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TANDEM MIRROR REACTOR SYSTEMS CODE (VERSION I)

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ABSTRACT

A computer code was developed to model a Tandem Mirror Reactor. This is the first Tandem Mirror Reactor model to couple, in detail, the highly linked physics, magnetics, and neutronic analysis into a single code. This report describes the code architecture, provides a summary description of the modules comprising the code, and includes an example execution of the Tandem Mirror Reactor Systems Code. Results from this code for two sensitivity studies are also included. These studies are (1) to determine the impact of center cell plasma radius, length, and ion temperature on reactor cost and performance at constant fusion power and (2) to determine the impact of reactor power level on cost.

1. INTRODUCTION

A computer code was developed to provide self-consistent determination of configuration, performance, and cost of a tandem mirror reactor as a function of plasma, magnetic, and engineering parameters. This first version of the Tandem Mirror Reactor Systems Code models a configuration similar to MARS¹ and FPD², which incorporates a solenoidal center cell and an end cell consisting of a choke coil, a "c" coil transition region, an anchor Yin-Yang coil set, a plug Yin-Yang coil set, and a recircularizing coil. The thermal barrier in this configuration is located in the plug. Figures 1, 2, and 3 show schematics of the center cell, choke, and end cell regions. An alternative code with octopole and axisymmetric end cells is also being developed.

This report describes the code architecture, provides a summary description of the modules composing the Tandem Mirror Reactor Systems Code, and includes a sample execution of the code. A more detailed description of the modules is presented in Reference 3.

The modules composing the Tandem Mirror Reactor Systems Code were provided by various sources within the fusion community. The physics, magnetics, magnet, and facility modules were the responsibility of Lawrence Livermore National Laboratory (LLNL). Neutronics, shielding, and tritium modules were modeled by Argonne National Laboratory (ANL). Blanket thermal hydraulics, heat transport/power conversion, cryogenics, direct converter, and plasma heating systems were provided by TRW. Magnet electrical, ac power, vacuum vessel, fueling, maintenance equipment, and I&C modules were modeled by the Fusion Engineering Design Center (FEDC). The integration of the modules into the Tandem Mirror Reactor Systems Code was the responsibility of the FEDC.

2. TANDEM MIRROR REACTOR MODEL

2.1 CODE ARCHITECTURE

The Tandem Mirror Reactor Systems Code consists of modules, each describing a reactor component or system, connected by a driver.

Fig. 1. Center cell configuration for a Tandem Mirror Reactor.

Fig. 2. Choke coil configuration for a Tandem Mirror Reactor.

Fig. 3. End cell configuration for a Tandem Mirror Reactor.

A flow diagram for the Tandem Mirror Reactor Systems Code is shown in Fig. 4. Three feedback loops are indicated by the dashed lines. These loops are necessary because of the strong coupling between the plasma physics, magnetics, neutronics, and magnet design parameters. The calculational procedure used in the Tandem Mirror Reactor Systems Code is to start at the plasma center line of the center cell and proceed radially (see Fig. 1). The center cell length and plasma radius are determined primarily from the desired fusion power, field on axis, beta, and plasma temperature. The center cell blanket thickness is determined consistent with the desired energy multiplication and tritium breeding ratio. The shield thickness is set consistent with nuclear response limits in the superconducting solenoidal coils. The center cell solenoidal coil radius is then determined from the summation of the plasma radius, blanket and shield thickness, and assembly gaps. Coil currents and conductor areas for the solenoidal coils are determined as a function of the coil radius, desired field on axis, and allowable coil current density.

The code now proceeds axially to the choke coil and end cell regions (see Figs. 2 and 3). The plasma radius at the choke coil is determined

Fig. 4. Tandem Mirror Reactor Systems Code flow diagram.

from the desired field on the choke coil axis and the requirement to pass the center cell magnetic flux. A choke coil (superconducting portion plus copper insert portion) is then sized, based on required currents and allowable current densities, to deliver the desired field on axis. Space for shielding of the choke coil is accounted for.

The "c" coil radii in the end cells are consistent with the plasma boundary, the desired field on axis, requirements for shielding, desired sweep angle, and allowable current densities. Axial positions of the coils are chosen consistent with recircularizing the flux in the anchor and plug wells and reducing to zero the average geodesic curvature. As previously noted, a feedback loop ensures compatibility between coil geometry, neutronics, magnetics, and plasma stability.

Modules downstream of the iteration loops are executed in a once-through manner according to the sequence shown in the flow diagram (Fig. 4).

2.2 MODULE DESCRIPTIONS

A brief summary of the modules of the Tandem Mirror Reactor Systems Code follows. (A more detailed description of each module is included in Reference 3.)

Physics

The physics module computes the steady-state plasma power and particle balance and the plasma supplemental heating requirements for tandem mirror reactors by solving multiple nonlinear linked equations. Quasi-neutrality is maintained at several cardinal points in the end cell region. Volumes, densities, potentials, and fusion power values are determined. Options to find minimum length, maximum power, or maximum Q are available. The center cell may be specified to be ignited or driven.

Neutronics

Options are available to select from various breeding, reflector, and structural materials in the center coil blanket and shield module. Tritium breeding ratio, energy deposition, and nuclear response in the coils are determined consistent with the neutron wall loading and material composition and thickness. End cell shielding is based on the neutron source strength. Costs of the blanket and shield are estimated.

Blanket Thermal Hydraulics

Coolant inlet and outlet temperature, pressure drops, pumping power, and structural temperatures are determined for liquid metal and gas-cooled components.

Magnetics

Magnetics for the center cell solenoidal coils, the choke coil, and the end cell "c" coils are determined. Required currents are computed based on the magnetic field profile, the coil radii, and the coil axial

location. The center cell coils may be discrete coils or a current sheet. Conductor current density and coil dimension or coil aspect ratio are input items. The end cell "c" coils are sized and positioned to provide (1) the desired magnetic field profile, (2) flux tube circularity in the magnetic wells, and (3) zero average geodesic curvature. This module runs the EFFI magnetic field code and the TEBASCO (tandem equilibrium and stability) code. Allowable values of beta in the center cell, anchor, and plug are determined consistent with magnetohydrodynamic (MHD) equilibrium and stability. These values of beta are coupled to the plasma physics through an external feedback loop.

Magnet Module

Center cell and end cell magnets are modeled. Magnet designs are consistent with limitations of current density, maximum field, cryo-stability, and fluence for various conductor types. Coil case thickness is based on allowable stress. Cost for each magnet is estimated.

Neutron Source (Auxiliary Physics)

This module determines the neutron source strength in the end cells (needed to determine shielding requirements); frequency requirements for the plasma radio frequency (rf) heating and drift pumping systems [electron cyclotron resonance heating (ECRH), lower hybrid resonance heating (LHRH), ion cyclotron resonance heating (ICRH)]; and magnetic flux, heat flux, magnetic field profile, and net electrical power associated with the direct converter.

Direct Converter

The direct converter is based on a gridless design and consists of four concentric collectors at each end. Radial drift pumping in the end cells forces most of the ions in the plasma into the halo, which is kept at ground potential by the outer two collectors. Electrons flow axially through the middle of the magnet sets and are deposited on the inner two collectors which are biased on the order of -100 kV. Direct electrical power is produced by the electrons; heat deposited by the ions and alphas can be recovered by a thermal cycle.

The model calculates the collector area required for each of the four regions based on a maximum energy flux allowed (input parameter). The electrical power produced, effective radii of the collectors, length of the direct converter, and size of the enclosing vacuum tank are also calculated. The thermal power is sent to the heat transport module. Costs are computed based on collector area for each region, direct electrical power for inverting equipment, and vacuum pumping requirements.

Plasma Heating

This module will size rf heating or neutral-beam heating systems to supply the required plasma supplemental heating in the center cell and end cell plasma regions. The rf systems compute required circulating power, efficiency, cost, and component sizes consistent with available space for access and required power at the launcher. The negative ion neutral-beam system computes the circulating power, efficiency, cost, and the number of sources and associated currents to deliver the required power to the plasma. Heating system component characteristics, such as power supplies, amplifiers, waveguides, launchers, and neutralizers, are determined. Positive ion heating systems are not currently included in the module but may be added later.

Also included in this module are rf systems for drift pumping application. The purpose of the drift pump system is to remove ions by the process of induced radial drifts that have become trapped in the end cells as they pass to the potential peaks. There are two coils in each end to pump on different groups of ions, and each is located where the radial extent of the plasma in the double-ellipse fan transition is maximized (one between the transition coil and the anchor coil, the other between the anchor coil and the plug coil). The model is based on the Mirror Advanced Reactor Study (MARS) system and produces a perturbation field normal to the ambient B field. Physics requirements of ion pumping speed, frequency, and geometry are used to calculate required rf, current required in the coils, and number and width of individual driver frequencies. Total power consumption and system cost are estimated.

Vacuum Vessel

A vacuum vessel exterior to the solenoidal coils, end cell "c" coils, and direct converter is sized and costed.

CRYO System

The cryogenic system model accumulates cryogenic loads from each of the subsystems requiring cryogenics and generates the required electrical power and capital cost of the cryoplant.

Heat Transport/Power Conversion

The heat transport and power conversion module sizes and costs the power conversion system. The blanket/reflector inlet and outlet temperatures and flow rates determine the cycle parameters. Thermal input from the end cell is also incorporated. The module consists of a heat transport routine to generate steam conditions, a turbine efficiency routine, and a costing routine. An option is available to dump the thermal power for experimental tandem mirror reactor (TMR) designs (nonelectrical power producers).

Tritium Processing

The tritium module determines mass flow rates for the primary tritium-deuterium fuel cycle based on input from the physics module. In the fueling section, an option of using tritium neutral beams during the burn is included. Tritium inventories in all major systems are calculated. The cost of the tritium needed per year is calculated both with and without a breeder blanket. An atmospheric tritium recovery system is assumed in four areas (reactor hall, hot cell, tritium building, and radwaste building). Capital costs for the major tritium processing and tritium recovery systems are computed.

Fueling Module

The fueling module computes pertinent design requirements and cost data for the gas injectors, first-stage pellet injectors, second-

stage electromagnetic (EM) rail gun accelerators, and their support systems. The pellet velocity, pellet size, pellet rate, vacuum power, helium/nitrogen refrigeration, and cost of the major equipment are determined.

AC Power Module

The ac power system code module calculates characteristic design and cost data for the electrical power systems needed to operate the reactor. This module identifies and computes the cost for major equipment such as circuit breakers, switches, transformers, lightning arrestors, diesel generators, load control centers, and power feeders. This module does not include the turbine generator nor the dc direct converter in the end cells, but it does include the switch gear and dc-to-ac inverters that interface with the main substation. An electrical power summary is computed.

Magnet Electrical Module

The magnet electrical module computes design and cost data for the power supplies and coil protection equipment of the central cell and end cell magnets. Specifically, design and cost data for power supplies, bussing, load centers, dump resistors, dc current breakers, and associated local controls and instrumentation are determined.

I&C Module

This module determines the costs of process I&C, plasma diagnostic instrumentation, data transmission, data processing, and consoles located in the control building. The cost of each I&C process and diagnostic includes both hardware and software.

Instrumentation and control defined in this module refer to the supervisory control and data system located in the main control building and to the associated data links to local control and instrumentation. This module does not include the local process control and instrumentation located in the proximity of the reactor vault.

Maintenance Equipment Module

This module consists of a compiled list of reactor cell and hot cell equipment and their unit costs. The user chooses the appropriate equipment for a particular device configuration from the comprehensive listing. The equipment either scales with reactor parameters or is fixed in size and cost.

Facility Module

The facility module estimates the size and cost of buildings based on reactor size, thermal power from the blanket and other components, gross electrical power output, and number and capacity of each turbine generator. Facilities considered include reactor building, hot cell building, tritium building, steam generator building, power supply building, cryogenics building, and central building.

Also, the costs of radwaste systems equipment, miscellaneous reactor and balance of plant equipment, and special materials are estimated in this module.

3. TRADE STUDIES

The Tandem Mirror Reactor Systems Code was used to determine the following:

- (1) the relationship between reactor center cell length, plasma radius, ion temperature, and cost at a given value of fusion power and
- (2) the impact of reactor power level on cost.

3.1 MAJOR CONSTRAINTS OR ASSUMPTIONS

Magnetic Field Profile

These studies were conducted with a magnetic field profile similar to that of MARS, which is presented in Table 1.

Table 1. Magnetic field profile

Field location	(tesla) Value
Center cell	2.5
Choke mirror	24
End cell mirror	7.5
Anchor well	3.75
Plug well	2.5

Beta

Values of beta were consistent with MHD stability. For this study, average values of beta were maintained at 0.6 in the center cell and 0.3 in the plug region for all cases presented. The value of beta in the anchor region varied from case to case.

Ignited Center Cell

The combination of plasma parameters for all cases was maintained consistent with an ignited center cell. All heating was applied to the end cells.

Neutronics

Adequate shielding was provided to limit the nuclear heating in the center cell solenoidal coils to 0.1 mW/cm^3 . Shielding of the end cell coils was not considered in this study.

Capital Costs

The costs estimated by the Tandem Mirror Reactor Systems Code are for equipment and installation labor only. Component engineering, indirect costs, and contingency are not included. The unit capital cost values (\$/kg, \$/kW, \$/m³, etc.) used in this study were derived from cost estimates for the Fusion Power Demonstration (FPD-II) reactor study.²

3.2 STUDY RESULTS

A trade study was done to determine the impact of center cell plasma radius, length, and ion temperature on reactor cost and performance at constant fusion power (1000 MW).

There are many combinations of center cell length, plasma radius, and ion temperature that will provide the same value of fusion power (recall that the magnetic field profile and beta are fixed). From the viewpoint of plasma power density, one would choose low values of ion temperature (10 to 20 keV at constant beta), but, in a tandem mirror reactor, the transport losses scale inversely with temperature and therefore limit the minimum temperature at which an ignited center cell can be achieved. Figure 5 shows the relationship between center cell length, ion temperature, heating power, and capital cost for a constant radius plasma (45.8 cm) producing 1000 MW of fusion power. The minimum length reactor is achieved at the limiting ion temperature of 29 keV. Figure 5 shows that, as temperature and length decrease at constant plasma radius, the required heating power increases. However, the net effect on cost is for cost to decrease with decreasing temperature, and the minimum cost is achieved at the minimum ion temperature. Recall that this analysis was for a constant value of center cell plasma radius. This analysis was repeated for additional values of plasma radius; the minimum temperature points were found, and the parameters corresponding to the minimum temperatures are plotted in Figs. 6 and 7. Figures 6 and 7 show that as plasma radius is increased at constant fusion power, the length decreases while the plasma heating power and minimum ion temperature for ignition increase. The capital cost initially decreases with increasing plasma radius (decreasing length and increasing plasma heating power), goes through a minimum, and then increases as plasma radius is further increased. It is noted that capital cost is not a strong function of the combination of plasma length and radius at constant fusion power. Changing the length and radius combination from 145 m length, 42 cm radius to 115 m length, 52 cm radius shows a capital cost reduction of approximately 5%.

Fig. 5. Center cell length, plasma heating power, and estimated capital cost as a function of ion temperature for fixed values of fusion power (1000 MW) and center cell plasma radius (45.8 cm) for an ignited center cell.

Fig. 6. Center cell length, plasma heating power, and minimum ion temperature as a function of center cell plasma radius at a fixed value of fusion power (1000 MW) for an ignited center cell.

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Fig. 7. Capital cost and unit capital cost as a function of center cell plasma radius at the minimum ion temperature required for an ignited center cell at a fixed value of fusion power (1000 MW).

The unit capital cost, $\$/W_e$, optimizes at a smaller plasma radius, longer center cell length, and lower plasma temperature and heating power than does the optimum point based on total capital cost (Fig. 7). A comparison of the tandem mirror reactor (TMR) parameters at minimum capital cost and minimum unit capital cost, $\$/W_e$, is presented in Table 2. The variation in cost between these two points is slight, approximately 1% in capital cost and 2.5% in $\$/W_e$.

A trade study was conducted to determine the impact of reactor power level on cost. The procedure described in the previous trade study was repeated at various fusion power levels. The minimum capital cost point at each power level was determined, and the results are presented in Table 3. As indicated in this table, the minimum ion temperature to achieve an ignited center cell decreases as power level increases. Length and radius both increase with fusion power. This study shows that there is a significant economy of scale for tandem mirror reactors.

Table 2. TMR parameters at 1000 MW fusion power

Parameters	Minimum capital cost	Minimum $\$/W_e$
Plasma radius, cm	52	46
Length, m	115	124
Ion temperature, keV	32	29
Heating power, MW	31	25
Capital cost, m\$	1620	1635
Unit capital cost, $\$/W_e$	4.05	3.95

The unit capital cost, $\$/W_e$, decreases from approximately $\$8/W_e$ to $\$3/W_e$ as fusion power increases from 500 to 1500 MW.

Table 3. TMR parameters as a function of fusion power

Parameter	(MW), Fusion Power		
	500	100	1500
Length, m	94	108	120
Radius, cm	45.8	53.7	57.6
Ion temperature, keV	40	33	29
Heating power, MW	22	32	43
Capital cost, m\$	1278	1622	1917
Unit capital cost, $\$/W_e$	8.45	4.10	2.95

4. CONCLUSIONS

1. The Tandem Mirror Reactor Systems Code has been developed with support from the fusion community and is now operational. Initial trade study using this code suggests the following:

For a fixed value of fusion power, the center cell plasma length and radius combination is not a strong cost driver. Changing the length and radius from 145 m, 42 cm to 115 m, 52 cm, respectively, shows a capital cost reduction of 5%.

2. At fixed fusion power, the unit capital cost, $\$/W_e$, minimizes at a longer center cell length, smaller plasma radius, and lower ion temperature combination than the minimum associated with total capital cost.
3. There is a strong economy of scale for a tandem mirror reactor. Increasing the fusion power from 500 to 1500 MW results in decreasing the unit cost from approximately $\$8/W_e$ to $\$3/W_e$.

5. SAMPLE CODE EXECUTION

To execute the Tandem Mirror Reactor Systems Code, the following procedure should be followed:

1. Retrieve the code from storage (i.e., filem) by the following command on the Cray machines:

```
filem
Read 1057 .msc   mscdlib
```
2. Extract the code and data files from the library file by:

```
LIB mscdlib ! X  all.!end
```
3. The code and two required input data files are now ready. Data file mscin (see Table 4) contains physics, neutronic, magnetic, and magnet input parameters (data necessary to run the code through the iteration loops). The minimum amount of input data is shown in this reference file. The remainder of the parameters are defaulted or estimated internally. See Reference 3 for a full list of input parameters for mscin. Data file mscindt (see Table 5) contains the input data for the remainder of the modules, and these data are rarely changed. The executable code is called mscx.

Table 4. Sample input data file mscin

```

*****
* This is the baseline input file for MSC which approximates the FPD2 *
* configuration (magnet model C83). End-cell nuclear heating and dose *
* limits are not specified, to inhibit a loop-back from ECCK. *
*****
* BYPASS FLDSUM AND MAGPLT:
  ixeq = 13(1) -1 1 -1
$
* FIXED CLENGTH, RCHOKE=14
  project="MSC DEV" model="t81"
* MAGNETICS INPUT:
  bcc=2.5 bch=24 ba=3.75 bm=7.5 bp=2.5 beta=.6 .2 .3
  jcc=4e7 4e7 wcc(2)=8.6 lacc=8.7 gcc=1
  ach=8.9 fch=2.6 5.1 6.2 wch=2 1.8 1.7 jch=1.7e7 1.8e7 2.5e7
  bin=8 win=8.6 tin=8.39
  jc=4.5e7 4.5e7 4.5e7 ls(3)=8.25
$
* MAGNET INPUT:
  unitcost=8 158. 158. 4(188.) 7(288.)
  caseymod=8 13(2.8e11)
$
* PHYSICS INPUT:
  tc=48 rchoke=14 loption=2 clength=9488
$
* NEUTRONICS INPUT:
  chheatmx = 1.8e-84 chdosemx = 1.8e+18
  ip= 1 2 3 4 xip= 1.11 7.5 29. 48.
  ibp=8 irtyp=1 ib=1 ir=2 ic=1 ism=2 iwt=1 cr=8.5
  id=2 xd=8.1 af=1.8 yo=1.8 gbs=2.5 ist=8 xst=58.8
  cost(2)=88. costch(1)=26. costec(1)=26.
$

```

4. Execute the code by typing mscx. The output from the run is collected in file msctout.
5. Table 6 lists the output from an execution of the Tandem Mirror Reactor Systems Code. Figures 8, 9, and 10 are computer drawings which show isometric, plan, and elevation views, respectively, of the Tandem Mirror Reactor configuration consistent with the output data of Table 6.

Table 5. Sample input data file MSCINDT

```

*****
**** program flow control input
* outfil = name of the combined output file. Default is "outfile".
* inblk = name of the input block data file for restart capability
* (optional)
* outblk = name of the output block data file which can be use for later
* restart or for input to auxillary programs (e.g. fiff4)
* (optional)
* pltnam = partial name of the plot file for the plan and elevation view
* of the configuration (optional)
* runmod = name of the module to be run. currently only "all" is
* recognized
* iout = output control option. iout=0 turns off most output.
* iout=1 turns on normal output.
* (some modules have additional output controls and options)
* iplot = plot control option. iplot=0 means no plot of configuration
* iplot=1 means to plot configuration
* ismry = summary output file option. ismry=0, no summary output
* ismry=1, summary output provided
* iskippm = program flow control. iskippm='skip' skips demo,
* reads mscnamls, doesn't write mscnamls; otherwise, opposite happens
&contr1
iout=1 ismry=1
runmod="all"
outfil="mscxout", inblk=" ", outblk="mscblk",
iplot=1, pltnam="mscx", iskippm='noskip'
&endcontr1
&inall
*****
**** physics input data
* Physics input currently comes from mscin which is a seperate file.
*****
**** input data for module ccmg
*****
**** Input for center cell and choke shield module (ccsh)
* input:
* ip =one dimensional array
* ip(1)=1, not used as input
* ip(2) indicates what variable should be maximized
* or minimized
* 1 -tritium breeding ratio
* 2 -lithium -6 enrichment
* 3 -breeding zone thickness (cm)
* 4 -reflector zone thickness
* 5 -shield zone thickness
* 6 -blanket+shield thickness (cm)
* 7 -energy multiplication factor
* 8 -percentage of Li or LiPb in reflector
* 11-first wall heating fraction
* 12 breeding zone heating fraction
* 13-reflector zone heating fraction
* 14-shield zone heating fraction
* 15-first wall heating (eV/DT neutron)
* 16-breeding zone heating (eV/DT neutron)
* 17-reflector zone heating (eV/DT neutron)
* 18-shield zone heating (eV/DT neutron)
* 19-blanket thickness (1st wall+breeding zone+reflector (cm))
* ip(3) may have the same values as ip(2)
* ip(3) is used as a third parameter to satisfy
* only if two or more blankets satisfy the conditions
* for tritium breeding ratio and ip(2)
* xip =one dimensional array
* xip(1)=1e10-find minimum tritium breeding ratio
* xip(1)=real value-find blanket to produce tritium
* breeding ratio equal to that value
* xip(1)=1e10-find maximum tritium breeding ratio
* xip(2)=1e10-find the minimum for the variable
* corresponding to the value of ip(2)
* xip(2)=real value-find the blanket which produces
* the value closest to xip(2) for the variable
* specified by ip(2)
* xip(2)=1e10-find the maximum for the variable
* corresponding to the value of ip(2)
* xip(3)=1e10-find the minimum for the variable
* corresponding to the value of ip(3) if
* several blankets satisfy the conditions
* for tbr and xip(2)
* xip(3)=real value-find the blanket which produces
* the value closest to xip(3) for the variable
* specified by ip(3) if there are several
* blankets which satisfy the conditions
* for tbr and xip(2)

```

```

*      xip(3)=1e10-find the maximum for the variable
*      corresponding to the value of ip(3) if
*      several blankets satisfy the conditions
*      for tbr and xip(2)
*      ibp =desired blanket number
*      allows the user to choose a
*      specific blanket from the set of blankets
*      when the user runs a given case a second
*      time and wants a particular blanket other
*      than that chosen by the subroutine
*      if ib=0 it is ignored.
*      irtyp=reactor type
*      1-commercial
*      2-experimental with tritium breeding
*      3-experimental without tritium breeding
*      4-MARS blanket
*
*      ib= breeding material
*      1-lithium lead
*      2-lithium
*      ir= reflector material
*      1-stainless steel
*      2-carbon
*      ic= coolant material
*      1-lithium lead
*      2-lithium
*      3-helium
*      ism= structural material
*      1-pca
*      2-ferritic steel
*      3-vanadium
*      wl= neutron wall loading (MW/m**2)
*      ccl= central cell length (m)
*      fwr= first wall radius (cm)
*      cost= array containing material costs ($/kg)
*      cost(1)-pca (35)
*      cost(2)-ferritic (80)
*      cost(3)-Lithium (13)
*      cost(4)-Lithium Lead (10.8)
*      cost(5)-carbon (12)
*      cost(6)-boron carbide (b4c) (35)
*      cost(7)-lead (3)
*      cost(8)-1422 steel (9)
*      note:if the costs are not input,
*      the default values shown in parentheses
*      are used
*      gbs= thickness of gap between blanket and shield (cm)
*      gsc= thickness of gap between shield and coil (cm)
*      note:the default value for these gaps is 2.5 cm
*
*****
*      input for blanket module (blkt)
*****
*      input for first wall module (fw)
*****
***** direct converter module (dc) input data
*      Variables:
*      Collector regions:
*      _ic inner collector (electrons) (material is TZM)
*      _oc outer collector (electrons) (material is TZM)
*      _hs halo scraper (ions) (material is TZM)
*      _hd halo dump (ions) (material is TZM)
*      Other notation:
*      _cp pertaining to cryopanel
*      _vp pertaining to mechanical vacuum pumps
*
*      Inputs:
*      from user (also defaulted):
*      udc_ unit cost of item
*      collectors/halo collectors ($/m2)
*      cryopanel ($/m2)
*      mechanical pump ($/(1/sec))
*      updcvp unit power required for mechanical vacuum pump (W/(1/sec))
*      eflx_ maximum energy flux allowed on region _ (MW/m2)
*      pressp1n plenum pressure (torr)
*      ipump select mechanical (default) or cryopanel pump
*      ithr(4) switch for low (0) or high (1) grade recovered heat
*      alphadc = 1.37
*      hrcfr = 1 1 1 1
*      ipump = 1
*      pressp1n = 4.e-2
*      ithr = 1 1 1 1
*****
***** Input or vacuum vessel module (vacvs)
*
*      cccost = cost of center cell module (dollars/calc)
*      cccwt = center cell module weight (kilograms/calc)

```



```

*      ct      - costing factor (dollars per kilogram/given)
*      density - weight per unit volume (kilograms/cubic meter)
*      diamisc - diameter of inner shell of center cell (meters/calc)
*      diamisc - diameter of inner shell of end cell (meters/calc)
*      diamosc - diameter of outer shell of center cell (meters/calc)
*      diamosc - diameter of outer shell of end cell (meters/calc)
*      e        - youngs modulus (megapascals/given)
*      eccost   - end cell cost (dollars/calc)
*      ecwght   - end cell weight (kilograms/calc)
*      ftu      - material ultimate tensile strength (mpa/given)
*      fty      - material tensile yield strength (mpa/given)
*      height   - depth of water (meters/largest diameter)
*      matl     - name of structural material (hollerith expression)
*      nringsc  - number of rings in center cell module (integer/given)
*      nringsc  - number of rings in end cell (integer/given)
*      nweb     - number of webs (integer/arbitrarily 12)
*      pumpres  - water pumping pressure (pascals/given)
*      safact   - safety factor for buckling stability (decimal no./given)
*      shieldc  - thickness of center cell water shield (meters/given)
*      shieldc  - thickness of end cell water shield (meters/given)
*      ta       - tensile allowable stress (mpa/calculated)
*      tblkhd1  - thickness of end cell inner bulkhead (meters/given)
*      tblkhd2  - thickness of end cell outer bulkhead (meters/given)
*      tcube    - thickness cubed (intermediate operator)
*      tishlc   - thickness of inner shell of center cell (meters/calc)
*      tishle   - thickness of inner shell of end cell (meters/calc)
*      toshlc   - thickness of outer shell of center cell (meters/calc)
*      toshle   - thickness of outer shell of end cell (meters/calc)
*      totpres  - combined pump + head pressures (mpa/calc)
*      tringc   - thickness of support rings in center cell (meters/inner sh)
*      tringc   - thickness of support rings in end cell (meters/inner sh)
*      twebc    - thickness of longitudinal webs of center cell (meters/
*                arbitrarily 2/3 inner wall)
*      tweb     - thickness of longitudinal webs of end cell (meters/arbi-
*                trarily 2/3 of inner wall)
*      vaccost  - total cost for vacuum vessel (dollars/calc)
*      volblkd  - volume of end cell closure bulkhead (cu meters/calc)
*      volec    - volume of end cell structure (cu meters/calc)
*      volisc   - volume of inner sh. in center cell mod. (cu meters/calc)
*      volisc   - volume of inner shell in end cell (cu meters/calc)
*      volmod1  - volume of center cell module (cu meters/calc)
*      volnrc   - volume of all rings in center cell (cu meters/calc)
*      volnwc   - volume of all webs in center cell (cu meters/calc)
*      volnwe   - volume of all webs in end cell (cu meters/calc)
*      volosc   - volume of outer sh. in center cell module (cu meters/calc)
*      volosc   - volume of outer shell in end cell (cu meters/calc)
*      volre    - volume of all rings in end cell (cu meters/calc)
*      volsupc  - volume of supports for center cell module (cu meters/calc)
*      volsupe  - volume of supports for end cell (cu meters/calc)
*      vacwght  - total weight of vacuum vessel (kilograms/calc)
*      wathead  - head pressure of water (psi/calculated)

```

```

cf=17.6
safact=4
pumpres=172369.8
shieldc=1.2
shieldc=2.8
nringsc=4
nringsc=3
nweb=12
ftu=517
fty=257
density=8228.93
e=286842.8
nwebc=12
nwebc=12

```

```

*****
** plasma heating systems input **
** notation: **
** drift pump coil systems have designations dpc and dp **
** electron cyclotron resonance heating systems - ecrh, ech, ec **
** ion cyclotron resonance heating systems - icrh, ich and ic **
** negative ion based neutral beam systems - ninb, nib and ni **
** positive ion based neutral beam systems - pinb, pib and pi **
** there can be three of each type of system: idp,iec,lic,ini,ipi=1,2,3 **

```

```

*****
** this set of input is usually supplied by the TMRSC physics **
** module but when PHSSYS is run independently must include here **
-----
*      definitions:                                     units
*      ispecpi(ipi) = 2/3 for deuterium/tritium beam      (m)
*      rkappa(idp) = central cell plasma radius          (A/N)
*      rkappa(idp) = drift inducing capability of idp-th dpc system [ ]
*      taump(idp) = normalized flux-line coordinate of idp-th dpc (sec)
*      taump(idp) = pumping time of idp-th dpc system      (m)

```

```

* cspcmax(idp) = maximum separation of idp-th dpc return currents (m) *
-----
csepmax = 0.55 0.7   cspcmax = 0.8 0.55
ispecpl = 2
rc = 0.458

*****
** this set of input is for ecrh systems and is considered "expert" **
** info - should not be altered unless one knows what he is doing! **
** each system can have up to 20 components: i=1,2,...,20. **
-----
* definitions:                                     units *
* bec(i,iec) = radius of i-th component of iec-th system (cm) *
* ifemer = 0/1 don't/do select energy recovery for FEM *
* indec(i,iec) = array to define system components, for details see *
* program listing of subroutine ECHSYS. e.g.s. - *
* indec(2,iec)=3: 1MW gyrotron w/o beam recovery and *
* indec(3,iec)=9: mode convertor *
* ipec = 0/1 don't/do print detailed component descriptions *
* irdnmec(iec) = total # of redundant gyrotrons for iec-th system *
* mm(iec) = mode number mm for TEmm,nn or TMmm,nn mode *
* mode(iec) = 1/2 for TE/TM modes *
* ncomp(iec) = number of ecrh system components in iec-th system *
* nn(iec) = mode number nn for TEmm,nn or TMmm,nn mode *
* pecmax(iec) = maximum allowable power in final element (w) *
* xkec(i,iec) = dielectric constant for i-th component [ ] *
* xlec(i,iec) = length of i-th component of iec-th system (cm) *
* xnucel(i,iec) = conductor resistivity of i-th component (uOhm-cm) *
-----
bec = 2(0.0) 3(3.18) 2(1.25) 6(3.18) 7(0.0)
      2(0.0) 3(3.18) 2(1.25) 13(0.0)   ifemer = 0
indec = 1 3 4 10 8 9 9 2 6 2 6 2 12 7(0)
        1 3 4 10 8 9 9 12 1 11(0)
ipec = 1   irdnmec = 2 4   mm = 0 0   mode = 1 1   ncomp = 13 9
nn = 1 1   pecmax = 301.e3 1.e6   xkec = 40(1.0)
xlec = 2(0.0) 3(50.) 2(100.) 2(20.e2 2.e2) 20.e2 8(0.0)
      2(0.0) 3(50.) 2(100.)   xnucel = 40(1.724)

*****
** this set of input is for icrh systems and is considered "expert" **
** info - should not be changed unless one knows what he is doing! **
** each icrh system can have up to 20 components: i=1,2,...,20. **
-----
* definitions:                                     units *
* bic(i,lic) = radial dimension of i-th component for i>1 (cm) *
* e0max = maximum electric field gradient launcher (V/cm) *
* indic(i,lic) = array of indices to define system components, *
* for details see program listing of subroutine *
* ICHSYS; e.g.s. indic(1,lic)=2 - ridged waveguide *
* and indic(3,lic)=2 - coaxial elbow. *
* ipic = 0/1 don't/do print detailed component descriptions *
* irdnmic(lic) = total # of redundant launchers for lic-th system *
* ncomp(lic) = number of icrh system components in lic-th system *
* nport(lic) = number of ports at location of lic-th icrh system *
* picmax(lic) = maximum power allowed in final element (w) *
* shtk(lic) = neutron shield thickness at location of lic-th (cm) *
* tauic(lic) = power factor for dielectric in waveguide [ ] *
* wallload(lic) = neutron wall load at location of lic-th system (MW/m2) *
* xkic(i,lic) = dielectric constant of i-th component [ ] *
* xlic(i,lic) = length of i-th component in lic-th system (cm) *
* xnucic(i,lic) = conductor resistivity of i-th component (uOhm-cm) *
* xnudic(i,lic) = dielectric resistivity of i-th component (uOhm-cm) *
* ymaxic(lic) = maximum port size (azimuthal) at lic-th location (cm) *
* zmax(lic) = maximum port size (in z) at lic-th location (cm) *
* zvac(i,lic) = impedance of i-th component in lic-th system (Ohm) *
-----
bic = 0.0 3(7.8) 15(11.6)   e0max = 5.e3
indic = 2 1 2 3 8 7 5 1 10 1 10 1 2 9 1 2 8 7 9
ipic = 1   irdnmic = 2   ncomp = 19   nport = 4   picmax = 2.e6
shtk = 1.e2   tauic = 0.0   wallload = 0.5
xkic = 1. 9.6 11(1.) 9.6 4(1.) 9.6
xlic = 0. 1. 1.e2 2.e2 3(0.) 2(1.22e3 0.) 1.22e3 1. 2 1. 1.22e3
      1.e2 2(0.0) 1.   xnucic = 19(1.673)   xnudic = 19(1.e20)
ymaxic = 30.   zmax = 2.e2   zvac = 0.0 3(15.) 15(50.)

*****
** this set of input is for the drift pump systems **
-----
* definitions:                                     units *
* clsep(idp) = separation of idp-th coil pair (m) *
* clspc(idp) = spacing of return currents in idp-th coil (m) *
* rcoil(idp) = radius of coil in idp-th system (m) *
* resist = resistivity of coil conductors (Ohm-m) *
-----
clsep = 0.5 0.5   clspc = 0.5 0.5   rcoil = 0.05 0.05   resist = 2.7e-8

```

```

** this input set is for the ninb systems
*-----*
* definitions: units *
* ductni(j,ini)= duct dimensions on plasma side of duct (y and z) (cm) *
* ibeamni(i,ini)= indices to define beamline, e.g.s. *
*      ibeamni(1,ini)=3 - tritium beamline, *
*      ibeamni(2,ini)= maximum # of sources/beamline *
*      ibeamni(3,ini)= 0/1 for laser/gas neutralizer *
* ipni = 0/1 don't/do print detailed component description *
* irdnmni(ini) = total # of redundant sources for ini-th system *
* irecvni(j,ini)=0/1 don't/do electrically recover j-th specie *
* nmberni(j,ini)=number of integration steps in j-th section *
* pressni(i,ini)=gas pressure in i-th section of ini-th beamline (torr) *
* scurni(ini) = maximum extracted current per source (A) *
* sdivni(ini) = source divergence of ini-th beamline (deg) *
* seffni(ini) = source gas efficiency [ ] *
* shthkni(ini) = neutron shield thickness for ini-th beamline (cm) *
* xlni(i,ini) = length of i-th section of ini-th beamline (cm) *
*-----*
ductni = 1.e2 24.      ibeamni = 1 4 1      ipni = 1
irdnmni = 2      irecvni = 6(0)      nmberni = 10 50 200 50 50
pressni = 1.e-3 3.e-5 1.e-3 2(1.e-5)      scurni = 4.5      sdivni = 0.5
seffni = 0.15      shthkni = 100.      xlni = 10. 300. 300. 200. 400.
*-----*
** the last set of input for the heating systems is for the pinb **
*-----*
* definitions: units *
* enmixpi(i,ipi)=fractional composition of beam - D1+,D2+,D3+ species *
* ibeampi(i,ipi)= indices to define beamline, e.g. *
*      ibeampi(1,ipi)=3 - tritium beamline, *
*      ibeampi(2,ipi)= maximum # of sources/beamline *
* ippi = 0/1 don't/do print detailed component descriptions *
* irdnmpi(ipi) = total # of redundant sources for ipi-th system *
* irecvpi(j,ipi)=0/1 don't/do electrically recover j-th specie *
* nmberpi(j,ipi)=number of integration steps in i-th section *
* presspi(i,ipi)=gas pressure in i-th section of ipi-th beamline (torr) *
* scurpi(ini) = maximum extracted current/source for ipi-th system (A) *
* sdivpi(ipi) = source divergence of ipi-th beamline (deg) *
* seffpi(ipi) = source gas efficiency for ipi-th system [ ] *
* shthkpi(ipi) = neutron shield thickness for ipi-th beamline (cm) *
* xlpi(i,ipi) = length of i-th section of ipi-th beamline (cm) *
*-----*
enmixpi = 0.8 0.12 0.08      ibeampi = 1 4 0
ippi = 1      irdnmpi = 2      irecvpi = 6(0)
nmberpi = 1 1 40 50 40      presspi = 3(5.e-3) 1.e-4 1.e-5
scurpi = 70.      sdivpi = 0.5      seffpi = 0.5
shthkpi = 100.      xlpi = 2(0.0) 1.5e2 2(6.e2)
*-----*
**** Input for magnet electrical module (magel)
*
$$$$$Input data mnemonics:
* (#input data from other modules)
*
nsc(j) -number of magnets in group (j)
amp(j) -design current of group (j) magnets, ka
bapcm2 -design current density of bussing, a/cm2
rhoocm -resistivity of bussing, ohm-cm
tchr -magnet charge time, hours
vdkv -max. voltage during fast coil discharge, kv
*
j=2 group 2 -main cc solenoids (ccm)
j=3 group 3 -cc trim solenoids (cct)
j=4 group 4 -choke insert solenoids (chi)
j=5 group 5 -choke backing solenoid #1 (cb1)
j=6 group 6 -choke backing solenoid #2 (cb2)
j=7 group 7 -choke backing solenoid #3 (cb3)
j=8 group 8 -transition c - coils (tl)
j=9 group 9 -anchor c - coils (al)
j=10 group 10 -anchor c - coils (a2)
j=11 group 11 -plug c - coils (pl)
j=12 group 12 -plug c - coils (p2)
j=13 group 13 -transition c - coils (t2)
j=14 group 14 -re-circularizing solenoids (rs)
j=15 group 15 -not yet defined (nd)
*
nsc(1)=35,nsc(2)=10,nsc(3)=9,nsc(4)=2,nsc(5)=2,nsc(6)=2,nsc(7)=0,
nsc(8)=2,nsc(9)=2,nsc(10)=2,nsc(11)=2,nsc(12)=2,nsc(13)=2,
nsc(14)=2,nsc(15)=0
amp(1)=7.5e3,amp(2)=5.0e3,amp(3)=4.0e3,amp(4)=5.0e4,amp(5)=8.0e2,
amp(6)=7.5e3,amp(7)=7.5e3,amp(8)=6.0e3,amp(9)=6.5e3,amp(10)=6.5e3,
amp(11)=7.0e3,amp(12)=7.0e3,amp(13)=6.0e3,amp(14)=5.0e3,
amp(15)=0.0
bapcm2=160.0,rhoocm=2.0e-6,tchr=4.0,vdkv=1.0
*-----*
**** Input for fueling module (fuel)

```

```

* Inputs from other modules/driver /
*
* coil at the fuel injection point, no./m3
* #npinj, number of pellet injectors
* #ngnoz, number of fuel gas nozzles
* #fmwt, molecular weight of fuel
* #effhe, liquid helium cooling effectiveness
* #effn2, liquid nitrogen cooling effectiveness
* #effv, vacuum system efficiency
* #fmwt, fuel molecular weight
*
* #plmafr, fraction of plasma mass in a fuel pellet
* #pelfr, fraction of fuel flow converted to pellets
* #hteft, fraction of h2 propellant entering the torus
* #tpgdk, temperature of the h2 propellant, deg. kelvin
* #pgmwt, propellant gas molecular weight
* #exn, elec. temperature distribution exponent
* #prlmp, pneumatic injector pellet rate limit
* #vlmcfi, centrifugal injector injection velocity limit, m/s
* #vlmrgi, em rail gun injector velocity limit, m/s
* #cpkj, rail gun power supply cost coefficient, $m/kj
* #rgcpm, rail gun cost per meter, $m
* #rgseff, rail gun system efficiency
* #maxrgp, max rail gun pressure on pellet, psi
* #fpfen, pellet penetration, (ppenm/rplchm)
fpfen=0.60
fmwt=5.0
plmafr=0.10
npinj=2.
ngnoz=6.
effhe=0.5
effn2=0.5
effv=0.5
pelfr=0.0
hteft=0.01
exn=0.0
tpgdk=600.
pgmwt=2.0
prlmp=10.
vlmcfi=1500.
vlmrgi=12000.
cpkj = 0.02
rgcpm = 0.10
rgseff=0.02
maxrgp=500.
*****
* Input for cryoplant module (cry)
* Variables:
* Input powers:
* pn2___ LN2 cooling requirement in Wt for subsystem ___
* phe1___ LHeI cooling requirement in Wt for subsystem ___
* phe2___ LHeII cooling requirement in Wt for subsystem ___
* ipcryo=0/1 don't/do print subsystem thermal loads
*
* Subsystems identified:
* inj fuel pellet injector
* dcp direct convertor cryopanel
* nb neutral beam cryopanel
* ccm central-cell magnets (total)
* ecm end-cell magnets (total)
* chk choke-coil magnets (total)
* trt tritium processing plant
*
* Scaling parameters
* up___ unit power requirements (We/Wt) for coolant ___
* uc___ unit costs ($/Wt) for coolant ___
* xc___ scaling exponent for costs of coolant ___
* xp___ scaling exponent for electrical requirements of coolant ___
* INPT: FILE: (example MARS system loads included)
ipcryo=1
pn2ccm=2.96e5 phe1ccm=5.25e3 pn2chk=1.95e4 phe1chk=268.
phe2chk=225. pn2ecm=9.81e4 phe1ecm=5.21e3 phe2ecm=1.89e3
pn2nb=12. phe1nb=500. phe2nb=45.
*****
**** tritium processing module input data (trit)
title1=" tritium facility and vacuum system"
title2=" parameters for the fpd-11 07/10/84"
tburn=100. tfrac=0.5
tn=1.0 peff=0.3 geff=0.1
dn=1.0 regen1=0.16 regen2=0.0
tbcon=0.001 ctrit=1.00
sconbd=2.0 xx=0.33 wclean=100.
cttc=120.0 cthc=120.0 cttb=120.00 ctwa=0120.
vetc=0.2 vehc=00.2 vetb=0.20 vewa=20
teff=0.9
scon1=50. scon2=50.0 scon3=50.00 scon4=050.0
*****

```

```

----- maintenance equipment input data
* The variables for the different types of equipment have the form
* nhxxxx, nrxxxx, and ucxxxx where xxxx is the 4 digit equipment
* descriptor as follows.
* nh prefix = number required in hot cell facility
* nr prefix = number required in reactor building
* nm prefix = number required for mockup
* uc prefix = unit cost (M$)
* ih prefix = option control for calculation of nhxxxx
* ir prefix = option control for calculation of nrxxxx
* cctv = closed circuit tv, overall viewing
* tlcc = transfer lock; air lock
* dewa = decontamination and waste handling; component cleaning
* pct5 = welder-cutter; pipes < 5 cm
* pct15 = welder-cutter; pipes 5 - 15 cm
* pct1 = welder-cutter; pipes > 15 cm
* eeff = end effectors; for use with manipulators
* scut = welder-cutter; large vacuum joints
* lift = lifting equipment, slings, cradles
* hant = hand tools; contact operations
* swin = shielded window; direct viewing
* crcc = crane; 100 - 500 tonne lift
* cr50 = secondary crane 50 tonne lift
* tc50 = transport cart; < 50 tonne
* trtm = transporter; test modules
* trbs = transporter; beamline sources
* trba = transporter; beamline assembly
* trdc = transporter; direct convertor/halo scraper assembly
* hanf = handling fixtures; misc.
* mecm = mechanical msm (thru-the-wall); bilateral, 20 kg lift
* mecb = mechanical msm (bridge mounted); bilateral, teleoperated, 20 kg lift
* mecf = floor mounted msm; bilateral, teleoperated, 20 kg lift
* powa = power arm emm; teleoperated, 50 - 100 kg lift
* ivis = in-vessel inspection syst.; operate in rad., vacuum environment
* inst = inspection ad test syst's; ex-vessel oper for view and elec,
*       coolant, mechanical joints
* mude = partial device mockup and hot cell replica
* muma = manipulators; one of each actual system
* mutr = transporters; sized to mockup components
* mucr = cranes; 50/10 lift
* mtoo = machine tools for hot cell; lathe, mill, boring....
* splg = shield plugs; various sizes
* nws = number of work stations in the hot cell facility
*****
*&meqin1
uccctv=.2 nrcctv=10 nhcctv=4 ircctv=" " ihcctv=" "
uctlcc=.16 nrtlcc=1 nhtlcc=0
ucdewa=.4 nrdewa=0 nhdewa=1
ucpct5=.07 nrpct5=2 nhpct5=2 nmpct5=1
ucpct15=.01 nrpct15=2 nhpct15=2 nmpct15=1
ucpct1=.017 nrpct1=2 nhpct1=2 nmpct1=1
uceeff=.20 nreeff=1 nheeff=1
ucscut=.66 nrscut=2 nhscut=0 nmcut=1
uclift=.01 nrlift=1 nhlift=1
uchant=.02 nrchant=1 nhchant=0
ucswin=.33 nrswin=10 nhswin=4 irswin=" " ihswin=" "
uccrcc=.121 nrcrcc=1 nhcrcc=1 ircrcc=" " ihcrcc=" "
uccr50=.05 nrcr50=1 nhcr50=1
uctc50=.05 nrtc50=1 nhrc50=2
uctrtm=.02 nrtrtm=1 nhtrtm=0
uctrbs=.03 nrtrbs=2 nhtrbs=0
uctrba=.267 nrtrba=1 nhtrba=0
uctrdc=.05 nrtrdc=1 nhtrdc=0
uchanf=.47 nrhanf=1 nhhanf=1
ucmecm=.013 nrmecm=0 nhmecm=2 ihmecm=" "
ucmecb=.03 nrmecb=2 nhmecb=1
ucmecf=.038 nrmecf=2 nhmecf=2
ucpowa=.056 nrpowa=1 nhpowa=1
ucivis=.02 nrivis=6 nhivis=0 irivis=" "
ucinst=.05 nrinst=1 nhinst=1
ucmude=.7 nrmude=0 nhmude=0 nmmude=1
ucmuma=.31 nrmuma=0 nhmuma=0 nmmuma=1
ucmutr=.0 nrmutr=0 nhmutr=0 nmmutr=1
ucmucr=.02 nrmucr=0 nhmucr=0 nmmucr=1
ucmtoo=.2 nrmtoo=0 nhmtoo=1
ucsplg=.02 nrspig=1 nhspig=0 irspig=" "
*&endmeqin1
*&meqin2
*&endmeqin
*****
* Input parameters for the facility module (fac):
*
* parameter unit definition
* -----
*
* htotal mut total waste heat removed

```

```

*
*
*      pgross      mwe      gross electric output of the plant
*
*      qblnkt      mwt      thermal power from blanket
*      qhxbnkt      mwt      capacity of each blanket heat exchanger
*      qtotal      mwt      total recoverable thermal power from plant
*****
*      msgmw - magnet power conversion prime ac power, mw
*      vacmw - vacuum system prime ac power, mw
*      htsw - heat transfer system prime ac power, mw
*      fpsmw - fuel processing system prime ac power, mw
*      acprt - print index option: 0.0 - summary output only
*              1.0 - complete output
*      effinv - direct converter dc/ac inverter efficiency
*      hv1kv - main utility line voltage, kv
*      fv1kv - facility power utility line voltage, kv
*      basemw - facility power base load, mw
*              (loads that are not dependent on floor area)
*      pkwpm2 - facility power lighting & hvac coefficient, kw/m2
*      ndg - number of backup power diesel generators
*      dgkw - rated power of a diesel generator, kw
*      nnips - number of non-interruptible (no-break) power supplies
*      nipskw - rated power of a no-break power supply, kw
*      cpmwm2 - low voltage power distribution cost coefficient, $/mw-m2
*      cpkwp8 - dc/ac inverter cost coefficient, $/kw**0.8
*      clthm - characteristic length of 13.8 kv cables, m
*      vacmw=2.0
*      htsw=10.0 fpsmw=8.0
*      acprt=1.0
*      effinv=0.95
*      hv1kv=230.
*      fv1kv=115.
*      basemw=2.0
*      pkwpm2=0.15
*      ndg=2
*      dgkw =2500.
*      nnips=3
*      nipskw=10
*      cpmwm2=1.5
*      cpkwp8=900.
*      clthm=600.
*****
*      input for instrumentation and control module (iac)
*      nohp(1)=0,nodp(1)=5,notp(1)=0,tmcpdm(1)=1.3,rhcpdm(1)=0.2,
*      nohp(2)=0,nodp(2)=3,notp(2)=0,tmcpdm(2)=1.2,rhcpdm(2)=0.2,
*      nohp(3)=0,nodp(3)=2,notp(3)=0,tmcpdm(3)=1.5,rhcpdm(3)=0.3,
*      nohp(4)=0,nodp(4)=3,notp(4)=0,tmcpdm(4)=0.7,rhcpdm(4)=0.2,
*      nohp(5)=0,nodp(5)=3,notp(5)=0,tmcpdm(5)=0.4,rhcpdm(5)=0.1,
*      nohp(6)=0,nodp(6)=5,notp(6)=0,tmcpdm(6)=0.3,rhcpdm(6)=0.0,
*      nohp(7)=0,nodp(7)=3,notp(7)=0,tmcpdm(7)=0.7,rhcpdm(7)=0.2,
*      nohp(8)=0,nodp(8)=3,notp(8)=6,tmcpdm(8)=0.6,rhcpdm(8)=0.3,
*      nohp(9)=0,nodp(9)=2,notp(9)=4,tmcpdm(9)=0.5,rhcpdm(9)=0.1,
*      nohp(10)=0,nodp(10)=12,notp(10)=6,tmcpdm(10)=0.4,rhcpdm(10)=0.1,
*      nohp(11)=13,nodp(11)=15,notp(11)=18,tmcpdm(11)=0.1,rhcpdm(11)=0.0
*****
*      input for hts module (hts)
*      tcbnkt      blanket inlet temperature (deg C)
*      tdcic      inner collector inlet temperature (deg C)
*      tdcoc      outer collector inlet temperature (deg C)
*      tcdchs      halo scraper inlet temperature (deg C)
*      tcdchd      halo dump inlet temperature (deg C)
*      tcref      reflector inlet temperature (deg C)
*      thbnkt      blanket outlet temperature (deg C)
*      thdcic      inner collector outlet temperature (deg C)
*      thdcoc      outer collector outlet temperature (deg C)
*      thdchs      halo scraper outlet temperature (deg C)
*      thdchd      halo dump outlet temperature (deg C)
*      icl10=2 ireac=1
*****
&endinall

```

Table 6. Sample output data file MSCTOUT

output from central cell blanket and shield module first version 6/30/84

	tritium breeding ratio	lithium-6 enrichment (%)	breeding zone thickness (cm)	reflector zone thickness (cm)	blanket thickness (breeder+reflector) (cm)	biological shield thickness (cm)	total thickness (blanket+shield) (cm)	percent lppb in reflector
1	1.1100	7.5	52.7	20.0	73.7	79.5	153.1	10.0
2	1.1130	7.5	38.9	30.0	69.9	80.3	150.2	10.0
3	1.1100	7.5	29.0	40.0	70.0	80.4	150.4	10.0
4	1.1100	7.5	24.2	50.0	75.2	78.3	153.5	10.0
5	1.1100	15.0	31.5	20.0	52.5	89.0	141.5	10.0
6	1.1100	15.0	20.2	30.0	51.2	89.6	140.8	10.0
7	1.1100	15.0	12.9	40.0	53.9	80.0	142.7	10.0
8	1.1100	15.0	9.9	50.0	60.9	86.0	146.9	10.0
9	1.1100	30.0	21.1	20.0	42.1	94.0	136.0	10.0
10	1.1100	30.0	12.0	30.0	43.0	93.8	136.8	10.0
11	1.1100	50.0	16.0	20.0	37.0	96.4	133.4	10.0
12	1.1100	50.0	9.3	30.0	40.3	95.2	135.5	10.0
13	1.1100	70.0	13.4	20.0	34.4	97.6	132.0	10.0
14	1.1100	90.0	11.9	20.0	32.9	98.4	131.3	10.0
15	1.1100	7.5	39.0	29.9	69.9	80.3	150.2	10.0
16	1.1100	15.0	19.0	31.3	51.3	89.6	140.9	10.0
17	1.1100	30.0	9.0	37.7	47.7	91.9	139.6	10.0
18	1.1100	30.0	10.0	21.5	41.5	94.2	135.7	10.0
19	1.1100	30.0	9.0	31.4	41.4	94.7	136.1	10.0
20	1.1100	70.0	9.0	28.1	38.1	96.2	134.3	10.0
21	1.1100	90.0	9.0	25.8	35.8	97.2	133.0	10.0
22	1.1100	57.7	9.0	30.0	40.0	95.3	135.3	10.0
23	1.1100	26.2	9.0	40.0	50.0	90.9	140.9	10.0
24	1.1100	18.5	9.0	50.0	60.0	86.5	146.5	10.0
25	1.1100	36.4	19.0	20.0	40.0	95.0	135.0	10.0
26	1.1100	16.2	19.0	30.0	50.0	90.2	140.2	10.0
27	1.1100	9.9	19.0	40.0	60.0	85.6	145.6	10.0
28	1.1100	8.1	19.0	50.0	70.0	81.1	151.1	10.0
29	1.1100	10.6	39.0	20.0	60.0	85.6	145.6	10.0

output from central cell blanket and shield module first version 6/38/84

energy fraction in blanket regions				energy fraction in blanket and shield				energy in each region (ev/dt neutron)			
first wall	breeding zone	reflector zone	blanket energy multiplication	blanket zone	shield zone	total energy multiplication		first wall	breeding zone	reflector zone	shield zone
1	0.0616	0.0838	0.1354	1.241	0.8965	0.1835	1.385	1.075e+06	1.481e+07	2.368e+06	2.018e+06
2	0.0595	0.0974	0.2438	1.271	0.9231	0.0769	1.377	1.063e+06	1.246e+07	4.344e+06	1.488e+06
3	0.0577	0.0642	0.3382	1.308	0.9517	0.0483	1.366	1.054e+06	1.185e+07	6.181e+06	9.275e+05
4	0.0566	0.05451	0.3985	1.322	0.9739	0.0261	1.358	1.049e+06	1.013e+07	7.485e+06	4.975e+05
5	0.0641	0.07199	0.2168	1.157	0.8411	0.1589	1.376	1.044e+06	1.171e+07	3.516e+06	3.075e+06
6	0.0617	0.05673	0.3789	1.193	0.8812	0.1188	1.354	1.036e+06	9.515e+06	6.221e+06	2.262e+06
7	0.0601	0.04486	0.4913	1.231	0.9257	0.0743	1.338	1.048e+06	7.764e+06	8.587e+06	1.388e+06
8	0.0592	0.03818	0.5598	1.259	0.9598	0.0418	1.313	1.049e+06	6.759e+06	9.898e+06	7.856e+05
9	0.0668	0.0527	0.2885	1.188	0.8892	0.1988	1.368	1.034e+06	1.018e+07	4.343e+06	3.651e+06
10	0.0645	0.04815	0.4548	1.147	0.8642	0.1358	1.327	1.048e+06	7.761e+06	7.326e+06	2.531e+06
11	0.0698	0.06882	0.3228	1.073	0.7972	0.2828	1.345	1.048e+06	9.179e+06	4.864e+06	3.834e+06
12	0.0667	0.04313	0.5828	1.124	0.8586	0.1414	1.389	1.054e+06	6.818e+06	7.936e+06	2.681e+06
13	0.0705	0.05823	0.3472	1.059	0.7928	0.2872	1.336	1.048e+06	8.679e+06	5.164e+06	3.886e+06
14	0.0716	0.05658	0.3634	1.051	0.7918	0.2898	1.328	1.057e+06	8.356e+06	5.363e+06	3.897e+06
15	0.0595	0.06984	0.2421	1.271	0.9229	0.0771	1.377	1.063e+06	1.248e+07	4.328e+06	1.493e+06
16	0.0615	0.05493	0.3893	1.198	0.8871	0.1129	1.358	1.036e+06	9.252e+06	6.556e+06	2.144e+06
17	0.0634	0.03828	0.5546	1.182	0.9069	0.0931	1.383	1.053e+06	6.348e+06	9.218e+06	1.785e+06
18	0.0663	0.06164	0.3173	1.188	0.8185	0.1815	1.354	1.034e+06	9.684e+06	4.946e+06	3.458e+06
19	0.0664	0.04119	0.5217	1.132	0.8675	0.1325	1.384	1.056e+06	6.553e+06	8.388e+06	2.438e+06
20	0.0684	0.04326	0.4998	1.184	0.8466	0.1534	1.385	1.062e+06	6.717e+06	7.758e+06	2.815e+06
21	0.0699	0.04488	0.4813	1.087	0.8328	0.1672	1.385	1.068e+06	6.854e+06	7.355e+06	3.066e+06
22	0.0672	0.04285	0.5122	1.128	0.8582	0.1418	1.385	1.058e+06	6.628e+06	8.063e+06	2.682e+06
23	0.0627	0.03751	0.5622	1.195	0.9174	0.0826	1.383	1.053e+06	6.385e+06	9.448e+06	1.513e+06
24	0.0683	0.03543	0.5855	1.245	0.9568	0.0432	1.381	1.055e+06	6.281e+06	1.025e+07	7.981e+05
25	0.0676	0.0353	0.2971	1.089	0.8837	0.1963	1.355	1.034e+06	9.726e+06	4.548e+06	3.738e+06
26	0.0628	0.05564	0.3816	1.187	0.8785	0.1215	1.351	1.035e+06	9.284e+06	6.367e+06	2.389e+06
27	0.0586	0.05141	0.4273	1.261	0.9354	0.0646	1.348	1.048e+06	9.115e+06	7.573e+06	1.225e+06
28	0.0568	0.04939	0.4493	1.384	0.9689	0.0311	1.346	1.043e+06	9.068e+06	8.239e+06	5.882e+05
29	0.0638	0.07529	0.1841	1.198	0.8616	0.1384	1.381	1.054e+06	1.268e+07	3.088e+06	2.686e+06

output from central cell blanket and shield module first version 6/30/84

reference blanket is number 3

Tritium breeding

tritium breeding ratio = 1.11000
lithium-6 enrichment = 7.500 %

Dimensions

central cell length = 97.00 m
first wall radius = 67.370 cm
breeding zone thickness = 29.034 cm
reflector zone thickness = 10.000 cm
blanket thickness (breeder+reflector) = 70.034 cm
thickness of shield between coils = 80.359 cm
total thickness between coils (blanket+shield) = 150.393 cm

thickness of shield under coils = 39.191 cm
total thickness under coils (blanket+shield) = 109.226 cm

Zone compositions

breeding zone
7.500 % ferritic steel
92.500 % lithium lead
reflector zone
10.000 % ferritic steel
10.000 % lithium lead
80.000 % carbon
shield zone
80.000 % 1422 steel
20.000 % water

Energy multiplication

blanket energy multiplication = 1.30047
fraction of blanket energy in first wall = 0.05769
fraction of blanket energy in breeding zone = 0.60417
fraction of blanket energy in reflector zone = 0.33021
total energy multiplication = 1.36643
fraction of total energy in blanket = 0.95172
fraction of total energy in shield = 0.04828
energy deposited in first wall = 1.05373e+06 (eV/DT neutron)
energy deposited in breeding zone = 1.10490e+07 (eV/DT neutron)
energy deposited in reflector zone = 6.10123e+06 (eV/DT neutron)
energy deposited in shield = 9.27472e+05 (eV/DT neutron)

Power

fusion power = $4.18599e+02$ MW
power deposited in first wall = $3.88836e+01$ MW
power deposited in breeding zone = $3.22618e+02$ MW
power deposited in reflector zone = $1.88593e+02$ MW
power deposited in shield = $2.78886e+01$ MW

Volume

volume of first wall = $4.13698e+00$ m**3
volume of breeding zone = $1.46688e+02$ m**3
volume of reflector zone = $2.86238e+02$ m**3
volume of shield between coils = $2.14219e+02$ m**3
volume of shield under coils = $2.33834e+02$ m**3

Mass

mass of pca = $8.$ kg
mass of ferritic steel = $3.21843e+05$ kg
mass of lithium = $8.$ kg
mass of lithium lead = $1.55381e+06$ kg
mass of carbon = $3.66384e+05$ kg

mass of boron carbide (b4c) = $1.28366e+05$ kg
mass of lead = $2.14713e+05$ kg
mass of fel422 steel = $2.89879e+06$ kg

Cost

cost of pca = \$ $8.$
cost of ferritic steel = \$ $2.56034e+07$
cost of lithium = \$ $8.$
cost of lithium lead = \$ $6.21286e+06$
cost of carbon = \$ $4.39661e+06$

cost of boron carbide (b4c) = \$ $4.57391e+06$
cost of lead = \$ $8.58853e+05$
cost of fel422 steel = \$ $3.47855e+07$
total cost of blanket = \$ $3.62921e+07$
total cost of shield = \$ $4.82182e+07$

Radiation damage in central cell coil

wall loading = 1.888 MW/m**2
reactor life = 1.888 years
availability factor = 1.888
total neutron fluence at the first wall = $9.99874e-01$ MWY/m**2
thickness of shield under coils = 39.191 cm

total neutron flux at coil case = 1.76817e+09 n/cm**2*s
 maximum heating in coil case = 1.88888e-01 mW/cm**3
 maximum heating in coil winding = 3.84885e-02 mW/cm**3
 total heating in coil case = 2.88369e+03 W
 total heating in coil winding = 2.36468e+03 W
 dose in thermal insulator = 8.55476e+07 rads
 dose in electrical insulator = 3.41188e+07 rads
 maximum dpa = 3.66314e-04 dpa
 maximum fluence in the winding material = 1.94619e+16 n/cm**2

mscx CHSH 03/14/85 18:06:51 d Time Used/Left: 413.573 1001.970

 nuclear responses in the choke coils and shielding analysis

copper coil

 max. nuclear heating in the coil case, w/cm**3 5.853e+00
 max. nuclear heating in the winding, w/cm**3 3.868e+00
 total nuclear heating in the coil case, w 9.974e+04
 total nuclear heating in the winding, w 5.937e+05
 max. dose in the electrical insulator, rads 2.635e+12
 max. dpa in the copper material, dpa 2.953e+00
 max. fast fluence in the copper material, n/cm**2 1.246e+22

superconductor coil

 max. nuclear heating in the coil case, w/cm**3 2.143e-04
 max. nuclear heating in the winding, w/cm**3 7.268e-05
 total nuclear heating in the coil case, w 9.858e-01
 total nuclear heating in the winding, w 1.184e+00
 max. dose in the thermal insulator, rads 2.267e+08
 max. dose in the electrical insulator, rads 9.468e+07
 max. fast fluence in the copper material, n/cm**2 5.848e+16
 max. dpa in the copper material, dpa 3.974e-05

coil shield

 total volume, m**3 5.361e+01
 fe1422 steel volume, m**3 4.288e+01
 b4c volume, m**3 8.883e-02
 total cost, \$ 8.575e+06
 fe1422 cost, \$ 8.569e+06
 b4c cost, \$ 5.981e+03

.....

3

mscx CCKK 83/14/85 18:12:24 d Time Used/Left: 427.618 1867.924

CCKK: Center-Coil/Choke Consistency Check Module

(1) Check Center-Coil Build-up...

First Wall Radius,	RW	=	6.738e-01
First Wall Thickness,	OFT	=	0.
Breeder Thickness,	OBT	=	2.983e-01
Reflector Thickness,	ORT	=	4.888e-01
Blanket-Shield Gap,	GBS	=	2.588e-02
Shield Thickness,	OTC	=	3.919e-01
Thermal Liner Thickness,	TLNRTHK1	=	1.888e-01
Casing Thickness,	CASETHK1	=	4.888e-02

Total Build-up (min. coil radius)		=	1.921e+00
Actual Coil Inside Radius, ACC		=	1.948e+00
Actual Gap Between Shield and Liner		=	1.876e-02

(2) Check Choke Shield Based on Coil Damage...

Choke Shield Thickness,	TCHSHLD	=	7.184e-01
Allowed Heating to Coil,	CHHEATMX	=	1.888e-04 W/cm**3
Calc. Heating to Coil,	OS(2)	=	7.268e-05 W/cm**3
Allowed Dose to Elec. Ins.,	CHDOSEM	=	1.888e+10 Rads
Calc. Dose to Elec. Ins.,	OS(6)	=	9.468e+07 Rads
Required Thickness, (new)	TCHSHLD	=	7.877e-01

(3) Check Choke Coil Build-up...

Insert Coil Radius,	AIN	=	1.588e-01
Choke Shield Thickness,	TCHSHLD	=	7.184e-01
Thermal Liner Thickness,	TLNRTHK1	=	1.888e-01
Casing Thickness,	CASETHK1	=	4.888e-02

Total Build-up (min. coil radius)		=	1.888e+00
Actual Coil Inside Radius, ACH		=	1.828e+00
Actual Gap Between Shield and Liner		=	1.958e-02

* 8 inconsistencies.

mscx ECMG 83/14/85 18:12:49 d Time Used/Left: 428.888 1867.535

ECMG:TUNER:

Tuner variables for cycle 1:

Jcc = 4.811e+87 Jch = 1.686e+87 Jc(1)= 4.471e+87 Jc(2)= 4.462e+87
 Lm(1)= 3.827e+88 Lm(2)= 4.479e+88 Lt = 2.553e+88 sa(2)= 7.399e+81
 Lc = 9.643e-81

ECMG:TUNER: Status Report

CYC	CP	Residual	Bcc	Bch	Bma	Bmp	Ba	Bp	Ea	Ep	GCF
8			2.58	24.8	7.58	7.58	3.75	2.58	1.88	1.88	1.88
1	14	6.19e-85	2.58	24.8	7.49	7.49	3.75	2.58	1.88	1.88	8.99*

Residual Convergence (EPSR = 1.888e-84) satisfied.

Tuner variables for cycle 1:

Jcc = 4.811e+87 Jch = 1.686e+87 Jc(1)= 4.471e+87 Jc(2)= 4.462e+87
 Lm(1)= 3.827e+88 Lm(2)= 4.479e+88 Lt = 2.553e+88 sa(2)= 7.399e+81
 Lc = 9.643e-81

COILSPEC: CC Magnetics - Solenoid Specifications

Coil Module Length: 8.818e+88 Gap: 1.888e+88

Coil	No.	Inner Rad.	Pack Width	Pack Build	Cur Densty
CC(main)	11	1.948e+88	5.782e+88	5.832e-82	4.811e+87
CC(trim)	22	1.948e+88	6.888e-81	1.254e-81	4.811e+87
Insert	2	1.588e-81	6.888e-81	3.988e-81	2.441e+87
Choke(1)	2	1.828e+88	2.888e+88	1.923e-81	1.686e+87
Choke(2)	2	1.212e+88	1.888e+88	4.454e-81	1.989e+87
Choke(3)	2	1.658e+88	1.788e+88	5.141e-81	2.632e+87

COILSPEC: EC Magnetics - C-Coil Specifications

Coil	Z-location	Major Rad.	Minor Rad.	Sweep Angl	St Section	Pack Width	Pack Build	Cur Densty
Trans-1	5.386e+81	1.738e+88	6.188e-81	9.888e+81	2.588e-81	8.197e-81	2.732e-81	4.462e+87
Anchor-1	5.698e+81	1.228e+88	6.188e-81	7.588e+81	8.	8.197e-81	2.732e-81	4.471e+87
Anchor-2	5.836e+81	1.228e+88	6.188e-81	7.588e+81	8.	8.197e-81	2.732e-81	4.471e+87
Plug-1	6.228e+81	1.738e+88	6.188e-81	7.399e+81	8.	8.197e-81	2.732e-81	4.462e+87
Plug-2	6.338e+81	1.738e+88	6.188e-81	7.399e+81	8.	8.197e-81	2.732e-81	4.462e+87
Trans-2	6.721e+81	1.228e+88	6.188e-81	7.588e+81	8.	8.197e-81	2.732e-81	4.471e+87

FIELD SUM: Center-Cell Field Summary

Bavg= 2.588e+00, $\Delta(B)$ = 2.522e+00, Bmin= 2.467e+00, Bmax= 2.522e+00

Ripple (peak/rms/rms curv): 2.214e-02 5.878e-03 1.851e-03

Bch= 2.488e+01, Bin= 8.888e+00

FIELD SUM: TM Field Profile

CP	Region	Z	B	Y/X	YAH	YUH	GCI	Int(d1/B)
1	CC	0.	2.522e+00	1.888e+00	4.989e-04	-4.658e-10	-2.198e-02	-2.926e-17
2	Choke	5.888e+01	2.488e+01	9.952e-01	3.228e-02	-1.568e-04	-2.187e-02	1.882e+01
3	Trans	5.334e+01	3.462e+00	2.821e+00	1.823e-01	1.345e-01	-1.438e-01	1.932e+01
4		5.494e+01	7.726e+00	3.882e+01	-8.155e-01	-8.183e-01	-1.883e-02	1.964e+01
5		5.531e+01	7.586e+00	3.996e+01	-1.366e+00	-1.367e+00	4.236e-01	1.969e+01
6	Ra=2.841	5.559e+01	7.653e+00	3.565e+01	-9.195e-01	-9.226e-01	7.587e-01	1.973e+01
7	Anchor	5.778e+01	3.749e+00	9.994e-01	3.949e-03	-1.388e-02	7.645e-01	2.816e+01
8	Ra=1.998	5.973e+01	7.491e+00	2.844e-02	-9.812e-01	9.846e-01	7.838e-01	2.859e+01
9		6.885e+01	7.395e+00	2.489e-02	-1.438e+00	1.439e+00	3.832e-01	2.863e+01
10	Rp=3.881	6.838e+01	7.588e+00	2.686e-02	-9.843e-01	9.871e-01	-2.587e-02	2.867e+01
11	Plug	6.279e+01	2.499e+00	9.571e-01	2.818e-02	7.589e-04	-9.282e-02	2.134e+01
12	Rp=2.998	6.519e+01	7.492e+00	3.823e+01	-9.815e-01	-9.844e-01	-2.892e-02	2.281e+01
13		6.552e+01	7.385e+00	4.884e+01	-1.437e+00	-1.438e+00	-2.353e-06	2.286e+01
14		6.588e+01	7.488e+00	3.585e+01	-9.824e-01	-9.859e-01	8.797e-09	2.218e+01

Effective Length of Center-Cell: 9.411e+01

mscx MHD 83/14/85 18:19:32 d Time Used/Left: 453.868 1841.683

MHD: TEASCO m=1 Ballooning Stability Results

For Rp= 4.578e-01, Rw= 6.738e-01, SBETA= 6.864e-01:

BETA(1)= 6.888e-01 1.727e-01 3.888e-01 (CC, Anchor, Plug)

mscx PMCK 03/14/05 18:26:24 d Time Used/Left: 465.381 1030.161

PMCK: Physics/Magnetics Variables Comparison

Tolerance on B-Field Values: 1.0000e-02
Tolerance on Beta Values: 1.0000e-02
Tolerance on Length Values: 1.0000e-02

Name	Phys Value	Mag Value	Rel Error
BVACBC	2.5000e+00	2.5000e+00	-1.711e-12
BBAR	2.4000e+01	2.4000e+01	-7.247e-13
BVACBT	3.462e+00	3.462e+00	-5.911e-13
BMANC	7.653e+00	7.653e+00	5.533e-13
B0ANC	3.749e+00	3.749e+00	-8.908e-13
BVACBP	7.5000e+00	7.5000e+00	-3.411e-14
BVACBB	2.499e+00	2.499e+00	2.161e-13
BVACMA	7.492e+00	7.492e+00	5.311e-14
BETAC	9.0000e-01	9.0000e-01	0.
BETAANC	2.591e-01	2.591e-01	0.
BETAB	4.5000e-01	4.5000e-01	0.
CLENGTH	9.411e+03	9.411e+03	-3.340e-13
ELACELL	4.810e+02	4.810e+02	6.126e-13
ELTRAN	1.038e+03	1.030e+03	-3.209e-12
XLmira	1.611e+02	1.611e+02	2.432e-12
YHAvg	1.343e-03	1.343e-03	5.166e-14

* 0 inconsistencies.

Contents of XPHYS output file: outmr

***** found a feasible starting point *****

estimate of the constraints (sqsumsq) = 1.6234e-12
ion energy balance (pdevi) = 1.1390e-15
electron energy balance (pdeve) = 7.1054e-16
alpha particle balance (fconsis) = 2.3199e-12

the following are the 14 constraints and components of the solution vector:

i		xcs	xcc	rc	residue	scafc	scale
1	bplagt	3.3996e+00	9.8201e-01	1.4211e-14	4.6652e-13	3.4619e+00	1.0000e+00
2	bpl	7.5660e+00	9.8859e-01	0.	2.1820e-13	7.6534e+00	1.0000e+00
3	bplaga	2.4402e+00	8.1371e-01	-4.6185e-14	6.4364e-14	2.9988e+00	1.0000e+00
4	xlllg	2.1831e+00	2.1831e-01	-5.7732e-15	1.8183e-13	1.0000e+01	1.0000e-01
5	xlllga	4.5887e+00	4.5887e-01	4.6541e-13	1.4438e-12	1.0000e+01	1.0000e-01
6	etat	2.3769e+00	2.3769e-01	3.4106e-14	4.0115e-13	1.0000e+01	1.0000e-01
7	etapl	1.2450e+00	1.2450e-01	-2.4158e-14	7.2929e-14	1.0000e+01	1.0000e-01
8	etaap	1.4339e+00	1.4339e-01	-2.1316e-14	7.4762e-14	1.0000e+01	1.0000e-01
9	etab	5.7991e+00	5.7991e-01	-5.5828e-14	7.8565e-14	1.0000e+01	1.0000e-01
10	etamp	1.4215e+00	1.4215e-01	2.4869e-14	8.6816e-14	1.0000e+01	1.0000e-01
11	etac	4.7677e+00	4.7677e-01	2.8422e-15	7.9190e-14	1.0000e+01	1.0000e-01
12	tec	2.7695e+01	6.9237e-01	-4.2633e-15	2.2073e-13	4.0000e+01	2.5000e-02
13	calph	2.9029e-02	2.9029e-01	-1.5525e-12	8.4652e-14	1.0000e-01	1.0000e+01
14	etae	6.9200e+00	6.9200e-01	-4.6222e-15	2.6620e-14	1.0000e+01	1.0000e-01

***** feasible starting point was found *****

***** end of starting point section *****

***** final feasible point output *****

```

*****
*      central cell output:      *
*****

```

enc	=	1.6431e+14	ion density (cm-3)
tc	=	4.8888e+01	ion temperature (kev)
tec	=	2.7695e+01	electron temperature (kev)
cradius	=	4.5778e+01	plasma radius (cm)
clength	=	9.4188e+03	central cell length (cm)
rffw	=	6.7378e+01	first wall radius (cm)
bvacsc	=	2.5888e+00	vacuum b field (tesla)
bplasc	=	7.9857e-01	plasma b field (tesla)
betac	=	9.8888e-01	peak beta
phie	=	1.9165e+02	floating (electron confining) potential (kev)
calph	=	2.9829e-02	fraction of alphas in central cell
fpart	=	5.1341e-01	fraction of alphas in the plasma core
fenergy	=	7.3641e-01	fraction of alpha energy in the plasma core
falphcu	=	4.3845e-01	fraction of alpha energy deposited to electrons
xjfuelv	=	2.5929e-01	cold ion fueling current (kamps)
xienddt	=	1.4284e-02	axial ion current (kamps)
entauci	=	7.6456e+14	ion confinement (sec/cm3)
entaucv	=	6.1828e+14	electron confinement (sec/cm3)
entaucv	=	1.8888e+16	axial ion confinement (sec/cm3)
xprofile	=	4.8888e+00	density profile exponent
bbara	=	2.1888e+01	max. magnetic field at inner peak (tesla)
rvacab	=	1.2139e+00	inner vacuum mirror ratio
bbar	=	2.4888e+01	choke coil magnetic field (tesla)
rvacmb	=	1.3873e+00	outer vacuum mirror ratio
bbarb	=	1.7388e+01	vacuum magnetic field in the end cell (tesla)
bbarbp	=	1.5887e+01	plasma magnetic field in the end cell (tesla)
betap	=	2.4758e-01	peak plasma plug beta
rpbm	=	1.5993e+00	plasma mirror ratio

```
*****
* transition output output: *
*****
```

```
eltran   = 1.0384e+03    transition length (cm)
radiust  = 2.2076e+01    plasma radius (cm)
bvac0t   = 3.4619e+00    vacuum b field (tesla)
bplao0t  = 3.3996e+00    plasma b field (tesla)
betat    = 3.5657e-02    transition midplane beta
phit     = 6.5828e+01    transition potential (kev)
enpasst  = 6.6737e+12    passing density (cm-3)
calt     = 5.3894e-02    fraction of alphas
xitrap   = 1.7247e-01    trapping current (kamps)
xlilg    = 2.1831e+00    required ion small g to achieve alpha pumping
xlilga   = 4.5807e+00    required alpha small g to achieve alpha pumping
fncsisdt = -1.1224e-03    ion balance in transition
```

```
*****
* pump beam location: *
*****
```

```
enpaspl  = 1.8039e+13    passing ion density (cm-3)
bpivac   = 7.6534e+00    vacuum b field (tesla)
betapl   = 2.2695e-02    midplane beta
phipl    = 3.4479e+01    potential at geodesic curvature max. (kev)
calpl    = 5.5594e-02    fraction of alphas
xlaneo   = 7.1238e-04    alpha current (kamps)
xidtno   = 1.5595e-02    ion current (kamps)
```

```
*****
* barrier output: *
*****
```

```
elacell  = 4.8102e+02    barrier length (cm)
radiusb  = 2.9899e+01    plasma radius (cm)
bvac0b   = 2.4990e+00    vacuum b field (tesla)
bplao0b  = 1.8533e+00    plasma b field (tesla)
bvac0ap  = 5.3744e+00    vacuum b field at a' (tesla)
bplaoap  = 4.7390e+00    plasma b field at a' (tesla)
bettot   = 4.5000e-01    total barrier beta
betab    = 4.5000e-01    perp. barrier beta
betaap   = 2.2246e-01    beta at a'
```

betaa	=	3.3788e-01	beta at ecrh injection point a
phib	=	1.6061e+02	barrier potential (kev)
phic	=	1.9071e+02	ion confining potential (kev)
phiap	=	3.9711e+01	potential at a' (kev)
phimp	=	3.9368e+01	potential at mp (kev)
enpassb	=	2.6872e+12	barrier passing ion density (cm-3)
enpassmp	=	1.7310e+13	passing ion density at mp (cm-3)
calb	=	2.6982e-02	fraction of alphas at barrier
calmp	=	5.5170e-02	fraction of alphas at mp
calap	=	5.5374e-02	fraction of alphas at ap'
ebprime	=	5.2788e+01	ion energy at b' (kev)
eehbar	=	6.5765e+02	average electron energy (kev)
tew	=	1.6836e+02	warm electron energy (kev)
fec	=	3.0000e-02	fraction of cold electrons at barrier
ftrapbs	=	2.9726e-01	sloshing beam trapping fraction
rb	=	4.0425e+00	plasma mirror ratio
rbeff	=	3.2490e+00	hot electron effective mirror ratio
reffs	=	1.1978e+00	sloshing ion effective mirror ratio
sdenrat	=	2.1954e+00	peak to midplane sloshing ion density ratio
slosh	=	1.2000e+00	warm electron heating point mirror ratio
xislosh	=	2.9489e-03	sloshing ion current (kamps)

 * anchor output: *

radanc	=	3.1172e+01	anchor plasma radius (cm)
xlmira	=	1.6115e+02	anchor effective length (cm)
b0anc	=	3.7491e+00	vacuum b field (tesla)
bplaanc	=	3.2271e+00	plasma b field (tesla)
betaanc	=	2.5905e-01	midplane anchor beta
phianc	=	0.	anchor potential (kev)
denanc	=	1.8466e+13	hot ion density (cm-3)
eneganc	=	6.1618e+02	average ion energy (kev)
entaun	=	4.8444e+13	ion confinement (sec/cm3)

 * power balance output: *

ccicrh	=	5.6643e-13	central cell auxiliary ion heating (mw)
ccscrh	=	3.5437e-14	central cell auxiliary electron heating (mw)
pnba	=	1.4007e+00	neutral beam at a power (mw)
pcrha	=	3.4827e-01	ocrh power at a (mw)
pcrhb	=	1.1174e+01	ocrh power at b (mw)
pdrag	=	8.6271e-01	ocrh drag power at b (mw)
ppump	=	1.4164e-01	transition power (mw)
bresanc	=	4.4845e+00	plasma b field at anchor ion cyclotron resonance (t)
panc	=	3.3268e-01	anchor icrh power (mw)
pbrem	=	2.6612e+00	bremsstrahlung radiation (mw)
psync	=	6.4605e+00	synchrotron radiation (mw)

pfus	=	4.9874e+02	fusion power (mw)
gamma	=	9.9987e-01	wall loading (mw/m2)
q	=	3.7625e+01	fusion q

 * general physics input parameters: *

ccscrh	=	3.5437e-14	power to c.c. electrons from auxiliary heating (mw)
ccicrh	=	5.6843e-13	power to c.c. ions from auxiliary heating (mw)
clength	=	9.4108e+03	central cell length (cm)
cradius	=	4.5778e+01	central cell radius (cm)
gamma	=	9.9987e-01	neutron wall loading when ifixgam = 1 (mw/m2)
idrive	=	0	0 for no heating; 1 for ion; 2 for electron; 3 for both
ifixccl	=	1	1: fixes clength for a fixed pfus and betac
			2: fixes clength for a fixed pfus and gamma
ifixcrad	=	0	1: fixes the cc radius for a fixed pfus and betac
			2: fixes the cc radius for a fixed pfus and gamma

amanc	=	2.8888e+88	mass of anchor ion species (amu)
amass	=	2.8888e+88	mass of sloshing ion species (amu)
anumb	=	1.8888e+88	atomic number of ion species
bigg	=	4.1831e+88	ratio of trapped, sloshing and passing ion to passing ion
elcoef	=	6.6788e-81	radial ion loss energy factor
elptb	=	5.8888e+88	ellipticity at the barrier
elptp	=	3.1888e+81	ellipticity at the plug
eloss	=	8.	radial ion loss energy factor
entauc	=	1.8888e+16	central cell dt axial confinement (s/cm3)
epump	=	5.8888e+81	charge exchange pumping energy (kev)
etaap	=	1.4339e+88	ratio of potential to electron temp. of sloshing beam point
etab	=	5.7991e+88	ratio of plug bottom potential to central cell electron temp.
etac	=	4.7677e+88	ratio of central cell ion potential to its temperature
etae	=	6.9288e+88	ratio of central cell electron potential to its temp.
etat	=	2.3769e+88	ratio of transition region potential to electron temp.
fec	=	3.8888e-82	density fraction of cold electron at plug bottom
fbvacb	=	8	option for computing bvac8b if set equals to 1
flinside	=	1	1: no axial cell; 8: with axicell
lselect	=	1	1: ion lost radially; 8: ion & electron lost radially
ntype	=	2	type of end cell configuration
rmirpt	=	3.1359e+88	ratio of choke coil field to transition coil field
selalp	=	1.8888e+88	selectivity of thermal alpha particle of lost mechanism
xlilg	=	2.1831e+88	ratio of trapped and passing ion to passing ion density
xlilga	=	4.5887e+88	ratio of trapped and passing alpha to passing alpha density
xkmua	=	7.4798e-22	loading coeff. in ecrh scattering/drag power term at a
xkmub	=	2.3448e-22	loading coeff. in ecrh scattering/drag power term at b
xksync	=	3.3838e-28	loading coeff. of synchrotron radiation term
yahavg	=	1.3432e-83	average yah of magnetic field lines

***** output summary *****

radius (cm)

central cell	transition cell	barrier/plug	anchor
4.578e+81	2.288e+81	2.998e+81	3.117e+81

length (cm)

central cell	transition cell	barrier/plug	anchor
9.411e+83	1.838e+83	4.818e+82	1.611e+82

vacuum b field (t)

central cell	transition cell	barrier/plug	anchor
2.580e+00	3.462e+00	2.499e+00	3.749e+00

plasma b field (t)

central cell	transition cell	barrier/plug	anchor
7.986e-01	3.480e+00	1.853e+00	3.227e+00

ifixfus = 0	1: fixes the fusion power
ifixrffw = 0	1: fixes rffw and calculates gamma from pfus and betac
	2: fixes rffw for a fixed pfus and gamma
ioptimz = -3	<0 no optimization; 1 use nag and vary reffs; 2 use nag and fix reffs;
	3 use vmcon and vary reffs; 4 use vmcon and fix reffs
ioption = 2	=1 fix pfus; =2 fix clength
maxcal = 1888	max. number of physics calls in optimizer
minmax = 0	=0 minimize clength or maximize pfus; >0 minimize; <0 maximize
neqns = 14	number of equality constraints
nlines = 0	number of lines printed by echoin
pfus = 4.9874e+02	fusion power (mw)
q = 3.7625e+01	fusion q
rchoke = 1.4888e+01	choke coil radius (cm)
rdiff = 5.4888e+01	distance between central cell plasma radius and wall (tesla/alpha larmour radii)
reffs = 1.1978e+00	sloshing ion mirror ratio
rffw = 6.7378e+01	radius of the wall (cm)
sdenrat = 2.1954e+00	peak to midplane sloshing ion density ratio
tc = 4.8888e+01	central cell ion temperature (kev)
tec = 2.7695e+01	central cell electron temperature (kev)

 * optional plasma physics input parameters: *

bbar = 2.4888e+01	choke coil magnetic field (tesla)
bbara = 2.1888e+01	max. vacuum magnetic field at the inner peak (tesla)
bbarb = 1.7388e+01	min. vacuum magnetic field in the endcell (tesla)
betaanc = 2.5985e-01	peak beta value of the anchor
betab = 4.5888e-01	peak beta value of the plug midplane
betac = 9.8888e-01	peak beta value of the central cell
betacmx = 9.8888e-01	max. central cell beta
betap = 2.4758e-01	peak beta value of the plug
bmanc = 7.6534e+00	min. anchor magnetic field (t)
bvacma = 7.4928e+00	outer plug magnetic field (t)

```

bvac#b = 2.499#e+#00 vacuum magnetic field of the plug mid plane (t)
bvac#c = 2.5#e+#00 central cell vacuum magnetic field (tesla)
bvac#p = 7.5#e+#00 vacuum inner mirror field of the plug (tesla)
bvac#t = 3.4619e+#00 transition region minimum magnetic field (tesla)
b#anc = 3.7491e+#00 anchor vacuum magnetic field (t)
calph = 2.9#e-#02 central cell thermal alpha particle density fraction
chokgap = 2.25#e+#00 distance between plasma and choke coil (cm)
< # use two alpha larmor radii
e#in#p = 4.75#e+#02 sloshing ion beam injection energy (mw)
elacell = 4.81#e+#02 plug region length (cm)
eltran = 1.#e+#03 transition region length (cm)
lecho = 3 1-3 echos input using writein
> /= 2 echos input using echoin
> /= 3 echos input using namelist
reffsmn = 1.3#e+#00 minimum allowed reffs
reffsmx = 1.5#e+#00 maximum allowed reffs
sdenmn = 2.#e+#00 minimum allowed sdenrat
sdenmx = 3.#e+#00 maximum allowed sdenrat
slosh = 1.2#e+#00 warm electron heating point mirror ratio (b(a)/b(b))
tew = 1.6836e+#02 warm electron temperature (kev)
tewmax = 2.#e+#02 maximum allowed tew (kev)
tewmin = 5.#e+#01 minimum allowed tew (kev)
xlmira = 1.6115e+#02 anchor length (cm)
xprofile = 4.#e+#00 density profile exponent

```

* detailed plasma physics input parameters:

beta			
central cell	transition cell	barrier/plug	anchor
9.#e-#01	3.566e-#02	4.5#e-#01	2.591e-#01

potential (kev)			
central cell	transition cell	barrier/plug	anchor
1.916e+#02	6.583e+#01	1.6#e+#02	#.

fusion power=	4.9874e+#02 mw	fusion q=	3.7625e+#01
wall loading=	9.9987e-#01 mw/m2	calph=	2.9#e-#02
ion temperature=	4.#e+#01 kev	electron temperature=	2.7695e+#01 kev

pdev1= 1.1398e-15 pdev= 7.1054e-16 fcons1= 2.3199e-12
sqsumsq= 1.6234e-12

feasible solution obtained

***** computer usage output *****

cpu= 6.046e+00 s io= 3.101e-01 s sys= 1.292e-03 s
iloop= 1 n total= 21 n calls= 63
17:24:37 03/14/85

the feasible point used 63 iterations
the optimization used 0 iterations
the final point used 0 iterations
there were 63 physics calls

45

[illegible]

collcost(1,2) = \$ 14471943.4382 3475963.81287 415477.484438 19878861.4334 \$ \$ 9299547.78542 5746429.29963 5746429.29963
 7464389.95877 7464389.95877 5746429.29963 \$
 collcost(1,3) = 152622283.869 6186862.85143 1279822.98458 317876.691176 2192463.84988 3838382.98282 7485128.83384 3344999.23297
 2289148.98989 2289148.98989 2784323.8724 2784323.8724 2289148.98989 \$
 collcost(1,4) = 152863643.69 5982555.63588 1618968.21312 98488.7132612 4412677.85399 1698514.49719 38167.7113887 4488621.24882
 2718122.39544 2718122.39544 3654227.38269 3654227.38269 2718122.39544 \$
 collcost(1,5) = 44588187.4312 2462524.95165 577988.695167 \$ 1828726.88593 \$ \$ 294385.121941 197386.97146 197386.97146
 238732.996192 238732.996192 197386.97146 \$
 collcost(1,6) = 9118776.28878 \$ \$ \$ \$ \$ 1171622.11849 549858.94364 549858.94364 867186.579489 867186.579489 549858.94364 \$
 S

mscx AXP 83/14/85 18:38:16 d Time Used/Left: 473.863 1822.488

AUXP: Controller for Auxiliary Physics Code XAUXP

Contents of XAUXP output file: outaux

+++++

* direct convertor physics calculations *

***** magnetic flux *****

fluxhd	=	1.9197e+88	magnetic flux to halo dump (webers)
fluxhs	=	2.1965e-81	magnetic flux to halo scraper (webers)
fluxic	=	9.8286e-81	magnetic flux to inner collector (webers)

***** heat flux *****

hhd	=	1.9229e+81	thermal power to halo dump (mw)
hhs	=	6.7294e+88	thermal power to halo scraper (mw)
hic	=	2.5388e+81	thermal power to inner collector (mw)
hoc	=	8.	thermal power to outer collector (mw)

***** net electrical power *****

peic = 4.2423e+01 power from inner collector (mw)
 peoc = 0. power from outer collector (mw)

***** b model from recirculizer to d.c. *****

alphadc = 1.3700e+00 exponent for length calc. (keyed to i.c.)
 z0 = 5.0000e-01 length parameter for d.c. length calc. (m)
 b0 = 1.2500e+00 b field at cardinal for length calc. (t)
 vdcic = 1.8703e+02 bias voltage on inner collector (kev)
 parcurdc = 2.1946e+02 charge particle current to collector (charge-amps/sec)

***** end of direct convertor calculations *****

 * drift pumping physics calculations *

bcp1 = 1.5811e+00 central cell plasma b field (tesla)

***** transition region *****

deltwb(1)	=	2.4984e+85	frequency spread of drift pump coil (rad/sec)
kappa(1)	=	6.6799e+88	integral of geodesic curvature
omegab(1)	=	6.4859e+85	bounce frequency (rad/sec)
taumax(1)	=	5.1682e+88	max(x,y)/(plasma radius)
taump(1)	=	4.9857e-82	pumping time (sec)
fluxtdl(1)	=	5.8925e-83	total flux drift pump supplies (webers)
fluxtpm(1)	=	5.8925e-83	flux/meter drift pump supplies (webers/m)
nfreqdp(1)	=	13	number of discrete tones generated

***** plug region *****

deltwb(2)	=	2.8356e+86	frequency spread of drift pump coil (rad/sec)
kappa(2)	=	3.8899e-82	integral of geodesic curvature
omegab(2)	=	5.1234e+86	bounce frequency (rad/sec)
taumax(2)	=	5.2451e+88	max(x,y)/(plasma radius)
taump(2)	=	8.3515e-81	pumping time (sec)
fluxtdl(2)	=	1.8544e-81	total flux drift pump supplies (webers)
fluxtpm(2)	=	1.8544e-81	flux/meter drift pump supplies (webers/m)
nfreqdp(2)	=	73	number of discrete tones generated

***** end of drift pumping calculations *****

 * auxiliary heating physics calculations*

***** electron cyclotron resonance heating (ecrh) *****

bpla8a	=	2.4482e+08	plasma b field at a (tesla)
pecrha	=	3.4827e-01	absorbed power at a (mw)
pecrhat	=	4.8972e-01	launched power at a (mw)
freqec(1)	=	6.8325e+10	frequency (hz)
trpfrcce(1)	=	8.5888e-01	assumed launching efficiency
bpla8b	=	1.8533e+08	plasma b field at b (tesla)
pecrhb	=	1.1174e+01	absorbed power at b (mw)
pecrhbt	=	1.5963e+01	launched power at b (mw)
freqec(2)	=	5.1893e+10	frequency (hz)
trpfrcce(2)	=	7.8888e-01	assumed launching efficiency

***** ion cyclotron resonance heating (icrh) *****

bresanc	=	4.4845e+08	plasma b field at anchor ion cyclotron resonance (t)
panc	=	3.3268e-01	absorbed power in anchor (mw)
panct	=	1.1889e+08	launched power in anchor (mw)
freqic(1)	=	6.8165e+07	frequency (hz)
trpfrcic(1)	=	3.8888e-01	assumed launching efficiency
bpla8c	=	7.9857e-01	plasma b field in central cell (tesla)
ccecrh	=	3.5437e-14	absorbed power to electrons (mw)
ccicrh	=	5.6843e-13	absorbed power to ions (mw)
idrive	=	8	>8: central cell rf system on; <8: off
pichcct	=	8	launched power in the central cell (w)
freqic(2)	=	1.2817e+07	frequency (hz)
trpfrcic(2)	=	1.8888e+00	assumed launching efficiency

***** negative ion neutral beam heating *****

einjap	=	4.7588e+02	sloshing ion beam energy from physics (kev)
pnba	=	1.4887e+08	sloshing ion beam power absorbed (mw)
pnbat	=	4.7122e+08	sloshing ion beam power injected (mw)
ftrapbs	=	2.9726e-01	sloshing ion beam power trapping fraction

***** end of heating physics calculations *****

 * preliminary plant power balance calcs.*

This Preliminary Plant Power balance is provided to estimate q, etc.
 when the physics and auxiliary physics modules are run in a stand-
 alone mode. When running the systems code, refer to the actual
 values given in the AC power output data.

***** physics input data *****

qphys	=	3.7625e+01	physics q (pfus/absorbed power)
qfus	=	2.2472e+01	fusion q (pfus/injected power)
qwtran	=	2.2330e+01	fusion q with transition power
pbr	=	2.6612e+00	bremsstrahlung' radiation (mw)
rs	=	6.4605e+00	synchrotron radiation (mw)
pechaa	=	4.0972e-01	ecrh power launched at a (mw)
pechba	=	1.5963e+01	ecrh power launched at b (mw)
panct	=	1.1089e+00	icrh power launched in anchor (mw)
pnbat	=	4.7122e+00	sloshing beam power launched(mw)
ppumpt	=	1.4164e-01	transition power not used in q (mw)
pichcct	=	0.	icrh power launched in central cell (mw)
ccecrh	=	3.5437e-14	icrh power to electrons in central cell (mw)
ccicrh	=	5.6843e-13	icrh power to ions in central cell (mw)

***** system efficiencies *****

elch	=	5.3888e-01	lcrh power generation efficiency
ech	=	3.5888e-01	ecrh power generation efficiency
enb	=	3.9888e-01	nbi power generation efficiency
bfrac	=	9.8888e-01	blanket fraction of heat to liob
amult	=	1.3588e+00	blanket absorber power multiplier
epump	=	9.8888e-01	lipb pump efficiency
cpump	=	1.9188e-02	lipb pump power/lipb power
elinv	=	9.5888e-01	inverter efficiency
egen	=	9.7588e-01	alternator (generator) efficiency

***** system power requirements ext. to plasma *****

pmage	=	2.3888e+01	prime power for magnet power supplies
pcre	=	2.5888e+01	prime power for magnet cryogen system
pauze	=	7.8888e+00	prime power for auxiliary pumps
pplante	=	1.8888e+01	prime power for plant facilities
pfsye	=	5.8888e+00	prime power for fueling system

***** steam cycle input data *****

efft	=	8.6888e-01	steam turbine efficiency
effp	=	7.5888e-01	efficiency of feedwater/condenser cooling pumps
thrp	=	1.8888e+03	steam inlet pressure to turbine (psia)
pcond	=	2.8888e+00	condenser pressure (psia)
exf	=	1.8888e-01	steam extraction fraction

***** base case power balance data *****

pnmw	=	3.8782e+02	neutron power (mw)
palpmw	=	9.9747e+01	alpha particle power (mw)
pfusmw	=	4.9874e+02	fusion power (mw)
pinmw	=	2.2193e+01	injected power (mw)
pinmwp	=	1.3256e+01	absorbed power (mw)
pllmw	=	4.8116e+02	lipb power (mw)
pwatmw	=	1.1793e+02	feedwater power (mw)

pthmw	=	5.9989e+02	thermal power (mw)
ethsc	=	3.6791e-01	steam cycle efficiency
pthemw	=	2.1490e+02	generator ac power (mw)
pdcmw	=	4.8382e+01	direct converter ac power (mw)
ptgemw	=	2.5528e+02	total generated electric power (mw)
precmw	=	1.3548e+02	electric power recycled to plant operating equipment (mw)
pnetmw	=	1.1973e+02	net electric power to utility line (mw)
prejmw	=	5.1447e+02	reject power to cooling tower (mw)
poutmw	=	6.3419e+02	total power output (thermal + electric) (mw)
effpl	=	1.8878e-01	overall plant efficiency
qeng	=	1.8837e+00	electric power multiplication factor

***** steam cycle data *****

scr	=	7.1784e+00	steam consumption rate (lbs/kwh)
shr	=	9.2768e+03	steam heat rate (btu/kwh)
ethsc	=	3.6791e-01	steam cycle efficiency
pcond	=	2.8888e+00	condenser pressure (inches of hg)
tcond	=	1.8122e+02	condensate temperature (*f)
cwr	=	1.1966e+04	condenser cooling water (flow, lbs/sec)
fwr	=	4.3950e+02	feedwater flow rate (lbs/sec)
tfwdc	=	1.8122e+02	feedwater temperature at exit of dc fw heater (*f)
tfwhl	=	2.4298e+02	feedwater temperature at exit of halo fw heater (*f)
tfwrs	=	3.5568e+02	feedwater temperature at exit of ref/shield fw heater (*f)
fpp	=	1.9888e+03	feedwater discharge pressure (psia)
tfw	=	4.9479e+02	feedwater temperature (*f)
tsat	=	6.3421e+02	saturation steam temperature corresponding to fpp (*f)
tmix	=	5.7879e+02	water temperature to steam generator (*f)
rcircr	=	1.1984e+00	steam generator recirculation water/fwr ratio
rcirwr	=	5.8522e+02	steam generator recirculation water flow rate (lbs/sec)
exf	=	1.8888e-01	steam extraction fraction
thrp	=	1.8888e+03	steam inlet pressure to turbine (psia)
efft	=	8.6888e-01	steam turbine efficiency
tsh	=	1.8888e+03	steam inlet temperature to turbine (*f)

***** power balance checks *****

poutmw	=	6.3419e+02	total power output (thermal + electric) (mw)
pgenerate	=	6.3419e+02	fusion pwr + neutron pwr (mw)
diff	=	-3.6388e-12	poutmw - pgenerate (mw)
rdiff	=	-5.7364e-15	diff/poutmw

```

prout   = 5.1622e+02    power out (mw)
prin    = 5.1622e+02    power in (mw)
diffrr  = -3.6380e-12   prout - prin (mw)
rdiffrr = -7.0474e-15   diffrr/prin

```

```

qeng     = 1.8837e+00    electric power multiplication factor

```

***** end of plant power balance; q calc. *****

+++++

54

***** computer time usages *****

```

direct conveter subroutine used:
cpu= 1.4395e-02 s  io= 0.          s  sys= 1.3000e-04 s

```

```

drift pumping subroutine used:
cpu= 1.6239e-02 s  io= 0.          s  sys= 1.0100e-04 s

```

```

neutron source subroutine used:
cpu= 4.9065e+00 s  io= 9.6768e-02 s  sys= 5.2500e-03 s

```

```

heating systems subroutine used:
cpu= 1.6711e-02 s  io= 0.          s  sys= 1.0000e-04 s

```

power balance subroutine used:

cpu= 4.3961e-02 s io= 0. s sys= 1.0100e-04 s

auxiliary physics routines used:

cpu= 6.3360e+00 s io= 1.5383e+00 s sys= 2.0892e-02 s

+++++

macx ECSH 03/14/85 18:32:50 d Time Used/Left: 480.543 1015.000

ECSH: End-Cell Neutron Shielding

Input Parameters for the Shield Calculation:

YO = 1.0000e+00 : years of operation
 AF = 1.0000e+00 : availability fraction
 ECST = 1.0000e+03 : max. allowable shield thickness
 STF = 1.0000e-02 : thermal liner steel fraction
 ZCHOKE = 5.1000e+01 : outer extent of choke coil winding

Geometric Input for the Shield Calculation:

Coil	Point	X	Y	Z	THK1	THK2	THK3	THK4
1	1	0.0000	1.320	52.066	0.0075	0.0001	0.0075	0.0001
1	2	0.0000	1.320	52.339	0.0075	0.0001	0.0075	0.0001
1	3	0.473	0.0000	54.382	0.0075	0.0001	0.0075	0.0001
1	4	0.473	0.0000	55.202	0.0075	0.0001	0.0075	0.0001
2	1	0.473	0.0000	55.347	0.0075	0.0001	0.0075	0.0001
2	2	0.473	0.0000	56.166	0.0075	0.0001	0.0075	0.0001
2	3	0.0000	0.905	57.224	0.0075	0.0001	0.0075	0.0001
2	4	0.0000	0.976	57.488	0.0075	0.0001	0.0075	0.0001
3	1	0.976	0.0000	57.852	0.0075	0.0001	0.0075	0.0001
3	2	0.905	0.0000	58.116	0.0075	0.0001	0.0075	0.0001
3	3	0.0000	0.473	59.174	0.0075	0.0001	0.0075	0.0001
3	4	0.0000	0.473	59.994	0.0075	0.0001	0.0075	0.0001
4	1	0.0000	0.473	60.138	0.0075	0.0001	0.0075	0.0001
4	2	0.0000	0.473	60.958	0.0075	0.0001	0.0075	0.0001
4	3	1.400	0.0000	62.369	0.0075	0.0001	0.0075	0.0001
4	4	1.475	0.0000	62.632	0.0075	0.0001	0.0075	0.0001
5	1	0.0000	1.475	62.943	0.0075	0.0001	0.0075	0.0001
5	2	0.0000	1.400	63.206	0.0075	0.0001	0.0075	0.0001
5	3	0.473	0.0000	64.617	0.0075	0.0001	0.0075	0.0001
5	4	0.473	0.0000	65.437	0.0075	0.0001	0.0075	0.0001

6	1	0.473	0.000	65.581	0.0075	0.0001	0.0075	0.0001
6	2	0.473	0.000	66.401	0.0075	0.0001	0.0075	0.0001
6	3	0.000	0.905	67.459	0.0075	0.0001	0.0075	0.0001
6	4	0.000	0.976	67.723	0.0075	0.0001	0.0075	0.0001

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 end call nucleolncs

results for coil no. 1

shield thickness including coil cases, m	4.001e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	7.240e+00
total nuclear heating in the winding, w	1.790e+03
total nuclear heating in the coil case no.1, w	8.669e+01
total nuclear heating in the coil case no.2, w	9.525e+01
max. nuclear heating in the winding, w/cm**3	1.256e-03
max. nuclear heating in the coil case no.1,w/cm**3	1.327e-03
max. nuclear heating in the coil case no.2,w/cm**3	1.457e-03
max. dose in the electrical insulator, rads	2.933e+09
max. dose in the thermal insulator, rads	6.255e+09
max. fast fluence in the copper material, n/cm**2	2.128e+18
max. dpa in the copper material, dpa	1.283e-03
total heat load in thermal insulator no.1, w	1.199e-02
total heat load in thermal insulator no.2, w	1.317e-02
max. neutron wall loading, MW/m**2	1.524e-02

results for coil no. 2

shield thickness including coil cases, m	3.785e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	4.627e+00
total nuclear heating in the winding, w	5.626e+03
total nuclear heating in the coil case no.1, w	3.245e+02
total nuclear heating in the coil case no.2, w	3.566e+02
max. nuclear heating in the winding, w/cm**3	5.026e-03
max. nuclear heating in the coil case no.1,w/cm**3	5.276e-03
max. nuclear heating in the coil case no.2,w/cm**3	5.795e-03
max. dose in the electrical insulator, rads	1.183e+10
max. dose in the thermal insulator, rads	2.519e+10
max. fast fluence in the copper material, n/cm**2	8.548e+18

max. dpa in the copper material, dpa	5.188e-03
total heat load in thermal insulator no.1, w	4.485e-02
total heat load in thermal insulator no.2, w	4.926e-02
max. neutron wall loading , MW/m**2	4.629e-02

results for coil no. 3

shield thickness including coil cases, m	3.896e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	4.808e+00
total nuclear heating in the winding, w	3.243e+03
total nuclear heating in the coil case no.1, w	1.579e+02
total nuclear heating in the coil case no.2, w	1.735e+02
max. nuclear heating in the winding, w/cm**3	3.919e-03
max. nuclear heating in the coil case no.1,w/cm**3	4.127e-03
max. nuclear heating in the coil case no.2,w/cm**3	4.534e-03
max. dose in the electrical insulator, rads	9.187e+09
max. dose in the thermal insulator, rads	1.958e+10
max. fast fluence in the copper material, n/cm**2	6.653e+18
max. dpa in the copper material, dpa	4.024e-03
total heat load in thermal insulator no.1, w	2.183e-02
total heat load in thermal insulator no.2, w	2.398e-02
max. neutron wall loading , MW/m**2	4.158e-02

results for coil no. 4

shield thickness including coil cases, m	3.976e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	6.055e+00
total nuclear heating in the winding, w	2.033e+03
total nuclear heating in the coil case no.1, w	9.857e+01
total nuclear heating in the coil case no.2, w	1.083e+02
max. nuclear heating in the winding, w/cm**3	2.292e-03
max. nuclear heating in the coil case no.1,w/cm**3	2.420e-03
max. nuclear heating in the coil case no.2,w/cm**3	2.658e-03
max. dose in the electrical insulator, rads	5.359e+09
max. dose in the thermal insulator, rads	1.143e+10
max. fast fluence in the copper material, n/cm**2	3.886e+18
max. dpa in the copper material, dpa	2.345e-03
total heat load in thermal insulator no.1, w	1.363e-02
total heat load in thermal insulator no.2, w	1.497e-02
max. neutron wall loading , MW/m**2	2.696e-02

results for coil no. 5

shield thickness including coil cases, m	3.974e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	6.046e+00
total nuclear heating in the winding, w	6.835e+02
total nuclear heating in the coil case no.1, w	3.314e+01
total nuclear heating in the coil case no.2, w	3.642e+01
max. nuclear heating in the winding, w/cm**3	3.508e-03
max. nuclear heating in the coil case no.1,w/cm**3	3.787e-03
max. nuclear heating in the coil case no.2,w/cm**3	4.160e-03
max. dose in the electrical insulator, rads	8.388e+09
max. dose in the thermal insulator, rads	1.789e+10
max. fast fluence in the copper material, n/cm**2	6.082e+18
max. dpa in the copper material, dpa	3.671e-03
total heat load in thermal insulator no.1, w	4.582e-03
total heat load in thermal insulator no.2, w	5.034e-03
max. neutron wall loading , MW/m**2	4.208e-02

results for coil no. 6

shield thickness including coil cases, m	3.892e-01
case no. 1 thickness, m	7.500e-03
case no. 2 thickness, m	7.500e-03
shield volume, m**3	5.333e+00

(2) Check the Dose to the Elec Insul in Each C-coil:

The allowable dosage is ECDSEMX= 8.

therefore, will not check dosage levels.

* 8 inconsistencies.

mscx INDUCT 83/14/85 18:37:23 d Time Used/Left: 584.293 991.258

INDUCT: Equivalent Self-Inductance and Stored Energy

No.	Name	Inductance	Stored-Energy
2	CC(main)	2.583e-06	1.711e+08
3	CC(trim)	1.169e-05	5.320e+07
4	Insert	1.430e-06	2.333e+07
5	Choke-1	9.528e-06	1.817e+08
6	Choke-2	6.886e-06	7.840e+08
7	Choke-3	5.330e-06	1.411e+09
8	Trans-1	5.703e-06	2.847e+08
9	Anchor-1	3.110e-06	1.559e+08
10	Anchor-2	3.110e-06	1.559e+08
11	Plug-1	4.107e-06	2.051e+08
12	Plug-2	4.107e-06	2.051e+08
13	Trans-2	3.110e-06	1.559e+08
Total:			1.002e+10

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 end cell nucleoncy

summary for both endcells

fusion neutron power, MW	1.985e+06
total nuclear heating in the winding, w	1.754e+04
total nuclear heating in the coil case no.1, w	2.327e+03
total nuclear heating in the coil case no.2, w	2.557e+03
max. nuclear heating in the winding, w/cm**3	5.826e-03
max. nuclear heating in the coil case no.1, w/cm**3	5.276e-03
max. nuclear heating in the coil case no.2, w/cm**3	5.795e-03
max. dose in the electrical insulator, rads	1.183e+10
max. dose in the thermal insulator, rads	2.519e+10
max. fast fluence in the copper material, n/cm**2	8.548e+18
max. dpa in the copper material, dpa	5.188e-03
total heat load in thermal insulator no.1, w	3.216e-01
total heat load in thermal insulator no.2, w	3.533e-01
max. neutron wall loading, MW/m**2	4.629e-02

coils shield

total volume, m**3	3.411e+01
fel422 steel volume, m**3	2.592e+01
b4c volume, m**3	1.389e+00
total cost, \$	5.321e+06
fel422 cost, \$	5.188e+06
b4c cost, \$	1.338e+05

mscx ECCK 83/14/85 18:37:08 d Time Used/Left: 583.986 991.637

ECCK: End-Cell Consistency Check Module

(1) Check the Nuclear Heating Levels in Each C-coil:

The allowable heating level is ECHZATMX= 8.

therefore, will not check heating levels.

***** maintyp *****

MSC - Tandem Mirror Systems Code - VERSION 1.0, 19 Feb 85

This run: 83/14/85 13:57:51 Machine: d
...cpu= 8.8 sec, io= 8.5 sec, sys= 8.8 sec...
Input is coming from file 'mscindt'
Executing subroutine physic
Namelist file 'mscnamls' written
Summary output is collected on file msxsmry
Block data written to file 'mscbk'
Output is collected on file 'mscxout'
...cpu= 45.1 sec, io= 288.8 sec, sys= 8.6 sec...

***** mrtyp *****

***** ccshtyp *****

***** ccmgtyp *****

***** chshtyp *****

***** ccmagtyp *****

***** ecmgtyp *****

***** ecmagtyp *****

***** auxtyp *****

***** ecshtyp *****

***** dctyp *****

Direct converter performance parameters by region

	Inner collector	Outer collector	Halo scraper	Halo dump
Collector voltage (kV)	187.834	8.888		
Electrical power (MW)	42.423	8.888		
Total thermal power (MW)	25.388	8.888	6.729	19.229
Energy flux (MW/m2)	2.485	8.888	4.488	8.478
Collector radius (m)	1.294	8.888	8.493	2.599
Collector area (m2)	5.268	8.888	8.765	28.456
Magnetic flux (Wb)	8.982	8.888	8.228	1.928
Field at collector (T)	8.171	8.888	8.287	8.894

Inner collector is not lowest field element

42.423 Total electrical power (MWe)
51.258 Recovered thermal power (MW)
51.258 Total thermal power (MW)
8.453 Direct converter efficiency
4.763 Direct converter length (m)
3.194 Direct converter radius (m)

Mechanical pump parameters
15.967 AC power consumed (kWe)
1864.458 Pump capacity (l/sec)

63

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*****
*****
*****
*****          PLASMA HEATING SYSTEMS          *****
*****
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*****
*****
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Component Description	Total Cost (\$)	Output Power (W/channel)	Radius (m)	Length (m)
System power supply	2.59e+06	5.95e+05	0.0000	0.0000
1 MW gyrotron source	1.00e+06	2.68e+05	0.0000	0.0000
Arc detector	4.64e+04	2.68e+05	0.0318	0.5000
Mode filter	1.09e+04	2.55e+05	0.0318	0.5000
Directional coupler	2.96e+04	2.54e+05	0.0318	0.5000
Mode converter	9.41e+04	2.42e+05	0.0125	1.0000
Mode converter	9.41e+04	2.30e+05	0.0125	1.0000
Launcher	4.00e+04	2.25e+05	0.0318	20.0000
Corrugated waveguide bend	9.53e+04	2.21e+05	0.0318	2.0000
Launcher	4.00e+04	2.17e+05	0.0318	20.0000
Corrugated waveguide bend	9.53e+04	2.13e+05	0.0318	2.0000
Launcher	4.00e+04	2.09e+05	0.0318	20.0000
Mode transducer-launcher	6.23e+04	2.05e+05	0.0318	0.0000

金

ECRH System # 2:
 24 Transmission Chains (of which 4 are redundant), Frequency = 5.19×10^7
 Total Cost (\$) Delivered Power (W) Prime Power (W) System efficiency
 3.22×10^7 1.60×10^7 4.69×10^7 0.3406

Component Description	Total Cost (\$)	Output Power (W/chain)	Radius (m)	Length (m)
System power supply	2.17×10^7	2.16×10^5	0.0000	0.0000
1 MW gyrotron source	6.00×10^6	9.70×10^5	0.0000	0.0000
Arc detector	2.78×10^5	9.70×10^5	0.0318	0.5000
Mode filter	6.00×10^4	9.22×10^5	0.0318	0.5000
Directional coupler	1.56×10^5	9.21×10^5	0.0318	0.5000
Mode converter	5.64×10^5	8.75×10^5	0.0125	1.0000
Mode converter	5.64×10^5	8.31×10^5	0.0125	1.0000
Mode transducer-launcher	3.48×10^5	8.14×10^5	0.0000	0.0000
Quasi-optical system	2.52×10^6	7.98×10^5	0.0000	0.0000

ICRH System # 1:
 4 Transmission Chains (of which 2 are redundant), Frequency = 6.82×10^7
 Total Cost (\$) Delivered Power (W) Prime Power (W) System efficiency Wall area (m²)
 3.76×10^6 1.11×10^6 2.09×10^6 0.5304 1.1406

Component Description	Total Cost (\$)	Output Power (W/chain)	Radius (m)	Length (m)
waveguide launcher	1.00×10^6	5.54×10^5	0.2234	2.4881
Single window	6.40×10^3	5.59×10^5	0.0780	0.0100
Coaxial elbow	3.58×10^3	5.59×10^5	0.0780	1.0000
Coaxial section, 1 ft. 20 ft	3.71×10^3	5.60×10^5	0.0780	2.0000
Arc detector	4.00×10^4	5.61×10^5	0.1160	0.0000
Directional coupler	1.84×10^3	5.70×10^5	0.1160	0.0000
D.C. break (choke)	1.84×10^3	5.77×10^5	0.1160	0.0000
20 ft coaxial sections	1.80×10^4	5.95×10^5	0.1160	12.2000
Double window	6.40×10^3	5.97×10^5	0.1160	0.0000
20 ft coaxial sections	1.80×10^4	5.99×10^5	0.1160	12.2000
Double window	6.40×10^3	6.02×10^5	0.1160	0.0000
20 ft coaxial sections	1.80×10^4	6.04×10^5	0.1160	12.2000
Coaxial elbow	7.10×10^3	6.07×10^5	0.1160	1.0000
Single window	6.40×10^3	6.07×10^5	0.1160	0.0100
20 ft coaxial sections	1.80×10^4	6.07×10^5	0.1160	12.2000
Coaxial elbow	7.10×10^3	6.10×10^5	0.1160	1.0000
Arc detector	4.00×10^4	6.10×10^5	0.1160	0.0000
Directional coupler	1.84×10^3	6.20×10^5	0.1160	0.0000
Single window	6.40×10^3	6.27×10^5	0.1160	0.0100
Single fpa + power supply	2.43×10^6	6.27×10^5	0.0000	0.0000

Additional Single-Ridged Waveguide Data
 Width (m) = 8.993 Height (m) = 8.223
 Ridge Width (m) = 8.745 Ridge Thickness (m) = 8.8168
 Impedance (Ohm) = 15.36

WARNING Port size too small in z direction

There are no DPC systems

NINB System # 1:
 8 Sources (of which 2 are redundant), 2 Beamlines, Energy = 475.88 keV
 Total Cost Delivered Power Prime Power System efficiency Wall area
 (\$) (V) (V) (m2)
 4.86e+87 4.71e+86 1.87e+87 8.4886 8.4088
 Cryopanel area Energy recovered
 (m2) (W)
 1.95e+81 8.

Component Description	Length (m)	Pressure (torr)
Source	8.188	1.88e-83
Accelerator	3.888	3.88e-85
Neutralizer	1.988	1.88e-83
Energy recovery/dumps	2.888	1.88e-85
Final duct	4.888	1.88e-85

There are no PINB systems

Heating Systems Summary
 (DP system not included in efficiency or delivered power)
 For 2 ECRH systems, 1 ICRH systems, 8 DPC systems, 1 NINB systems,
 and 8 PINB systems

Total Cost (\$)	Delivered Power (W)	Prime Power (W)	System efficiency
8.88e+87	2.22e+87	6.18e+87	8.3641

***** vacvtyp *****

Vacuum vessel weight (kg)	2298487.44
Vacuum vessel cost (\$M)	40.45
Total pressure (pa)	295240.78
Equivalent head pressure of water, (pa)	122871.78

***** fueltyp *****

fuel system design and cost data:

{#inputs from other modules/dfile}
(*outputs to other modules)

#pfus, center cell fusion power, mw	498.7
#rp1ccm, center cell plasma radius, m	0.4577
#lp1ccm, center cell plasma length, m	94.11
#pctsec, particle confinement time, sec	0.0000
#bvac0c, cc magnetic field on axis, t	2.5000
#bbar, ch magnetic field on axis, t	24.000
#neccm3, cc plasma elec density, no./m3	1.6431e+20
nechm3, ch plasma elec density, no./m3	5.5682e+19
#tec, plasma elec temperature, kev	27.69
#npinj, number of pellet injectors	2.0000
#ngnoz, number of gas nozzles	6.0000
tbmdot, tritium consumption rate, g/hr	3.173
tdmgph, fuel injection rate, g/hr	48.38
*tmfgph, tritium supply rate, g/hr	58.64
*dmfgph, deuterium supply rate, g/hr	39.09
*hmfgph, hydrogen injection rate, g/hr	0.2015
dpmm, td pellet diameter, mm	2.782
tdpm, td pellet weight, grams	4.2263e-03
perate, pellet rate, no. per sec	3.180
velop, pellet velocity, meters per sec.	0.1200e+05
rp1chm, plasma inject point radius, m	0.1551
#fpfen, pellet penetration, (ppenm/rp1chm)	0.5392

***INJECTOR VELOCITY LIMITED PENETRATION,
MAXIMUM INJECTION VELOCITY=12000. M/S***

ppenm, pellet penetration, meters	8.3654e-02
pinjkw, electric power for injectors, kw	117.5
vacipm, vacuum pumping requirement, lpm	2835.
pvackw, electric power for vacuum, kw	4.253
vlpni, pellet pni velocity, m/s	500.0
pgpsi, pneumatic gun supply pressure,psi	125.0
blpni, pneumatic gun barrel length, m	0.8735
vlcfi, pellet cfi velocity, m/s	0.0000
cisrps, centrifugal injector speed, rps	0.0000
diartr,centrifugal injector rotor dia,m	0.0000
maxika,maximum rail gun current, ka	10.58
blrglm, em rail gun barrel length, m	16.72
rgeskj,rail gun energy storage supply,kj	15.21
lpinjm,overall injector length, meters	19.36
*pn2inj, liquid nitrogen refrig. ,watts	40.85
ln2gph, liquid nitrogen required,g/hr	339.1
pln2kw,electric power for ln2 refrig,kw	0.2859
*phelinj, liquid helium refrig. , watts	16.45
lhegph, liquid helium required g/hr	190.8
plhekw,electric power for lhe refrig,kw	13.16
*fismw,total electrical power, megawatts	0.1352
cgpuf, cost of gas injection system, \$m	0.1900
cvacs, cost of vacuum sys. & valves, \$m	0.1567
cpinj, cost of pneumatic injectors, \$m	0.0000
ccinj, cost of centrifugal injectors, \$m	0.0000
crinj, cost of rail gun injectors, \$m	5.353
*cfuels, total fuel system cost, \$m	6.500

***** mageltyp *****

magnet bussing data

magid#	busamps	buslm	bapcm2	busmohm	busv	buskw	buscmd	
ccm	11	5000.	167.	160.	1.069	5.34	26.72	0.104
cct	22	4000.	167.	160.	1.336	5.34	21.38	0.083
chl	2	50000.	167.	160.	0.107	5.34	267.20	1.044
cb1	2	8000.	167.	160.	0.668	5.34	42.75	0.167
cb2	2	7500.	167.	160.	0.713	5.34	40.08	0.157
cb3	2	7500.	167.	160.	0.713	5.34	40.08	0.157
tl	2	6000.	86.	160.	0.459	2.75	16.51	0.064
al	2	6500.	86.	160.	0.423	2.75	17.09	0.070
a2	2	6500.	86.	160.	0.423	2.75	17.89	0.070
pl	2	7000.	86.	160.	0.393	2.75	19.26	0.075
p2	2	7000.	86.	160.	0.393	2.75	19.26	0.075
t2	2	6000.	86.	160.	0.459	2.75	16.51	0.064
rs	2	5000.	86.	160.	0.550	2.75	13.76	0.054
nd	0	0.	0.	160.	0.000	0.00	0.00	0.000
55	126000.	1604.	na	7.706	51.33	559.30	2.185	

magnet power supply data

magid#	epcgmj	ppcgmw	psamp	psvolt	pskw	psacmw	pscmd	
ccm	11	1882.	0.0	5250.	54.9	288.2	0.317	0.057
cct	22	1170.	0.0	4200.	42.7	179.2	0.197	0.039
chl	2	47.	17.3	52500.	362.9	19453.2	20.959	1.627
cb1	2	363.	0.0	8400.	6.6	35.6	0.061	0.015
cb2	2	1408.	0.0	7875.	27.4	215.6	0.237	0.045
cb3	2	2822.	0.0	7875.	54.9	432.1	0.475	0.079
tl	2	569.	0.0	6300.	13.8	87.7	0.096	0.022
al	2	312.	0.0	6825.	7.0	47.0	0.053	0.014
a2	2	312.	0.0	6825.	7.0	47.8	0.053	0.014
pl	2	410.	0.0	7350.	8.5	62.8	0.069	0.017
p2	2	410.	0.0	7350.	8.5	62.8	0.069	0.017
t2	2	312.	0.0	6300.	7.6	47.8	0.053	0.014
rs	2	0.	0.0	5250.	0.0	0.0	0.000	0.000
nd	0	0.	0.0	0.	0.0	0.0	0.000	0.000
55	10017.	17.3	132300.	601.9	20580.0	22.638	1.958	

magnet protection data

	magid#	ndcbkrs	ndump	rdrohm	tcsec	pdrmw	edrmj	cprotmd
ccm	11	7	22	0.400	68.	2.50	85.5	1.241
cct	22	13	44	0.500	27.	2.00	26.6	2.017
chf	2	0	0	0.000	5.	0.00	26.6	0.442
cb1	2	3	4	0.250	45.	4.00	90.8	0.369
cb2	2	3	4	0.267	188.	3.75	352.0	0.447
cb3	2	3	4	0.267	376.	3.75	705.4	0.560
t1	2	3	4	0.333	95.	3.00	142.4	0.337
a1	2	3	4	0.308	48.	3.25	70.0	0.325
a2	2	3	4	0.308	48.	3.25	70.0	0.325
p1	2	3	4	0.286	59.	3.50	102.5	0.348
p2	2	3	4	0.286	59.	3.50	102.5	0.340
t2	2	3	4	0.333	52.	3.00	70.0	0.313
rs	2	0	0	0.000	0.	0.00	0.0	0.100
nd	0	0	0	0.000	0.	0.00	0.0	0.000
	55	47	102	3.537	na	35.50	1841.8	7.172

magnet power conversion summary table
(*outputs to other modules

*magmw, magnet system prime ac power, mw	22.64
dram2, dump resistor field area, m2	1020.
bkam2, sc magnet dc breaker floor area, m2	237.5
slcam2, sc magnet load center floor area, m2	0.5652
spsam2, sc magnet power supply floor area, m2	109.7
rlctam2, rc magnet lc&t field area, m2	3.044
rpsam2, rc magnet power supply floor area, m2	143.1
*mpcam2, magnet power conv. floor area, m2	490.9
*mpcvm3, magnet power conv. bldg volume, m3	2946.
tcbusm, magnet power conv. bus cost, \$m	2.185
tcpsm, total cost of power supplies, \$m	1.958
tcprotm, total cost of magnet protection, \$m	7.172
*cmgpcm, total magnet power conv. system, \$m	11.31

***** crytyp *****

CRYOPLANT SUMMARY				
	LN2 (77 K)	LHeI (4.5 K)	LHeI (3.0 K)	LHeII (1.8 K)
System loads (Wt)				
Fuel injectors	4.09e+01	1.64e+01		0.
DC cryopanel	0.	0.		0.
Neutral beams	6.04e+03	5.37e+02		4.50e+01
Tritium plant	0.	0.		0.
Magnets (non-nuclear)	2.88e+05	9.78e+03	0.	3.15e+02
C-Cell Magnets (nuclear)	2.62e+02	4.99e+03	0.	0.
E-Cell Magnets (nuclear)	1.12e+03	1.73e+04	0.	4.04e+03
Choke coils (nuclear)	1.04e-01	1.04e-01	0.	1.88e+00

Total load + 20% (Wt)	3.55e+05	3.91e+04	0.	5.20e+03
Cost scaling exponent	1.00	1.00	1.00	1.00
Capital cost (\$)	5.32e+06	4.33e+07	0.	1.85e+07
AC power load (We)	4.26e+06	1.68e+07	0.	9.00e+06
Total electric load (We)	3.02e+07			
Total rejected heat (Wt)	3.05e+07			
Total system cost (\$)	6.71e+07			

***** thtyp *****

1 OUTPUT FOR BLANKET THERMAL HYDRAULICS

parameter input echo

```

first tube diameter      = 1.000e+01 cm
first tube structural thickness = 2.000e-01 cm
  (note: the 1cm first wall & blanket power are modified)
first wall conductivity = 4.000e-01 W/cm/K
coolant param eval temp  = 4.250e+02 C
coolant electrical conductivity = 2.098e+06 (ohm*m)**-1
coolant conductivity     = 1.955e-01 W/cm/K
coolant density          = 8.765e+00 gm/cm**3
coolant rhocp            = 1.743e+00 J/K/cm**3
energy exp in coolant (beng) = -6.740e-01
  (exp[beng*depth/tube diameter])
liquid metal pump efficiency = 5.000e-01
first wall radiated heat flux = 2.290e+00 W/cm**2

```

blanket temperature summary

coolant inlet temperature	=	3.588e+02 C
maximum exit temperature	=	5.451e+02 C
coolant bulk delta temp	=	1.282e+02 C
bulk exit temperature	=	4.782e+02 C
maximum first wall temperature	=	5.466e+02 C

blanket coolant flow data

breeding region 1

average power density br-1	=	2.367e+00 MW/m**3
peak/average power density br-1	=	2.573e+00
mass flow rate br-1	=	1.362e+04 kgm/s
volume flow rate br-1	=	1.554e+00 m**3/s
average coolant velocity br-1	=	2.882e+00 cm/s

breeding region 2

average power density br-2	=	6.389e-01 MW/m**3
mass flow rate br-2	=	7.882e+03 kgm/s
volume flow rate br-2	=	8.879e-01 m**3/s
average coolant velocity br-2	=	1.841e+01 cm/s

blanket summary data

equiv surface heat on coolant	=	3.779e+00 w/cm**2
minimum coolant transit time	=	4.648e+01 s
first tube coolant velocity	=	4.892e+00 cm/s
total breeder coolant flow	=	2.361e+00 m**3/s
coolant pressure drop	=	3.898e-01 MPa
pumping power	=	1.841e+00 MW
pump power/useful thermal power	=	3.448e-03
max first wall corrosion rate	=	1.629e+02 microns/fpy

***** htpctyp *****

***** htstyp *****

main heat transport system parameters

total recoverable thermal energy = 585.3 mw

blanket + reflector cycle heat trnspt parameters

recoverable thermal energy = 534.8 mw
 coolant type is lead-lithium
 coolant outlet temperature = 478.2 deg c
 coolant inlet temperature = 358.8 deg c
 coolant flow rate = 28698.7 kg/s
 number of steam generators = 2
 capacity of each steam generator = 267.8 mwt
 steam pressure = 17.888 mpa
 steam temperature = 458.2 deg c
 feedwater temperature = 275.8 deg c

end cell heat transport parameters

recoverable thermal energy = 51.3 mw
 coolant type is water
 coolant outlet temperature = 328.8 deg c
 coolant inlet temperature = 288.8 deg c
 coolant flow rate = 226.6 kg/s
 steam pressure = 6.422 mpa
 steam temperature = 382.8 deg c
 feedwater temperature = 225.8 deg c

cost of main heat transport system

account name	cost, \$millions
main heat transport system	54.267
blanket main htsp	46.555
pumps and drives	2.428

pipng, supports, etc.	25.753	
steam generators/hx	16.238	
tanks, vessels, etc.	0.731	
insulation, valves, etc.	1.404	
end cell main htsp		7.712
pumps and drives	0.706	
pipng, supports, etc.	2.444	
steam generators/hx	3.892	
tanks, vessels, etc.	0.264	
insulation, valves, etc.	0.407	

auxiliary heat transport system parameters

auxiliary heat transport subsystem	waste heat removed mwt	subsystem cost m\$
***** primary loop *****		
shield heat transport	27.1	0.560
positive nbi heat transport	0.0	0.000
negative nbi heat transport	6.0	0.167
ecrh heat transport	31.8	0.637
dump heat transport	0.0	0.000
resistive coil heat transport	17.3	0.391
misc. reactor comp. heat xport	3.0	0.096
tritium process heat transport	0.0	0.000
primary heat exchanger	85.1	1.467
primary coolant loop total	85.1	3.318
***** secondary loop *****		
cryogenics heat transport	30.5	0.617
miscellaneous heat transport	14.0	0.331
secondary heat exchanger	129.7	1.647
secondary coolant loop total	129.7	2.594
cooling tower loop	129.7	3.662
bulk materials		3.830
total auxiliary heat transport	129.7	13.404

power conversion system parameters

total recoverable thermal power	= 585.3 mwt
overall efficiency of thermal conversion	= 0.40
overall gross electric power	= 235.3 mwe

blanket power conversion parameters:
 efficiency of blanket thermal conversion = 0.41
 gross electric power from blanket = 217.4 mwe

other power conversion parameters:
 (combined dir. conv., halo scraper, reflector)
 efficiency of other thermal conversion = 0.55
 gross electric power from other cycle = 17.9 mwe

turbine-generator information:

no. and type of turbine-generator units = one tandem-compound unit
 gross power of the t-g unit = 235.3 mwe

cost of turbine plant equipment:
 total cost of turbine plant equipment = 59.831 m\$
 cost of turbine-generator system = 26.200 m\$
 cost of main steam system = 2.259 m\$
 cost of heat rejection system = 7.678 m\$
 cost of condensing system = 2.591 m\$
 cost of feed heating system = 3.816 m\$
 cost of instrumentation and controls = 3.787 m\$
 cost of other turbine plant equipment = 13.499 m\$
 including bulk materials

***** factyp *****

facility buildings and structures

building	length	width	height	floor area	volume
-----	m	m	m	m2	m3
-----	-----	-----	-----	-----	-----
reactor building	144.0	14.1	21.1	2826.	42677.
hot cell building	63.0	14.1	18.0	886.	15954.
tritium building (incl. radwaste)	51.4	16.0	16.0	1646.	13168.
power supply bldg	94.0	16.0	17.0	4512.	25568.
cryogenics bldg	30.0	16.0	17.0	480.	8160.
heat exch. bldg	94.0	20.0	31.3	1880.	58770.
control building			12.0	3480.	28877.

turbine building	48.8	8491.	113218.
plant maint. bldg	15.8	2288.	16588.
misc. structures	8.8	4768.	35288.
total area of all buildings floors		38361.	

estimated cost of plant facilities

account name	estimated cost, \$million
--------------	---------------------------

land and land rights		5.888
structures and site facilities		143.836
site improvements & facilities	18.888	
reactor building	19.481	
hot cell building	17.818	
tritium & radwaste bldg.	9.797	
heat exchanger building	32.428	
power supply building	6.416	
cryogenics building	2.438	
control building	8.547	
turbine building	18.223	
plant maintenance building	1.613	
cooling system structure	4.525	
miscellaneous structures	12.575	
--mockup, health physics, water treatment, admin., diesel gen., stack		
radwaste system		7.383
liquid radwaste process eqpt.	3.868	
gaseous radwaste process eqpt.	2.843	
solid radwaste process eqpt.	1.488	
other reactor plant equipment		6.551
special heating system eqpt.	1.687	
coolant receiving, storage, & makeup equipment	8.937	
gas supply system eqpt.	8.937	
leak detection system eqpt.	2.474	
standby cooling system eqpt.	8.517	
miscellaneous bop equipment		22.478
transportation & lifting eqpt.	5.153	
air & water services syst eqpt	3.559	
communications system eqpt.	2.172	
misc. facilities & furnishings	1.198	
bulk materials	18.483	

special materials

49.683

***** trittyp *****

1

tritium facility and vacuum system
parameters for the fpd-11 07/10/84

burn cycle	
*burn time (hr)	= 100.0
*plant availability factor	= 1.000
*power per burn pulse(mw)	= 498.7
*ion density (ions/m**3)	= 1.64e+20
*plasma volume(m**3)	= 62.
*surface area (m**2)	= 398.
*current to cen cell (kamp)	= 0.259
*current to end cell (kamp)	= 0.010
*cycles/yr	= 87.600
fractional burnup	= 0.219

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tritium and fuel processing parameters

tritium initial load/burn (g)	= 0.0255
tritium burnup per hour(g)	= 3.178
tritium burnup per day (g)	= 76.25
tritium burnup per cycle (g)	= 317.762
tritium exhaust per hour(g)	= 4.55e+01
tritium exhaust per day (g)	= 1.09e+03
tritium exhaust per cycle(g)	= 4.55e+03
tritium to plasma/day (g)	= 3.50e+02
tritium to beams/day (g)	= 8.17e+02
trit. fueler waste/d (g)	= 0.
tritium total input/day (g)	= 1.17e+03
tritium input/cycle (g)	= 4.86e+03
tritium total input/yr (g)	= 4.26e+05

1

helium exhaust per day (g)	= 101.430
protium exhaust per day (g)	= 3.144
carbon exhaust per day (g)	= 18.866
oxygen exhaust per day (g)	= 1.521
nitrogen exhaust per day (g)	= 0.000
argon exhaust per day(g)	= 12.577

breeding ratio = 1.118
 tritium bred per day (g) = 84.65
 tritium bred/yr (g) = 30897.87
 tritium burned/yr (g) = 27835.92
 tritium decay per year (g) = 14.41
 doubling inventory(g) = 5.15e+02
 doubling time(yr) = 0.17
 *cost of t (\$/curie) = 1.000
 annual tritium consumption (g) = -2.62e+03
 annual cost of tritium (\$) = -2.52e+07

1

*tritium inventories (g)*****
 halo cryo pumps = 0.0
 structure = 30.0
 beam pumps = 5.4
 storage = 97.3
 surge tank = 5.4
 fuel cleanup unit = 51.7
 cryogenic distillation = 61.7
 pellet fueler = 0.0
 breeder blanket = 1.6
 blanket recovery system = 4.2
 deuterium beams can cell = 2.04e-07
 total tritium inventory = 257.3

1

d burned per day(g) = 51.10
 d burned/cycle (g) = 212.90
 d burned/yr (g) = 18650.07
 d pumped/d center cell (g) = 547.48
 deut. fueler waste/d (g) = 0.
 t pumped/d center cell(g) = 0.0000
 d to center cell/d (g) = 234.63
 d total to center cell/day (g) = 782.11
 d fueling to end cell/d (g) = 178.65
 d total fueling/d (g) = 960.76
 d total fueling/cycle (g) = 4.00e+03
 d total fueling/yr (g) = 3.51e+05

1

atmospheric tritium recovery-test cell

maximum conceivable release (g) = 10.00
 initial t conc. (uci/m**3) = 2.25e+06
 *cleanup time (hours) = 120.00

*volume of test cell (m**3) = 4.27e+04
 *decontamination factor = 1.00e-04
 *cleanup efficiency = 0.9000
 *t level stacked (uci/m**3) = 50.0000
 atr flow rate (Xvbldg/min) = 0.501
 atr flow rate (m**3/s) = 3.564
 vent rate(m**3/s) = 9.88e-02
 tritium release (ci) = 2.134
 tritium vented to env.(ci) = 2.66e-01

atmospheric tritium recovery- hot cell

maximum conceivable release (g)= 10.00
 initial t conc. (uci/m**3) = 6.02e+06
 *cleanup time (hours) = 120.00
 *volume of hot cell (m**3) = 1.60e+04
 *decontamination factor = 1.00e-04
 *cleanup efficiency = 0.9000
 *t level stacked (uci/m**3) = 50.0000
 atr flow rate (Xvbldg/min) = 0.547
 atr flow rate (m**3/s) = 1.455
 vent rate(m**3/s) = 3.69e-02
 tritium release (ci) = 0.798
 tritium vented to env.(ci) = 2.44e-01

atmospheric tritium recovery-trit bldg

maximum conceivable release (g)= 10.00
 initial t conc. (uci/m**3) = 7.29e+06
 *cleanup time (hours) = 120.00
 *volume of trit bldg (m**3) = 1.32e+04
 *decontamination factor = 1.00e-04
 *cleanup efficiency = 0.9000
 *t level stacked (uci/m**3) = 50.0000
 atr flow rate (Xvbldg/min) = 0.556
 atr flow rate (m**3/s) = 1.220
 vent rate(m**3/s) = 3.05e-02
 tritium release (ci) = 0.658
 tritium vented to env.(ci) = 2.40e-01

atmospheric tritium recovery-waste area

maximum conceivable release (g)= 10.00
 initial t conc. (uci/m**3) = 1.63e+06
 *cleanup time (hours) = 120.00
 *volume of waste area (m**3) = 5.88e+04

*decontamination factor = 1.88e-04
 *cleanup efficiency = 8.988
 *t level stacked (uci/m**3) = 58.888
 atr flow rate (%vldg/min) = 8.486
 atr flow rate (m**3/s) = 4.761
 vent rate(m**3/s) = 1.36e-01
 tritium release (ci) = 2.939
 tritium vented to env.(ci) = 2.74e-01

1

*tritium system costs (\$)*****
 receiving (\$) = 2.88e+05
 shipping (\$) = 1.28e+05
 tritium storage (\$) = 6.43e+05
 deuterium storage (\$) = 4.31e+05
 fuel cleanup (\$) = 2.89e+06
 isotopic separation unit (\$) = 6.17e+06
 misc. t facility costs (\$) = 1.18e+06
 gas waste processing (\$) = 1.28e+06
 blanket proc. (\$) = 8.32e+07
 analytical systems (\$) = 1.68e+06
 tritium monitors (\$) = 2.88e+06
 control systems (\$) = 5.82e+06
 gloveboxes and purifiers(\$) = 1.68e+06
 water recovery system (\$) = 6.15e+06
 solid waste (\$) = 1.38e+06

1

total fuel proc. costs (\$) = 1.137e+08
 cost -atr-test cell (\$) = 9.45e+06
 cost -atr- hot cell (\$) = 5.85e+06
 cost -atr-trit bldg (\$) = 4.46e+06
 cost -atr-waste area (\$) = 1.16e+07
 total- atr systems (\$) = 3.85e+07
 total-tritium systems (\$) = 1.442e+08

***** meqtyp *****

Maintenance equipment costs

item description	unit cost MS	number for reactor bldg.	number for hot cell facility	number for mock-up	total cost MS
closed circuit tv	0.20	10	4	0	2.80
transfer lock	1.60	1	0	0	1.60
decontamination and waste handling	4.00	0	1	0	4.00
welder-cutter; pipes < 5 cm	0.07	2	2	1	0.35
welder-cutter; pipes 5 - 10 cm	0.10	2	2	1	0.50
welder-cutter; pipes > 15 cm	0.17	2	2	1	0.85
welder-cutter; structures and vacuum joints	0.66	2	0	1	1.90
end effectors	0.20	1	1	0	0.40
lifting equipment	0.10	1	1	0	0.20
main crane 100 - 500 tonnes	1.21	1*	1*	0	7.26
secondary crane 50 tonnes	0.50	1	1	0	1.00
transport cart < 50 tonnes	0.50	1	2	0	1.50
transporter test modules	0.20	1	0	0	0.20
transporter of beamline sources	0.30	2	0	0	0.60
transporter of beamline assembly	2.67	1	0	0	2.67
transporter of direct convertor/halo	0.50	1	0	0	0.50
shielded window	0.33	14*	14*	0	9.24
handling fixtures	0.47	1	1	0	0.94
mechanical msm - thru wall	0.13	0	20*	0	2.60
mechanical msm - bridge mounted	1.03	2	1	0	3.09
floor mounted msm	1.30	2	2	0	5.52
power arm msm - teleoperated	0.56	1	1	0	1.12
in-vessel inspection system	0.20	9*	0	0	1.80
inspection and test systems	0.50	1	1	0	1.00
partial device mockup, hot cell	7.00	0	0	1	7.00
manipulators for each system	3.10	0	0	1	3.10
transporters sized to mock-up	2.50	0	0	1	2.50
cranes 50/10 tonnes	0.20	0	0	1	0.20
machine tools for hot cell	2.00	0	1	0	2.00
shield plugs	0.20	1	0	0	0.20
hand tools	0.20	1	0	0	0.20

reactor building maintenance equip. costs	27.67
hot cell facility maintenance equip. costs	25.45
mockup facility equip. costs	13.88

TOTAL MAINTENANCE EQUIP. COSTS

67.00

* - indicates that these items depend on device and plant parameters calculated by the program.
All other items are taken directly from input.

***** acptyp *****

tmr ac power system output data
inputs from other system code modules/dfile
* outputs to other system code modules

#basemw, facility base power load, mw	2.00
#afloor, effective total floor space, sq.m	30361.00
#pkwpm2, power needed per floor area, kw/sq.m	0.15
cpmmw2, lv power distribution cost coeff.	1.50
clthm, characteristic cable length, m	600.00
ptgmw, total generator output power, mw	235.31
pdcacmw, total direct converter ac power, mw	40.30
tgacmw, total generated ac power, mw	275.62
#fismw, power to fuel injection system, mw	0.14
#magmw, power to magnet power supplies, mw	22.64
#pecmw, end cell injection prime ac power, mw	60.95
#crymw, power to cryogen system motors, mw	30.15
#vacmw, power to vacuum pump motors, mw	2.00
#htsmw, power to hts pump motors, mw	10.00
#fpsmw, power to tritium processing, mw	8.00
facbmw, backup power to facility loads, mw	6.55
*tracmw, total recycle ac power load, mw	140.43
#hvlkv, main ac power utility line voltage	230.00
n3pht, number of 3 phase transformers	2.00
tmva, max. mva of each transformer	75.00
pnbkrs, number of 13.8kv circuit breakers	12.00

bkrmva, short circuit mva of circuit breakers	750.00
cphvsm, cost of equipment on hv side, \$m	1.27
ctranm, cost of xformers & lightning protect.	2.46
cpmvsm, cost of equipment on 13.8kv side, \$m	1.52
cpacpm, cost of main ac power system, \$m	5.25
#fv1kv, facility power line voltage	115.00
facpmw, maximum facility power, mw	13.58
ftmva, max. mva of the facility transformer	20.00
fnbkrs, number of 13.8kv circuit breakers	4.00
fbkmva, short circuit mva of circuit breakers	250.00
cfhvsm, cost of equipment on hv side, \$m	0.22
cxfrm, cost of xformer & lightning prot. \$m	0.36
cfmvsm, cost of equipment on 13.8kv side, \$m	0.37
cfacpm, cost of facility ac power system, \$m	0.95
ndg, number of diesel generators	2
dgkw, rated output power per dg, kw	2500.00
cdgsm, total cost of the dg system, \$m	1.57
nnips, number of non-interruptible p.s.	3
nipskw, rated output power per p.s., kw	10.00
cnipsm, cost of non-interruptible system, \$m	0.28
tlvpmw, approximate low voltage power, mw	30.80
clvdsm, cost of lv power distribution, \$m	3.71

dc inverter system data:

dcno	pdcmw	vdckv	ldca	p3phmw	v3phkv	i3pha	cinvm
1	42.4	187.0	226.8	40.3	13.8	1686.	4.52
sum	42.4		226.8	40.3		1686.	4.52

ndc, number of direct converter systems	1
tcinvm, total cost of dc/ac inverters, \$m	4.35
tcdbkr, total cost of 13.8kv breakers, \$m	0.05
tcddcam, total cost of cable & bussing, \$m	0.12
cdcifm, total cost of the dc interface, \$m	4.52

turbine generator-substation interface data:

#ntg, number of turbine generators	1
#ptg, rated output power/generator, mw	235.31
vtgkv, rated full load tg voltage, kv	13.80
ltgka, rated current per tg, ka	9.84
ctgcbm, cost of tg switch gear, \$m	0.27
ctgcsm, cost of tg bussing & cables, \$m	0.71
ctgxfm, cost of tg auto transformers, \$m	0.00
ctgifm, total cost of the tg interface, \$m	0.98

electrical power summary

#pfusmw, central cell fusion power, mw	498.74
#preimw, reject power to cooling towers, mw	479.64
#ptgmw, turbine generator ac power, mw	235.31
pdcacmw, direct converter ac power, mw	40.30
tgacmw, total generated ac power, mw	275.62
*tracmw, total recycle ac power load, mw	140.43
pnetmw, net power to the utility line, mw	133.83
qe, electrical q=tgacmw/tracmw	1.96
effplt, plant efficiency, percent	21.82
#hvlkv, main utility power line voltage, kv	230.00
fapmw, total facility power load, mw	13.58
#fvkv, facility power line voltage, kv	115.00
cpacpm, cost of the main ac power system, \$m	5.25
cfacpm, cost of facility ac power system, \$m	0.95
cdgsm, cost of dg units(480v,2500kw ea.)\$m	1.57
cnipsm, cost of no break power supplies, \$m	0.28
cdcifm, cost of direct converter interface,\$m	4.52
ctgifm, cost of turbine gen. interface, \$m	0.98
clvdr, cost of lv power distribution, \$m	3.71
*ctapcm, total cost of the ac power system, \$m	17.27

***** factyp *****

cost of the control building i&c hardware and software,
and the cost of the plasma diagnostics.

(scds--supervisory control and data system.)

process scds cost estimate

tcofph-plasma heating & cond. scds cost, \$m	3.43
tcofmc-magnet systems scds cost, \$m	1.27
tcofac-ac power systems scds cost, \$m	0.69
tcpgen-electrical power generation scds cost,\$m	1.54
tcofrc-reactor comp. & structures i&c cost,\$m	1.60
tcofcv-cryogenic & vacuum systems scds cost, \$m	3.13
tcoffs-fueling & processing scds cost, \$m	2.78
tcofht-heat transport systems scds cost, \$m	3.03
tcofmn-facility & site mon. scds cost, \$m	0.77
tcofbf-building facilities i&c cost, \$m	0.82
tcofrh-remote handling sys. scds cost, \$m	5.43
tcopsc-total cost of process scds, \$m	24.50

plasma diagnostics cost estimate table

nohp-no. of diagnostic types in group k for the h2 phase
 nodp-no. of diagnostic types in grp k added for the d2 phase
 notp-no. of diagnostic types in grp k added for the td phase
 tmcpdm-average cost of a diagnostic type in group k, \$m
 hpdgcm-cost of diagnostics in group k for the h2 phase
 dpdgcm-cost of diagnostics in grp k added for the d2 phase
 tpdgcm-cost of diagnostics in grp k added for the td phase
 fprodpar-fusion product particle diagnostics group
 ecellpar-end cell particle diagnostics group

k	diag.grp	nohp	nodp	notp	tmcpdm	hpdgcm	dpdgcm	tpdgcm	total
1	edensity	0	5	0	1.30	0.00	6.50	0.00	6.50
2	e.temp	0	3	0	1.20	0.00	3.60	0.00	3.60
3	ion temp	0	3	0	0.70	0.00	2.10	0.00	2.10
4	impurity	0	4	0	0.70	0.00	2.80	0.00	2.80
5	pwr loss	0	3	0	0.40	0.00	1.20	0.00	1.20
6	magnetic	0	5	0	0.30	0.00	1.50	0.00	1.50
7	p.instab	0	3	0	0.70	0.00	2.10	0.00	2.10
8	fprodpar	0	3	6	0.60	0.00	1.80	5.40	7.20
9	environ	0	2	4	0.50	0.00	1.00	2.40	3.40
10	ecellpar	0	12	6	0.40	0.00	4.80	3.00	7.80
total cost of diagnostics for each phase using the default input table.						0.00	27.40	10.80	38.20

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archiving computer hardware and software

hydrogen phase archiving,	\$m	1.30
deuterium phase archiving,	\$m	1.50
tritium phase archiving,	\$m	1.80

total scds & plasma diagnostics cost summary
 (through the tritium phase)

tcopsc-total cost of process scds cost,	\$m	24.50
tcopdg-total cost of plasma diagnostics,	\$m	38.20
tcarch-total cost of archiving & processing,	\$m	4.60
tcscdg-total cost of diagnostics & scds,	\$m	67.30

***** costtyp *****

cost account output file

capital cost accounts

#3/14/85

[19:06:35]

account #	title	cost (million dollars)
20000000	Land and Land Rights	5.00

capital cost accounts

#3/14/85

[19:06:35]

85

account #	title	cost (million dollars)
21000000	Structures and Site Facilities	143.04
21010000	Site Improvements and Facilities	10.00
21020000	Reactor Building	19.48
21030000	Turbine Building	18.22
21040000	Reactor Maintenance Buildings	17.01
21040100	Hot Cell	17.01
21040200	Mockup/Fabrication Facility	0.00
21050000	Tritium Building	9.80
21060000	Electrical Equipment Buildings	6.42
21060100	Field Power Supply Building -z-	6.42
21060200	PF Power Supply Building -z-	0.00
21060300	Motor-Generator Building -z-	0.00
21070000	Other Buildings and Structures	62.11
21070100	Administration Building -z-	0.00
21070200	Control Room Building -z-	0.00
21070300	RAD-Waste Processing Building -z-	0.00
21070400	Shop/Fab/Assy/Maint Buildings -z-	1.61
21070500	Heat Exchanger Building -z-	32.42
21070600	Cryogenics Building -z-	2.43
21070700	Switchyard -z-	0.00

21070800	Ventilation Building -z-	0.00
21070900	Sewage Treatment Building -z-	0.00
21071000	Security Building -z-	0.00
21071100	Warehouse -z-	0.00
21071200	Health Physics/Change Building -z-	0.00
21071300	Water Treatment and Storage Buildings -z-	0.00
21071400	Miscellaneous Structures -z-	12.57
21071500	Cooling System Structure -z-	4.53

capital cost accounts

03/14/85

[19:06:36]

account #	title	cost (million dollars)	
22000000	Reactor Plant Equipment		1026.52
22010000	Reactor Systems		133.54
22010100	First Wall (Included in Blanket)	0.00	
22010101	Central Cell	0.00	
22010102	End Tank	0.00	
22010200	Blanket System	36.29	
22010201	Blanket Structure	0.00	
22010202	Breeder	0.00	
22010203	Reflector	0.00	
22010204	Multiplier	0.00	
22010300	Shielding	54.11	
22010301	Bulk Shielding - Central Cell	40.22	
22010302	Penetration Shielding	0.00	
22010303	Localized Shielding - End Cell	5.32	
22010304	Shielding-Choke Coil	0.57	
22010400	Reactor Structure	40.45	
22010401	Reactor Support Structures	0.00	
22010402	External Vacuum Vessel	40.45	
22010403	Magnet Structural Support (Primary & Intercoil)	0.00	
22010404	Misc. Support Structures -z-	0.00	
22010500	Energy & Particle Removal/Control System	2.68	
22010501	Drift Pumping	0.00	
22010502	Halo Scraper	0.00	
22010503	Direct Energy Converter	2.68	
22020000	Magnet Systems		359.10
22020100	Magnets	359.10	
22020101	Central Cell Solenoid	235.66	
22020102	Choke Coil	40.59	
22020103	Transition Coil	18.60	
22020104	Anchor Coil	22.99	
22020105	Plug Coil	29.86	
22020106	Recircularizer Coil	11.49	
22020107	Recircularizer Solenoid	0.00	

22020109	Axiclell Magnet	0.00	
22020200	Vacuum Dewar	0.00	
22020201	Central Cell Solenoid Dewar	0.00	
22020202	End Cell Magnet LN2 Shields	0.00	
22020203	Cryostat -z-	0.00	
22020204	Center Cell Coil Cryostat	0.00	
22020205	PF Coil Cryostat -z-	0.00	
22020206	-z-	0.00	
22020207	-z-	0.00	
22020208	-z-	0.00	
22020209	Power Injection Systems	0.00	
22020210	ECRH System	0.00	
22020211	RF Power Source	0.00	
22020212	Power Distribution System	0.00	
22020213	Launcher	0.00	
22020214	Ancillaries	0.00	
22020215	ICRH System	0.00	
22020216	RF Power Source	0.00	
22020217	Power Transmission System	0.00	
22020218	Launcher	0.00	
22020219	Ancillaries	0.00	
22020220	LHRH System	0.00	
22020221	RF Power Source -z-	0.00	
22020222	Power Distribution System -z-	0.00	
22020223	Launcher -z-	0.00	
22020224	Ancillaries -z-	0.00	
22020225	Neutral Beam Injection	0.00	
22020226	Sloshing Ion Beam	0.00	
22020227	Central Cell Beam	0.00	
22020228	Vacuum Systems	0.00	
22020229	Plasma Chamber	0.00	
22020230	Internal Systems	0.00	
22020231	External Systems	0.00	
22020232	External Vacuum Vessel	0.00	
22020233	Hi-Vac System -z-	0.00	
22020234	Roughing/Forepump System -z-	0.00	
22020235	Secondary Vacuum Systems	0.00	
22020236	Diagnostics -z-	0.00	
22020237	Leak Detection System Equipment -z-	0.00	
22020238	Power Conditioning Systems	0.00	
22020239	Magnet System Power Conditioning	0.00	
22020240	Central Cell Solenoids	0.00	
22020241	Choke Coil	0.00	
22020242	Transition Coil	0.00	
22020243	Anchor Coil	0.00	
22020244	Plug Coil	0.00	
22020245	Recircularizer Coil	0.00	
22020246	Recircularizer Solenoid	0.00	
22020247	Axiclell Magnet	0.00	
22020248	Power Injection System Power Conditioning	0.00	
22020249	ECRH Power Supplies	0.00	
22020250	ICRH Power Supplies	0.00	
22020251	LHRH Power Supplies	0.00	
22020252	NBI Power Supplies	0.00	
22020253	Energy & Particle Removal/Control Systems PC	0.00	
22020254	Direct Energy Converter	0.00	
22020255		0.00	
22020256		0.00	
22020257		0.00	
22020258		0.00	
22020259		0.00	
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22020457		0.00	
22020458		0.00	
22020459		0.00	
22020460		0.00	
22020461		0.00	
22020462		0.00	
22020463		0.00	
22020464		0.00	
22020465		0.00	
22020466		0.00	
22020467		0.00	
22020468		0.00	
22020469		0.00	
22020470		0.00	
22020471		0.00	
22020472		0.00	
22020473		0.00	
22020474		0.00	
22020475		0.00	
22020476		0.00	
22020477		0.00	
22020478		0.00	
22020479		0.00	
22020480		0.00	
22020481		0.00	
22020482		0.00	
22020483		0.00	
22020484		0.00	
22020485		0.00	
22020486		0.00	
22020487		0.00	
22020488		0.00	
22020489		0.00	
22020490		0.00	
22020491		0.00	
22020492		0.00	

22050302	Drift Pump Power Conditioning	0.00		
22050400	Energy Storage System		0.00	
22060000	Heat Transport Systems			134.80
22060100	Blanket Heat Transport System		46.55	
22060101	Fluid Circularization Driving System	0.00		
22060102	Piping	0.00		
22060103	Heat Exchangers	0.00		
22060104	Storage System	0.00		
22060200	Shield Heat Transports System		0.00	
22060201	Fluid Circularization Driving System	0.00		
22060202	Piping	0.00		
22060203	Refrigeration	0.00		
22060204	Storage System	0.00		
22060300	Cryogenic Cooling System		67.13	
22060301	Liquid Nitrogen System	0.00		
22060302	Liquid Helium System	0.00		
22060400	Water Cooling System		13.40	
22060401	Fluid Circulation Driving Systems	0.00		
22060402	Piping	0.00		
22060403	Refrigeration	0.00		
22060404	Storage Systems	0.00		
22060405	Purification & Treatment Systems	0.00		
22060500	Gas Cooling System		0.00	
22060600	End Cell Heat Transport		7.71	
22070000	Fuel Handling			150.00
22070100	Fuel Injection Systems		6.50	
22070101	Pellet Injector	0.00		
22070102	Gas Puffing	0.00		
22070103	Non-Tritium Gas Delivery -z-	0.00		
22070200	Fuel Processing & Purification		113.66	
22070300	Storage and Receiving		0.00	
22070400	Atmospheric Recovery Systems		30.54	
22070500	Water Recovery Systems		0.00	
22070600	Blanket Recovery Systems		0.00	
22070700	Radwaste System		7.30	
22080000	Instrumentation			67.30
22080100	Process Instrumentation & Control		0.00	
22080200	Safety Instrumentation		0.00	
22080300	Diagnostics		0.00	
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22090600	Remote Cutting/Welding Systems		0.00	
22090700	Mockup Equipment		0.00	
22090800	Miscellaneous Tools		0.00	
22090900	Maintainability Assurance -z-		0.00	
22100000	Other Reactor Plant Equipment			6.55

capital cost accounts

03/14/85

[19:06:48]

account #	title	cost (million dollars)	
23000000	Turbine Plant Equipment		59.83
23010000	Turbine Generators	26.28	
23020000	Main Steam System	2.26	
23030000	Condensing System	2.59	
23040000	Feed Water Heating	3.82	
23050000	Other Turbine Plant Equipment	13.58	
23060000	Turbine Plant I&C	3.79	
23070000	Heat Rejection System	7.68	

capital cost accounts

03/14/85

[19:06:55]

account #	title	cost (million dollars)	
24000000	Electric Plant Equipment		17.27
24010000	Switchgear	8.88	
24020000	Station Service Equipment	8.88	
24030000	Switchboards	8.88	
24040000	Protective Equipment	8.88	
24050000	Electrical Structure & Wiring Containers	8.88	
24060000	Power and Control Wiring	8.88	
24070000	Energy Supply -2-	8.88	

capital cost accounts

03/14/85

[19:06:56]

account #	title	cost (million dollars)
25000000	Miscellaneous Plant Equipment	72.16
25010000	Transportation and Lifting Equipment	5.15
25020000	Air and Water Service Systems	3.56
25030000	Communications Equipment	2.17
25040000	Furnishing & Fixtures	1.19
25050000	Bulk Materials	10.40
25060000	Gas Supply System Equipment -z-	0.00
25070000	Special Materials -z-	49.68

capital cost accounts

03/14/85

[19:07:15]

account #	title	cost (million dollars)
90000000	DIRECT COST	1323.82

***** mscindt *****

ORNL-DWG 85-2626 FED

Fig. 8. Computer drawing (isometric view) consistent with the sample execution of the Tandem Mirror Reactor Systems Code.

ORNL-DWG 85-2627 FED

Fig. 9. Computer drawing (plan view) consistent with the sample execution of the Tandem Mirror Reactor Systems Code.

ORNL-DWG 85-2628 FED

Fig. 10. Computer drawing (elevation view) consistent with the sample execution of the Tandem Mirror Reactor Systems Code.

Nomenclature for mscin data file

ixeg	option to execute or skip individual modules if = 1, execute the module if = 0, skip the module
bcc	center cell magnetic field (T)
bch	choke coil magnetic field (T)
ba	anchor well field (T)
bm	end cell mirror field (T)
bp	plug well field (T)
beta	center cell, anchor, and plug betas
bin	insert coil self field (T)
Jcc	center cell coil current density (A/m^2)
wcc	cc coil pack width (m)
Lmcc	cc module length (m)
gcc	gap between adjacent cc modules (m)
ach	first guess choke coil inner radius (m)
fch	fraction field of choke sub coils
wch	choke coil pack width (m)
Jch	coil current density (A/cm^2) (up to 3 sub coils)
win	insert coil pack width (m)
tin	insert coil pack build (m)
Jc	end cell "c" coil current densities (A/m^2)
ls	length of "c" coil straight sections (m)
unit cost	coil unit cost values (\$/kg)
casey mod	coil case Youngs modulus (Newtons/ m^2)
tc	plasma ion temperature (keV)
rchoke	radius of choke coil (cm)
ioption	if = 1 fixed fusion power if = 2 fixed cc length
pfus	fusion power (MW)
clength	cc length (cm)
chheatmx	allowed nuclear heating (W/cc) in superconducting choke coil (if zero, no iteration on choke shield thickness)
chsodemx	allowed dose to electrical insulation in super- conducting choke coil (if zero, no iteration) (rad)
neutronics input - see definition in Table 5	

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