GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No./(Center No.) E-25-665 (R6261-0A0) GTRC/GIT DATE 2 / 4 / 87

Project Director: C.E. Thomas School/Lab ME

Sponsor: Martin Marietta Energy Systems, Inc.

Agreement No.: Subcontract No. 19X-91326C

Award Period: From 11/1/86 To ~~9/30/87~~ 6/30/88 (Performance) 9/30/87 Reports

Sponsor Amount: New With This Change / Total to Date

Contract Value: $ ______ $ 36,853

Funded: $ ______ $ 36,853

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

Title: Modification of Princeton Charge Exchange Data Analysis Code

ADMINISTRATIVE DATA OCA Contact John B. Schonk X-4820

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Military Security Classification: N/A ONR Resident Rep. is ACO: ____ Yes ____ No

(or) Company/Industrial Proprietary: N/A Defense Priority Rating: ______

RESTRICTIONS

See Attached Govt. 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 Sponsor

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SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 6/9/88

Project No. E-25-665   School/~~Lab~~ ME

Includes Subproject No.(s) N/A

Project Director(s) C. E. Thomas   GTRC/~~GIT~~

Sponsor Martin Marietta Corporation

Title Modification of Princeton Charge Exchange Data Analysis Code

Effective Completion Date: 6/30/88 (Performance) 6/30/88 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Copy of Last Invoice Serving as Final
- [x] Release and Assignment
- [x] Final Report of Inventions and/or Subcontract: Patent and Subcontract Questionnaire sent to Project Director [x]
- [x] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______

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PROGRESS REPORT

The bulk of the work required thus far in modifying TEXAS (the PPPL charge-exchange data analysis code) has been cleaning out the extraneous code not necessary for analysis of data for ATF. Most of this work has been devoted to removing sections of code that were specifically written for the PPPL charge-exchange analyzers and sections that were necessary for specific shots or sets of shots.

All of the original TEXAS database retrieval routines have been replaced by calls to the ATF Data Management System. At the present time, no charge-exchange data has been written to the ATF Data Management System and therefore, these sections of code have not been tested.

The attached subroutines (create pts, create cfg) have been written to help accomplish this task. The subroutines constitute a simulation routine which calculates counts data that the charge-exchange analyzer should measure given specific plasma parameters (ion temperature, neutral and ion densities, and plasma minor radius). The anode gains that are assigned to each anode, the polynomial fits, and geometrical configuration of the analyzer are the actual values for the charge- exchange analyzer to be used on ATF.

This simulation will help in two ways: (1) Provide counts data to be inputted to the ATF Data Management System so that our retrieval routines can be tested; and (2) Provide charge exchange personnel with fairly accurate estimates of the signal that the analyzer will see. Using this routine to create the counts data since the database retrieval routines are inoperative, TEXAS is now functional with all types of analysis that have been tested working properly.

```
      subroutine create_pts ( manuf_data)

c     -- This subroutine creates counts for each anode given
c     an ion tempeature and y-intecept of flux vs. energy (defined
c     in create_cfg). This routine will randomly fluctuate the
c     ion temperature between .9 -1.10 the given ion tempeature.
c     After calculating the expected count for anode, we will
c     provide this count with a random error correction.

      include 'param.com'
      include 'parm.com'

      integer*2 manuf_data(p_nchan/2, p_nsteps)
      INTEGER i,j,k,n_pads
      REAL
     %     ion_temp,
     %     ampl,
     %     energy,
     %     strip_eff,
     %     geom_fac,
     %     rypoly,
     %     res_eff,
     %     cx,
     %     enerdist,
     %     flux,
     %     abs_kkmass,
     %      no,
     %      ni

      i1 = 0
      i2 = 0

c     /** Ion temperature hard-wired for now **/
      ion_temp = 1032.
       max_ypos = tdetypos(3) + 12.

      abs_kkmass = abs(kkmass)

c     /** Define Density profiles and minor radius for plasma **/
      no = 1.0E+07
      ni = 5.0E+13
      minor_rad = 30

c     /** Calculate y-intercept of graph **/
      ampl =  no*ni*minor_rad / ion_temp**1.5

C     /** Define energy range in which TI will be calculated **/
      emark =  4 * ion_temp / 1000
      emax = 10 * ion_temp / 1000
C
C     /** Calculate necessary magnetic field for this range **/
      rypoly = 0.
      do 30 i = 1, 6
        rypoly = rypoly + ttjcoeff(i) * ( max_ypos ** (i-1) )
 30   continue

      tbefbf = sqrt ( emax * abs_kkmass  / rypoly )
c     print *, 'Magnetic field is ', tbefbf
```

```
      tbefef = (abs_kkmass - 0.5 - 0.3) * (tbefbf**2) /
     &             (1.53 * 5.72 * abs_kkmass)

      pi = ACOS ( -1. )

c     /** Calculate count for each time step **/
      do 100 j = 1, ktotts

c        /** Create random ion temperature **/
         call randu ( i1, i2, factor )
         tmpion_temp = ion_temp * ( factor/5 + .9 )

         do 100 i = 1, p_nchan/2

c           /** Determine corresponding anode pad **/
            do k=1, p_npads
               if ( i .eq. kapchan(k,1) ) then
                ianode = k
c               print *, 'Anode for channel ',i,' is ',ianode
                goto 150
               end if
            end do

 150        if ( ianode .le. 25 ) then
               rypos(ianode) = tdetypos(1) + 0.5*(ianode-1)
            else if ( ianode .gt. 25 .and. ianode .le. 50 ) then
               rypos(ianode) = tdetypos(2) + 0.5*(ianode-26)
            else
               rypos(ianode) = tdetypos(3) + 0.5*(ianode-51)
            end if

            rypoly = 0.
            do k=1,6
               rypoly = rypoly + ttjcoeff(k)*(rypos(ianode)**(k-1))
            end do

c           /** Define energy for given anode **/
            energy =  1000 * (tbefbf**2) * rypoly / abs_kkmass

c           /** CX cross section for given energy **/
            cx = sigcx(energy/1000) * sqrt(energy*1.602e-15*2 *
     %            5.98e+26/abs_kkmass)
            cx = 1e-15 * cx
c
            geom_fac = sent * sexit / (4*pi*sl112**2)
c
            res_eff = 0.
            do 40 k = 1, 6
              res_eff = res_eff + trcoeff(k) * (rypos(ianode)**(k-1))
40          continue
            res_eff = res_eff / 100
c
            strip_eff = 0.
            do 50 k = 1, 6
             strip_eff = strip_eff + tecoeff(1,k) *
     %         ( (energy/(1000*abs_kkmass))**(k-1) )
 50          continue
c
c           /** Calculate energy distribution **/
            enerdist =  ampl * exp(-energy/tmpion_temp)
```

```
c
          flux = enerdist * cx * 2 * sqrt( energy/pi )
c
          manuf_data (i,j) = int( geom_fac * res_eff * strip_eff *
     &      flux * energy * ttstep / exp ( rapgain(ianode,1) ) )
c     print *,ianode,energy,res_eff, geom_fac, strip_eff,manuf_data(i,1)

c
100   continue


      return

      end
```

```
c
      subroutine create_cfg ( ier )
c
c     -- Creates a configuration set-up for the charge
c     exchange analyzer.  Defines geometric configuration
c     of analyzer and calculates necessary values such as
c     magnetic field and electric field.
C
      include 'param.com'
      include 'parm.com'

      INTEGER i,j,k,n_pads
      REAL
     &     max_ypos,
     &     no,
     &     ni,
     &     ion_temp,
     &     minor_rad,
     &     rypoly,
     &     ampl
c
      pi = ACOS ( -1. )
C
c     /** Define Aperature sizes for stripping cell **/
      sent = 0.0696
      sexit = 0.0696
      sl112 = 26.
      smiss = 1.

c     /** Define simulated acquistion rate **/
      kmultst = 0
      ktotts = 1000
      ttstep = .010

c     /** Determine POSITION of anode from analyzer **/
      tdetypos ( 1 ) = 5.25
      tdetypos ( 2 ) = 17.75
      tdetypos ( 3 ) = 30.25

c     /** Set resolution coefficients **/
      trcoeff(1) = 13.10000
      trcoeff(2) = -1.457
      trcoeff(3) = .1113
      trcoeff(4) = -4.802e-03
      trcoeff(5) = 1.018e-04
       trcoeff(6) = -8.214e-07

c     /** Set trajectory coefficients **/
      ttjcoeff(1) = .39400
      ttjcoeff(2) = 3.433e-02
      ttjcoeff(3) = 8.061e-03
      ttjcoeff(4) = 2.596e-04
      ttjcoeff(5) = -6.395e-06
      ttjcoeff(6) = 5.594e-08

      /** Set efficiency coefficients for polynomial fit **/
      tecoeff(1,1) = -6.9191e-2
      tecoeff(1,2) = 9.43533e-2
      tecoeff(1,3) = -1.52351E-2
      tecoeff(1,4) = 1.19137E-3
```

```
      tecoeff(1,5) = -4.39089E-5
      tecoeff(1,6) = 6.08733E-7

c     /** Set relative gains of each anode pad **/
      rapgain(1,1) = .38
      rapgain(3,1) = .45
      rapgain(5,1) = .58
      rapgain(7,1) = .71
      rapgain(9,1) = .74
      rapgain(11,1) = .56
      rapgain(13,1) = .59
      rapgain(15,1) = .81
      rapgain(17,1) = 1.05
      rapgain(19,1) = 1.04
      rapgain(21,1) = .90
      rapgain(23,1) = .86
      rapgain(25,1) = .88
      rapgain(26,1) = .97
      rapgain(28,1) = 1.06
      rapgain(30,1) = 1.00
      rapgain(32,1) = .98
      rapgain(34,1) = 1.02
      rapgain(36,1) = 1.01
      rapgain(38,1) = 1.06
      rapgain(40,1) = .91
      rapgain(42,1) = 1.02
      rapgain(44,1) = 1.01
      rapgain(46,1) = .92
      rapgain(48,1) = 1.03
      rapgain(50,1) = 1.
      rapgain(51,1) = 1.09
      rapgain(53,1) = 1.27
      rapgain(55,1) = .89
      rapgain(57,1) = .92
      rapgain(59,1) = .92
      rapgain(61,1) = .86
      rapgain(63,1) = .91
      rapgain(65,1) = .92
      rapgain(67,1) = .95
      rapgain(69,1) = .97
      rapgain(71,1) = .93
      rapgain(73,1) = .93
      rapgain(75,1) = 1.47

c     /** Set relative gains of each anode pad **/
      rapgain(1,2) = .32
      rapgain(3,2) = .32
      rapgain(5,2) = .66
      rapgain(7,2) = .62
      rapgain(9,2) = .68
      rapgain(11,2) = .78
      rapgain(13,2) = .74
      rapgain(15,2) = .78
      rapgain(17,2) = .87
      rapgain(19,2) = .85
      rapgain(21,2) = .81
      rapgain(23,2) = .76
      rapgain(25,2) = .86
      rapgain(26,2) = .93
      rapgain(28,2) = 1.08
```

```
      rapgain(30,2) = 1.00
      rapgain(32,2) = .99
      rapgain(34,2) = .96
      rapgain(36,2) = .99
      rapgain(38,2) = 1.01
      rapgain(40,2) = .97
      rapgain(42,2) = 1.03
      rapgain(44,2) = .99
      rapgain(46,2) = 1.05
      rapgain(48,2) = .97
      rapgain(50,2) = 1.
      rapgain(51,2) = .9
      rapgain(53,2) = .96
      rapgain(55,2) = .92
      rapgain(57,2) = .87
      rapgain(59,2) = .92
      rapgain(61,2) = .81
      rapgain(63,2) = .83
      rapgain(65,2) = .68
      rapgain(67,2) = .81
      rapgain(69,2) = .77
      rapgain(71,2) = .78
      rapgain(73,2) = .83
      rapgain(75,2) = 1.00
c     /** Define status of anode and corr. scaler and channel **/
      do 200 i = 1, 2
         chan = 0
         do  200 j = 1,p_npads
           kapstat(j,i) = 0
           odd = mod ( j, 2 )
           if ( (j .le. 25 .or. j .gt. 50) .and. odd .eq. 1) then
                   chan = chan + 1
                   kapchan(j,i) = chan
                   kapstat(j,i) = 1
c                   PRINT *,'Aperature # ',j,' is on'
           end if

           if ((j .gt. 25 .and. j .le. 50) .and. odd .eq. 0) then
                 chan = chan + 1
                 kapchan(j,i) = chan
                 kapstat(j,i) = 1
c                   PRINT *,'Aperature # ',j,' is on'
           end if
           kscaler ( j, i ) = i
 200  continue

      kminapst(1) = 1
      kminapst(2) = 1
      kmaxapst(1) = 75
      kmaxapst(2) = 75

      RETURN

      END
```

Charge Exchange Ion Studies on ATF
Progress Report, June 1989 - June 1990

Progress has been made along several fronts in neutral particle measurements and analysis on ATF since the last progress report in June, 1989. The neutral particle analyzer (NPA) on ATF has been used extensively over the last year in obtaining information on ion energy distributions during various forms of auxilliary heating in ATF.

Instrumentation The first and foremost of these is the addition of the full two-dimensional scanning capability to the neutral particle analysis system. This capability gives the NPA on ATF the most flexible viewing capabilities of any analyzer currently operating on any of the world's fusion devices. The NPA was removed from its fixed stand in June, 1989 and installation of the NPA on the scannable stand was completed in late August, 1989. Considerable work was done during this time to insure vacuum and electronic integrity of the NPA system during remote operation of the system. This task included routing instrumentation wiring and vacuum hoses so that any movement of the NPA would not accidentally damage one of these components. Magnetic shielding was provided for the turbomolecular pump to reduce the amount of stray magnetic field present when the pump is located close to the magnetic coils (e.g., when the NPA is viewing tangential in either direction).

Other tasks during this time included the design and implementation of data acquisition instrumentation to monitor and control the movement of the movable stand. Considerable time was spent calibrating and installing a binary encoder and an inclinometer which measure the horizontal and vertical angle of the analyzer, respectively. With these instruments the absolute angle of the analyzer can be measured to within $\pm 2°$. This accuracy is important in interpreting the data obtained by the NPA during horizontal and vertical scans.

A control program was developed that moves the analyzer to any position that the NPA operator chooses. This allows remote control of the analyzer movement from the control room and reduces the amount of time necessary to complete full scans of the analyzer. Several scans have been performed over the past year with a full horizontal scan (from co-passing to counter-passing) needing approximately 40 reproducible shots. Details of the entire NPA system were presented in Ref. 1.

Data Collection Sufficient automation of the NPA system has allowed data to be taken almost every operating day since the two-dimensional scanning capability was installed. For the most part the analyzer is positioned in either the perpendicular or tangential orientation for an entire operating day depending on the needs of the particular experiment being conducted. In general, the NPA is oriented perpendicularly during electron cyclotron heating (ECH) experiments in order to measure the ion temperature and is oriented tangentially during NBI to measure the fast-ion slowing-down spectra. Also, several operating days have been devoted to sequences in which the NPA can do the aforementioned horizontal and vertical scans.

These scans have been made during both neutral beam injection (NBI) and ion cyclotron heating (ICH). Typical data obtained during a horizontal scan of the NPA during neutral beam injection are shown in Fig 1. The three peaks near the tangential viewing direction are the full, one-half, and one-third energy components of the injected beam. Thus far, the measurement of the ion temperature during injection of a hydrogen neutral beam into a deuterium plasma has been difficult because of the $\sim$ 20/1 mass rejection ratio of the analyzer. Steps are being taken to resolve this issue in hopes of having ion temperature measurements during NBI before the end of the current year.

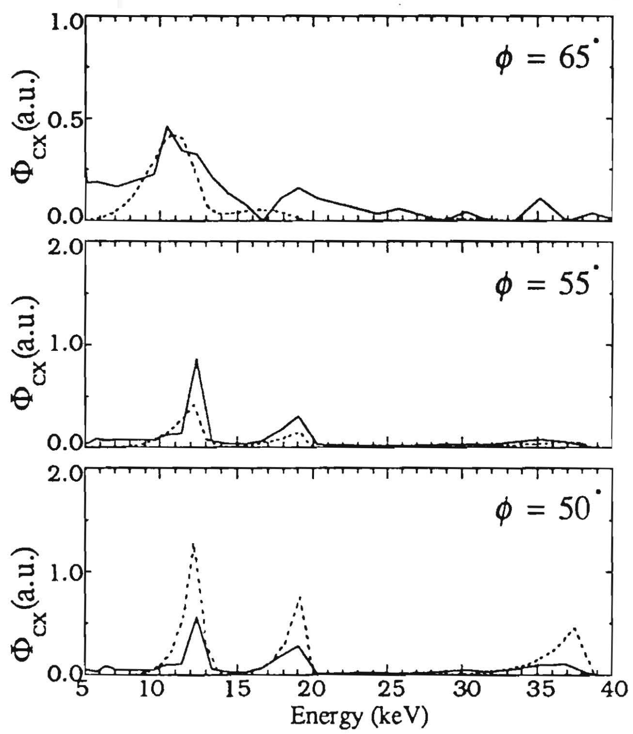

Figure 1: Measured (solid lines) and modeled (dashed lines) NPA spectra at three horizontal viewing angles 12 ms after beginning of NBI. The horizontal viewing angle, ϕ, is defined such that 90° is perpendicular to the magnetic axis.

Initial operation of the NPA during ICH was limited by an rf interference problem. The launched rf power was conducted into the ATF enclosure area through ungrounded instrumentation (limiters, bolometers) that penetrated the ATF vacuum vessel and was then picked up by the NPA electronics. This problem was corrected by wrapping both limiters and a few bolometers with aluminum foil, effectively grounding the instruments. After correcting this problem, some of the most intriguing data yet measured by the NPA has been taken during ICH. As an example, data obtained during horizontal and vertical scans are shown in Fig. 2 and Fig. 3. The two slightly asymmetric peaks near the perpendicular in the horizontal scan have yet to be explained. Experiments moving the resonance layer (by changing the launched wave frequency) show considerably different

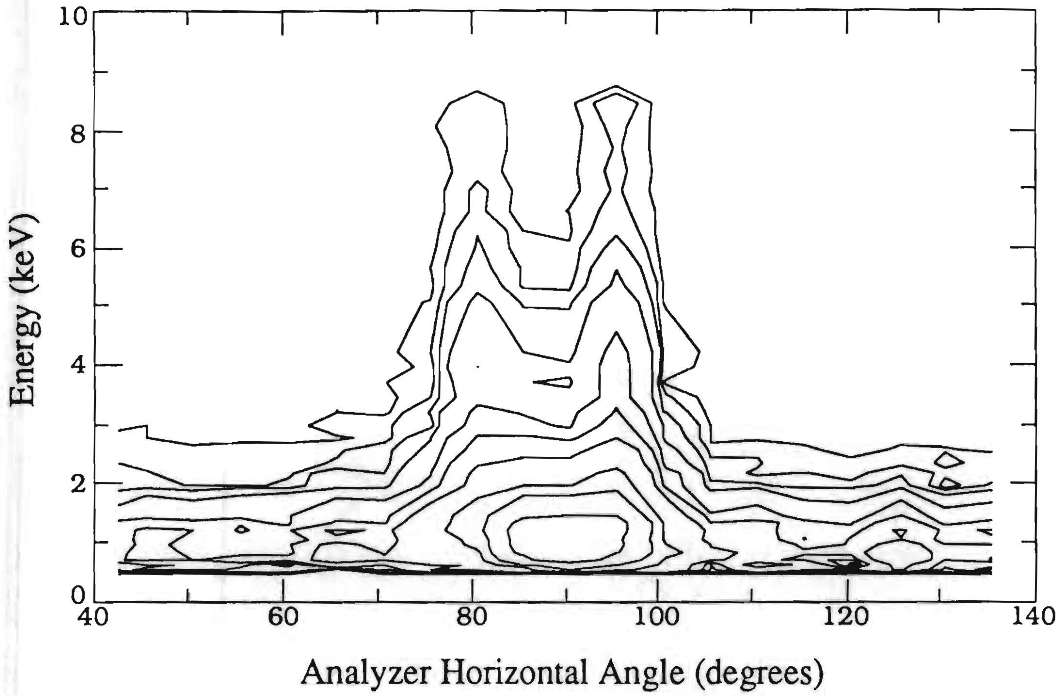

Figure 2: Contours of constant proton charge-exchange flux obtained during hydrogen-minority ICH at $f = 14.4$ MHz and $B_o = 0.95$ T. The vertical viewing angle of the analyzer is maintained at $\theta = 0°$.

results. Interpretation of these results is ongoing.

Data Analysis Most of the time and effort during this past year has been devoted to analyzing and interpreting the NPA measured data during electron cyclotron heating (ECH), NBI, and ICH. Results of this ongoing analysis effort have been presented at several ATF Data Discussion Meetings along with papers and posters submitted to various plasma physics conferences.[2,3] The highlights of the analysis and analysis tools will be presented here.

Measurements of the ion temperature during ECH have been used to help document several experiments during the past year. The most detailed use of the ion temperature measurement has been made during the bootstrap current studies. Transport calculations using Proctr-Mod show that the ion temperature measured by the NPA is consistent with those predicted by using one times the neoclassical transport coefficient, χ_i. These ion temperature measurements are consistent with those inferred from Doppler broadening of central impurity lines.

To model the energy spectra measured by the NPA during NBI, a modeling code based on the Fokker-Planck equation has been developed. This code makes extensive use of the Fast Ion Fokker-Planck Code (FIFPC) written by R.H. Fowler at ORNL. This model (1) calculates the fast ion source distribution using appropriate plasma conditions; (2) computes the neutral density profile using a neutrals transport code; (3) uses FIFPC to solve

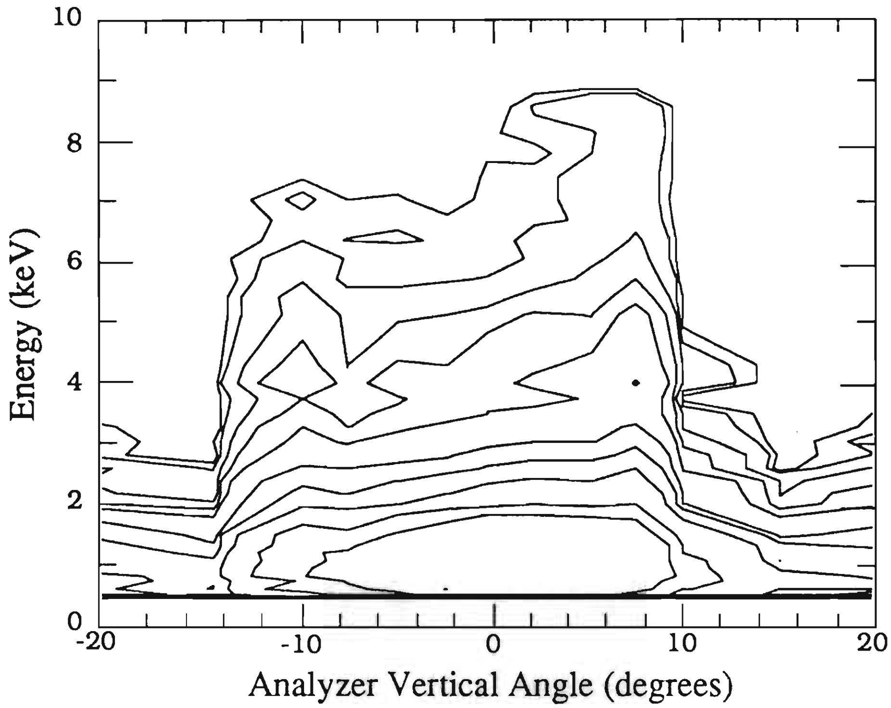

Figure 3: Contours of constant proton charge-exchange flux at a horizontal angle of 95° obtained during hydrogen minority ICH at $f = 14.4$ MHz and $B_0 = 0.95$ T.

for the ion distribution, given this source function and plasma conditions; and (4) calculates the signal expected to be measured by the NPA by integrating the charge-exchange contributions along the analyzer chord. To simulate the experiment, input parameters to the code were based on experimentally measured values. The electron temperature and density profile were measured at several different times during the NBI portion of the discharge by a 15-channel Thomson scattering system; the temporal evolution of the central electron temperature was monitored by the central channel of a 16-channel electron cyclotron emission system. The central ion temperature was obtained from Doppler broadening of central impurity lines.

Comparisons have been made between the predicted and measured spectra for both low density and medium density discharges. The comparison for the low density case is quite good as can be seen in Fig. 1. However, the spectra measured during the medium density discharges exhibit some sort of anomalous loss mechanism that cannot be explained by the model. Possible explanations for this discrepancy are currently being explored with the most plausible being blocking of the beam in the beam duct. Currently, there is no way of testing this theory so further mechanisms are being explored in hopes of explaining this discrepancy.

References

[1]M. R. Wade et al., "ATF Neutral Particle Analysis System", accepted for publication, Rev. Sci. Instrum. (Oct., 1990).

[2]M. R. Wade et al., Bull. Am. Phys. **34**, 2Q11 (1989).

[3]M. R. Wade et al., "Measurements of the Fast Ion Distribution during Neutral Beam Injection and Ion Cyclotron Heating in ATF", in *17th European Conference on Controlled Fusion and Plasma Heating, Amsterdam*, 1990.

Final Report:

First Year of Contract

"Modification of Princeton

Charge-Exchange Data Analysis Code"

M.R. WADE

C.E. THOMAS

October 1, 1987

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

<u>III. Operation of GEORGIA TEXAS</u>

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 $\frac{n_o n_i a}{T_i^{3/2}}$
- 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.