Role of RFSP and General Capabilities

- Solves the two-group 3D diffusion equations by a finite difference iterative technique using cell-centre fluxes.
- Capable of generating nominal power distributions and simulating reactor operations, including refuelling and burnup steps as well as time dependent transients.
- It allows variable mesh spacings.
- It can use, at any boundary, extrapolated boundary conditions or symmetric boundary conditions.
- It is of modular design.
- Reactivity devices and structural materials are represented by incremental cross-sections which are added to the fuel cross-sections of the affected lattice cells.

Types of Simulations
*TIME-AVER

Time-Average Calculations:

- **The fuel cross-sections are averaged over the residence (dwell) time of the fuel at each point in the core.**
- **Accounts for fuelling scheme**

Types of Simulations (con't)
*INSTANTAN

Instantaneous Calculations:

- **random age distribution (based on time average beginning and end of cycle)**

$$\omega(i,j,k) = \omega_1(k) + f(i,j)\ (\omega_2(k) - \omega_1(k))$$

- **produces hot spots**
- **patterned age distribution**
- **starting point for equilibrium fuelling study**

Types of Simulations (con't)
*SIMULATE

Core Tracking

- time history of the flux and power distributions is calculated at discrete time steps with the irradiation distribution incremented from the previous step using the previous flux distribution

During design stage:

- used to simulate the initial transient from startup to equilibrium
- used to investigate the effect of various fuelling rules
- to obtain accurate estimates of maximum powers, discharge burnups, etc.

Types of Simulations (con't)
*SIMULATE

During reactor operation:

- to obtain bundle power, channel power, and bundle irradiation histories use to:
  - select channels for refuelling
  - ensure that channel and bundle powers are kept within specified limits
  - evaluate burnup

"Quasi-Static" Simulations *TIME-AVER or *SIMULATE

"Quasi-static" calculations used to predict the static core conditions at specific times in a slow transient, such as that associated with changes in Xe-135 concentration.

This type of calculation solves:

- the two-group time-independent neutron diffusion equation and,
- the time-dependent I-135/Xe-135 kinetics equations

“Quasi-Static” Simulations Cont…

Uses:

- To follow the time variation of the spatial distributions of Xe-135 concentration following a power manoeuvre, device movement, or refuelling operation.
- To mimic the actions of the zone-control system (bulk and spatial control)

Kinetics Simulations *CERBERUS

Kinetics calculations analyze the time-dependent behaviour of the reactor flux distribution.

Main applications:

- large-loss-of-coolant accident
- pressure-tube rupture
- main steam line break

Kinetics calculations must take into account delayed-neutron effects.

RFSP Data Base

- Modules communicate through direct access (database) file
- Hierarchical structure
- Up to 7 levels
- Up to 40 records and/or subindices per level
- All model data stored, minimizing input requirements

Communication with Other Codes or Platforms

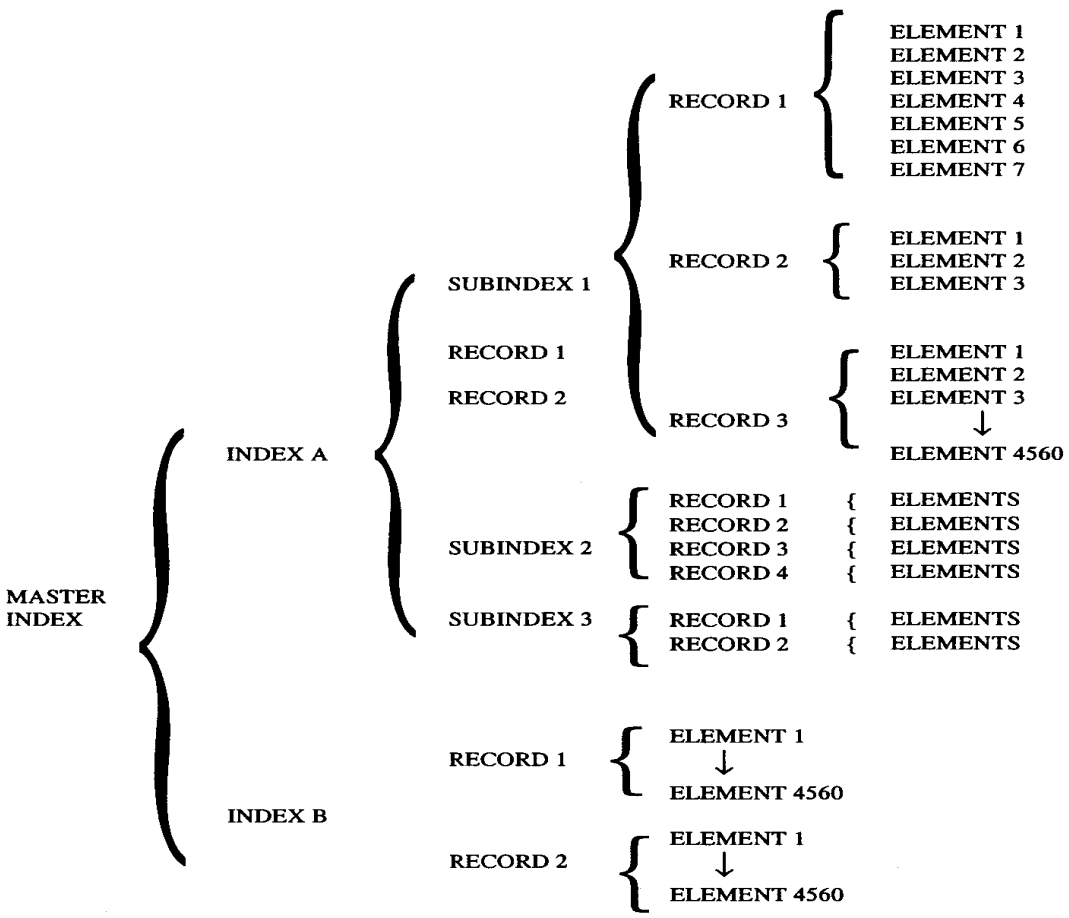
- ***RMICASCII, *WMICASCII**
  - read and write direct access file in ASCII format
- ***RNSES, *WNSES**
  - read and write direct access file to NSES ASCII format (for link to HQSIMEX)
- ***NUCIRCLNK**
  - read coolant properties from NUCIRC and write bundle powers to NUCIRC

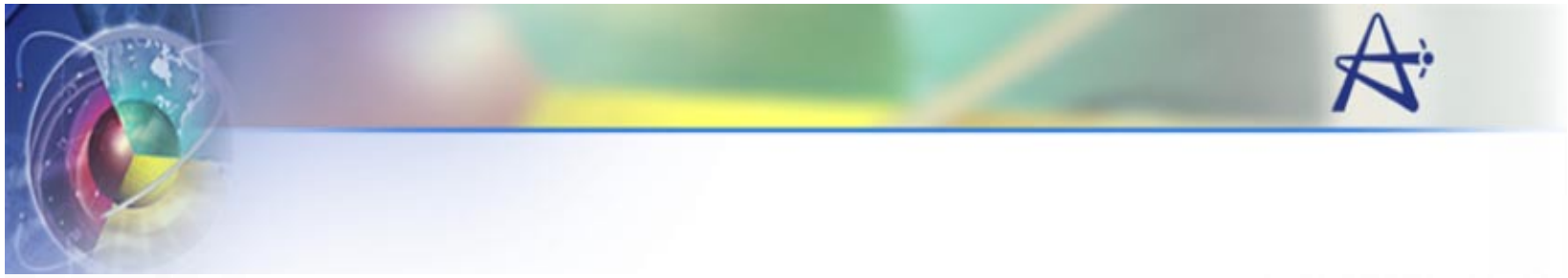
    ***CERBERUS, *CERBRRS**
  - links to CATHENA, FIREBIRD, SOPHT, NUCIRC

RFSP Direct-Access File

- Hierarchical or tree-like organizational structure.
- Local direct-access file called “STORE”.
- Composed of indices and records.
- Up to 7 levels of indices.
- Under any index may be combined total of 40 subindices and records.
- Move from lowest-level (Level-1) index to higher-and higher-level subindices.
- Not all records are at the same level.
- Records and index identified by 10-character alphanumeric name.
- Names need be unique only within an index.

Example of the Structure of a Direct-Access File





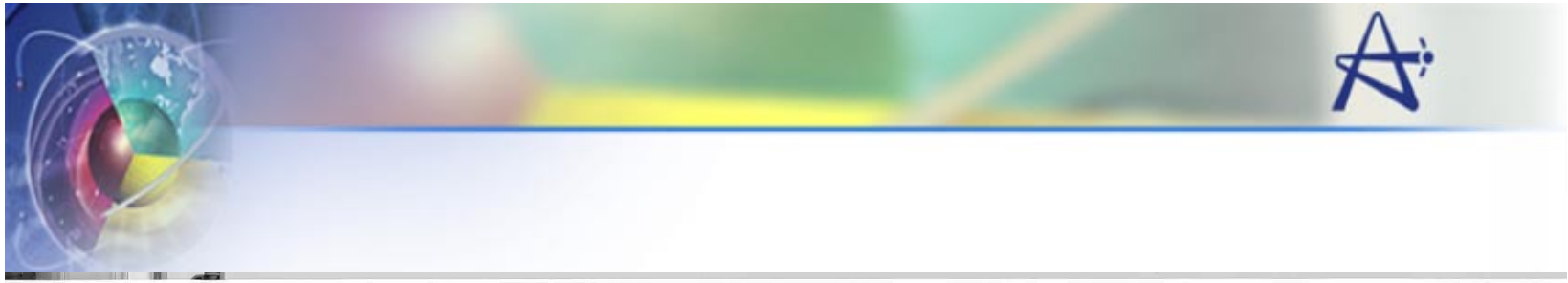
*PRNT MASS

CONTENTS OF SOME DATA BLOCKS IN THE DIRECT-ACCESS FILE

```
0    INDEX  MASTERINDX     256  0401211608

   1     INDEX  HOLES        256  0401211607        <---Location of available space in the direct access file
   2          RECORD HOLES       800

   1     INDEX  MODEL        256  0401211124ACR-700 <--- Model name assigned by user, stored in index
284 CHANNELS 2-GROUP RFSP MODEL, 2.1% SEU CENTRAL
NU

   1     INDEX  GEOMETRY       256  0401211607      <--- Main Level Index (*DATA GEOMETRY)
   2          RECORD DIMENSIONS      30            <--- Data from A,B,C and P GEOMETRY trailer cards
   2          RECORD MESH SPACE     364            <--- Mesh spacing as input on X, Y and Z cards
   2          RECORD FUEL TYPES    6816            <--- Fuel type input on K card as per fuel tables from WIMS
   2          RECORD CHANL NUMS     324            <--- Row/column to channel number reference - used internally
   2          RECORD REGIONS        568            <--- Channel groupings usually burnup regions input on J card
   2          RECORD ROWCOLUMNS      48            <--- Row, column, plane id, input on F,G,H cards
   2          RECORD SERIAL NUM    6816            <--- Bundle serial numbers (date and position) from L and S card
   2          RECORD NOTCHRADII       6            <--- Calandria radius and notch position - input on M, N cards
   2          RECORD MESH NUMS     6084            <--- Mesh numbering per plane (1 to NPTS) - used internally
   2          RECORD ILIMITS       2028            <--- Mesh starting and ending point for each row - used internally
   2          RECORD NA ARRAY    159216            <--- Indicator of material type in each mesh 0-outside,1-inside model

   1     INDEX  DEVPROPS2G     256  0401211124      <--- Main Level Index (*DATA DEVSPROP2G)
   2          RECORD MOVEPROPS2      54            <--- Moveable device types, i.e.2-group incremental cross sections
   2          RECORD MOVE DEVS2     752            <--- Movable device positions

   1     INDEX  LATPROPS2G     256  0401211124      <--- Main Level Index (*DATA LATPROPS2G)
   2          RECORD SEU21DY75C    1952
   2          RECORD SEU21DY75V    1952            <--- Fuel-type name properties, i.e. 2-group cross sections for this type of fuel
   2          RECORD REFLECTOR       13            <--- Reflector cross sections and any additional fixed property
```

```
INDEX  IRRADIATON     256  0401211608              <--- Main Level Index (*DATA IRRADIATON)
   2          RECORD T.A.FF*PHI    3408           <--- Time-average fuel flux
   2          RECORD FUEL SCHEM     284           <--- Fuelling scheme for each channel - input on B and C cards
   2          RECORD EXIT IRRAD     284           <--- Time average exit irradiations specified on A cards
   2          RECORD TIMAVEXITW    3408           <--- Time average bundle exit irradiations at end-of-cycle
   2          RECORD MULTICYCLE     222           <--- Definition of multi-cycle scheme input on E card
   2          RECORD GENFULSCH        1           <--- Generalized fuelling schemes as defined on D cards
   2          RECORD BOC IRRADS    6816           <--- Time average beginning and end of cycle bundle burnups
   2          RECORD DELTA RHO     3408           <--- Bundle reactivity change on refuelling each channel
   2          RECORD DWELL TIME     284           <--- Time-average channel dwell times (time between refuellings)
   2          RECORD CHN BURNUP     284           <--- Time-average channel exit burnup (*SUMMARY)
   2          RECORD BUN BURNUP    3408           <--- Time-average bundle exit burnups at end-of-cycle (*SUMMARY)
   2          RECORD BOC BURNUP    6816           <--- Time-average beginning and end-of-cycle bundle burnups
   2          RECORD K INCREASE     284           <--- Reactivity due to fuelling for low-Z half of core
   2          RECORD TAFFFORXEN    3408           <--- Time-average fuel flux with xenon
   2          RECORD FUEL IRRAD    3408           <--- Snapshot of fuel bundle irradiation (n/kb)
   2          RECORD AGE MAP        324           <--- Channel ages
   2          RECORD FUELBURNUP    3408           <--- Snapshot of fuel burnup
   2          RECORD FUEL FLUX     3408           <--- Snapshot of fuel flux
   2          RECORD LASTFULCYC     284           <--- Cycle indicator for multi-cycle scheme
   2          RECORD LAST FUEL      284           <--- Energy index for last fuelling of each channel(from *SIMULATE)

   1     INDEX  XENONPROP2     256                <--- Main level index for xenon properties
   2          RECORD SEU21DY75C     536           <--- Xenon properties used to calculate ••a2,function of irradiation

   1     INDEX  FUEL PROPS     256  0401211607    <--- Main Level Index (*DATA FUEL PROPS)
   2          RECORD ZC NAME         36           <--- Current zone-controller names
   2          RECORD ZC LEVEL        18           <--- Current zone-controller levels (positions)

   1     INDEX  FLUX/POWER     256  0401211608    <--- Main Level Index (*DATA FLUX/POWER)

   2          INDEX  SLOW FLUX      256           <--- 2" level index for thermal-flux
   3             RECORD       2   3317           <--- Thermal-flux distribution at each mesh plane
   3             RECORD       3   3317
   etc. ....                                     …
   3             RECORD      25   3317
   3             RECORD CELL PHI  3408           <--- Cell-averaged thermal flux

   2          INDEX  FAST FLUX      256           <--- 2" level index for fast-flux
   3             RECORD       2   3317           <--- Fast-flux distribution at each mesh plane
   3             RECORD       3   3317
   etc. ....
   3             RECORD      25   3317           <--- Cell-averaged fast flux
   3             RECORD CELL FLXF 3408

   2          INDEX  POWERS     256             <--- Level 2 index under which powers are stored
   3             RECORD CHANNEL    284           <--- Channel powers
   3             RECORD BUNDLE    3408           <--- Bundle powers
```

```
2          INDEX  OVERPOWERS     256          <--- Level 2 index under which overpowers are stored
3              RECORD CHNLOVPWR  284          <--- Channel overpowers (e.g.*SIMULATE vs REFORM)
3              RECORD BNDLOVPWR 3408          <--- Bundle overpowers (e.g. *SIMULATE vs REFORM)

2          INDEX  XENON DIST     256          <--- 2ndlevel index under which saturating fission product concentrations are
                                              stored for end of time step
3              RECORD TAFFFORXEN3408          <--- Time-average fuel flux with xenon
3              RECORD IODINE    3408          <--- Iodine concentration at end of time step
3              RECORD XENON     3408          <--- Xenon concentration at end of time step
3              RECORD FUEL FLUX 3408          <--- Fuel flux at end of time step

2          INDEX  XENON INIT     256          <--- 2ndlevel index under which saturating fission product concentrations are
3              RECORD TAFFFORXEN3408          stored for beginning of time step
3              RECORD IODINE    3408
3              RECORD XENON     3408

1     INDEX  ZONE CNTL      256  0401211218

1     INDEX  PHYS PARMS     256  0401211608  <--- Main level index for material properties
2          RECORD BNDRPLANES      6          <--- Plane boundaries for modelling moderator level
2          RECORD 2GFFACTOR     3408         <--- F factor - ratio of thermal fuel flux to cell flux
2          RECORD 2GH1FACTOR    3408         <--- H1 factor - epithermal bundle power/cell flux ratio for each bundle
2          RECORD 2GH2FACTOR    3408         <--- H2 factor - thermal bundle power/cell flux ratio for each bundle

2          INDEX  2GSIGA1    256             <--- 2-group fast absorption cross sections for each plane
3              RECORD       2   3317         <--- values for Z plane 2 (NPTS)
3              RECORD       3   3317
etc. ....
3              RECORD      25   3317

2          INDEX  2GSIGA2    256             <--- 2-group thermal absorption cross sections for each plane
3              RECORD       2   3317
3              RECORD       3   3317
etc. ....
3              RECORD      25   3317

2          INDEX  2GSIGR12    256            <--- 2-group fast-to-thermal transfer (moderation) cross sections for each plane
3              RECORD       2   3317
3              RECORD       3   3317
etc. ....
3              RECORD      25   3317

2          INDEX  2GSIGR21    256            <--- 2-group thermal-to-fast transfer cross sections for each plan
3              RECORD       2   3317
3              RECORD       3   3317
etc. ....
3              RECORD      25   3317

2          INDEX  2GSIGTR1    256            <--- 2-group fast transport cross sections for each plan
3              RECORD       2   3317
3              RECORD       3   3317
etc. ....
```



```
3             RECORD       25   3317

2          INDEX  2GSIGTR2     256
3             RECORD        2   3317            <--- 2-group thermal transport cross sections for each plan
3             RECORD        3   3317
etc. ....
3             RECORD       25   3317

2          INDEX  2GNUSIG1     256
3             RECORD        2   3317            <--- 2-group fast production cross sections for each plan
3             RECORD        3   3317
etc. ....
3             RECORD       25   3317

2          INDEX  2GNUSIG2     256
3             RECORD        2   3317            <--- 2-group thermal production cross sections for each plan
3             RECORD        3   3317
etc. ....
3             RECORD       25   3317

1     INDEX  T-AVERAGE      256  0401211514      <--- Main level index containing time-average power distribution (*TIME-AVER)
2          RECORD K-INFINITY    3408            <--- Reference power-shape k-infinity
2          RECORD TAEQVIRRAD    3408            <--- Time-average-equivalent exit irradiations

1     INDEX  T-AVERAGED     256  0401211607

2          INDEX  FLUX/POWER     256

3             INDEX  POWERS        256
4                RECORD CHANNEL        284      <--- Reference power-shape channel powers
4                RECORD BUNDLE        3408      <--- Reference power-shape bundle powers

1     INDEX  REFORM         256  0401211607      <--- Main level index containing reference power distribution

2          INDEX  FLUX/POWER     256

3             INDEX  POWERS        256
4                RECORD CHANNEL        284
4                RECORD BUNDLE        3408

1     INDEX  AUXILDATA      256  0401211608      <--- Data used by *PRTPWR
```

```
1     INDEX  LOCAL PARM      256  0401211514      <--- Local parameter index
2          RECORD DENSITY        3504            <--- Coolant density distribution
2          RECORD COOL TEMP      3504            <--- Coolant temperature distribution

1     INDEX  INSTANTAN       256  0401211607      <--- Main level index containing instantaneous power distribution (*INSTANTAN)

2          INDEX  RANDIS 1    256               <--- Name assigned by user, stored in 2nd level index

3              INDEX  IRRADIATON 256
4                  RECORD AGE MAP         324
4                  RECORD FUEL IRRAD     3408
4                  RECORD FUELBURNUP     3408
4                  RECORD FUEL FLUX      3408

3              INDEX  FLUX/POWER 256

4                  INDEX  POWERS          256
5                     RECORD CHANNEL          284
5                     RECORD BUNDLE          3408

4                  INDEX  OVERPOWERS      256..
5                     RECORD CHNLOVPWR        284
5                     RECORD BNDLOVPWR        3408

4                  INDEX  SLOW FLUX       256 .
5                     RECORD CELL PHI         3408
4                  INDEX  FAST FLUX       256 .
5                     RECORD CELL FLXF        3408

      INDEX  SIMULDATA       256  0401211608      <--- Main Level Index (*SIMULDATA)

2          INDEX  ACR284_RD       256             <--- Reactor name assigned by user, stored in 2nd level index

3              INDEX         0    256             <--- Energy block assigned by user, stored in 3rd level index

4                  INDEX         0     256        <--- Energy clock
5                       RECORD SERIAL NUM    6816 <--- Serial number of all bundles in the core
5                       RECORD FUEL TYPES    6816 <--- Model names of fuel bundles in the core
5                       RECORD CELL PHI      3408 <--- Bundle-averaged thermal fluxes
5                       RECORD FUEL IRRAD    3408 <--- Irradiations of fuel bundles in the core
5                       RECORD 2GFFACTOR     3408 <--- F factor - ratio of thermal fuel flux to cell flux
5                       RECORD 2GH1FACTOR    3408 <--- H1 factor - epithermal bundle power/cell flux ratio for each bundle
5                       RECORD 2GH2FACTOR    3408 <--- H2 factor - thermal bundle power/cell flux ratio for each bundle
5                       RECORD CELL FLXF     3408 <--- Cell fast flux
5                       RECORD LAST FUEL      284 <--- Energy index for last fuelling of each channel (from *SIMULATE)
5                       RECORD LASTFULCYC     284 <--- Cycle indicator for multi-cycle scheme
5                       RECORD BUNDLE        3408 <--- Bundle power distribution
5                       RECORD CHANNEL        284 <--- Channel power distribution
5                       RECORD FUELBURNUP    3408 <--- Burnup of bundles in the core
5                       RECORD CHNLOVPWR      284 <--- Ratio of instantaneous to time-average channel power
5                       RECORD BNDLOVPWR     3408 <--- Ratio of instantaneous to time-average bundle power
```

- The system of indices is used to gain access to any record by giving the proper sequence of indices, from lowest level to highest level, leading to that record.
- [Note: Since names are not necessarily unique, the user must be careful to properly identify the record desired.
- Usually the index names correspond to the module that creates them i.e.:

  *DATA GEOMETRY creates GEOMETRY index

  *DATA IRRADIATION creates IRRADIATION index

  *DATA FLUX/POWER creates FLUX/POWER index

  *SIMULATE creates SIMULDATA index
- Each index contains names, lengths, and addresses of its subindices and records.
- Also index can be used to store information, 6 words called the IDENT array, displayed by *PRINT MASS

- Modules ***DELETE** and ***STORE** can be used to delete or copy, respectively, records or whole indices (including everything under them) e.g.,:

  *STORE

  FROM FLUX/POWERPOWERS

  TO REFORM FLUX/POWERPOWERS

  *DELETE FLUX/POWERPOWERS CHANNEL

- ***PRINT** can be used to print most records (without listing the complete path) and in some cases whole indices and everything below them:

  *PRINT GEOMETRY

  *PRINT IRRADIATION

  *PRINT PHYS PARMS

  *PRINT DIMENSIONS (no need for GEOMETRY)

  Exception is *SIMULATE records:

  *PRINT RECORD SIMULDATA REACTOR ENERGY

*USE DAF/*MAKE DAF vs. *READ TAPE/RITE Tape

Advantages of *USE DAF/MAKE DAF

- RFSP data base is saved as a direct-access file
- Better than copying “STORE” file since name is shown in output file
- Faster
- Full path names can be given (70 characters available)

Disadvantages of *USE DAF/*MAKE DAF

- File size large
- For calculations where file keeps growing e.g. *SIMULATE, *CERBERUS or *CERBRRS may be unusable with limited disk space

USE DAF/*MAKE DAF vs. *READ TAPE/RITE Tape (con't)

Advantages of *READ TAPE/*RITE Tape

- File size is kept to minimum; *DELETE can be used to control size
- Can be used to merge models:

```
*READ TAPE file 1
*READ TAPE file 2    TEMP
*STORE
FROM TEMP GEOMETRY
TO GEOMETRY
*DELETE TEMP
```

USE DAF/*MAKE DAF vs. *READ TAPE/RITE Tape (con't)

Disadvantages of *READ TAPE/*RITE Tape

- Slower because direct-access file must be created each time from sequential file
- File name limited to 10 characters