P42	16	HQ CBL SH 80' #41 11 P42	16	HQ CBL SH 80' #41 11 P42
2	HQ CBL SH 80' #41 12 P42	17	HQ CBL SH 80' #41 11 P41	17	HQ CBL SH 80' #41 11 P41
3	HQ CBL SH 80' #41 13 P42	18	HQ CBL SH 80' #41 12 P42	18	HQ CBL SH 80' #41 12 P42
4	HQ CBL SH 80' #41 14 P42	19	HQ PIPE SURFACE 100' #41	19	HQ PIPE SURFACE 100' #41
5	HQ CBL SH 80' #41 15 P41	20	HQ PIPE JACKET 12 80' #41	20	HQ PIPE JACKET 12 80' #41
6	HQ CBL SH 80' #41 16 P41	21	HQ PIPE JACKET 13 80' #41	21	HQ PIPE JACKET 13 80' #41
7	HQ CBL SH 80' #41 17 P42	22	HQ PIPE JACKET 14 80' #41	22	HQ PIPE JACKET 14 80' #41
8	HQ CBL SH 80' #41 18 P42	23	HQ PIPE JACKET 15 80' #41	23	HQ PIPE JACKET 15 80' #41
9	HQ CBL SH 80' #41 19 P42	24	HQ EARTH AMBIENT 80' #41	24	HQ EARTH AMBIENT 80' #41
10	HQ CBL SH 80' #41 20 P42	25	HQ PIPE JACKET 12 300' #41	25	HQ PIPE JACKET 12 300' #41
11	HQ CBL SH 80' #41 21 P41	26	HQ PIPE JACKET 13 300' #41	26	HQ PIPE JACKET 13 300' #41
12	HQ CBL SH 80' #41 22 P42	27	HQ PIPE JACKET 14 300' #41	27	HQ PIPE JACKET 14 300' #41
13	HQ CBL SH 80' #41 23 P42	28	HQ PIPE JACKET 15 300' #41	28	HQ PIPE JACKET 15 300' #41
14	HQ CBL SH 80' #41 24 P41	29	HQ EARTH AMBIENT 300' #41	29	HQ EARTH AMBIENT 300' #41
15	HQ CBL SH 80' #41 25 P42	30	HQ EARTH AMBIENT 300' #41	30	HQ EARTH AMBIENT 300' #41

NO.	REVISION
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TE: POWER CABLE
CABLE NO. 247477-1-1
TE: POWER CABLE
CABLE NO. 247477-1-2
TE: POWER CABLE
CABLE NO. 247477-1-3
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CABLE NO. 247477-1-6
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CABLE NO. 247477-1-8
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CABLE NO. 247477-1-9
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CABLE NO. 247477-1-10

HINCHMANS AVENUE SUBSTATION
CMARS REMOTE TERMINAL UNIT NO.2
WIRING DIAGRAM ELECTRICAL
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
ENGINEERING DEPARTMENT
NEWARK, N. J.

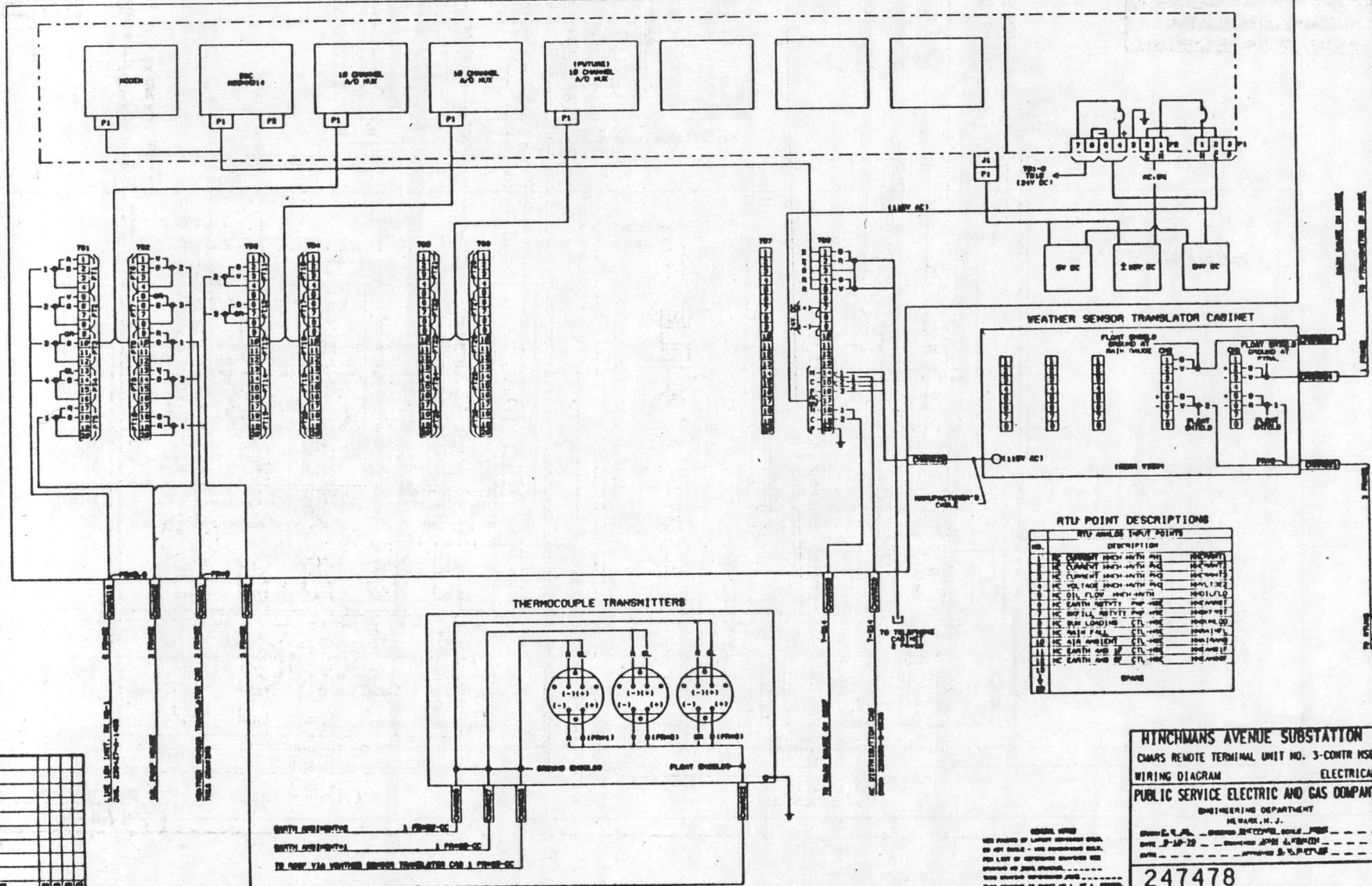
REVISION
SEE POINTS OF LAYER REVISIONS ONLY.
ON 1/2" SCALE - SEE CONNECTIONS ONLY.
FOR A LIST OF REVISIONS CHECKED SEE
CHECKED BY THIS ENGINEER.
THIS DRAWING IS UNDER THE CONTROL OF THE
DRAWING OFFICE OF P. S. E. & G. CO.

247477

247478

REMOTE TERMINAL UNIT NO.3 (CONTROL HOUSE)

34



RTU POINT DESCRIPTIONS

NO.	RTU ADDRESS	POINT NAME	DESCRIPTION
1	1000	1000-1	1000-1
2	1000	1000-2	1000-2
3	1000	1000-3	1000-3
4	1000	1000-4	1000-4
5	1000	1000-5	1000-5
6	1000	1000-6	1000-6
7	1000	1000-7	1000-7
8	1000	1000-8	1000-8
9	1000	1000-9	1000-9
10	1000	1000-10	1000-10
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100	1000	1000-100	1000-100

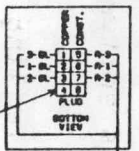
HITCHMANS AVENUE SUBSTATION
 CHMRS REMOTE TERMINAL UNIT NO. 3-CONTR MSE
WIRING DIAGRAM ELECTRICAL
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
 ENGINEERING DEPARTMENT
 H. S. BAKER, CH. E.
 JOHN E. W. ...
 DATE 8-10-70 ...
 247478

REVISION

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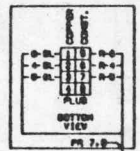
247480

#1 POTHEAD ACCESS PORT

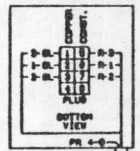


12) REMOTE CONNECTOR FEMALE (MIL-STD-883C-7)

#2 POTHEAD ACCESS PORT



#3 POTHEAD ACCESS PORT

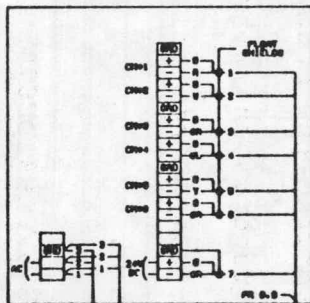
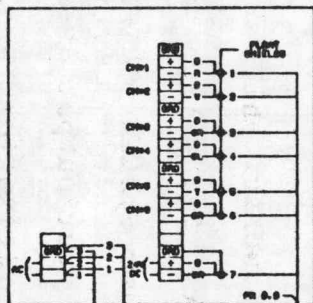
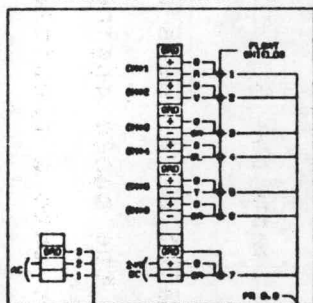


1/2 TRANSMITTER CABLE (MIL-STD-883C-7)

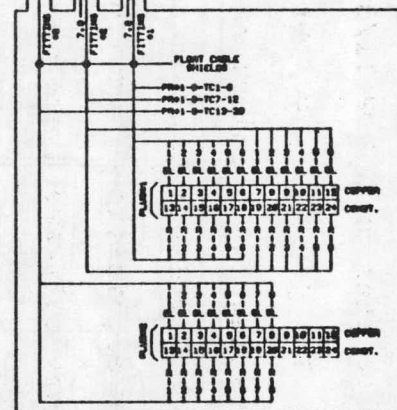
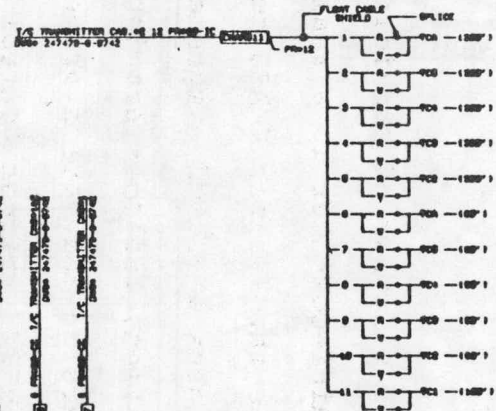
RECEIVER CABINET #1

RECEIVER CABINET #2

RECEIVER CABINET #3



MANHOLE #1



36

NO.	DESCRIPTION	DATE

REVISION

HITCHMANS AVENUE SUBSTATION
 CHAMPS POTHEAD AND MANHOLE
 WIRING DIAGRAM ELECTRICAL
 PUBLIC SERVICE ELECTRIC AND GAS COMPANY
 ENGINEERING DEPARTMENT
 NEWARK, N. J.

DRAWN BY: J. J. ...
 CHECKED BY: J. J. ...
 DATE: 10-1-68

247480

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SOFTWARE INSTALLATION AND DEVELOPMENT

Systems Control, Inc. was charged with the task of providing 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 application software.

This section describes the considerations involved in the software development and reports on the progress to date in implementing the various software components within the integrated 11/34 data acquisition system.

OVERALL SOFTWARE SYSTEM DESIGN

Figure 1 is a flowchart which describes the software configuration for this project. Central to the software system is the SCI Process Controller System (SCI/PCS). This software acts as a controller for input/output data logging and conversion, task scheduling, prioritization, etc. The flowchart describes the relationships between the SCI/PCS and the various software tasks.

SCI/PCS is a real-time Process Control System, blending the requirements of the cable engineer, the computer systems engineer, and the operator into a flexible and capable package for process data acquisition, direct digital and supervisory control. SCI/PCS

is the result of the experience of Systems Control, Inc., in dealing with the problems of system identification, installation, short and long-term fine-tuning, operator transactions, maintenance, and reliability. The man/machine interface is oriented toward high-level transactions, with the associated ease-of-use and quick learning curve. The software design is highly modular and open-ended, to allow the most efficient utilization of the process-control hardware resources.

SCI/PCS uses a table-driven software technique to allow the cable engineer full freedom in defining scan rate, validity and alarm limits, type, and number of points for both analog and digital input-output. Variables are kept in the system in engineering units in the table referred to in Figure 1 as the Engineering Unit Table (E.U.T.). All points in the system are referred to by mnemonic names.

SCI/PCS includes a specialized process control language to define and implement the control loops, calculations, and tasks described in Figure 1. Each task is uniquely identified by name, and is ~~executed as a specified rate appropriate for the loop.~~

Alarm limits and actions, as well as instrument validity checks, are accessible to the cable engineer. In addition, a standard facility exists to call and execute special action programs for any point going to alarm or limit conditions. These programs may be added or deleted at any time.

Man/machine interactions occur via CRT data entry terminals. Tasks can be activated by the computer operator by light pen selection or in the same mnemonics used by the cable engineer.

SCI/PCS is a multi-tasking system, providing rapid response, due to the a synchronous nature of the software. The operating system used is a multi-programming, multi-tasking, priority-oriented base, allowing full time and event scheduling of system elements. Certain crucial data-base elements are core-resident, while the bulk reside on Fortran IV random-access files. Only the highest priority tasks are core-resident, leaving a large free core pool in which to execute the disk resident programs and the CMARS application software.

SCI/PCS consists of several sub-systems, each operating at a priority level appropriate for the job performed. The following is a condensed outline of these levels, from highest to lowest:

1. Process Input-Output. This includes analog and digital scan control, all conversions to and from engineering units, scaling, instrument failure detection, and zero-reference automatic calibration of the analog input hardware.
2. Alarm Limits Checking, Logging and Appropriate Automatic Corrective Actions. Included in this category are such things as sequencing algorithms and power failure/restart cycles.
3. Historic data storage on disk and tape for subsequent off-line processing or system re-start.

4. Calculations, Switching Algorithms, and Control Loop Algorithms. All elements of the high-level SCI/PCS are processed at this level. All standard control mode algorithms are pre-programmed as part of the standard calculation package.
5. Operator Transaction Processing and Man/Machine Interface. This level has been chosen for these functions to allow the higher levels to achieve a more consistent and exact time-base. It should be noted that the operator has the ability to control the actions of all of the higher levels, as well as the lower ones.
6. System Logging Functions. Periodic logs, CRT system status refresh, and data-base output functions are executed in this class.

Each of the tasks shown in Figure 1 is under the direct control of SCI/PCS. Certain tasks such as the minute and hour tasks are automatically executed by the system. Others such as the cable cross sectional set up tasks are executed at the discretion of the operator. The SCI/PCS defines the interface between the operator and the discretionary tasks and controls their execution.

CMARS/PCS INTEGRATION AND DATA BASE DESIGN

The primary part of the data base is the "Engineering Units Table" (EUT) of the SCI/PCS software package. The EUT contains information for four kinds of points -- analog, virtual, statistical and cable cross section points. This information consists of the value of the point itself, an eight-character identifier name, a 24-character description, plus a list of attributes such as alarm limits associated with each point.

Analog points are engineering unit values of measurements upon the cable system. These include temperatures, voltages, currents, etc. Associated with each analog point is a unique name and a list of 16 attributes. These attributes include alarm flags, error flags, out-of-service flags, alarm limits, deadbands, etc. The value of any analog point can be determined by any task in the CMARS/PCS system by means of a point name cross reference table.

Virtual points are identical to analog points except that they are calculated by system software rather than measured.

Statistical points are a special class of virtual points whose attributes differ from the standard analog and virtual point attributes and take on special meanings. These points represent results of recursive calculations that produce a mean and variance of some user defined value over a 24-hour period. Attributes for this point include:

- . Mean value
- . Variance
- . Time the last increment to the statistic was calculated
- . Alarm limits on the variance

Cable cross section points are special points required by CMARS software. One such point exists for each cable cross section being monitored by the CMARS. Each such point consists of a pointer which directs the CMARS tasks to an area of disk memory where the large amount of auxiliary cable data is stored. The listing of information contained in this auxiliary file is contained in the "Data Base Organization" design document which is included in Appendix I. The purpose of the auxiliary table is to store parameters specific to one cable cross section. All the cable-specific parameters required by the CMARS tasks reside at this location. Since there are large amounts of data for each cross section and up to thirty cross sections, the only practical storage medium is the disk. Core resident storage is impractical due to large CMARS/PCS storage requirements.

DESIGN OF SYSTEM SCAN AND ENGINEERING UNIT STORAGE PROCEDURES

Input data from the RTU's to the main computer is scanned and converted in a more-or-less continuous manner. Depending on their priorities, automatic CMARS tasks are executed at pre-selected, less-frequent intervals. Consequently, the frequently sampled and converted analog data resident within the EUT appears to be a continuous measurement.

Analog point attributes include information required for converting the incoming RTU signal to engineering units. Whenever a new measurement is added to the data base, this information is required as input. Appendix I contains a data sheet whose completion is required in order to input the analog point attributes.

Appendix I also contains a data sheet whose completion is required prior to the input of the cable cross section points. The values specified by the data sheet are required to set up the cable-specific data which is stored on disk.

MAN/MACHINE INTERFACE DESIGN

This task is represented in Figure 1 by the two blocks labelled "CMARS Tabular and Plot Displays" and "User-Built Graphic Displays". The man/machine interface is the software which provides communication between the user and the various software tasks. These tasks -- such as the minutes and hour tasks -- generate information which is displayed in a graphical or tabular form to the operator.

Figure 2 provides a summary of the cable cross sections being monitored. Although only one cross section is displayed, groups of cross sections arranged at the user's discretion, will be displayed in the operational display.

The main display from the CMARS minute task is shown in Figure 3. This display shows all calculated and measured temperatures, thermal parameters and ratings associated with one cable cross section. A separate display will exist for each cross section.

Figure 4 is a graphical display of the calculated ratings for a given cross section. This display is actually a graphical representation of the ratings given in Figure 3.

A time history display of temperatures and loads are shown in Figures 5 and 6. These displays are written to the CRT at the discretion of the user. Both use historic data which is stored on disk and is generated by the minute task.

Figure 11 is an example of a tabular display which will be automatically printed every twelve hours. This display shows the value and status of EUT points and is useful in documenting changes or additions to the EUT point list.

Figure 7 is an example of a possible pictorial display which can be called on demand. This figure is easily input to the CMARS/PCS system by means of graphical input upon the screen of the CRT. Under PCS, the user can generate any desired picture, name it, display any point value within the EUT, and recall the picture at any time to observe changing point values. It is envisioned that the user will define many such pictures over the life of the demonstration project because they provide a convenient graphical means to observe the state of the cable system.

INTERACTIVE DATA CONVERSION SOFTWARE DEVELOPMENT

This task is a user-initiated task whose purpose is to input cable physical parameters and data and convert this data into a form required by the CMARS. This data is provided by the utility on the cable cross section data from (Appendix I). Also included in Appendix I is a task design document which provides details of its operation.

CMARS SOFTWARE REVISION

Previously existing CMARS FORTRAN programs have been adapted and incorporated within the CMARS/PCS system. There are three main tasks shown in Figure 1 which are the primary routines of the CMARS. These include:

- . The minute task
- . The hour task
- . The prediction task

The CMARS minute task is so named because it is primarily concerned with monitoring parameter identification and calculating ratings, each of which is performed automatically every few minutes by PCS.

The function of the monitor is to estimate cross-sectional cable temperatures in real-time. The only inputs required by the monitor are conductor current and earth ambient temperature. If readily

accessible temperature measurements, such as oil or pipe temperatures, can be incorporated, the monitor provides more accurate temperature estimates that reflect the true dynamic state of the cable. Moreover, additional temperature measurements are required for parameter identification.

Parameter identification continuously updates cable parameters, such as earth resistance, which may change over time. These updated parameters are made available to the monitor, which provides more accurate temperature estimates, and to the rating and prediction tasks.

The rating function calculates maximum cable loading levels which can exist for various time periods without exceeding specified temperature limits. The calculations are performed continuously in real-time based on the changing cable state as calculated by the monitor. The ratings therefore reflect actual dynamic cable conditions.

Details of the algorithms which perform monitoring, rating and parameter identification can be found in the final report of the project which was the forerunner to this demonstration reference [1].

The hour task is concerned with the calculation of rating factors used in the rating programs. These factors change very slowly and are automatically recalculated every few hours by PCS.

Appendix I includes task design descriptions of both the minute and hour tasks.

The prediction task is executed at the user's discretion and is intended to predict future cable temperatures, given an expected user-input loading. Displays of the user's input and the resulting predicted conductor temperature are processed through the PCS man/machine interface. Examples of these displays are found in Figures 8, 9 and 10.

Each of these CMARS tasks relies upon cable cross-sectional data stores upon disk. For those tasks which are automatically executed, the PCS examines each cable cross section sequentially and indicates the scheduled tasks. Data transfer and storage is automatically accomplished through the PCS controller. Tasks which are user-initiated, such as the predictor, use the PCS interactive capability to determine which cross section should be examined. Once the correct name is given, the PCS searches the point name table to find the disk address vector for that cable cross section and transfers data from the correct cable cross section disk location.

STATISTICAL ANALYSIS PACKAGE

Since the prime goal of the demonstration is to assess the performance of CMARS, quantitative measure of performance must be picked to evaluate those statistics. The framework of the PCS data base has been modified as explained previously to accommodate the calculation, display and logging of these measures.

The statistical analysis task consists of two routines. The first, called automatically along with the monitoring task, compares measured and calculated temperatures for one cross section, and calculates axial variance (several cross sections) of the temperature estimates over time.

The second routine is included with the prediction task and is performed on demand. This task calculates the forecast error covariance, a measure of the accuracy of the predictor.

Both statistical routines are described in Appendix I.

HISTORICAL STORAGE

The purpose of the historical storage task is to store test data on a permanent medium such as a magnetic tape for subsequent retrieval and off-line processing. Two storage schemes are presently being evaluated.

The first would store complete measurement records on disk for every scan. In addition, once a day a complete record of cable parameters and global common would also be stored. When the disk is full, a message would inform the operator to dump the file to tape. Consequently, complete measurement files would be recorded on tape which would greatly facilitate data retrieval.

The second scheme would store a complete record of cable parameters and global common once a day on disk, but would only store measurement changes. When full, the disks would be copied to tape as above. This scheme minimizes tape handling, but complicates data retrieval.

A decision regarding the choice between these schemes will soon be made.

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.

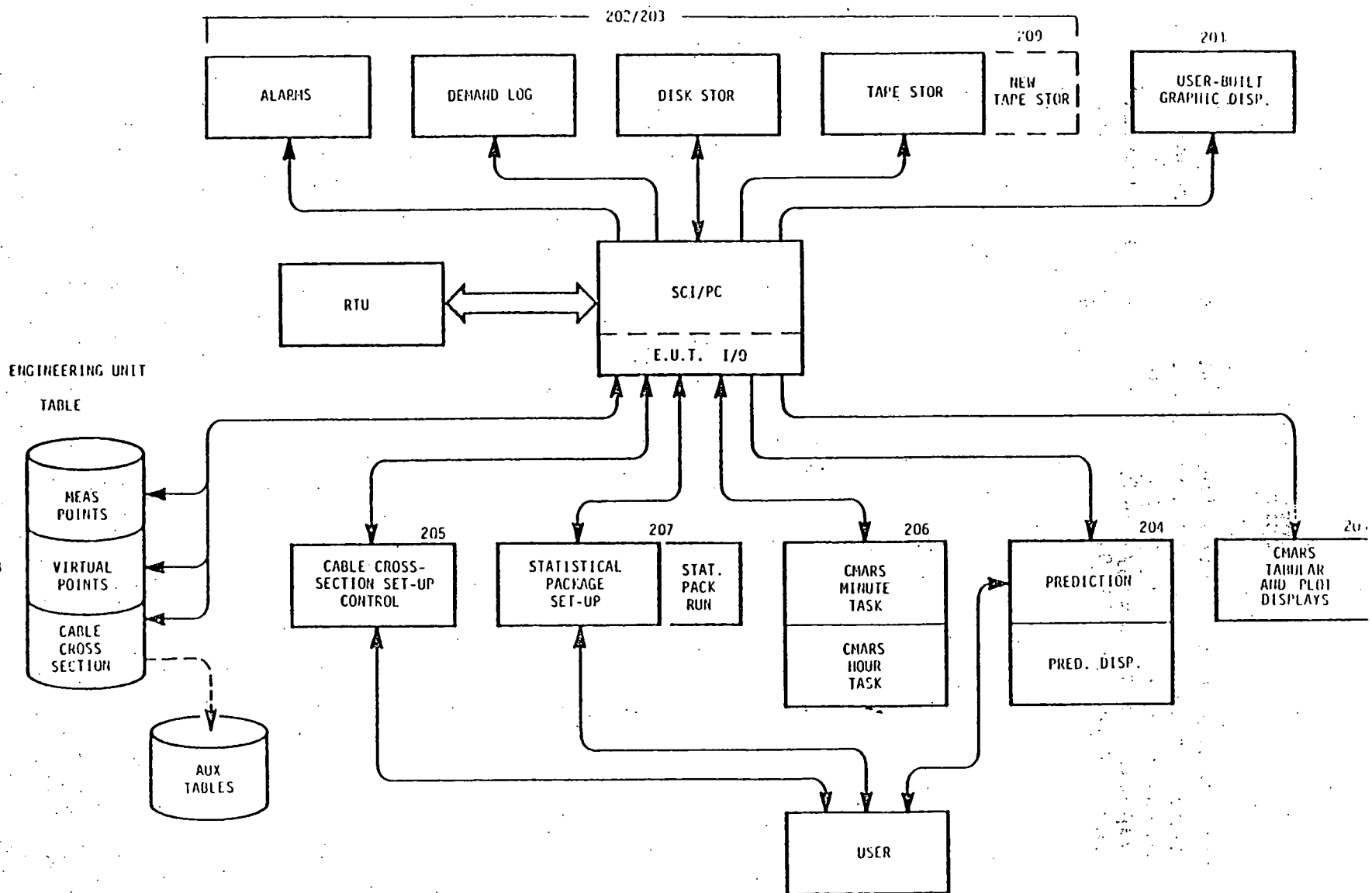


Figure 1 - CMARS SOFTWARE

Figure 2

CMARS
CABLE STATUS SUMMARY

CABLE	DESCRIPTION	COND TEMP CENT	NORM LIM CENT	VOLT KV	LOAD AMPS	PCT. CONT RTNG	CONT RTNG
MAIN ST1	230KV MAIN & 3RD AVE SUB	.78	85	241	1250	87	1437

Figure 3

MAIN STL.
MAIN & 3RD AVE SUB

744 AMP
345 KV
5 DEG C

OIL CIRCULATION ON
COOLING PLANT ON
CHILLED OIL 10 DEG C

	CUR. TEMP (DEG C)	OPERATING MODE PEAK TEMP. (DEG C)	CONDUCTOR		PIPE		CIRCULATION CONDUCTOR		COOLING CONDUCTOR	
			85	105	50	55	85	105	85	105
		PEAK TIME	CABLE RATING IN AMPS							
COND	59	NORMAL	1185	1302	1013	1086	1575	1732	1801	1979
INS	54	300 HR	1187	1305	1014	1087	1578	1736	1804	1984
SHLD	47	100 HR	1203	1325	1028	1106	1600	1762	1829	2014
OIL	44	24 HR	1285	1443	1101	1209	1709	1918	1953	2193
PIPE	40	8 HR	1466	1689	1313	1500	1950	2246	2228	2567
ETH1	32	2 HR	1861	2215	2162	2605	2475	2946	2829	3367
ETH3	14	.50 HR	2657	3253	3662	4492	3534	4326	4039	4945

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Figure 4

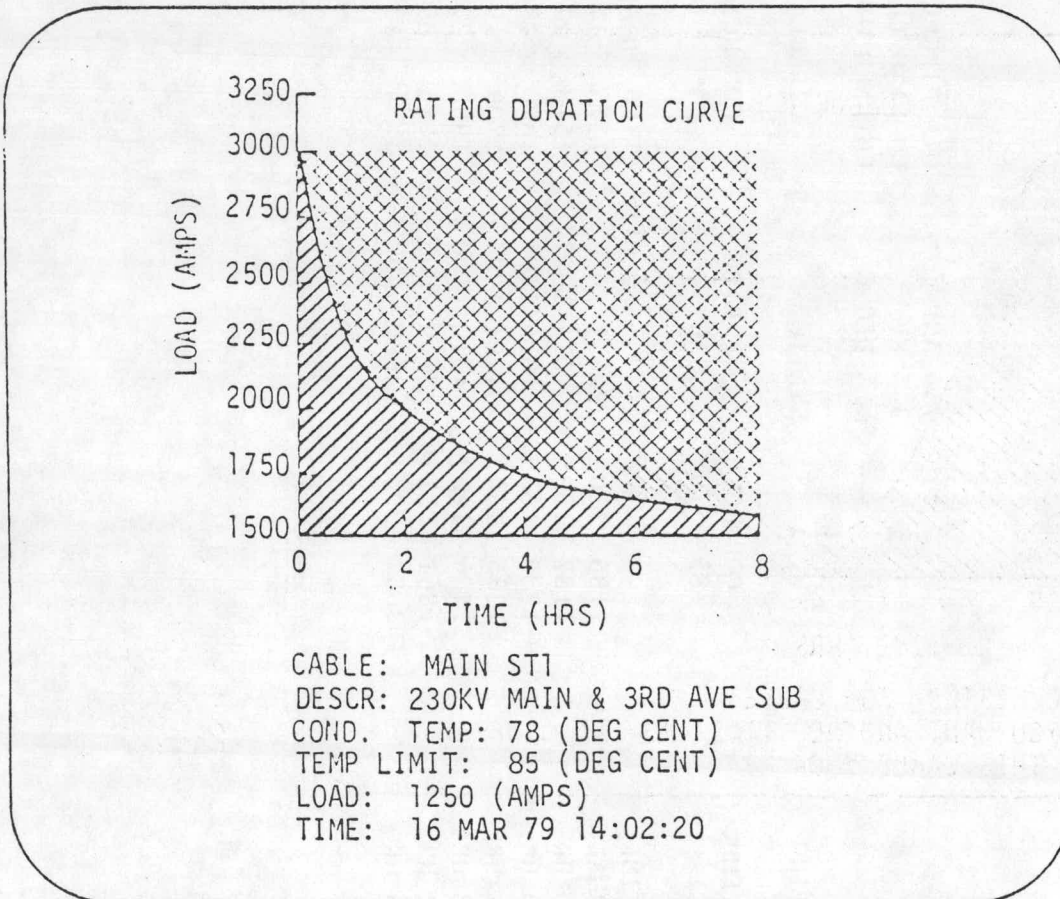


Figure 5

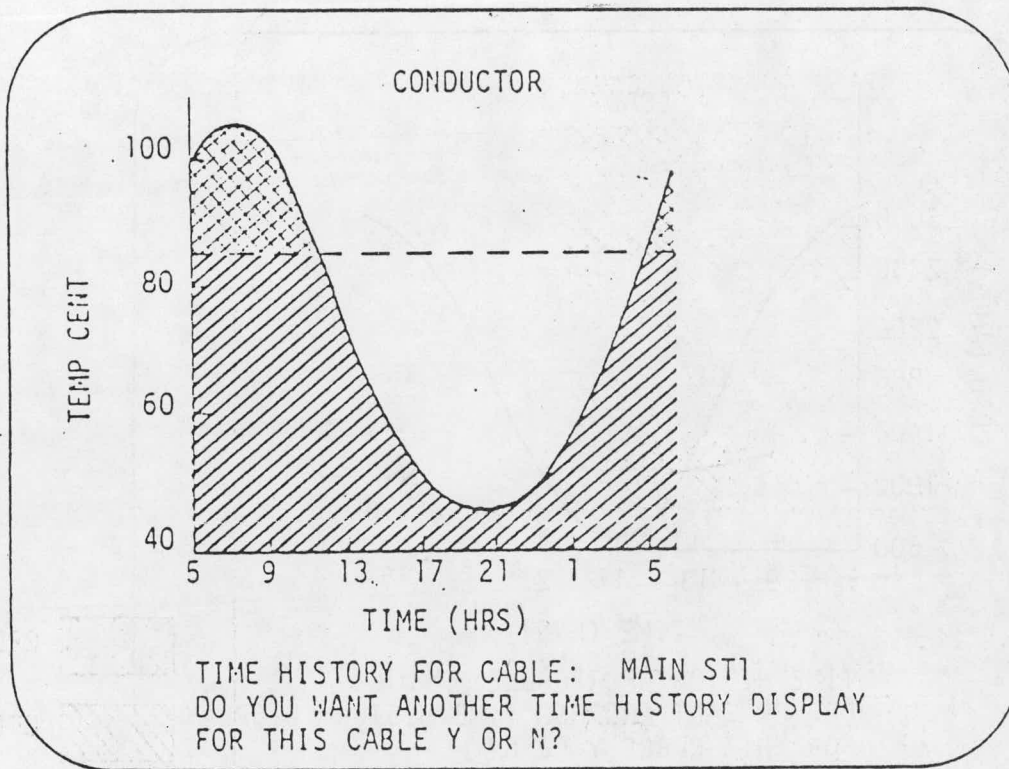


Figure 6

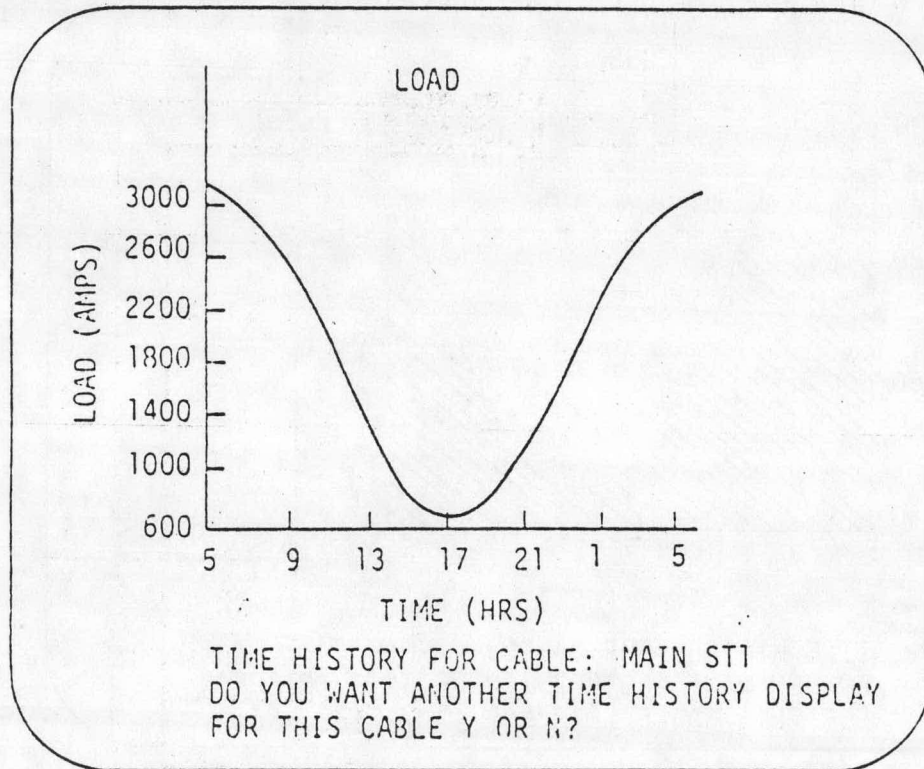
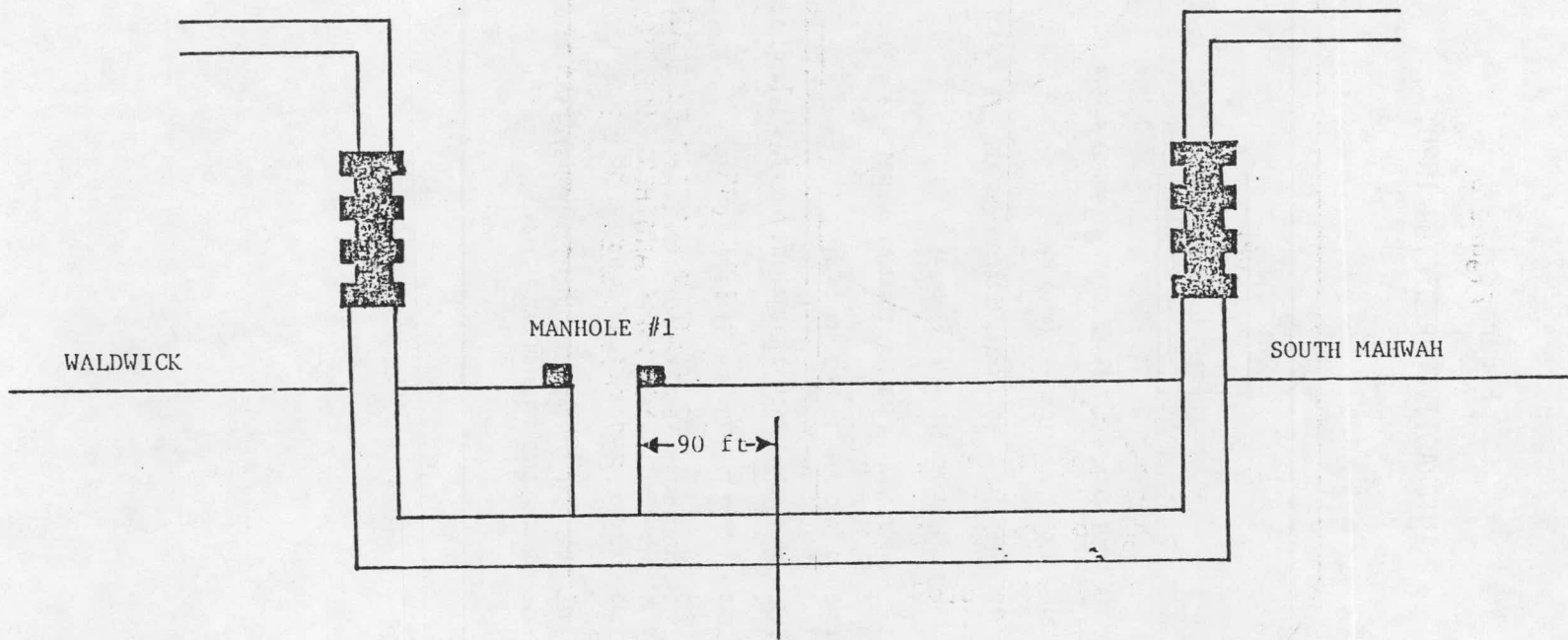


Figure 7
MEASUREMENT LOCATION SCHEMATIC

VOLTAGE kV

LOAD A AMPS

57



CONDUCTOR A °C

CONDUCTOR B °C

SHIELD B1 °C

SHIELD B2 °C

PIPE °C

Figure 8
INTERACTIVE PREDICTOR INPUT

N.Y. AVE CABLE
PRES LOAD = 1.2500
PRES TEMP = 52.3207

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
1.,2.

LOAD = 1.0000 DURATION = 2. (Y OR N)
Y

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
2.,2.

LOAD = 2.0000 DURATION = 2. (Y OR N)
Y

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
3.,2.

LOAD = 3.0000 DURATION = 2. (Y OR N)
Y

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
1.,4.

LOAD = 1.0000 DURATION = 4. (Y OR N)
Y

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
2.5,2.

LOAD = 2.5000 DURATION = 2. (Y OR N)
Y

ENTER INPUT DATA: LOAD (KA), DURATION (HOURS) - F6.4,F3.0
HAVE YOU COMPLETED ENTERING DATA? (Y OR N)

Y

Figure 9

DISPLAY OF PREDICTOR INPUT

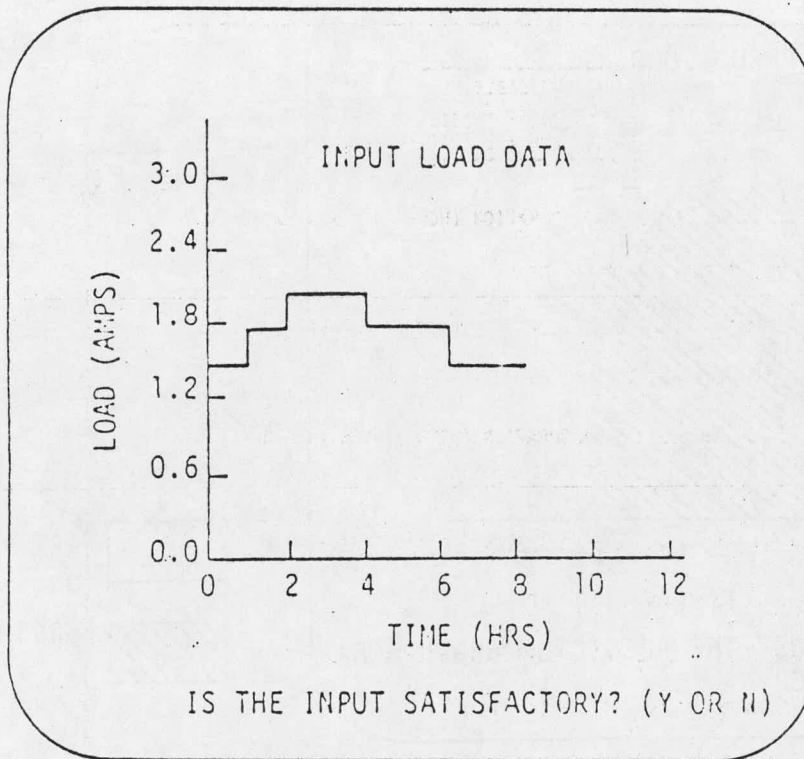
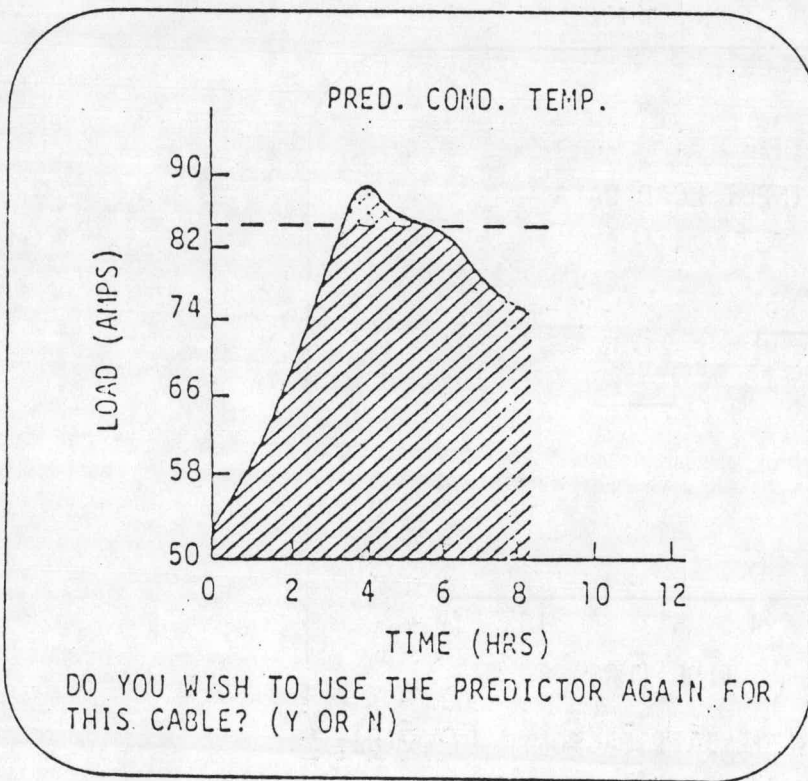


Figure 10

DISPLAY OF PREDICTOR OUTPUT



 RED

 GREEN

STATION NAME: B100

DATE: 10/10/80 TIME: 10:00:00

POINT	RTG	DESCRIPTION	UNIT	UNITS	IN/OUT	MODE
LIT06	5	NARRYAT R LEVEL	FEET	FEET	IN	AUTO
LIT07	5	NAPARINA R LEVEL	0.00	FEET	IN	AUTO
LIT08	5	CHACON R LEVEL	0.00	FEET	IN	AUTO
CTL003	5	S FERNANDO R LEVEL	0.00	FEET	IN	AUTO
PT.000	5	S FER BPS I PR FR CAR WT	0.00	FEET	IN	AUTO
PT.00000	5	S FER BPS I FL FR CAR WT	0.00	FEET	IN	AUTO
PT.001	5	S FER BPS OUTLET PRES	0.00	FEET	IN	AUTO
RY.N9.10	5	NAVET LINE FLOW IN	0.00	FEET	IN	AUTO
RY.N9.20	5	NAVET LINE FLOW OUT	0.00	FEET	IN	AUTO
LSHK6	5	NARRYAT R HGH LVL ALRM	OFF		IN	AUTO
LSHK7	5	NAPARINA R HGH LVL ALRM	OFF		IN	AUTO
LSHK8	5	CHACON R HGH LVL ALRM	OFF		IN	AUTO
LSHH1	5	S FER R HGH LVL ALRM	OFF		IN	AUTO
RS.HH1	5	S FER R AC PWR FAIL	OFF		IN	AUTO
ZS.PH1	5	S FER R ENG VLV CLS ALRM	OFF		IN	AUTO
QCFC101	5	SAN FERNANDO BPS PUMP 1 FAILURE	OFF		IN	AUTO
QCFC102	5	SAN FERNANDO BPS PUMP 2 FAILURE	OFF		IN	AUTO
QCFC103	5	SAN FERNANDO BPS PUMP 3 FAILURE	OFF		IN	AUTO
QS.CC3	5	S FER BPS COM ALRM	OFF		IN	AUTO
QS.CC4	5	S FER BPS AC PWR FAIL	OFF		IN	AUTO

Figure 11 - EXAMPLE TABULAR DISPLAY

A P P E N D I X I
Software Design Descriptions

1. DATA BASE ORGANIZATION
2. MINUTE TASK DESCRIPTION
3. HOUR TASK DESCRIPTION
4. INTERACTIVE DATA ENTRY AND CONVERSION TASK DESCRIPTION
5. DATA SHEET FOR ANALOG MEASUREMENTS
6. DATA SHEETS FOR CABLE CROSS SECTION
7. STATISTICAL ANALYSIS TASK DESCRIPTION

**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:

- Six character identifier
- 24 character description
- Monitored cable cross section temperature
- Conductor temperature limit

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
- 24 character description
- Predicted cable cross section temperature
- Conductor temperature limit

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:

- Mean value
- Variance
- Time the last increment to the statistic was calculated
- Alarm limits on the variance

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 auxiliary 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
 ICROSS = (LOGICAL*2)*NCROSS

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

Another disk file directory is required for the predicted cable points. Similar in structure and function to the monitored cable directory, the predicted cable directory has a logical variable which is set to .TRUE. whenever the predictor is used upon a particular cable cross section. As with the monitored cable directory, the predicted cable directory will permit tasks that access the predicted cable file to skip over unused records.

TABLE 1

ENGINEERING UNITS TABLE STRUCTURE FOR VARIOUS TYPES OF POINTS

n = number of points

CONTENTS					
<u>EUTCOM</u>	# BYTES	ANALOG	DIGITAL	STATISTICAL	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		1 → out of normal analog signal range		0	0
9		Alarm acknowledged →			
8		0	0	0	1
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			
1		0	0	1	0
0		0	1	0	0

¹ Both monitored and predicted cable points have same structure

TABLE 1 CONTINUED

CONTENTS

	# BYTES	ANALOG	DIGITAL	STATISTICAL	CABLE
EUCKLO	4*n	Lower alarm limit	Input buffer indices	Lower alarm limit	→
EUCKHI	4*n	Upper alarm limit	Previous state name	Upper alarm limit	→
<u>EUSCOM</u>					
EUALTD	4*n		Input bit #'s	Same as analog	→
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 offset conversion constant	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	DPACBL	Displays attributes for a particular point type
UPDANA	UPDSTA	UPDCBL	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.

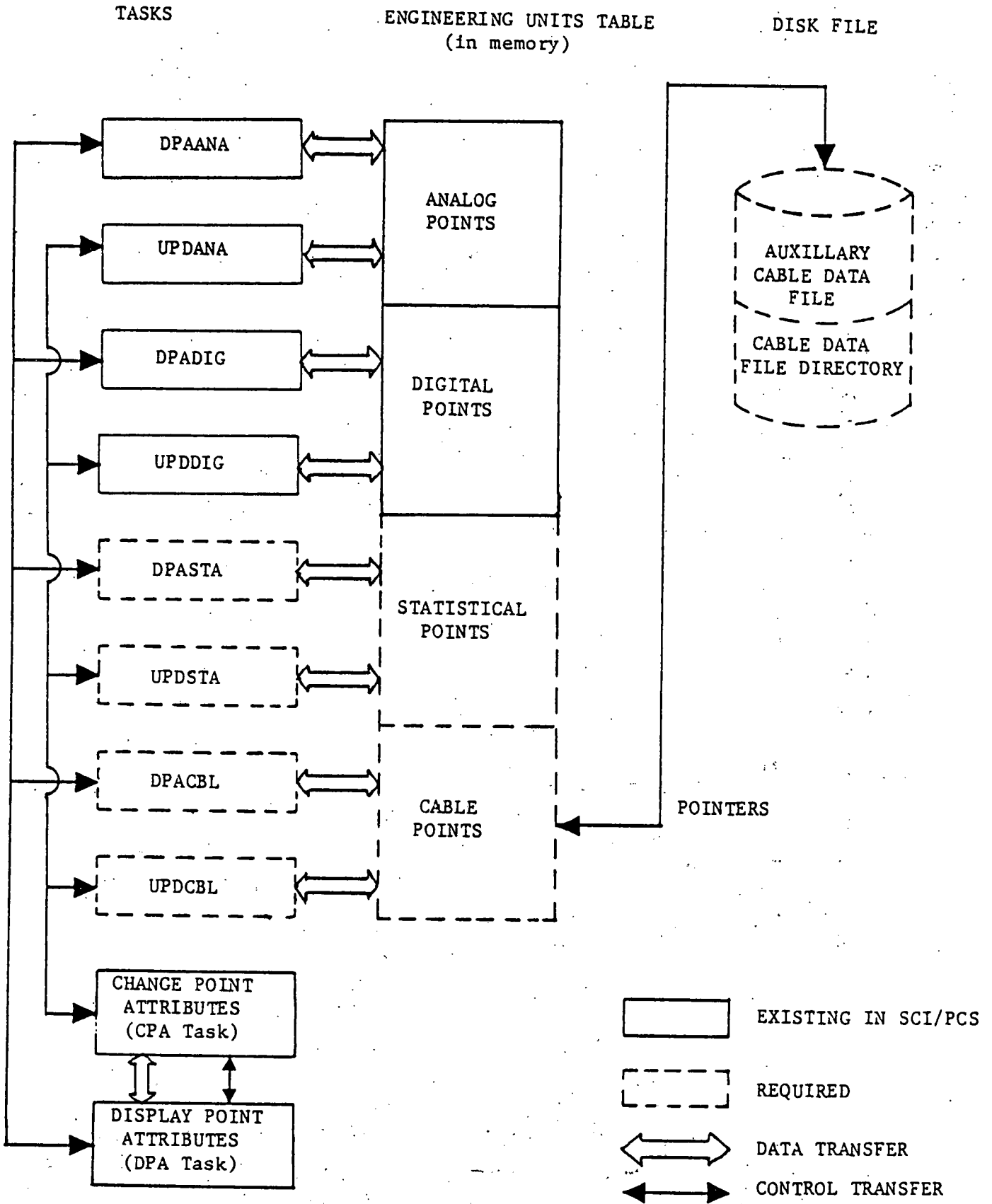


FIGURE 1

DATA BASE STRUCTURE AND POINT TYPE DEPENDENT OPERATIONS

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(8)	IDCABL(4)	Cable cross section eight character identifier	Byte	8
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).

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
	TEMP(11-30)	Spare	"	80
	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
THETAC(30)	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 capacitance, watt·hr/ft/°C	"	4
	COIL	Oil thermal capacitance, watt·hr/ft/°C	"	4
	CPIPP	Pipe + pipe cover thermal capacitance, 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
	HCON5	AC electrical loss of the pipe, watts/KA ² ·ft	"	4
	HCONP5	Temperature sensitivity of HCON5, 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 ambient 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	Insultation 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		"	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	

VARIABLE GROUP	(6 CHARACTERS)	DESCRIPTION	VARIABLE TYPE	# OF BYTES
	OILFL	Oil flow, gpm	Real	4
	PZERO	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
	RI(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	56
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
NCREFY(21)	NCREFY(7,3)	Sequence numbers for referenc- ing the analog points specified by ICREFY in the engineering units table	Integer	42
INDXP(30)	INDXP(30)	Flags for parameter identifi- cation. If INDXP(I) = .TRUE., identify parameter I	Logical	60
IFLAG(16)	IFLAG(16)	General purpose flags	Logical	32
IFLAG(16)	IFLAG	General purpose flags Flag Number	Logical*2	32
		1 = .TRUE. restart cross- section monitoring using the initialization routine to reset tempera- ture 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. Other- wise, cradled.		
		5 = .TRUE. calculate Kalman gains. Otherwise user input		
		6-16 = spare		

**MINUTE TASK
DESCRIPTION**

MINUTE TASK DESCRIPTION

PURPOSE

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.

INPUTS

<u>NAME</u>	<u>DESCRIPTION</u>
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.

OUTPUTS

<u>NAME</u>	<u>DESCRIPTION</u>
Event Logger	Notation of the following changes in status: <ol style="list-style-type: none">1. Cross-section out-of-service2. 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	EUTCON, EUSCON, CRTCOM (CABLE, COM)
Local	CABLE, CABLE2, CNAMEs, CNTRL, MAIN1, INOU

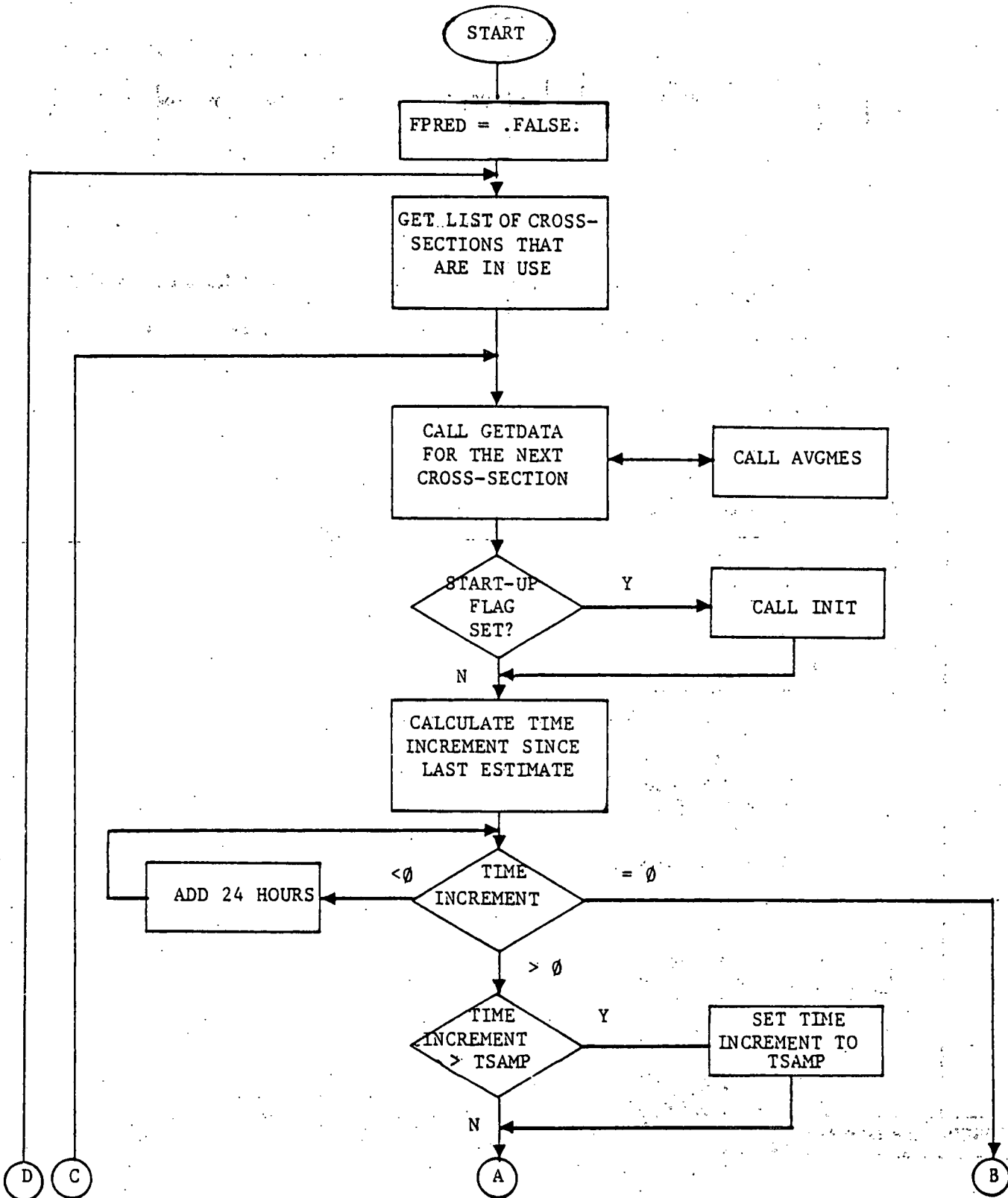
SUBROUTINES USED

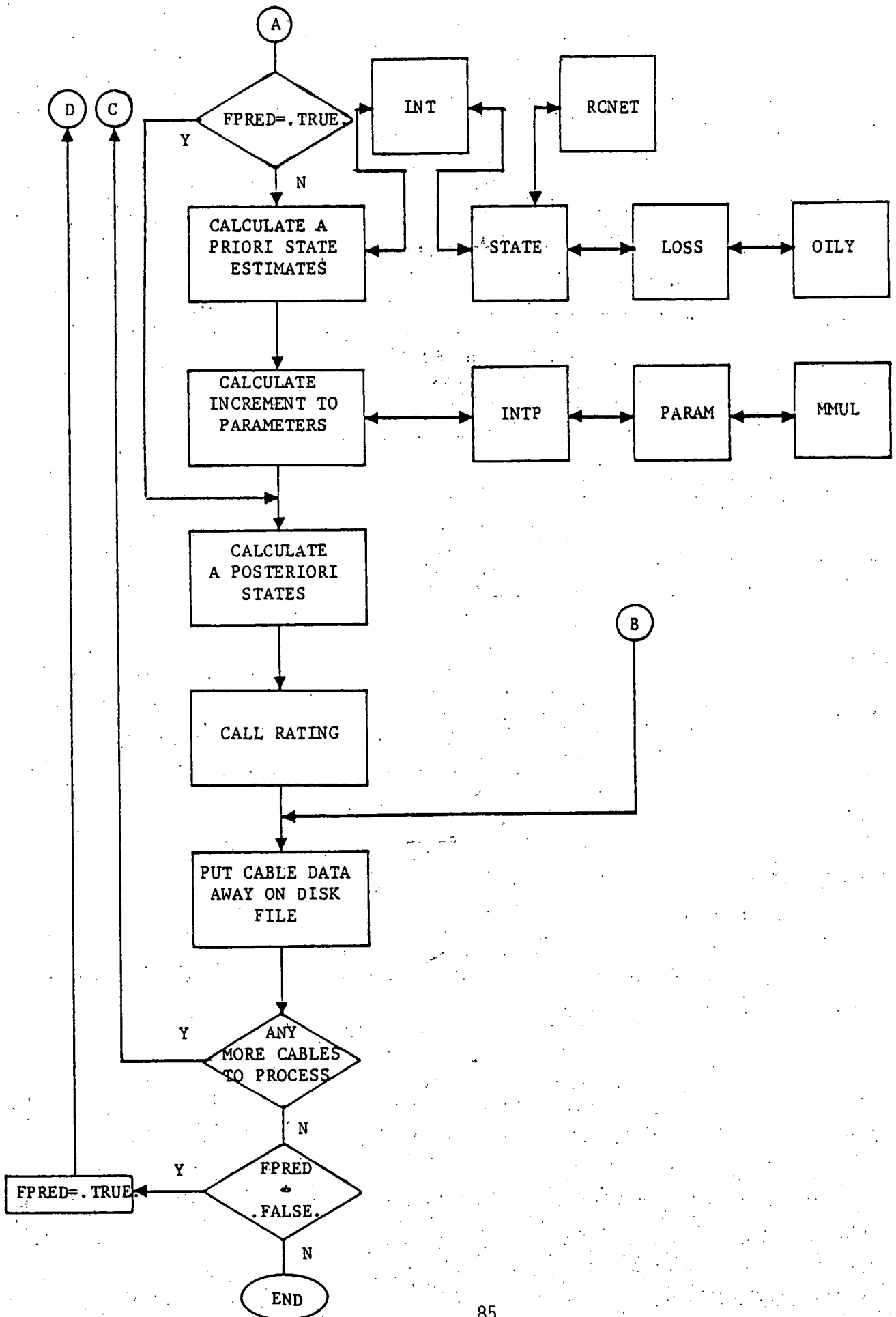
CLRCRT, CRTASN, CRTXIT, EXIT, GETDAT, INIT, INT, INTP, IRAD50, LIMIT, MEAS, POSCUR,
PTLOOK, RATNG, RECEIV, RECOEX, SEND, STATE

COMPUTATION PROCEDURES

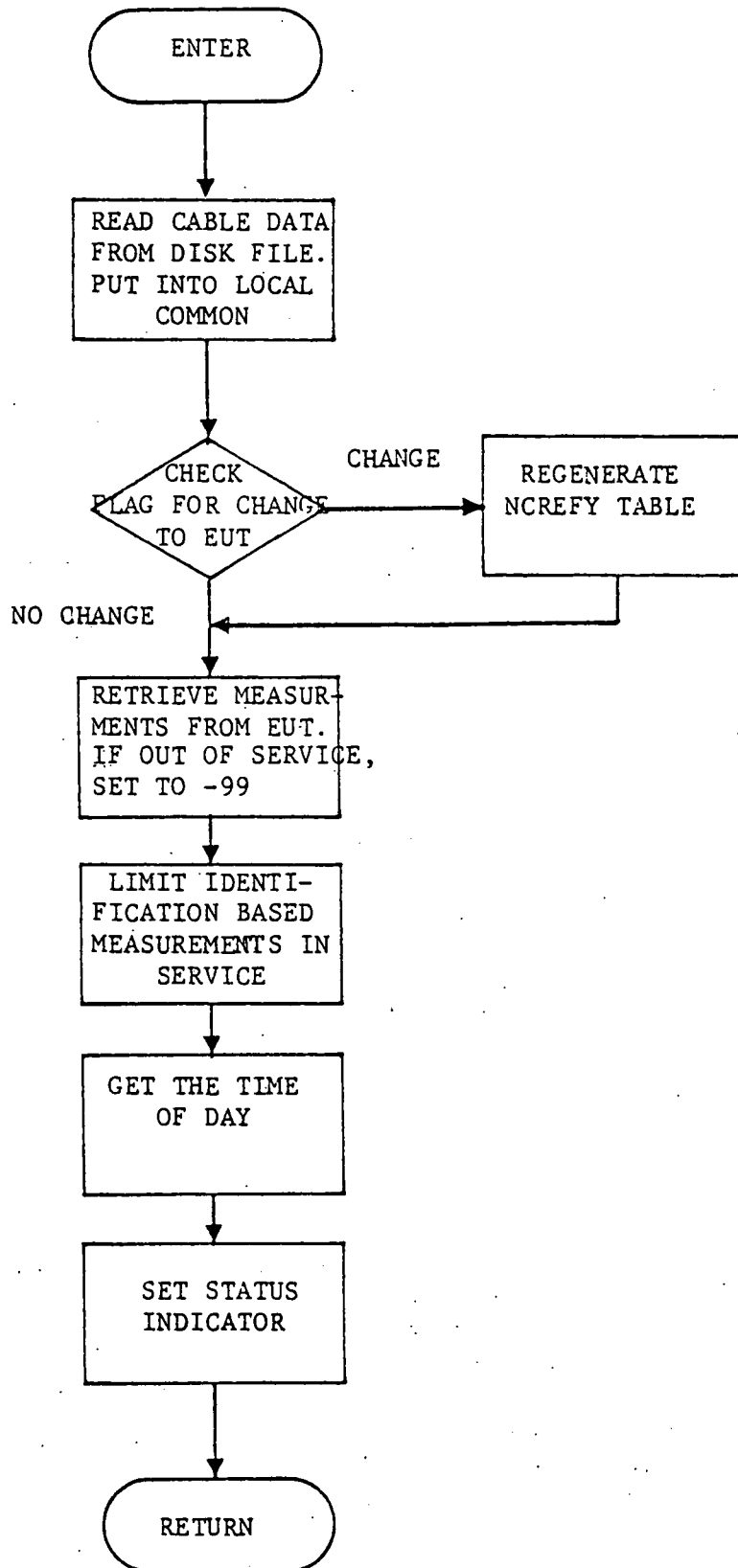
See attached flow chart

FLOW CHART FOR THE MINUTE TASK





FLOW CHART FOR GETDATA



HOUR TASK
DESCRIPTION

HOURLY TASK DESCRIPTION

PURPOSE

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

EXECUTION CRITERIA

Task should run synchronously off the real time clock once a day at midnight. Also, it can run asynchronously on operator demand from the SCI/PCS task index table. Priority should be low since rating factors will not change much from day to day, but only over a long period of time.

INPUTS

DESCRIPTION

Disk	Data base for the cable cross sections and a directory for the cross section data base of cables that are in use.
------	---

OUTPUTS

DESCRIPTION

Disk	New values for the rating factors
------	-----------------------------------

COMMON BLOCKS

NAME

DESCRIPTION

Global	CRTCOM, CABLE, EUTCOM
Local	CNTRL, MAIN1, INOU

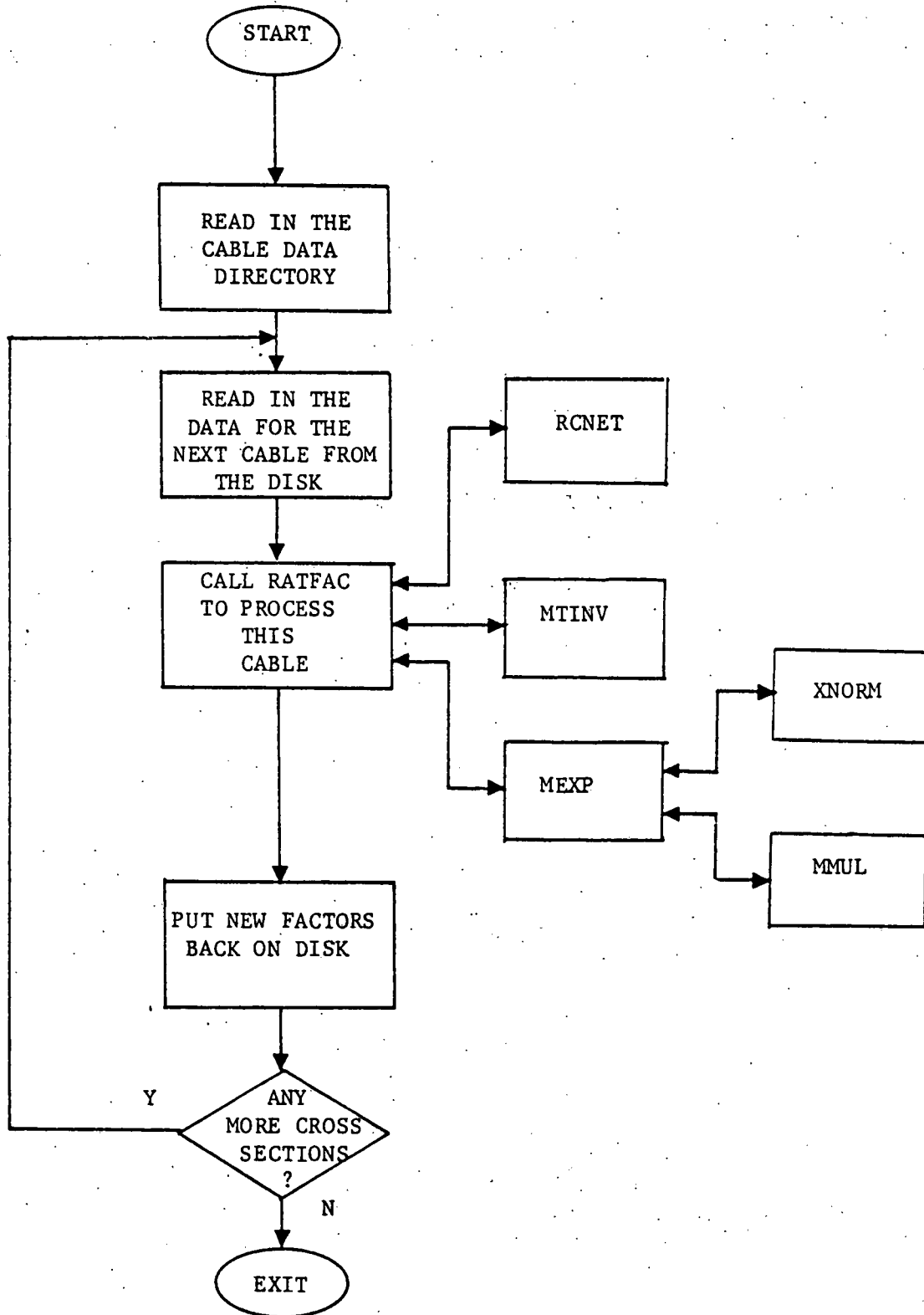
SUBROUTINES USED

RATFAC, RCNET, MTINV, MEXP, MMUL, XNORM

COMPUTATIONAL PROCEDURE

See the attached flow chart.

FLOW CHART FROM THE HOUR TASK



INTERACTIVE DATA ENTRY
AND CONVERSION
TASK DESCRIPTION

TASK #205 INTERACTIVE DATA ENTRY AND CONVERSION

PURPOSE

This task serves two main purposes: (1) to allow for operator entry, modification, inspection, or deletion of cable cross section parameters and program control information, and (2) to perform the initial processing of the raw data into a form acceptable to the CMARS minute task programs.

STRUCTURE

The program consists of two main modules, ENT, in which the interactive entry takes place, and INI, where the initialization occurs. These are distinct driving programs. However, INI is executed only through a link from ENT, which is executed by operator demand.

REQUIREMENTS

ENT requires that the names of measured points be entered into the system via the PCS programs CPA or PNTCRE prior to creation of a cable cross section which uses those points. Since ENT looks up the location of points in global common storage area, they must exist. INI requires successful creation of data buffer on disk by ENT.

INPUT

ENT gives the user his choice of operating modes. Add mode is an interactive question/answer session designed for user entry of all data of one cable cross section. The update modes (modify, inspect, delete) give the user an opportunity to do as their name implies to an existing cable cross section.

ENT prompts for all user enterable data and control information by displaying a description, abbreviation, and appropriate units on the CRT. The program will then accept input from the keyboard.

After each entry, a check is made to determine if the correct type of data was entered, and if numeric, the value is compared to preset normal upper and lower limits for that particular parameter. If an unacceptable entry is made, the program will prompt the user to try again, and display a reason for rejection of the data entered.

INI gets its input from the data files created on disk by ENT. One file contains all the data needed by the other CMARS tasks for up to 30 cross sections. Another contains names of all cables in use, and another, their position in the data file.

OUTPUT

Upon acceptance of all user enterable data, ENT places the buffer of data on a single record in the data file, which is 30 records long. Additionally, the names file and directory file are created and/or updated. When in Add mode, a printed summary is optionally available. When in one of the update modes, a printed summary of data is automatic when permanent changes are made. ENT then stops and begins execution of INI.

INI sends a summary to the report printer of values which it calculates, e.g. various gains and thermal parameters.

Upon completion of INI, the data buffer is again stored on disk, and control is returned to the process controller function menu.

DATA SHEET FOR ANALOG MEASUREMENTS

POINT NUMBER	IDENTIFYING LABEL (16 characters)	SIGNAL TYPE (check one)						CMARS to supply power for current loop?	SIGNAL RANGE		
		4 to 20 ma	10 to 50 ma	-1 to +1 ma	0 - 1 volts	1 to 5 volts	0 to 5 volts		Low	High	Unit
1	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
2	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
3	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
4	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
5	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
6	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
7	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
8	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
9	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
10	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
11	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
12	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
13	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
14	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
15	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
16	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
17	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
18	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
19	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
20	-----	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____

DATA SHEETS FOR A
CABLE CROSS SECTION

Cross Section _____

CMARS Device Serial No. _____

DATA SHEET FOR A CABLE CROSS SECTION

OPTION SELECTION

IDENTIFYING LABEL (32 characters, including spaces)

TEMPERATURE LIMITS FOR RATING CALCULATIONS (Select one or two temperature limits for each criteria)

	Temperature Limit 1	Temperature Limit 2
CONDUCTOR	_____ °C	_____ °C
PIPE/EARTH INTERFACE	_____ °C	_____ °C

TIME PERIODS FOR RATING CALCULATIONS (Select six, of which one may be less than one hour. Note that a normal rating is calculated in addition to these six short period ratings)

_____ hr _____ hr _____ hr _____ hr _____ hr _____ hr

ANALOG MEASUREMENTS (Fill in the appropriate analog point numbers for analog measurements applicable to this cross section. Spaces are provided for multiple measurements of the same quantity)

Required	}	CURRENT	_____	_____	_____
		PIPE TEMPERATURE	_____	_____	_____
		BULK OIL TEMPERATURE	_____	_____	_____
		SHIELD TEMPERATURE	_____	_____	_____
Optional	}	CONDUCTOR TEMPERATURE	_____	_____	_____
		*EARTH AMBIENT TEMPERATURE	_____	_____	_____
		*VOLTAGE	_____	_____	_____

* If analog measurements are unavailable for these quantities, the user must supply substitute values below.

VOLTAGE	_____	KV
EARTH AMBIENT TEMPERATURE	_____	°C maximum value for the year
	_____	°C minimum value for the year
	_____	days from January 1 when the maximum temperature is achieved

Cross Section _____

CMARS Device Serial No. _____

DATA SHEET FOR A CABLE CROSS SECTION
OPTION SELECTION

THERMAL PARAMETER IDENTIFICATION (The user may elect automatic adjustment of thermal parameters to allow the model to adapt to actual, installed physical conditions. Note, however, that parameter identification is only feasible if the temperature measurements shown below are available.)

If a temperature measurement is not available for the quantity shown below, cross out all blocks in that column. Place a check in the remaining empty blocks for those parameters selected for identification

MEASURED TEMPERATURES

THERMAL PARAMETER	CONDUCTOR	SHIELD	BULK OIL	PIPE
CONDUCTOR CAPACITANCE				
INSULATION RESISTANCE	-			
INSULATION CAPACITANCE				
OIL RESISTANCE				
OIL CAPACITANCE				
PIPE CAPACITANCE				
EARTH RESISTANCE				
EARTH CAPACITANCE				



Parameter not identifiable when only the temperature measurement in the column indicated is available

Cross Section _____

CNARS Device Serial No. _____

DATA SHEET FOR A CABLE CROSS SECTION

PHYSICAL DATA

All of the items on this page must be completed.

DIMENSIONAL DATA

Conductor Cross Sectional Area	_____	millions of circular mil
Conductor Diameter	_____	inches
Insulation Thickness	_____	inches
Shield Thickness	_____	inches
Skid Wire Cross Sectional Area	_____	inches ²
Number of Skid Wires per Cable	_____	dimensionless
Skid Wire Lay Length	_____	inches
Pipe Inner Diameter	_____	inches
Pipe Wall Thickness	_____	inches
Pipe Covering Thickness	_____	inches
Burial Depth (pipe center to earth surface)	_____	inches
Cable Geometry	_____ Triangular	_____ Cradled

THERMAL PROPERTIES

Thermal Resistivities

Insulation	_____	°C cm/watt
Pipe Covering	_____	°C cm/watt
Earth	_____	°C cm/watt

Oil Properties

Thermal Resistivity	_____	°C cm/watt
Kinematic Viscosity	_____	ft ² /hr
Specific Heat at Constant Pressure	_____	watt hrs/°C cm ³
Thermal Coefficient of Volumetric Expansion	_____	%/°C
Density at _____ °C	_____	lbm/ft ³

Specific Heats per Unit Volume

Conductor	_____	watt hrs/°C cm ³
Insulation	_____	watt hrs/°C cm ³
Shield	_____	watt hrs/°C cm ³
Skid Wire	_____	watt hrs/°C cm ³
Pipe	_____	watt hrs/°C cm ³
Pipe Covering	_____	watt hrs/°C cm ³
Earth	_____	watt hrs/°C cm ³

STATISTICAL ANALYSIS.

TASK DESCRIPTION

TASK DESCRIPTION: STATISTICAL PACKAGE (207)

PURPOSE

To establish quantitative measures to assess the performance of CMARS.

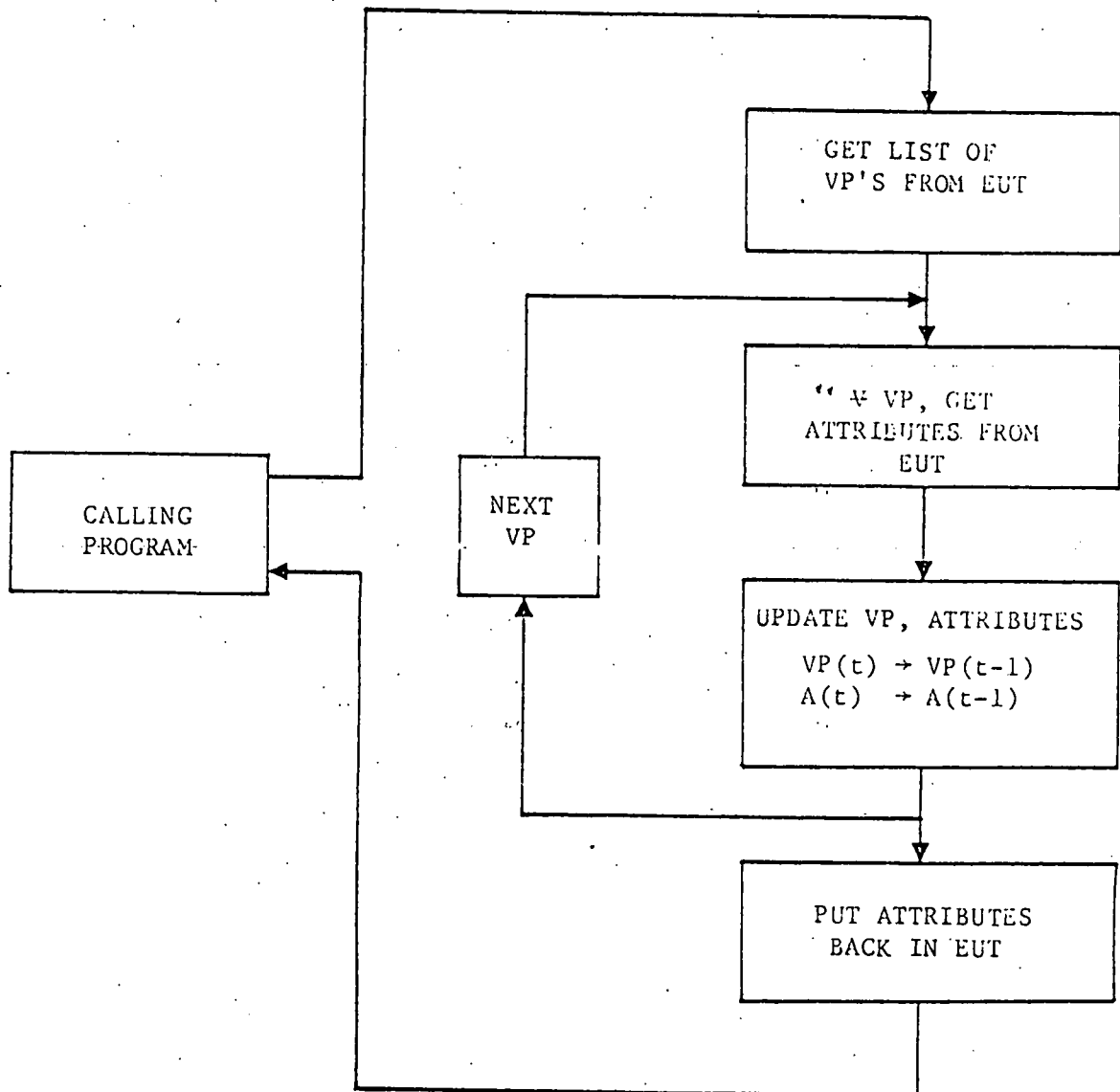
EXECUTION CRITERIA

The statistical package consists of two software routines. The first routine calculates the error covariance between calculated and measured temperatures and the axial temperature covariance. The second routine calculates the forecast temperature covariance.

The first routine is called automatically every time the CMARS monitoring routine is called. Since this routine compares actual measured temperatures to calculated temperatures, all temperature calculations must have been completed. Furthermore, the first routine must be completed prior to a new scan of analog points which could result in mismatching actual and calculated temperatures.

The second routine, the Forecast Error Covariance, is included as a modification of the Predictor Task and consequently is performed on demand at the user's discretion. The operator initiates the Predictor Task and determines whether he wishes to use hypothetical load data or historic load data as input to the Predictor. If he chooses to use historic load data, the operator specifies from what time (as far back as 24 hours) the historic data should be taken. The Predictor then fetches the load data and the initial state data from disk, calculates temperatures up to the present time, performs statistical calculations, and displays the result.

Computational Procedure -- Real Time Task



TEMPERATURE ERROR COVARIANCE VIRTUAL POINT

The value of the virtual point for temperature error covariance is the mean squared difference between calculated and measured temperatures over time.

$$VP_i(t) = [VP_i(t-1) * (n-1) + (TC_i(t) - TM_i(t))^2] \frac{1}{N}$$

where $VP_i(t)$ = value of virtual point i at time t
 n = number of observations counted in $VP_i(t)$
 $TC_i(t)$ = calculated temperature used in VP_i at time t
 $TM_i(t)$ = measured temperature used in VP_i at time t

Attributes include:

n = defined above
 $\overline{VP_i}(t)$ = average value of VP_i from time = 0, t
 $\overline{TC_i}(t)$ = average value of TC_i from time = 0, t
 $\overline{TM_i}(t)$ = average value of TM_i from time = 0, t
 $L(TM_i)$ = name or location of TM_i (internal)
 $L(TC_i)$ = name or location of TC_i (internal)

AXIAL TEMPERATURE VARIANCE VIRTUAL POINT

The value of the virtual point for axial temperature variance is the mean standard deviation of pre-selected temperature estimates over time.

$$VP_j(t) = [VP_j(t-1) * (n-1) + S_j(t)] \frac{1}{N}$$

where $VP_j(t)$ = value of virtual point j at time t
 n = defined above
 $S_j(t)$ = standard deviation of a group of pre-selected temperature estimates over time

$$S_j(t) = \sqrt{\frac{\sum_{m=1}^M (TC_{jm}(t))^2 - \frac{\left(\sum_{m=1}^M TC_{jm}(t)\right)^2}{n}}{n-1}}$$

where $TC_{jm}(t)$ = calculated temperature associated with virtual point j at time t. (There are M calculated temperatures associated with virtual point j.)

Attributes Include:

n = defined above
 M = number of measurements
 $S(t)$ = defined above
 $\Sigma S^2(t)$ = sum of variance from time = 0, t
 $\hat{S}^2(t)$ = largest value of S^2 from time = 0, t
 $G(t)$ = Cochran Test Statistic, described below

$$G(t) = \frac{\hat{S}^2(t)}{S^2(0) + S^2(1) + \dots + S^2(t)}$$

$$= \frac{\hat{S}^2(t)}{\sum S^2(t)}$$

The Cochran Test Statistic is used off-line to decide whether several variances are equal for a given level of significance. A value g_α is selected from a table (attached) for a given n and M . The hypothesis that $S^2(0) = S^2(1) = \dots = S^2(t)$ is accepted with $(1-\alpha)\%$ probability if $G(t) \leq g_\alpha$

Table 7.8. Upper 1 Percentage Points of the Ratio of the Largest to the Sum of n Independent Estimates of Variance, Each of Which is Based on m Observations¹

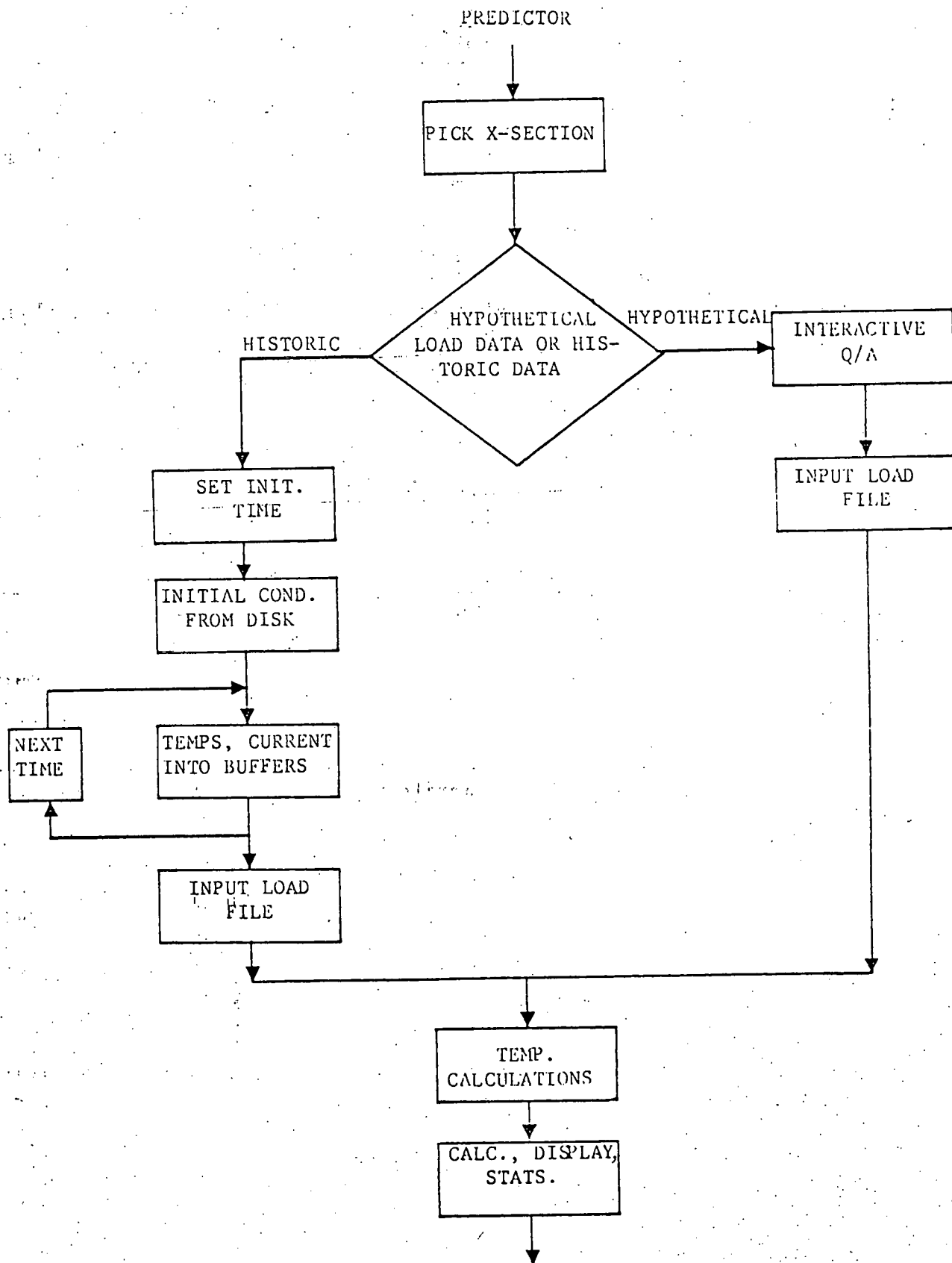
$n \backslash m$	2	3	4	5	6	7	8	9	10	11	17	37	145	∞
2	0.9999	0.9950	0.9794	0.9536	0.9373	0.9172	0.8988	0.8823	0.8674	0.8539	0.7949	0.7057	0.6052	0.5000
3	0.9933	0.9423	0.8831	0.8335	0.7933	0.7606	0.7335	0.7107	0.6912	0.6743	0.6059	0.5153	0.4230	0.3333
4	0.9676	0.8643	0.7814	0.7212	0.6761	0.6410	0.6129	0.5897	0.5702	0.5536	0.4884	0.4057	0.3251	0.2500
5	0.9279	0.7885	0.6957	0.6329	0.5875	0.5531	0.5259	0.5037	0.4854	0.4697	0.4094	0.3351	0.2644	0.2000
6	0.8828	0.7218	0.6258	0.5635	0.5195	0.4866	0.4608	0.4401	0.4229	0.4084	0.3529	0.2858	0.2229	0.1667
7	0.8376	0.6644	0.5685	0.5080	0.4659	0.4347	0.4105	0.3911	0.3751	0.3616	0.3105	0.2494	0.1929	0.1429
8	0.7945	0.6152	0.5209	0.4627	0.4226	0.3932	0.3704	0.3522	0.3373	0.3248	0.2779	0.2214	0.1700	0.1250
9	0.7544	0.5727	0.4810	0.4251	0.3870	0.3592	0.3378	0.3207	0.3067	0.2950	0.2514	0.1992	0.1521	0.1111
10	0.7175	0.5353	0.4469	0.3934	0.3572	0.3308	0.3106	0.2945	0.2813	0.2704	0.2297	0.1811	0.1376	0.1000
12	0.6528	0.4751	0.3919	0.3428	0.3099	0.2861	0.2680	0.2535	0.2419	0.2320	0.1961	0.1535	0.1157	0.0833
15	0.5747	0.4069	0.3317	0.2882	0.2593	0.2386	0.2228	0.2104	0.2002	0.1918	0.1612	0.1251	0.0934	0.0667
20	0.4799	0.3297	0.2654	0.2288	0.2048	0.1877	0.1748	0.1646	0.1567	0.1501	0.1248	0.0960	0.0709	0.0500
24	0.4247	0.2871	0.2295	0.1970	0.1759	0.1608	0.1495	0.1406	0.1338	0.1283	0.1060	0.0810	0.0595	0.0417
30	0.3632	0.2412	0.1913	0.1635	0.1454	0.1327	0.1232	0.1157	0.1100	0.1054	0.0867	0.0653	0.0480	0.0333
40	0.2940	0.1915	0.1508	0.1281	0.1135	0.1033	0.0957	0.0898	0.0853	0.0816	0.0668	0.0503	0.0363	0.0250
60	0.2151	0.1371	0.1069	0.0902	0.0796	0.0722	0.0668	0.0625	0.0594	0.0567	0.0461	0.0344	0.0245	0.0167
120	0.1225	0.0759	0.0585	0.0489	0.0429	0.0387	0.0357	0.0334	0.0316	0.0302	0.0242	0.0178	0.0125	0.0083
∞	0	0	0	0	0	0	0	0	0	0	0	0	0	0

¹ Reproduced from G. Eisenhart, M.W. Hastay, W. A. Wallis, *Techniques of Statistical Analysis*, Chapter 15, McGraw-Hill Book Company, Inc., New York, 1947.

Table 7.8. (continued). Upper 5 Percentage Points of the Ratio of the Largest to the Sum of n Independent Estimates of Variance, Each of Which is Based on m Observations

$n \backslash m$	2	3	4	5	6	7	8	9	10	11	17	37	145	∞
2	0.9985	0.9750	0.9392	0.9057	0.8772	0.8534	0.8332	0.8159	0.8010	0.7880	0.7341	0.6502	0.5813	0.5000
3	0.9669	0.8709	0.7977	0.7457	0.7071	0.6771	0.6530	0.6333	0.6167	0.6025	0.5466	0.4748	0.4031	0.3333
4	0.9065	0.7679	0.6841	0.6287	0.5895	0.5598	0.5365	0.5175	0.5017	0.4884	0.4366	0.3720	0.3093	0.2500
5	0.8412	0.6838	0.5981	0.5441	0.5065	0.4783	0.4564	0.4387	0.4241	0.4118	0.3645	0.3066	0.2513	0.2000
6	0.7808	0.6161	0.5321	0.4803	0.4447	0.4184	0.3980	0.3817	0.3682	0.3568	0.3135	0.2612	0.2119	0.1667
7	0.7271	0.5612	0.4800	0.4307	0.3974	0.3726	0.3535	0.3384	0.3259	0.3154	0.2756	0.2278	0.1833	0.1429
8	0.6798	0.5157	0.4377	0.3910	0.3595	0.3362	0.3185	0.3043	0.2926	0.2829	0.2462	0.2022	0.1616	0.1250
9	0.6385	0.4775	0.4027	0.3584	0.3286	0.3067	0.2901	0.2768	0.2659	0.2568	0.2226	0.1820	0.1446	0.1111
10	0.6020	0.4450	0.3733	0.3311	0.3029	0.2823	0.2666	0.2541	0.2439	0.2353	0.2032	0.1655	0.1308	0.1000
12	0.5410	0.3924	0.3264	0.2880	0.2624	0.2439	0.2299	0.2187	0.2098	0.2020	0.1737	0.1403	0.1100	0.0833
15	0.4709	0.3346	0.2758	0.2419	0.2195	0.2034	0.1911	0.1815	0.1736	0.1671	0.1429	0.1144	0.0889	0.0667
20	0.3894	0.2705	0.2205	0.1921	0.1735	0.1602	0.1501	0.1422	0.1357	0.1303	0.1108	0.0879	0.0675	0.0500
24	0.3434	0.2354	0.1907	0.1656	0.1493	0.1374	0.1286	0.1216	0.1160	0.1113	0.0942	0.0743	0.0567	0.0417
30	0.2929	0.1980	0.1593	0.1377	0.1237	0.1137	0.1061	0.1002	0.0958	0.0921	0.0771	0.0601	0.0457	0.0333
40	0.2370	0.1576	0.1259	0.1082	0.0968	0.0887	0.0827	0.0780	0.0745	0.0713	0.0595	0.0462	0.0347	0.0250
60	0.1737	0.1131	0.0895	0.0765	0.0682	0.0623	0.0583	0.0552	0.0520	0.0497	0.0411	0.0316	0.0234	0.0167
120	0.0998	0.0632	0.0495	0.0419	0.0371	0.0337	0.0312	0.0292	0.0279	0.0266	0.0218	0.0165	0.0120	0.0083
∞	0	0	0	0	0	0	0	0	0	0	0	0	0	0

COMPUTATIONAL PROCEDURE - PREDICTOR TASK



FORECAST ERROR COVARIANCE

The Forecast Error Covariance is a statistic calculated by the Predictor when historic data is used as input. Unlike the Temperature Error Covariance and the Axial Temperature Variance, the Forecast Error Covariance is not a virtual point. Rather it is a local quantity which is calculated by the Predictor and is available for display only at the end of the Predictor Task.

The Forecast Error Covariance is the mean squared difference between measured and predicted temperatures at the present time based on a prediction from historical data

$$FEC = \sum_{i=1}^k \frac{(TC_i(0) - TM_i(0))^2}{k}$$

where

$TC_i(0)$ = Predicted (calculated) temperature of point i at time = 0 (present time)

$TM_i(0)$ = Measured temperature of point i at time = 0

k = Number of component temperatures measured in a cross-section

In addition a statistic called the Sample Correlation Coefficient is calculated. Correlation between measured and predicted values can be positive or negative. We would expect a high positive correlation, indicating that both measured and predicted values move together. This statistic is useful because it provides a convenient 0-1 scale rating the ability of the Predictor to accurately predict cable temperatures.

The Sample Correlation Coefficient is defined as:

$$r = \frac{\sum_{i=1}^k (TC_i(0) - \overline{TC}(0))(TM_i(0) - \overline{TM}(0))}{\sqrt{\sum_{i=1}^k (TC_i(0) - \overline{TC}(0))^2 \sum_{i=1}^k (TM_i(0) - \overline{TM}(0))^2}}$$

where

- \underline{r} = Sample correlation coefficient
- $\overline{TC}(0)$ = Average of calculated temperatures at time = 0
- $\overline{TM}(0)$ = Average of measured temperatures at time = 0
- $k, TC_i(0), TM_i(0)$ are defined previously