GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No./(Center No.) E-25-686 (R6318-0A0) GTRC/~~XXX~~ DATE 6 / 10 / 87

Project Director: W. Z. Black School/~~Lab~~ ME

Sponsor: Georgia Power

Agreement No.: P.O. # E-07100 and change 01 and Research Project Agmt. dated 5/28/87.

Award Period: From 5/1/87 To 8/31/87 (Performance) 9/30/87 Reports

Sponsor Amount:

	New With This Change	Total to Date
Contract Value:	$	$ 12,580
Funded:	$	$ 12,580

Cost Sharing No./(Center No.) ______ Cost Sharing: $ ______

Title: Implementation of a Real-Time Ampacity Program

ADMINISTRATIVE DATA

OCA Contact William F. Brown x4-4820

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Military Security Classification: N/A
(or) Company/Industrial Proprietary: None

ONR Resident Rep. is ACO: ______ Yes X No
Defense Priority Rating: N/A

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with None proposed or anticipated.

COMMENTS:

Change 01 to the purchase order changes sponsor internal account number

COPIES TO:

SPONSOR'S I.D. NO. 02.256.000.87.013

Project Director	Procurement/GTRI Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Contract Support Div.(OCA)(2) Rat	Project File
Accounting	Research Communications	Other ______

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date November 23, 1987

Project No. E-25-686 School/~~Lab~~ ME

Includes Subproject No.(s) N/A

Project Director(s) W. Z. Black GTRC / ~~GIT~~

Sponsor Georgia Power Company

Title Implementation of a Real-~~Tiem~~ Time Ampacity Program

Effective Completion Date: 8/31/87 (Performance) 9/30/87 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ____________

Continues Project No. ____________ Continued by Project No. ____________

COPIES TO:

Project Director
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Research Property Management
Accounting
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Reports Coordinator (OCA) ✓
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Research Communications (2)
Project File
Other Duane Hutchison
Angela DuBose
Russ Embry

FORM OCA 69.285

CONDUCTOR THERMAL STUDIES
(GPAMP VERSION 3.01)

George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

October 1987

Final Report
Research Project E25-686

REAL-TIME DYNAMIC LINE RATING PROGRAM (GPAMP)

Submitted to

William Loard

Georgia Power Company
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submitted by

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George W. Woodruff School of Mechanical Engineering
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October 1987

CONTENTS

INTRODUCTION

This report describes a computer program called GPAMP for Georgia Power Real-Time Ampacity Program. The program is an extension of one developed jointly by Georgia Tech and Georgia Power for EPRI. The EPRI program has the capability of predicting the transient temperature of a wide range of overhead conductors subjected to practically any weather condition. The program accuracy was verified in an extensive three year project carried out at the Research Center at Forest Park. During the evaluation of the program, two conductors were installed in a 700 foot test span and instrumented with numerous thermocouples. Comparison of the thermocouple measurements with the predicted temperatures showed that the program was within $\pm$ 8° C over 90 percent of the time for temperatures as high as 100°C.

The EPRI Program cannot predict conductor temperatures on a real-time basis. Weather and current data must be assembled into an input file and entered into the program at one time. The program then provides a single set of output temperatures corresponding to the pre-assembled input data. To modify the EPRI ampacity program so that it could operate on a real-time basis, a second interface program was written to regulate input data to the ampacity program. The interface program is written in the C language and it activates the ampacity program only when a new set of current and weather data are received. Therefore a weather station that sends periodic data to the program can converse directly with the ampacity program and conductor temperatures can be calculated on a real-time basis.

In its present state, GPAMP will calculate the real-time temperatures of a single conductor. The input information corresponding to the single conductor is placed into the program in a properties file and the program is activated to calculate the conductor temperatures each time a weather station sends weather and current data to the program. The program prints the current data, weather data and conductor temperatures to the screen.

The program has the capability of predicting the temperature for eight different conductor types listed in Table 1.

Type	Conductor Material	Core Material
ACSR	1350-H19 Aluminum	Steel
AAC	1350-H19 Aluminum	1350-H19 Aluminum
AAAC	6201-T81 Aluminum	6201-T81 Aluminum
ACAR	1350-H19 Aluminum	6201-T81 Aluminum
All Copper	Hard Drawn Copper	Hard Drawn Copper
Alumoweld	1350-H19 Aluminum	Alumoweld
AAAC	5005-H19 Aluminum	5005-H19 Aluminum
SSAC	1350-H19 Aluminum 63% cond.	Steel

Table 1. Eight Different Conductors that can be Considered by GPAMP

HARDWARE AND SOFTWARE REQUIREMENTS

The hardware requirements to execute GPAMP are as follows:

1. An IBM-PC, IBM-PC XT or IBM-PC AT with a serial port.
2. A minimum of 384 K of RAM (user memory).
3. A minimum of one double-sided disk drive.
4. A monitor with an 80-column width display (recommended but not necessary).
5. An Intel 8087 or 80287 math coprocessor.

The software requirements necessary to execute GPAMP are DOS 3.0 or higher.

EXECUTING GPAMP

GPAMP can be executed only after the user has established a PROPERTY input file. Error messages during execution are written to an ERROR output file that must also be declared by the user. This section describes the information that must be assembled into the input file.

Properties Input File

The PROPERTIES input file contains the following information:

```
Line 1: ITYPE DIAI DCOND DCORE NSCOND NSCORE RAC
Line 2:  LATD LONG TZONE BETA GAMMA ELEV
Line 3:  SUNA EMISS
```

These input variables and their meanings are defined below.

<u>Line 1:</u>	Conductor Properties
Note:	Composite conductors, such as ACSR conductors, consist of two layers of different types of strands. The inner supporting strands are referred to as "core" strands. The outer current-carrying strands are called the "conductor" strands.
ITYPE = 1	ACSR Conductor
2	AAC 1350-H19 Conductor
3	AAAC 6201-T81 Conductor
4	ACAR Conductor
5	All Copper Conductor
6	Alumoweld Conductor
7	AAAC 5005-H19 Conductor
8	SSAC Conductor
	(see materials for core and instructor strands in Table 1.)
DIAI	Outer diameter of conductor in inches
DCOND	Diameter of individual conductor strands in inches

DCORE	Diameter of individual core strands in inches. This value is ignored for composite conductors with no core strands; that is conductors for which core and conductor material are identical (ITYPE=2,3,5,7).
NSCOND	Number of strands of conductor material, not including core strands.
NSCORE	Number of strands of core material.
RAC	The A.C. resistance of the composite conductor at 25°C in ohms per mile.
<u>Line 2:</u>	Line Location
LATD	Latitude of the conductor location in degrees north from the equator (See map in Fig. 1 for values).
LONG	Longitude of the conductor location in degrees east of Greenwich, England (See map in Fig. 1 for values).

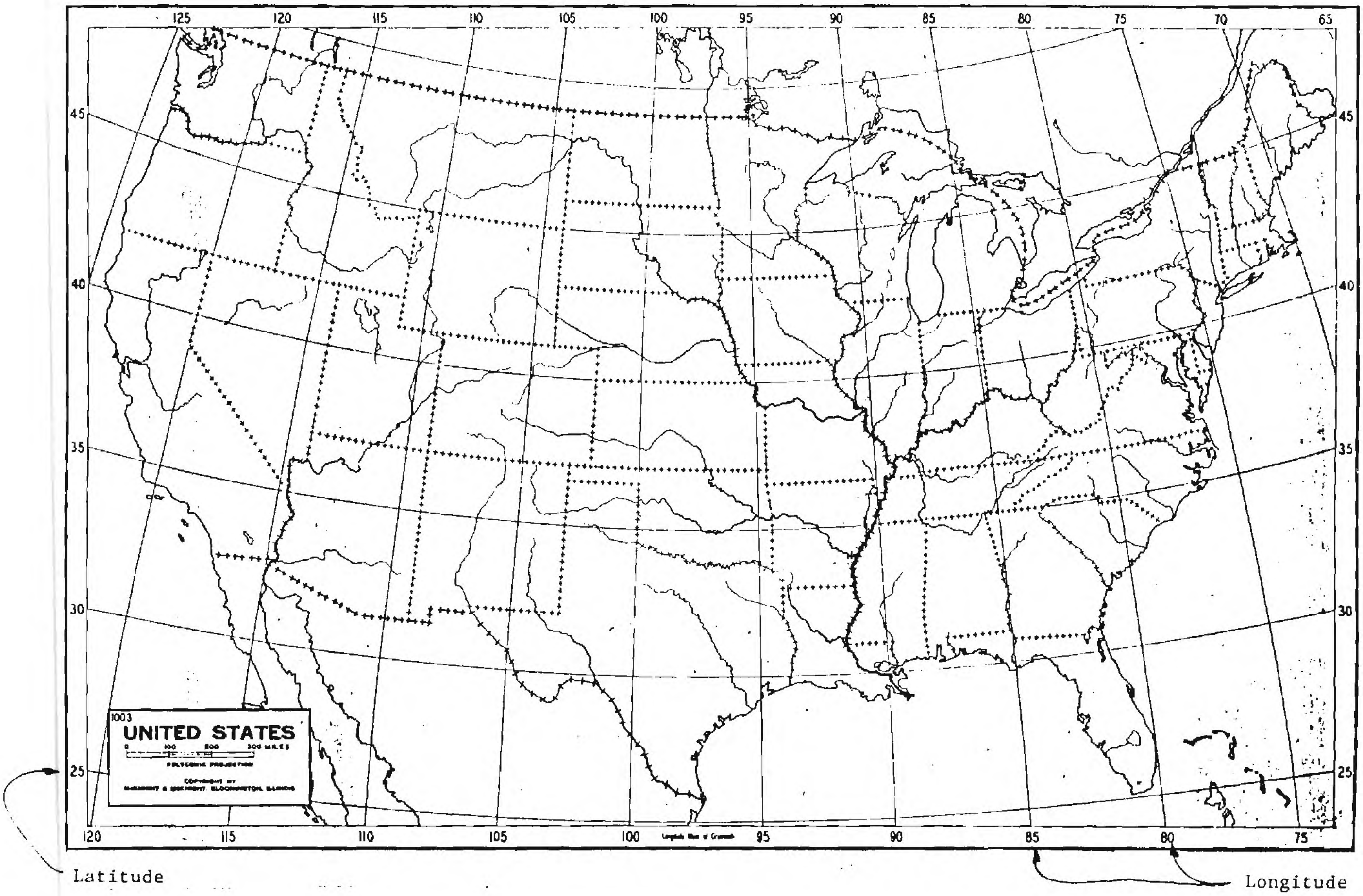

Figure 1. Latitude and Longitude for Continental U.S.

TZONE=	1	Eastern Time Zone
	2	Central Time Zone
	3	Mountain Time Zone
	4	Pacific Time Zone

BETA — The conductor inclination is the angle in degrees between a line through the conductor axis and the horizontal plane. The end of the conductor used to determine the inclination is the same one that is used to determine the conductor azimuth (GAMMA). If the end of the conductor lies below the horizon, then the inclination is negative. If the end of the conductor used to determine the conductor azimuth lies above the horizon, then the inclination (BETA) is positive. A horizontal conductor has BETA=0.

GAMMA — Conductor azimuth which is the angle in degrees measured clockwise from north to the horizontal projection of the axis of the conductor. The conductor azimuth must be between 0 and 180°. For example, an east-west line has GAMMA=90°. A conductor oriented from northwest to southeast has an azimuth of 135°. The azimuth of a north-south line can be either 0° or 180°.

ELEV — Elevation of the conductor above sea level in feet.

Line 3: Radiation Properties

SUNA The solar absorptivity of the conductor surface. The value of SUNA must be between 0 and 1. Recommended values for copper and aluminum conductors are given in the tables below.

EMISS The infrared emissivity of the conductor surface. The value for EMISS must be between 0 and 1. Recommended values for copper and aluminum conductors are given in the tables below.

These three lines of input data are the only ones necessary to execute GPAMP.

COPPER CONDUCTORS	
Oxidization	Absorptivity
None	0.23
Light	0.5
Normal	0.7
Heavy	1.0

ALUMINUM CONDUCTORS		
Years in Service	Line Voltage	
	<15 kV	>15 Kv
0	0.43	0.43
5-10	0.55	1.00
10-20	0.66	1.00
20-30	0.80	1.00
> 30	0.90	1.00

Recommended Values for Solar Absorptivity (SUNA) for Copper and Aluminum Conductors.

COPPER CONDUCTORS	
Oxidization	Emissivity
None	0.03
Light	0.3
Normal	0.5
Heavy	0.8

ALUMINUM CONDUCTORS		
Years in Service	Line Voltage	
	<15 kV	>15 Kv
0	0.23	0.23
5-10	0.35	0.82
10-20	0.46	0.88
20-30	0.60	0.90
> 30	0.70	0.90

Recommended Values for Infrared Emissivity (EMISS) for Copper and Aluminum Conductors.

In addition to the information placed into the input file, GPAMP expects date, time, weather conditions, and line current in real-time before it is able to calculate the conductor temperature. This information is sent via an optical fiber link from the weather station to the personal computer. This information includes:

date in julian notation

time that the data is sent in hours and minutes

wind direction in degrees CW from North

wind velocity in ft/sec.

ambient air temperature in °C

conductor current in amps

Output Information

GPAMP provides a single line of real-time data or output to the screen. The output consists of wind velocity in ft/sec, wind direction in degrees CW from north, ambient air temperature in °C, conductor current in amps and the line temperature in °C. In addition, the calculated value of the conductor temperature is interpoluted and written to hex address 300 so that an A/D converter can output a value between 0 and 5 volts.

Error File

The program also writes any error messages encountered upon execution to a user-declared error file. The error file can be edited and the contents printed to determine the exact nature of the error in program execution. If no errors occur during execution of the program, the error file will be empty.

OPERATION OF GPAMP ON AN IBM-PC

The following steps illustrate the way in which GPAMP can be executed on an IBM-PC. The user must first create a single PROPERTIES input file for the conductor being monitored. This file must be established according to the guidelines outline in the previous section. Once the input file has been created, log onto the drive unit that contains GPAMP and the input data file. Then type the command:

```
GPAMP
```

and the computer will clear the screen and wait until any key is pressed.

Then the following prompt will appear:

```
WHAT IS THE NAME OF THE PROPERTIES INPUT FILE?
```

Once the user supplies the name of a property file, the screen will clear and the following message will appear:

```
WHAT IS THE NAME OF THE ERROR FILE?
```

The user must then declare the name of the error file which is used to store any error messages. After the name of the error file has been established, the screen will clear and the following message wi'' appear.

```
        SERIAL CONFIGURATION PARAMETERS ARE:


BAUD           WORD         PARITY            # OF STOP
RATE           LENGTH   (0=N, 1=E, 2=0)         BITS

300             7            1                   1

PRESS <CTRL-X> TO TERMINATE EXECUTION
```

When the message:

```
SETUP COMPLETED.  READY TO RECEIVE DATA
```

appears, the program is ready to receive conductor current and weather data. The calculated conductor temperatures will follow as the incoming weather station data are received. Program calculations will continue uninterrupted as long as input data are available.

The program execution can be terminated at any time by entering CTRL - X.

PROGRAMMING RECOMMENDATIONS

The program internally sets the stack size equal to 64,000 bytes, so the user does not need to be concerned about adjusting the value for the stack size.

The program execution can be terminated by pressing <CTRL-X>. The user should not use either <CTRL-C> or <CTRL-BREAK>.

The user should only use valid input and output file names. The operating system will check file names for validity, but it may not always catch inconsistencies.

The program sets the time interval for calculations of conductor temperature and for the printing interval by using the time sent by the weather station. Any reasonable time interval is acceptable; however, the minimum value is one minute and a value greater than about twenty minutes will cause calculations to approach steady-state temperatures, even though the program is expected to calculate transient or real-time temperatures.

EXAMPLE PROPERTIES FILES

This section contains two example property input files. The first illustration is for a 230kv ACSR 1033 kcmil Curlew conductor that is located in the Atlanta area. The line is oriented in a North-South direction and it is horizontal. The conductor has been in service for over 30 years.

The three lines of input data are arranged in the manner specified in a previous section. The input file is shown below.

```
1  1.245  0.1383  0.1383  54  7  0.091
34  84  1  0  0  1000
1.0  0.9
```

The first line contains the following conductor property data:

1	Specifies an ACSR Conductor
1.245	Outside diameter of the conductor in inches
0.1383	Diameter of conductor (aluminum) strands in inches
0.1383	Diameter of the core (steel) stands in inches
54	Number of conductor (aluminum) strands
7	Number of core (steel) strands
0.091	A.C. Resistance in ohms per mile

The second line contains the following line location date:

34	Latitude of Atlanta
84	Longitude of Atlanta
1	Time zone of Atlanta (Eastern time zone)
0	Conductor inclination (horizontal)
0	Conductor azimuth (N-S line)
1000	Elevation above sea level in feet.

The third line contains the follow radiation properties data:

1.0	Solar absorptivity of the aluminum outer strands (see table on page 7)
0.9	Infrared emissivity of aluminum outer strands (see table on page 8).

As a second example, consider an AAC Marigold conductor located in the San Francisco area. The conductor is horizontal and oriented in a North-South direction at an elevation of 600 feet. The emissivity and absorptivity of the aluminum strands are 0.3 and 0.5. The data file for the example is shown below.

```
2  1.216  0.1351  0.0  61  0  0.0872
38.0  122.0  4  0.0  0.0  600.
.5  .3
```

First line:

2	Specifies an AAC Conductor
1.216	Outside diameter of the conductor in inches
0.1351	Diameter of the conductor (aluminum strands in inches)
0.0	Diameter of the core strands in inches (an AAC does not have any core strands, so this value is ignored upon input).
61	Number of conductor (aluminum) strands
0	Number of core strands
0.0872	AC resistance of the conductor in ohms per mile

Second line:

38	Latitude of San Francisco
122	Longitude of San Francisco
4	Time zone of San Francisco (Pacific Time Zone)
0	Conductor inclination (Horizontal Conductor)
0	Conductor azimuth (North-South line)
600	Elevation above sea level in feet.

Third line:

0.5	Solar absorptivity of aluminum strands
0.3	Infrared emissivity of aluminum strands