Final Report:

First Year of Contract

"Modification of Princeton Charge-Exchange Data Analysis Code"

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I. History of GEORGIA TEXAS code

GEORGIA TEXAS is a modified version (by Georgia Tech) of the TEXAS code developed by Steve Scott at Princeton Plasma Physics Laboratory (PPPL). The TEXAS code was developed to analyze the data collected by the E parallel to B charge exchange analyzer used at the Toroidal Fusion Test Reactor (TFTR). Since an analyzer similar to the one used on TFTR was purchased by Oak Ridge National Laboratory (ORNL) for use on the Advanced Toroidal Facility (ATF), the TEXAS code was also imported by ORNL to analyze the data for ATF. Modifications have been made to the TEXAS code by Georgia Tech to make it compatible with the computer systems used at ORNL. With several other enhancements, this data analysis package is now known as GEORGIA TEXAS.

II. Explanation of GEORGIA TEXAS

The charge exchange analyzer is used to infer the central ion temperature in a fusion experiment by measuring the energy spectrum of the neutral hydrogen isotopes escaping from the plasma. The basic equations used are as follows:

$$f_i = \frac{\dot{N}_i}{\frac{2}{\sqrt{\pi}} \frac{s_1 s_2}{4\pi l_{12}} \eta_s \left(\frac{\Delta E}{E}\right)_i \langle\sigma v\rangle_{cx} E_i^{3/2}} \qquad (1)$$

and

$$f_i = \frac{n_o n_i a}{T_{ion}^{3/2}} \exp\left(-\frac{E_i}{T_{ion}}\right) \qquad (2)$$

The parameters in the denominator of the first equation are known from the geometry and calibration of the analyzer and thus, from the signal ($\dot{N}_i$) measured by the CEX analyzer, an energy spectrum (f_i) can be calulated from the first equation. With this energy distribution, the ion temperature (T_{ion}) can be obtained from the second equation by performing a least-squares fit on log f versus energy.

GEORGIA TEXAS is capable of several different types of analyses that provide pertinent information about the ion distribution of the plasma. The user of GEORGIA TEXAS determines which of the various types of analyses is to be performed through a menu-driven interface that prompts the user for all the critical information for the selected type of analysis. Types of parameters specified here include:

1) Type of analysis to perform
2) Energy range for fitting routines
3) Shot list
4) Type of noise subtraction (if any)

An option is also include that will write/read the selected analysis parameters to disk so the user does not have to specify everything each time he/she runs a similar analysis.

2. Data necessary for analysis

To perform these various analyses, GEORGIA TEXAS must have access to the data collected by the various collection devices for the CEX system. This data is retrieved and written to a Data Management System (DMG) database at the completion of each shot by the data acquisition package. The data retrieved and recorded by the data acqusition package include parameters for:

1) CEX analyzer configuration
2) Detection efficiency of the CEX analyzer
3) Detected signal

After the user has specified all the analysis parameters (including the shot number(s) of interest) and asks GEORGIA TEXAS to perform the analysis, the recorded data will be retrieved through the DMG and the analysis will proceed.

3. Output of analyzed data

GEORGIA TEXAS has only one form of output, TEXTRONIX plots. The user has complete control of the make-up of each plot and can specify such characteristics as the following:

1) Which graphs to include on a certain plot
2) Graph locations on plot
3) Variable list to display -- all variables necessary for analysis can be displayed.
4) Scales of graphs

III. Operation of GEORGIA TEXAS

All the source code necessary for proper operation of GEORGIA TEXAS is located in the following directory:

```
SYS$USERD:[CEX.TEXAS.SOURCE]
```

If there is a desire to modify the GEORGIA TEXAS package in any way, the modified subroutine should be compiled and included in the following library :

```
SYS$USERD:[CEX.TEXAS]TEXAS.OLB
```

To link the GEORGIA TEXAS code, from within the SYS$USERD:[CEX.TEXAS] directory, simply type

```
@TEXAS_ORNL
```

This command file will include all the necessary libraries for linkage and will produce the executable image:

```
SYS$USERD:[CEX.TEXAS]GA_TEX.EXE
```

Therefore, to execute the GEORGIA TEXAS analysis package, simply type

```
RUN GA_TEX
```

from the SYS$USERD:[CEX.TEXAS] directory.

The program will prompt for your initials and then proceed to the Main Menu. This is where you will specify the type of analysis to be performed. Each of these options are explained in the user's guide for TEXAS.

If there ever arises a need to recreate the GEORGIA TEXAS executable image from scratch, the following procedure should be followed:

1) From within the SYS$USERD:[CEX.TEXAS] directory, simply type

```
@COMPILE TEXAS.
```

This command file will compile all the source files necessary for the proper execution of GEORGIA TEXAS and will insert the object codes into the library SYS$USERD:[CEX.TEXAS]TEXAS.OLB.

2) Proceed as outlined above starting with the command file to perform the linking with the appropriate libraries.

IV. Modifications/Enhancements made to GEORGIA TEXAS

1. Interface to database

The acquired version of TEXAS from PPPL contained input/output subroutines that were site-specific to the computer systems at PPPL. These subroutines could not be used at ORNL due to the lack of compatibility. To provide this compatibility, subroutines that could read/write the same information as the PPPL subroutines were developed. The new subroutines read the data from a DMG database and are contained in the source file (attached):

```
SYS$USERD:[CEX.TEXAS]DMG_READ_CEX.FOR
```

This file contains two subroutines:

```
DMG_READ_INT ---> for reading data stored as integer values
DMG_READ_REAL ---> for reading data stored as real values
```

These subroutines are called from the subroutines READ_CONFIG and READ_AND_BIN_COUNTS in the new source files (attached):

```
SYS$USERD:[CEX.TEXAS]READ_CONFIG.FOR
SYS$USERD:[CEX.TEXAS]READ_AND_BIN_DATA.FOR
```

These two subroutines control the input of the data from the DMG database. In the original version, the data input by the READ_CONFIG subroutine was previously read through a sucession of calls to the TEXAS subroutines READCON, READPAR, and READCAL.

Note: The DMG database routines assume all data variables to be either INTEGER*4 or REAL*4 and because of the 64KB limit on the size of an array variable, the largest dimension of the array can be only 16K.

2. Simulation Routine

Since ATF has not yet become operational, the data necessary to perform testing of GEORGIA TEXAS had to be created by some form of simulation. A set of subroutines has been developed that can create counts data that the analyzer should detect given the temperature and density of the plasma. With these subroutines, the user simply chooses an ion temperature and the simulation routine will calculate optimum electric and magnetic fields for the CEX analyzer and then will compute an estimate of the number of counts the CEX analyzer should collect in a given time frame. The two subroutines that perform this simulation are CREATE_CONFIG and CREATE_DATA which can be found in the source files (attached):

SYS$USERD:[CEX.TEXAS]CREATE_CONFIG.FOR
SYS$USERD:[CEX.TEXAS]CREATE_DATA.FOR ,
respectively.

These subroutines were used to create a DMG database in order to test the DMG subroutines outlined above and are also included as an option within GEORGIA TEXAS. To use the simulation routine within GEORGIA TEXAS, simply type SIM ← at the Main Menu. At this point, you will be prompted to specify whether or not you wish to use simulated data (Default is No) and if you choose to use the simulation routine, the central ion temperature (in eV) of the plasma to be simulated. From this point, proceed as normal and when data is to be input for analysis, the subroutines READ_CONFIG and READ_AND_BIN_COUNTS will call the simulation subroutines to create the necessary data instead of reading data through the DMG subroutines outlined above.

3. Removal of extraneous code

The acquried version of TEXAS contained sections of code that were specifically written for the PPPL charge exchange analysers and sections that were necessary for specific shots or sets of shots. Also, because of intermittent problems with correctly calibrating the analyzer, some values were "hard-wired" within the TEXAS code since it was known that the values input from the calibration database were incorrect. Within GEORGIA TEXAS, these corrective measures have been removed and assuming the perfect operation of the CEX analyzer, they should not have to be added at a later date.

Final Report: Additional Modifications and Enhancements of the Charge Exchange Data Analysis Code

During the last nine months, work has progressed along two fronts on charge-exchange software development. The first is the addition of several features to the GEORGIA TEXAS data analysis code. Secondly, a data acquisition system has been developed. The additions to GEORGIA TEXAS have been thoroughly tested and seem to be working properly while testing still continues on the data acquisition package. Hopefully, this testing can be completed in June to allow for collection of charge-exchange data.

I. GEORGIA TEXAS Data Analysis Code

A. Automatic Analysis: An automatic mode for GEORGIA TEXAS has been developed that will be able to perform analysis on charge-exchange data immediately after a completed ATF shot. This mode operates as follows:

i) User will enter GEORGIA TEXAS as usual.

ii) At the Main Menu, the user should choose the automatic option: GOA

iii) The standard analysis parameter file (previously created/modified by Charge Exchange Personnel) will be loaded automatically.

iv) The program will now wait for notification from SAMS that a shot has been completed and the data is available for analysis.

v) GEORGIA TEXAS will perform its analysis (as specified in the loaded parameter file), display a set of "standard" plots (to be determined), and write the analyzed data to the Ion Temperature data file.

vi) If the parameter file has been changed during the operation of the automatic mode through some other attached process, then the new file's parameters will be loaded at this point.

vii) Return to Step iv. Note that an escape key (yet to be determined) will be available here that will allow the operator to exit the automatic mode if desired.

B. Output of Ion Temperature: An option has been added to GEORGIA TEXAS that allows the output of the calculated ion temperature to the ATF Data Management System. Because of the dependency of this computed value on various user-defined parameters, an exhaustive list has been compiled of these parameters and each will be output to the Data Management System.

The following is a listing of these parameters:

- Minimum counts allowed
- Minimum signal/noise ratio allowed
- Rejection factor
- Minimum anode allowed
- Limits of the fit versus energy (versus time)
- Data Point weighting scheme (standard or non-standard)

The capability of the Charge-Exchange analyzer to scan over both toroidal and poloidal angles necessitates the output of the location of the point on the analyzer sight-line closest to the center-line of the plasma. This location will be necessary for other analysis routines since the calculated ion temperature is assumed to be representative of this point.To specify this location completely, the following values must be included in the DMG database:

- Major Tangency Radius
- Minor Tangency Radius
- Azimuthal Angle

The values computed by GEORGIA TEXAS that will be written to this database are:

- Ion temperature versus time
- Ion temperature standard deviation versus time
- χ^2 versus time
- Intercept versus time $\left(\frac{n_o n_i a}{T_i^{3/2}}\right)$
- Intercept standard deviation versus time
- Effective minor radius

To implement this feature, the user must first signify to GEORGIA TEXAS that the calculated ion temperature should be written to the ATF Data Management data file. To do this, the user must simply type WTI from the main menu of GEORGIA TEXAS and specify that the ion temperature should be saved (the default is that ion temperature not be saved). Unless this feature is turned off again during the session, a prompt will appear after each plotting of ion temperature versus time similar to the following:

```
Write ion temperature to database?
          1) Write ion temperature to database
          2) Redisplay plot
          3) Return to Main Menu
Choice?
```

The second option has been added in case the user wishes to review the plot again before deciding on whether to save the calculated ion temperature values. Choosing option 1 will take a few seconds to save the data and then will return to the main menu.

II. Data Acquisition System

The charge-exchange (CEX) data acquisition (DAQ) system for ATF was adapted from the system developed by Ed Blair for ISX charge-exchange data acquisition. Although several modifications (outlined below) were made to the ISX package, the amount of work has been substantially decreased by using this existing package.

Description

The CEX DAQ package is divided into three separate processes to be described below:

1) Initialization: The initialization process is performed once during the system startup phase. During this phase various internal system tables are initialized from parameters contained in the CEX system configuration data file. CAMAC modules utilized by the data system are initialized to provide an initial integrity check on the operability of the data system instrumentation.

2) Acquisition: Several steps comprise this process:

- i) Connect to SAMS
- ii) Wait for the ATF -30 sec. signal
- iii) Initialize CAMAC Modules for upcoming ATF shot -- Scalars, Clocks, etc.
- iv) Wait for ATF end-of-shot signal
- v) Collect data from CAMAC Modules

3) Output of Data: Write collected data to the ATF Data Management System.

Modifications

A. Because the charge-exchange analyzer used for ATF was purchased from Princeton Plasma Physics Laboratory, the CAMAC modules controlling and monitoring data acquisition were entirely different from the modules normally used for ORNL data acquisition. Therefore, considerable time was spent developing and testing subroutines to control and monitor each of the PPPL CAMAC modules. A description of these routines follows:

1) H911_LB.FOR -- Princeton 911 Latching Scalar

The Princeton 911 Latching Scalar records counts for a maximum of 32 channels and will dump these values to a maximum of 32 memories (only one used for CEX DAQ) when a rising pulse is seen on the count enable (CE) input. The memories are specially designed to be read by access through the 911 Latching Scalar. The scalar-channel to column-anode mapping is defined in the data acquisition configuration file (CEXCONFIG.DAT) and is read by CEX DAQ during initialization. If any anode pad number is excluded in this definition, the system assumes that the anode pad is not operational and will not collect/record data for this anode pad.

Included Subroutines:

H911_ID	Reads Scalar ID
H911_ARM	Arms Scalar -- Ready to take data
H911_READBACK	Puts scalar in mode to read data
H911_STANDBY	Puts scalar in wait mode
H911_COUNT	Reads number of count enable pulses
H911_STATUS	Reads Scalar status register
H911_CHANS	Reads number of attached channels
H911_MEMORY	Reads number of attached memories
H911_READ	Reads counts for each channel

2) JW412_LB.FOR -- Jorway 412 Time Sequencing Module

The Jorway 412 Time Sequencing Module (TSM) allows programmable control of the amount of time that each scalar will collect data before dumping to the corresponding memory. The TSM module output signal will change from logic zero (scalar taking data) to logic one (scalar dumping to memory) when the total number of input clock pulses since the module was triggered is equal to one of the values programmed by the user (via the JW412_SET_BINS subroutine). The TSM output signal will remain at logic one for one clock pulse. The input clock used here will be a LeCroy 8501 Programmable Clock programmed to operate at 1 MHz. An example of a typical configuration follows:

Lecroy 8501 Clock Speed:1 MHz

Jorway 412 Settings:
10000
20000
30000
35000
40000
50000
etc...

Scalar will latch at:
.01 sec
.02 sec
.03 sec
.035 sec
.04 sec
.05 sec
etc...

NOTE: In this case, the TSM output pulse will remain at logic one for 1 μsec.

The values programmed into the TSM are calculated from settings defined in the CEX DAQ configuration file. Defined in this file are:

- Number of acquisition rates
- Frequency of each acquistion rate
- Starting time for each acquisition rate

At the present time, the number of acquisition rates has been limited to 10 but can be modified if necessary by changing a compile-time parameter.

Because the ISX DAQ system used a constant acquisition rate, several changes were required for the present package to take advantage of this variable acquisition rate capability.

Included Subroutines:

JW412_ID	Reads TSM ID
JW412_ENABLE	Enables TSM
JW412_DISABLE	Disables TSM
JW412_SET_BINS	Sets scalar binning times
JW412_STATUS	Reads TSM status register
JW412_SET_CYCLES	Set number of TSM recycles
JW412_READ_SETUP	Reads TSM settings

3) PPPLLB.FOR

These subroutines were developed by Princeton Plasma Physics Laboratory and tested by J.B. Mankin at ORNL. They control and monitor the following CAMAC modules:

i) H409 Digital Timed Gate
ii) H302 Relay Type Digital Output Module
iii) H304 Digital Output Module
iv) H322 Digital Input Module
v) H320 16 Channel Analog-Digital Converter
vi) H321 8 Channel Digital-Analog Converter

These modules control and read such things as analyzer magnetic field strength, stripping cell pressure, etc. The PPPL module-channel mapping to its corresponding signal is defined in the CEX DAQ configuration file. Testing is not complete on the interface between the data acquisition program and these modules.

B. Because the ISX data management system was developed before the advent of the Data Management System, considerable effort was necessary to develop the code for the output of data to the ATF Data Management System.The library of subroutines written for this purpose is included in the file:

WRITE_DATA.FOR

All data is accumulated by the data acquisition system before the data is outputted to the Data Management System. This alleviates any problems that may result during the reading of the various CAMAC modules that could possibly lead to an abnormal exit of the program.

C. Taking advantage of the ATF Run-Time Library Routines, all messages (general, error, etc.) are now handled by the subroutine LOG_MESSAGE.FOR. This subroutine uses the ATF_LOG_MESSAGE routine to record the message in the appropriate CEX DAQ log file specified in the CEX DAQ general parameter file CEXSTATE.NCL (see below).

General

The source code for the Data Acquisition Program are located in the directory:

SYS$USERF:[WADEMR.DAQ.DEVELOP]

The following is a list and brief description of each of the files in this directory:

1. CEXMAIN.FOR

   This file contains the main routine for general purpose CEX data acquisition system. It implements the stage control of the system.

2. CEXCONFIG.FOR

   This file contains the initialization routines for the general purpose CEX data acquisition system. It includes the routines that read the configuration file and parameter verification routines.

3. CEXDAQ.FOR

   This file contains the stage action routines for the general purpose CEX data acquisition system. It implements the actual data acquisiton for the system.

4. WRITE_DATA.FOR

   This file contains the routines that output the collected data for the CEX data acquisition system to the ATF Data Management database. (Described above).

5. LOG_MESSAGE.FOR

   This file contains the routine for logging message within the CEX data acquisition system (Described above).

6. H911_LB.FOR

   This file contains the routines for controlling and monitoring the Princeton 911 Latching Scalar for the CEX data acquisition system (described above).

7. JW412_LB.FOR

   This file contains the routines for controlling and monitoring the Jorway 412 Time Sequencing Module for the CEX data acquisition system (described above).

8. GET_FILE_VERSION.FOR

   This file contains a routine for retrieving the version of the specified file.

9. CEXSTATE.NCL

   This file contains the global data base COMMON block for the CEX data acquisition system. This file is included in those routines needing to access general system global parameters and/or data.

10. CEXCLOCK.NCL

    This file contains the state COMMON block for the CAMAC clock modules utilized by the CEX data acquisition system. As mentioned before, the LeCroy 8501 clock will be used for this system. This file is included in those routines needing to access clock data and/or parameters.

11. CEXSCALE.NCL

    This file contains the state COMMON block for the Princeton 911 Latching Scalar utilized by the CEX data acquisition system. This file is included in those routines needing to access scalar data and/or parameters.

12. CEXTSM.NCL

This file contains the state COMMON block for the Jorway 412 Time Sequencing Module utilized by the CEX data acquisition system.This file is included in those routines needing to access the time sequencing data and/or parameters.

13. CEXCAM_MODS.NCL

This file contains the state COMMON block for the Princeton CAMAC Modules utilized by the CEX data acquisition system. This file is included in those routines needing to access CAMAC module data and/or parameters.

14. CEX_SIGNAL_NAME.NCL

This file contains the assignment of Data Management System signal names for all data to be stored by the CEX data acqusition system.

15. ATF_MESSAGE.NCL

This file contains the state COMMON and parameters necessary for the logging of message by the CEX data acquisition system.

16. CEXANAL.NCL

This file contains the state COMMON for the charge-exchange analyzer for which the CEX data acquisition is collecting data. This file is included in those routines needing to access analyzer data (calibration/configuration) and/or parameters.

17. CEXDEBUG.NCL

This file contains the state COMMON necessary for debugging control of the CEX data acquisition system.

18. MEACONFIG.DAT

This is the CEX data acquisition configuration data file.

19. CEX_CALIB.DAT

This is the charge-exchange analyzer configuration/calibration file.

20. CEXDEBUG.DAT

    This is the CEX data acquisition debugging control file. Changing this file allows selected debugging of the data acquisition program.

21. CEXDAQ.MMS

    This is an MMS descriptor file that controls the compilation and linking of the CEX data acquisition system.

To compile and link this program, run the CEXDAQ.COM command procedure from within the above directory and the CEX data acquisition executable CEXDAQ.EXE will be created.