Dokumen Pengembangan TRIAMIX (TRIso *Analysis Code* coupled with THERMIX capabilities)

LABORATORIUM KOMPUTASI

PUSAT TEKNOLOGI DAN KESELAMATAN REAKTOR NUKLIR

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Daftar Isi

Daftar Gambar

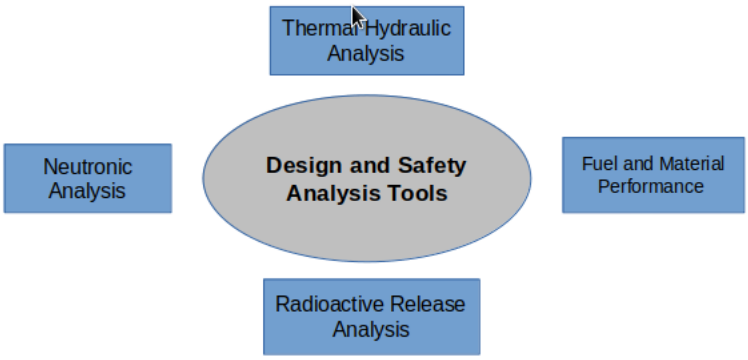
Daftar Program

BAB 1

Pendahuluan

1.1 Latar Belakang

Analisis keselamatan reaktor nuklir melibatkan sejumlah aspek seperti diperlihatkan pada Gambar 1.1. Setelah upaya melakukan rekayasa balik terhadap PANAMA [2, 3] untuk aspek kinerja bahan bakar [4], dipandang perlu untuk melanjutkan analisis keselamatan di aspek *thermal hydraulics*.



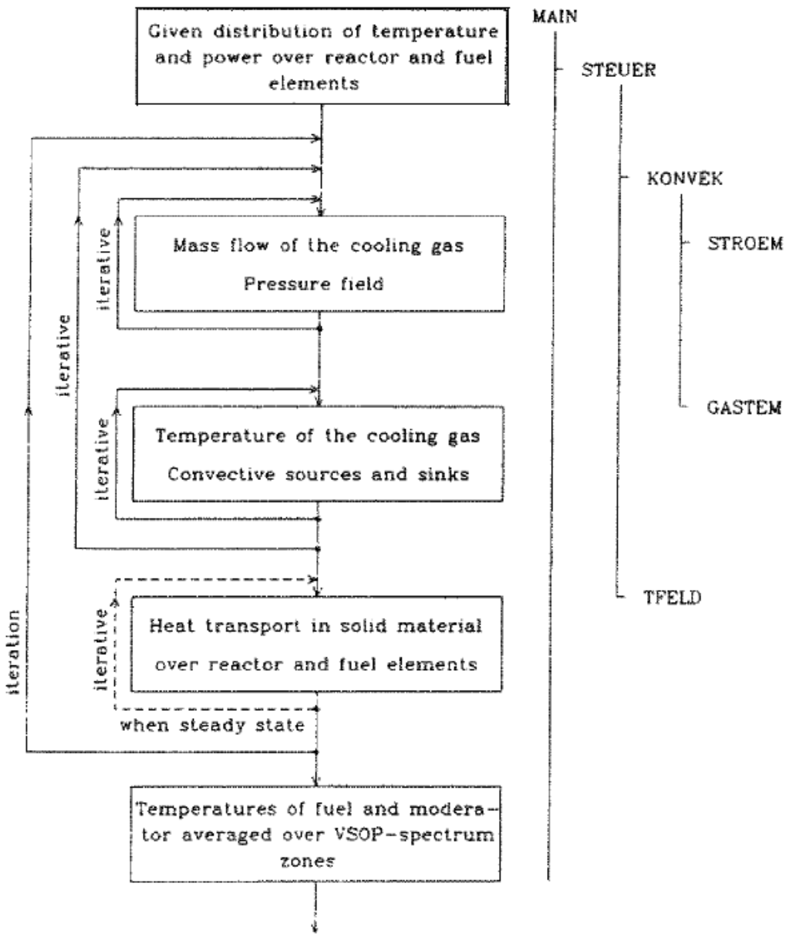
Gambar 1.1: Aspek keselamatan reaktor nuklir

Kode komputer THERMIX [1, 5] sebagai salah satu kode baku dalam analisis keselamatan reaktor di aspek termal yang turut menghantarkan Jerman sebagai *center of excellent* pada penelitian tersebut. Dari THERMIX, sejarah irradiasi dan kecelakaan yang dialamai partikel triso dapat disimulasikan.

Karenanya, perangkat lunak akan dikembangkan berdasarkan data referensi dan dokumentasi **[1, 5]**. Hasil rekayasa balik akan berupa prototipe kode komputer/perangkat lunak yang terintegrasi dengan modul analisis keselamatan bahan bakar berbasis partikel triso [4] dan analisis ketidakpastian [6].

1.2 Konsep Dasar

Skema alur program THERMIX dapat dijelaskan melalui Gambar 1.2. Skema alur tersebut didasarkan pada 3 konsep kekealan dalam fisika, masing-masing adalah kekekalan massa, momentum dan energi. Ketiga aspek kekekalan yang akan dibahas berikut ini juga berbasis pada [1]



Gambar 1.2: Skema alur program THERMIX [1]

Kekekalan massa gas pendingin dalam bentuk *quasi-static* menghasilkan vektor alir $G = \rho_G \vec{v}$ sepanjang *loop*. Kekekalan massa gas tersebut dinotasikan dalam persamaan (1.1). ρ_G adalah kerapatan gas pendingin $\left[\frac{kg}{m^3}\right]$. $\vec{v}$ adalah kecepatan $\left[\frac{m}{s}\right]$. Sedangkan q adalah kerapatan laju massa sumber $\left[\frac{kg}{s.m^3}\right]$.

$$\nabla \rho_G \vec{v} = q \tag{1.1}$$

Kekekalan momentum dalam bentuk *quasi static* menghasilkan medan tekanan p sepanjang *loop*, dengan p adalah tekanan statis, $\vec{g}$ adalah gravitasi dan $\vec{R}$ adalah gaya gesek.

$$\nabla p - \rho_G \vec{g} + \vec{R} = 0 \tag{1.2}$$

Persamaan (1.2) memberikan *gradient* kesetimbangan tekanan, gaya hidrostatik dari gravitasi serta gaya gesek per satuan volume. Percepatan spasial dan inersia diabaikan di sini. Selanjutnya, gaya gesek didefinisikan sebagai persamaan (1.3). Dengan ψ adalah koefisien penurunan tekanan untuk aliran melalui *pebble bed* sedangkan d adalah diameter *pebble*.

$$\vec{R} = \frac{\psi}{d} \frac{1-\varepsilon}{\varepsilon^3} \frac{|G|}{2\rho_G} \vec{G} \tag{1.3}$$

Evaluasi persamaan (1.2) dan (1.3), seperti pada Gambar 1.2, dilakukan dalam sub rutin `STROEM` dalam `KONVEK2.FOR`.

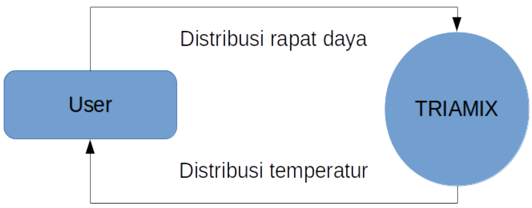
Sementara untuk kekekalan energi

BAB 2

Struktur Program

2.1 Diagram konteks

Sistem yang akan dikembangkan memiliki diagram konteks level 0 seperti pada Gambar 2.1. Triamix akan menerima masukan berupa distribusi rapat daya dan menghasilkan distribusi temperatur. Distribusi temperatur tersebut selanjutnya akan menjadi masukan bagi TRIAC-BATAN yang sebelumnya dikembangkan [4].



Gambar 2.1: Konteks level 0 dari sistem Triamix

2.2 Kebutuhan fungsi

Tahapan selanjutnya adalah membuka struktur program dan melihat keterkaitan antar fungsi yang terdapat di kode komputer THERMIX. Terdapat 4 program, masing-masing `THERMIX1.FOR` - `THERMIX4.FOR`. Subrutin dan fungsi pada masing program tersebut disajikan pada Tabel 2.1 - Tabel 2.4. Deskripsi yang disajikan merupakan translasi bebas dari Bahasa Jerman menggunakan google translate.

Selain itu, terdapat juga fungsi/sub rutin yang didefinisikan pada program di luar `THERMIX`. Tabel 2.5 menyajikan fungsi-fungsi tersebut.

Keterkaitan antar fungsi/sub rutin ditampilkan secara grafis disajikan pada Gambar 2.2. Penyajian tersebut menggunakan konvensi:

- merah → terdefinisi di `THERMIX1.FOR`
- kuning → terdefinisi di `THERMIX2.FOR`
- hijau → terdefinisi di `THERMIX3.FOR`
- biru → terdefinisi di `THERMIX4.FOR`

Tabel 2.1: Daftar fungsi dan subrutin dalam program `THERMIX1.FOR`

Fungsi / Subrutin	Deskripsi
ABEND	Membuat penanganan kesalahan
BILD	Lembar penciptaan buatan dan halaman akhir
BUBIL	Perhitungan sumber panas konvektif saat ini dan kompensasi komposisi ini. Hanya aktif jika sumber panas dibuat dengan $\alpha * f$ dan `TFLU`
CALT	Hitung suhu pada kondisi tunak
CALT1	Menghitung suhu suhu padat yang homogen
CALT2	Menghitung suhu padat heterous (temperatur zona bola) solusi TRISSIAG dari sistem persamaan penghapusan matriks (GAUSS)
CALT2H	Menghitung suhu padat heterous (temperatur zona bola) solusi sistem persamaan TRIDIAG matriks penghapusan (GAUSS)
CALTA	Menghitung temperatur padat heterous (*stationary billing*) solusi sistem persamaan sebagai SR CALT2 (eliminasi matriks)
CALTAH	Menghitung temperatur padat heterous (*stationary billing*) solusi sistem persamaan sebagai SR CALT2 (eliminasi matriks)
EXPLIZ	Perhitungan eksplisit ke fungsi panas
MAITHX	Program utama THERMIX, 50x80 tingkat perubahan
STEUER	Menetapkan suhu tengah, menciptakan plot waktu, temperatur corr. rangkaian dalam arah y
WTSTEU	Kendali penghapusan kinerja di pertukaran panas

- biru muda → terdifinisi di program selain `THERMIX1.FOR` s/d `THERMIX4.FOR`
- bayangan oranye → memiliki ketergantungan terhadap fungsi/sub rutin di bawahnya, fungsi/sub rutin tersebut dapat berada di `THERMIX1.FOR` s/d `THERMIX4.FOR` atau bahkan di luar keempat program tersebut.
- secara umum, panah menunjukkan ketergantungan yang setara antara fungsi/sub rutin di lapisan pertama dengan lapisan-lapisan di bawahnya. Seperti ditunjukkan pada Gambar 2.2, sub rutin `MAITHX` membawahi semua sub rutin di bawahnya secara langsung, kecuali `SETBER`, `ABEND` dan `BILD`.

Kemudian, sub rutin di bawah `MAITHX` yang membawahi sub rutin lain adalah:

1. `EINL1` (Gambar 2.3),
2. `SETE` (Gambar 2.4),
3. `SUCHET` (Gambar 2.5),
4. `KONST1` (Gambar 2.6),
5. `TFELD` (Gambar 2.7),

Tabel 2.2: Daftar fungsi dan subrutin dalam program `THERMIX2.FOR`

Fungsi / Subrutin	Deskripsi
DDF1	Tidak tersedia penjelasan
CALT3	Perhitungan suhu pada heterous (temperatur zona bola) solusi sistem persamaan Gauss-Siedel. Hati-hati menggunakan → `kapasitas panas*WK` APH, tidak bekerja untuk *flash ball*
EINL1	Program `READOUT` untuk bagian program `HEATER`
GFIT	Perhitungan perubahan akurasi panas irradiasi
GRPR	Penetapan `GR*PR` untuk cetakan konveksi bebas, `P` harus disediakan
INTEST	Aktif dalam IFTEST=1 → angka minimum untuk uji masukan
IPLOG	Interpolasi logaritmik pada nilai konstan melampaui rentang definisi
ISOPLT	Plot iso-linear
ITPL	Interpolasi linear
KONST1	Perhitungan kemampuan pemanasan dan fungsi geometri untuk *shelves*
KOPFB	Program *coupling* untuk suhu dan umpan balik XENON
KUEHLK	Tidak tersedia penjelasan
MARK	Tanda batas komposisi dari luaran grid besar
MIMAX	Menentukan minimum dan maksimum ruang grid terhubung
ORDNE1	Tidak tersedia penjelasan
ORDNE2	Pilih dari jumlah total 3 cm dukungan terbesar
PDFELD	Masalah besar yang dilakukan di sini, konsentrasi VSOP untuk release produk fisi
PRAIZ	Tidak tersedia penjelasan
PREIN	Pengendalian dan output sifat komposisi
PRFELD	Edisi grid yang hebat
PRINTT	Masalah grille kecil
READRZ	Masukan grille aksial dan radial

6. `ISOPLT` (Gambar 2.8) dan
7. `STEUER` (Gambar 2.9).

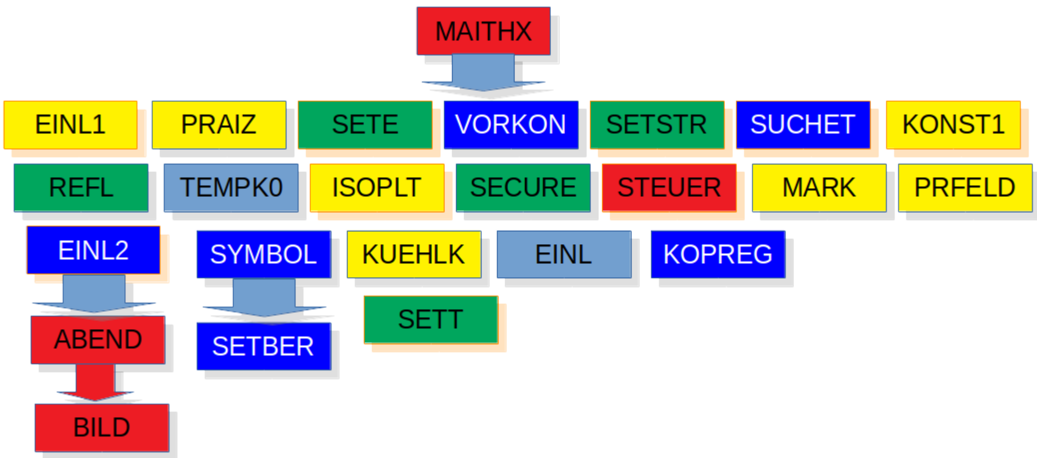
Untuk sub rutin `SETSTR` tidak ditampilkan karena hanya membawahi `ABEND` yang sudah ditampilkan di Gambar 2.2. sedangkan sub rutin `SETT` bersama sub rutin `SETF1`, `SETF2`, `SETK1` ditampilkan pada Gambar 2.10. Sub rutin tersebut sama-sama membawahi sub rutin `ABEND`.

2.3 Diagram alir data level 1

Diagram yang disajikan pada Gambar 2.11 adalah penjabaran dari diagram konteks yang disajikan di Gambar 2.1. Triamix harus menyediakan sub rutin yang dapat menerima informasi rapat daya berikut informasi pendukung berupa dimensi reaktor pada arah radial dan axial, lengkap dengan jumlah *mesh* pada kedua arah tersebut. Untuk informasi rapat daya,

Tabel 2.3: Daftar fungsi dan subrutin dalam program `THERMIX3.FOR`

Fungsi / Subrutin	Deskripsi
LAGRAS	Interpolasi lagrange
POWTHX	Menerima layanan VSOP + EVTL konsentrasi terhadap grid thermix
PRTEIN	Tidak tersedia penjelasan
REDUM	Perhitungan daya termal (lokasi, waktu)
REDUN	Perhitungan kekuatan termal (lokasi, waktu) untuk OTTO
REDUZ	Pengendalian perhitungan daya panas
REFL	Mengatur Kondisi RIM adiabatis pada grid
REIPO	Program interpolasi (ke transmisi grid)
RUND	Tidak tersedia penjelasan
SECURE	Membuat berkas untuk *restart*
SETBER	Tidak tersedia penjelasan
SETD	Set dosis cepat
SETE	Set kinerja daya dan konsentrasi
SETF1	Membaca grille thermix
SETF2	Membaca ketebalan zona inti
SETK1	Menempatkan grille thermix dengan komposisi
SETSTR	Mengidentifikasi dan memeriksa kolom beam
SETT	Konfigurasi suhu awal
SETZT1	Mengalihkan suhu awal yang diambil dengan bantuan grille
VOLMAT	Volume matriks `VSOP-THERMIX*BIRGIT`

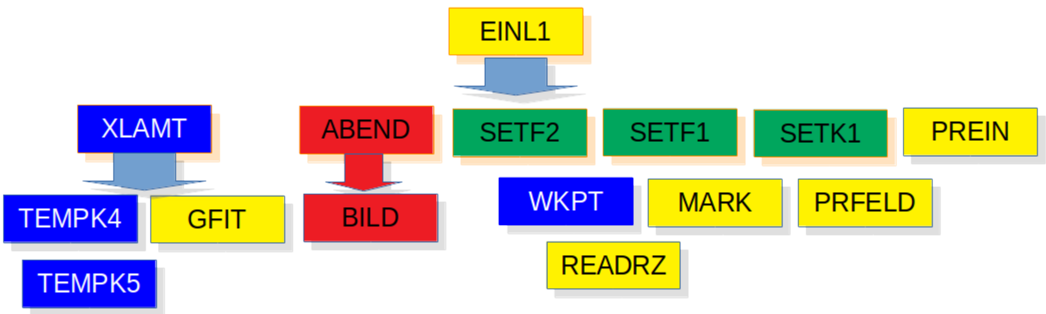


Gambar 2.2: Fungsi/sub rutin `MAITHX`, terbesar dari yang didefinisikan di `THERMIX`

Triamix dirancang untuk dapat membacanya dari berkas teks berisi matriks dua dimensi yang. Jumlah *mesh* di arah radial harus sama dengan jumlah kolom dalam informasi rapat daya. Demikian juga dengan jumlah *mesh* di arah axial, harus sama dengan jumlah baris

Tabel 2.4: Daftar fungsi dan subrutin dalam program `THERMIX4.FOR`

Fungsi / Subrutin	Deskripsi
EINL2	Program sub *dummy* untuk masukan `KINEX`
KINEX	Program sub *dummy* faktor tanpa `KINEX` (sub rutin kosong)
KOPREG	Program sub *dummy* untuk akun tanpa pengendalian (sub rutin kosong)
SUCHET	Mendefinisikan lokasi tugas het-grid dan pengendalian `IFBH`
SUCHMI	Menetapkan panel kendali `IFBH` campuran
SYMBOL	Menetapkan `IFBER`
TFELD	Kendali perhitungan iteratif suhu padat
TNEU	Terkait relaksasi
TPROZ	Membuat temperatur-volume analisis untuk teras dan menghitung suhu bahan bakar mediumdan moderator (untuk daerah `HET`)
VORKON	Unsur hitung quarter-flaechen
WDUKON	Menghitung aksesibilitas panas
WKAP	Menghitung kapasitas panas untuk setiap waktu, untuk zone *mesh* dan bola
WKN	Memperhitungkan unsur dengan sumber panas konvektif
WKPT	Menghitung $\rho * C$ untuk meteri yang berbeda untuk Al_2O_3 dan tidak tergantung pada temperatur
WPKON	Menghitung sumber panas konvektif, kerapatan sumber dan volumen asosiasi
XKORR	Tidak tersedia penjelasan
XLAM	Menghitung aksesibilitas panas
XLAM1	Menghitung aksesibilitas panas anisotropis
XLAMT	Menghitung konduktivitas panas
XLAMT1	Karakterisasi temperatur anisotropis dan termperatur resistan pada arah-Y
ZKUGL	Menghitung jumlah Be di mesin HET dan mesin campuran

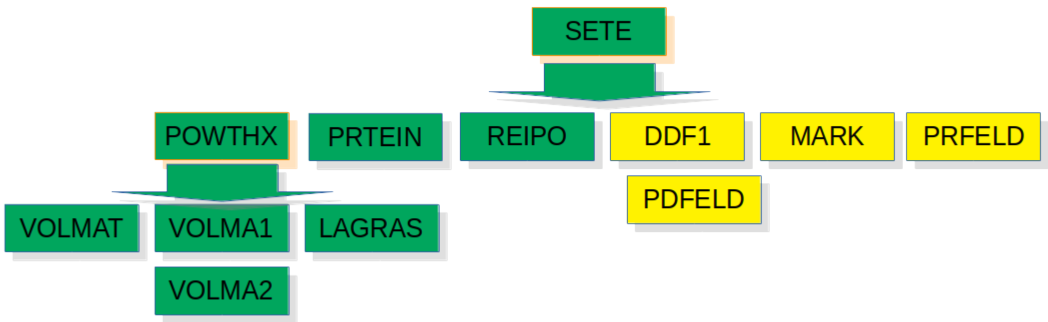


Gambar 2.3: Sub rutin `EINL1`

dalam informasi rapat daya. Sub rutin tersebut dalam Gambar 2.11 merupakan sub rutin 1.1, *Input Adapter*. Sedangkan diagram 1.3, *Output Adapter* merupakan sub rutin yang

Tabel 2.5: Daftar fungsi dan subrutin yang didefinisikan dalam program `THERMIX4.FOR`

Sub rutin	Dipanggil dari	Didefinisikan di	Keterangan
EINL	`THERMIX1.FOR`	`KONVEK1.FOR`	didefinisikan menggunakan `SUBROUTINE`
FRIST	`THERMIX1.FOR`	`VSOP0.FOR`	didefinisikan menggunakan `SUBROUTINE`
KONVEK	`THERMIX1.FOR`	`KONVEK1.FOR`	didefinisikan menggunakan `SUBROUTINE`
WTSTE1	`THERMIX1.FOR`	`THERMIX1.FOR`	dipanggil dengan `ENTRY`, tanpa definisi (kosong)
NACHW	`THERMIX1.FOR`	`DECHEAT.FOR`	didefinisikan menggunakan `SUBROUTINE`
DDF	`THERMIX1.FOR`	`THERMIX1.FOR` (dalam fungsi yang sama)	tidak ditemukan fungsi/sub rutin yang pernah menggunakannya
VOLMA1	`THERMIX3.FOR`	`THERMIX3.FOR`, sub rutin VOLMAT	dipanggil dengan `ENTRY`
VOLMA2	`THERMIX3.FOR`	`THERMIX3.FOR`, sub rutin VOLMAT	dipanggil dengan `ENTRY`
FRIST	`THERMIX4.FOR`	`VSOP0.FOR`	didefinisikan menggunakan `SUBROUTINE`

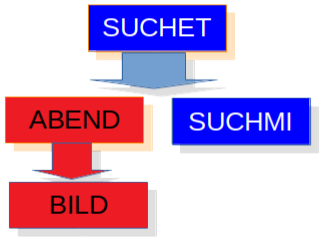


Gambar 2.4: Sub rutin `SETE`

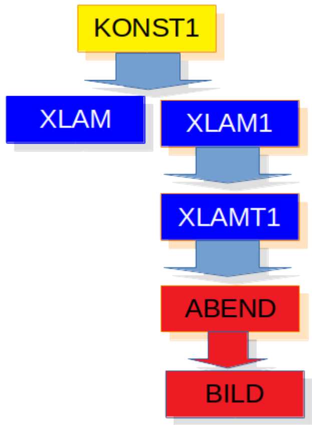
memformat hasil perhitungan distribusi temperatur sesuai dengan karakterisktik masukan TRIAC-BATAN [4].

Sub rutin 1.1 (*Input Adapter*) juga melingkupi daftar variabel yan digunakan. Sampai saat dokumen ini disusun, belum ada informasi yang berarti tentang peran dari sangat banyaknya variabel yang digunakan dalam kode sumber Thermix yang dibangun menggunakan Fortran. Variabel-variabel tersebut bahkan banyak yang dideklarasikan berulang, yang tidak mungkin diijinkan dalam konsep bahasa pemrograman saat ini.

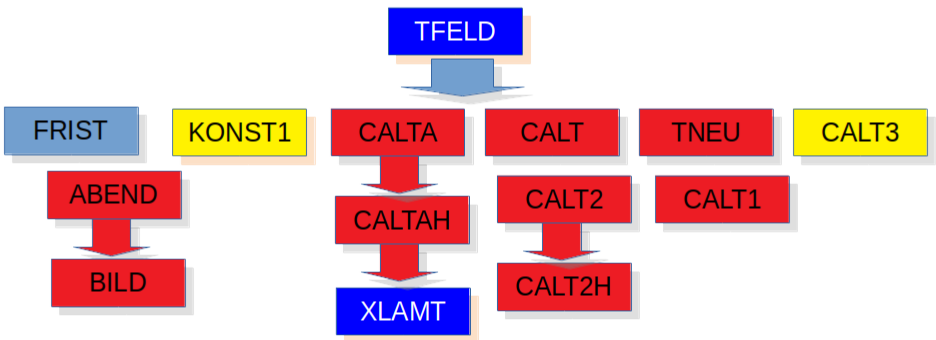
Variabel-variabel tersebut akan dideklarasikan dalam berkas yang diberi nama `globalVar.py`. Untuk variabel yang dideklarasikan dalam Thermix sebagai `COMMON`, variabel tersebut akan



Gambar 2.5: Sub rutin `SUCHET`



Gambar 2.6: Sub rutin `KONST1`



Gambar 2.7: Sub rutin `TFELD`

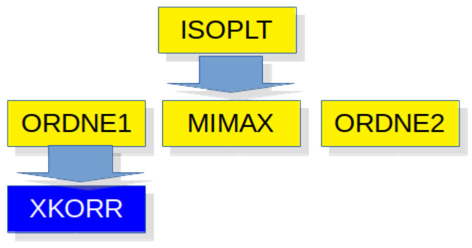
dideklarasikan dalam `python` sebagai `dictionary`. Elemen COMMON akan menjadi `elemen dictionary`. Sebagai contoh, variabel `COMMON` di `Fortran` (Listing 2.1) akan dideklarasikan sebagai dictionary di `python` (Listing 2.2).

Listing 2.1: Deklarasi variabel berjenis COMMON di Fortran

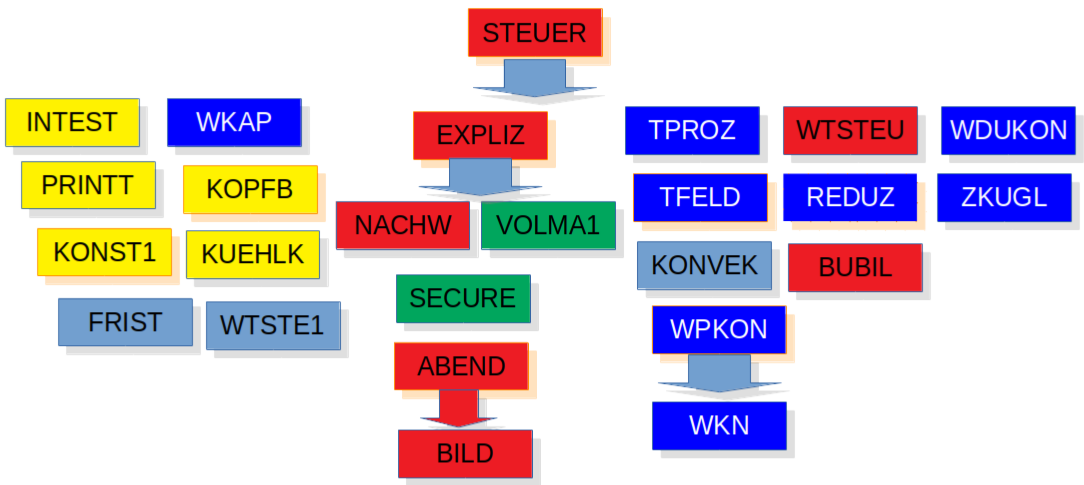
```
COMMON/DRUKK/MZ(40,25),MR(40,25),P(40,25),XKR(40,25),XKZ(40,25)
```

Listing 2.2: Deklarasi variabel berjenis dictionary

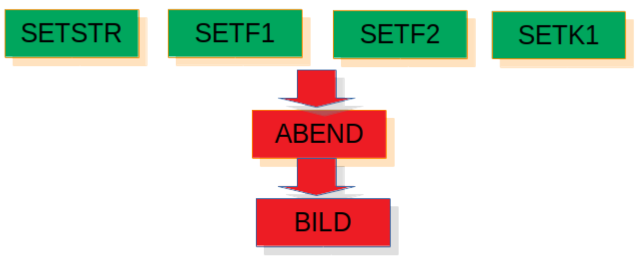
```
drukk={}
drukk['mz']=[]  """40x25 elements"""
```



Gambar 2.8: Sub rutin `ISOPLT`



Gambar 2.9: Sub rutin `STEUER`

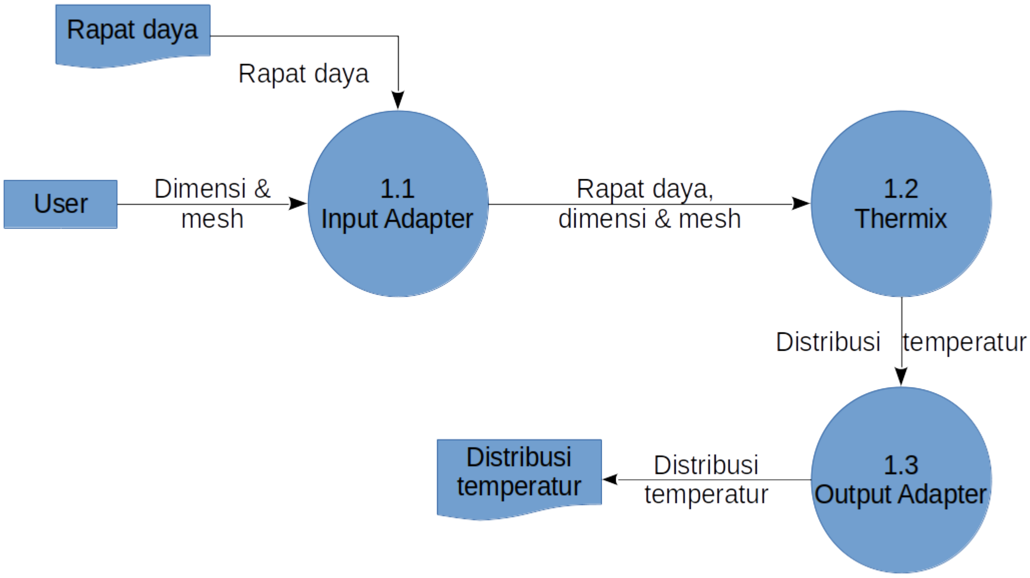


Gambar 2.10: Sub rutin `VARSET`

```
drukk['mr']=[]  """40x25 elements"""
drukk['p']=[]  """40x25 elements"""
drukk['xkr']=[]  """40x25 elements"""
drukk['xkz']=[]  """40x25 elements"""
```

Sub rutin perhitungan distribusi temperatur akan dijalankan oleh sub rutin 1.2, `THERMIX`. Sub rutin tersebut adalah sub rutin `MAITHX` yang disajikan pada Gambar 2.2. Sub rutin `MAITHX` menerima empat argumen, masing-masing adalah

- `N200`



Gambar 2.11: Diagram alir data level 1

- `NXS`
- `NDR`
- `KMAT`: jumlah nuklida yang dipertimbangkan dalam simulasi

Selanjutnya, sub rutin STEUER menerima argumen IFKON, ITLAM, TDIFF, NLOOP, IFRED, IFZW, ITM3, CP0, IFTEST, NHET, ZEITH, XFR, IEXPR, N200, NDR, NXS, POV, ZF, NRY, QNW, DELDZ, QTHX, dan WTGINT. Sub rutin `STEUER` disajikan pada Gambar 2.9. Terakhir, sub rutin `TFELD` akan menerima argumen ITLAM, OVRM, IFKO1, IFWARN, CP0, IFZENT. Sub rutin `TFELD` disajikan pada Gambar 2.7.

BAB 3

Rancangan Pengujian

Pengujian yang akan dilakukan pada Triamix adalah white box testing [7, 8]. Pengujian secara white box meliputi:

- *Unit testing*: merupakan pengujian unit perangkat keras atau lunak, maupun kelompok unitnya. Dalam hal ini, pengujian hanya akan difokuskan pada pengujian setiap fungsi dan modul.
- *Integration testing*: merupakan pengujian terintegrasi antar fungsi dan modul. Validasinya dilakukan terhadap hasil dari berkas masukan yang sama seperti telah dijelaskan dalam dokumen kebutuhan.

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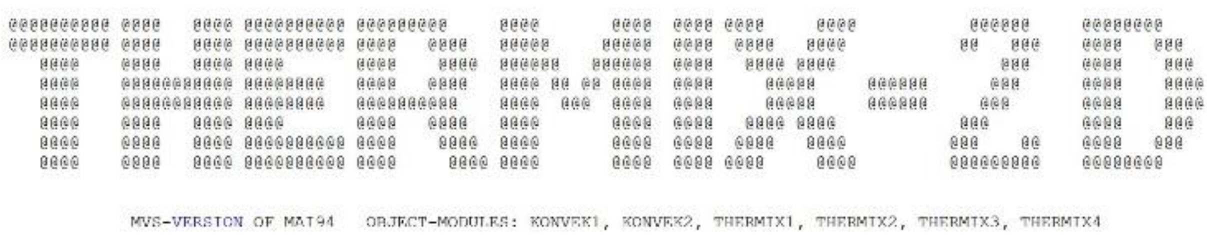

SAMPLE INPUT and MANUAL

Topan Setiadipura (tsdipura@batan.go.id)

Pusat Teknologi dan Keselamatan Reaktor Nuklir

BATAN

```
 0.      HTR-PM 250MWth  HDG 06/14 9.6% Bypass
 -1   0   2   3   0   0   0   02000 500   0  10 500  19   0
 250.0   0. 946.   0.01   1.7   0.6 5.E-4   10.   0.    0.
         0.       -236.    0   0   1   1
 24  43   0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  3  3  3  3  3  3  4  4  4  4  4  4  0  0  0  0  0
  2  2  2  2  2  2  4  4  4  4  4  4  0  0  0  0  0
  1  1  1  1  1  1  6  6  6  6  6  6  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  1  1  1  1  1  1  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  7  7  7  7  7  7  4 11  4  4  4 10  0  0  0  0  0
  8  8  8  8  8  8  8  8  4  4  4  9  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
  7  7  7  7  7  7  7  7  7  7  7  7  7 11 12 13 19
  3  3  3  3  3  3  4  4  4  4  4  4 10 11 12 13 19
  3  3  3  3  3  3  4  4  4  4  4  4 10 11 12 13 19
  3  3  3  3  3  3  4  4  4  4  4  4 10 11 12 13 19
  2  2  2  2  2  2  4  4  4  4  4  4 10 11 12 13 19
  1  1  1  1  1  1 16 16 16 16 16 16 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
```

```
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
  1  1  1  1  1  1  4 22  4  4  4 15 10 11 12 13 19
 17 17 17 17 17 17  4 22  4  4  4 15 10 11 12 13 19
 17 17 17 17 17 17  4 22  4  4  4 15 10 11 12 13 19
 18 18 18 18 18 18  4 22  4  4  4 15 10 11 12 13 19
  5  5  5  5  5  5  4 22  4  4  4 15 10 11 12 13 19
  5  5  5  5  5  5  4 22  4  4  4 15 10 11 12 13 19
  5  5  5  5  5  5  4 22  4  4  4 15 10 11 12 13 19
  5  5  5  5  5  5  4 22  4  4  4 15 10 11 12 13 19
  6  6  6  6  6  6  6  6  4  4  4 14 10 11 12 13 19
  8  8  8  8  8  8  8  8  8  8  8  8  8 11 12 13 19
 21 21 21 21 21 21 21 21 21 21 21 21 21 21 21 21 21
HET  1 -1  0 27  0  0  0  .613  3.02  0.       0.   0.0    0.   -1.0   0.
    0.387         6.    5
      5.0   24   17       0.0
      3.0   24   17       1.0
      1.0   24   17       1.0
      0.3   24   17       1.0
      0.0   24   17       1.0
VOI  2 -1  0  0  0  0  0    0. 0.001 .0030    0.    0.    0.    0.    0.
TRF  3  0 13  0  0  0  0   1.0  3.02  0.26    0.    0.    0.    0.    0.
SRI  4  0 13  0  0  0  0   1.0  3.02  0.26    0.    0.    0.    0.    0.
CRF  5 -1 13  0  0  0  0  .965  3.02  0.26    0.    0.    0.    0.    0.
BRF  6 -1 13  0  0  0  0  .965  3.02  0.26    0.    0.    0.    0.    0.
TPL  7  0  0  0  0  0  0    1. 4.212  0.17    0.    0.    0.    0.    0.
BPL  8  0  0  0  0  0  0    1. 4.212  0.17    0.    0.    0.    0.    0.
SHI  9  0  0  4 10  0  0    0. 0.001    0.   90.   0.8    0.    0.    0.
CBL 10  0  0  0  0  0  0   .85 4.017 0.178    0.    0.    0.    0.    0.
SHE 11  0  0  4 10  0  0    0. 0.001    0.   90.  0.85    0.    0.    0.
RPV 12  0  0  0  0  0  0   .85 4.350  0.40    0.    0.    0.    0.    0.
AIR 13  0  0  4 10  0  0    0. 0.001 .0003    1.  0.91    0.    0.    0.
IPL 14 -1 13  0  1  0  0   0.8  3.02  0.26    0.    0.    0.    0.    0.
RCH 15 -1 13  0  0  0  0  .705  3.02  0.26    0.    0.    0.    0.    0.
SRA 16 -1 13  0  0  0  0   0.8  3.02  0.26    0.    0.    0.    0.    0.
BRP 17 -1 13  0  0  0  0  .807  3.02  0.26    0.    0.    0.    0.    0.
HGK 18 -1 13  0  0  0  0   0.8  3.02  0.26    0.   0.0    0.    0.    0.
SBR 19  1  0  0  0  0  0    0.    0.    0.    0.    0.   70.    0.   0.5
TBR 20  1  0  0  0  0  0    0.    0.    0.    0.    0.   20.    0. 1.e-6
BBR 21  1  0  0  0  0  0    0.    0.    0.    0.    0.   20.    0. 1.e-6
```

```
SAS 22 -1 13  0  0  0  0   0.8  3.02  0.26    0.    0.    0.    0.    0.
SR0 23  0 13  0  0  0  0  .942  3.02  0.26    0.    0.    0.    0.    0.
CCH 24  0 13  0  0  0  0  .001  3.02  0.26    0.    0.    0.    0.    0.
    0    6        0.       70.      150.      185.      235.      290.
    0    6     -200.      -50.      600.      800.     1200.     1400.
      280.      280.      280.      280.      280.      280.
      420.      420.      415.      405.      380.      315.
      815.      815.      740.      725.      480.      360.
      990.      995.      920.      880.      480.      360.
     1010.     1010.      960.      860.      485.      360.
      850.      860.      870.      870.      785.      475.
     0  0 37         200.           0.          0.          0.          0.
         10.          1.      1600.          0.          0.        0. 01
     1.E-5      0.01       0.5        1.      0.02 1000 5000    5
        6.     0.390     5190.     0.667     70.0     0
     1     0     1     0     0    0.    0.    1.  0.39    0.    0.    0.
     2    -1     5     0     0   -1.    0.    0.    1.  170.    0.    0.
     3     0     0     0     0    0.    0.    0.    0.    0.    0.    0.
     4     0     0     0     0    0.    0.    0.    0.    0.    0.    0.
     5     0     0     0     0    0.    0.    0.    0.    0.    0.    0.
     6     0     5     0     0   -1.    0.    0.   0.2  33.5    0.    0.
     7     0     2     0     0   -1.    0.    0.   0.2   7.0    0.    0.
     8     0     5     2     0   -1.    0.    0.   0.2  14.4    0.    0.
     9     0     5     0     0   -1.    0.    0.   0.2  33.5   96.0 250.
    10     0     2     0     0   -1.    0.    0.  0.30  17.0    0.    0.
    11     0     2     0     0   -1. .600     0.  0.22  13.0    0.    0.
```

2.5 THERMIX/KONVEK, 2d-Thermal Hydraulics. TX1 - KX5

Cards TX1 - TX23, KX1 - KX5

Card TX1		Format (F4.1,4X,16A4)
1	TXNEW	= 0.: New THERMIX input corresponding to subsequent input cards. = 1.: Old input cards (before the year 1994).
2 : 17	TITLE(I), I=1,16	Literal description.

Card TX2		Format (18I4)
		Steering of the calculation:
1	IFKON	= 0: THERMIX calculation only, no KONVEK. **Note:** The input of KONVEK is needed anyway. ≠ 0: THERMIX-KONVEK coupling: =-1: Coupling between the temperatures of gas and solid material by heat transfer coefficient α. Recommended for steady state calculations, not valid in transient runs. = 1: Coupling via the source/sink distribution. = 2: Internal decision of coupling (not recommendable).
2	IHMAX	= 0: Temperature calculation in fuel elements by matrix-elimination (Gauss). > 0: Approach by iteration (Gauss-Seidel). Not valid for graphite spheres in transient runs.
3	IPRINT	=-2: Minimum output. = 1: Recommendable output. = 2: Maximum output. ≥ 3: In addition distribution of heat sources.
4	IPUN	= 0: No effect.

		= 3: Write restart on the data set no. IREST.
5	IFRSTA	= 0: No restart. > 0: Restart. Starting temperature distribution is read from data set IREST. (In case IREST = 0 the code requires the former input cards TH20 - TH22). Homogenized structure of fuel elements: = 1: Time starts at T = 0. = 2: Time scale continues. Heterogeneous structure of fuel elements: = 3: Time starts at T = 0. = 4: Time scale continues.
6	INTVAL	= 0: Steady state run. > 0: Number of time steps for the transient run. (≤ 50) = 1: Coupling with VSOP: The time steps are given by the VSOP-burnup scheme (JNSTOP, DELDAY on card R14).
7	KOMVAR	= 0: Normal.
8	IFRED	= 0: Power distribution independent of the time. = 3: Explicite calculation of the decay heat according to the explicite life history of the fuel elements and to the DIN 25485. = 1: Decay heat function of OTTO scheme. = 2: Decay heat function of MEDUL or implicite formular $0.0622 * (T^{-0.2} - (T+T_0)^{-0.2})$.
		Iterations:
9	MITMAX	> 0: Maximum number of iterations of temperature calculation. = 0: Default value = 2000
10	IKORM	> 0: Maximum number of changes of the relaxiation factor. = 0: Default value = 100
11	IFREL	= 0: Inner iteration in radial direction (I). = 1: Inner iteration in axial direction (N).
12	ITLAM	> 0: Drop recalculation of temperature dependent material data for ITLAM−1 time steps (only for steady state THERMIX-KONVEK iteration). = 0: Default value = 10

13	NLOOP	> 0: Maximum number of THERMIX-KONVEK ("Loop") iterations (steady state). = 0: Default value = 100
		Datasets:
14	IREST	= 0: No effect. > 0: Data set no. for storing the temperature field of steady state THERMIX runs. Must also be defined in transient THERMIX run, starting from this temperature field.
15	IEXPR	= 0: No effect. > 0: Data set no. for temperature field for the 2D-plots.

Card TX3		Format (12F6.1)
1	QNORM	> 0.: Total power (MW). Input power field is normalized to QNORM. In transient run the QNORM defines the reactor power to which the decay heat is related. = 0.: Drop normalization.
2	Z0	Axial position of the upper edge of the reactor fuel zone (cm). (Normally = 0.)
3	ZU	Axial position of the lower edge of the reactor fuel zone (cm). (Height of the core)
4	ETHA	> 0.: Convergence criterium for local THERMIX temperature field. (°C) = 0.: Default value = 0.01
5	OVMAX	> 0.: Maximum relaxiation factor. = 0.: Default value = 1.7
6	OVMIN	> 0.: Minimum relaxiation factor. = 0.: Default value = 0.6
7	TDIFF	> 0.: Relative convergence criterium of the time independent THERMIX-KONVEK iteration. = 0.: Default value = 0.0005
8	EFAK	> 0.: Multiplication factor for maximum allowable error le-

		vel, which stops the run. = 0.: Default value = 1.
9	DTVOR	> 0.: Maximum of the relative temperature change ΔT / T < DTVOR in a time interval Δt of a transient run. The time intervals Δt are correspondingly adapted. = 0.: Default value = 0.05
10	ZEITMI	Minimum length of the time intervals Δt in the transient run.

Card TX4 only when INTVAL > 0 on card TX2.

Card TX4		Format (3(F6.1,2I2,E10.3))
1	DZEIT(1)	Length of the first little time interval. (sec)
2	NPRIN(1)	> 0: Print the fields of temperature and streaming for all NPRIN little time steps. = 0: Default value = 50
3	NKONV(1)	> 0: Run the KONVEK every NKONV little time step (only when IFKON ≠ 0 on card TX2). = 0: Default value = 1
4	ZEI(1)	End of this 1. large time interval. (hours)
		Same for the next large time interval:
5	DZEIT(M)	= 0.: Free choice of the little intervals. < 0.: Also free choice, but maximum = |DZEIT(M)|. (sec) > 0.: Constant length of the little time intervals. (sec)
6	NPRIN(M)	As above.
7	NKONV(M)	As above.
8	ZEI(M) M=2,INTVAL	As above. **Note:** In coupling with VSOP (INTVAL = 1) only the first large time interval must be defined, and DZEIT(2) holds for the further time history, which is steered by the VSOP burn-up time steps.

Card TX5		Format (2E12.5,12I4)
1	RAD0	Position of the first radial mesh point I = 1. (cm) (Normal = 0.).
2	PHI0	Position of the first axial mesh point N = 1. (cm) (Normal = –height of compositions above the core). **Note:** The upper edge of the core must be located at the position 0. The axial core dimension is counted from top to bottom.
3	IFRFI	= 0: Normal. = 1: Adiabatic boundary condition in the first radial mesh.
4	IFRFA	= 0: Normal. = 1: Adiabatic boundary condition in the last radial mesh.
5	IFRFL	= 0: Normal. = 1: Adiabatic boundary condition in the first axial mesh.
6	IFRFR	= 0: Normal. = 1: Adiabatic boundary condition in the last axial mesh.

Card TX6		Format (18I4)
1	KMAX	Number of compositions to be defined on cards TX10. (≤ 31)
2	NTHX	Data set no. of BIRGIT-library (see Section 2.3, card B11).
3	IFTEST	= 0: Normal. = 1: Testoption. For checking the input, the code runs without iterations.

Cards TX7 - TX9 define the coarse mesh grid, a subdivision of the fine grid, and the positions of KONVEK- and THERMIX-compositions in the coarse grid.

Card TX7		Format (6(I3,F9.0))
1	IC(1)	Number of fine mesh intervals in the 1. coarse radial interval.

2	C(1)	Width of the 1. coarse radial interval. (cm)
.	.	
.	.	
	IC(I)	> 0: Number of fine mesh intervals in the I. coarse radial interval. = 0: End of radial mesh definition.
	C(I)	Width of the I. coarse radial interval. (cm)

Card TX8		Format (6(I3,F9.0))
1	NC(1)	Number of fine mesh intervals in the 1. coarse axial interval.
2	C(1)	Width of the 1. coarse axial interval. (cm)
.	.	
.	.	
	NC(I)	> 0: Number of fine mesh intervals in the I. coarse axial interval. = 0: End of axial mesh definition.
	C(I)	Width of the I. coarse axial interval. (cm)

Two sets of cards TX9:
First set with KONVEK compositions as defined on cards KX3. One card TX9 is required for each axial coarse mesh "N" (even when no KONVEK composition is present in this mesh).
Second set of cards TX9 is to be given subsequently, containing THERMIX compositions as defined on cards TX10 - TX13.

Card TX9		Format (24I3)
1	KOC(1,N)	> 0: Id. no. of composition in the 1. radial coarse mesh. = 0: No composition is present.
.	.	
.	.	
I	KOC(I,N)	> 0: Id. no. of composition in the I. radial coarse mesh.

		= 0: No composition is present.

One card TX10 (optionally followed by TX11 - TX13) for each of the KMAX different THERMIX compositions.

Card TX10		Format (A3,7I3,8E6.0)
1	BEM	XYZ: Literal description of this composition. HET: Temperatures are calculated in the inner of the fuel elements. Analysis of temperature/volume. COR: Analysis of temperature/volume for this composition.
2	II	Id. no. of this composition.
3	IFTV	= -1: "Solid material zone". Temperature calculation comprises the heat exchange with the coolant of KONVEK by source/sink heat transfer. = 0: "Solid material zone". No heat exchange with the coolant is involved. = 1: "Fluid zone". No temperature calculation is performed for this zone. Coupled with the neighbours by the heat transfer coefficient ALP on this card. **Note:** For instance these zones are used as the heat sink of the liner. At the top and right of the reactor one mesh is sufficient for this zone. At the bottom two meshes are required.
4	IFWKT	= 0: Heat capacity given by C on this card. > 0: Identification no. of the material function for temperature dependent heat capacity (see Tab. VIII).
5	IFLT	= 0: Thermal conductivity λ given by LAM on this card. > 0: Identification no. of the material function for temperature and dose dependent λ (see Tab. IX). = 7: The temperature dependent function of id.no. = 7 uses LAM0 of this card as $\lambda(T = 0°C)$. = 4: In case of EPS > 0. (see below) the function uses LAM0 of this card as pressure (bar) of the gas in the gap. In case of EPS = 0. the function uses helium at the pressure 1 bar.
6	IDIR	Only when EPS > 0.:

		= 0: Radiation in radial direction. = 10: Exclusively in radial direction. = 1: Radiation in axial direction. = 11: Exclusively in axial direction.
7	NTVAR	= 0: No effect. > 0: In case of fluid zone (IFTV = 1) provide time dependent temperatures on card TX13.
8	IDUM	Dummy.
9	RHO	Volumetric fraction of solid material in this composition. RHO is used for calculation of the heat capacity.
10	C	= 0.: When IFWKT > 0. > 0.: Heat capacity of the solid material. ($J/cm^3/°K$)
11	LAM	= 0.: When IFLT > 0. > 0.: Thermal conductivity in solid material zones (only when IFTV = 0 or -1). (W/cm/°K)
12	LAM0	= 0.: Normal. > 0.: When IFLT = 7, LAM0 is $\lambda(T = 0°C)$. When IFLT = 4 and EPS > 0., LAM0 is the pressure of the gas in this composition.
13	EPS	= 0.: No heat radiation. > 0.: Coefficient of emission for the heat radiation between the side walls of the composition. (Maximum number of compositions with heat radiation = 19).
14	TVOR	= 0.: Start up temperature field results from the input temperature field of the cards TX14 - TX16. > 0.: Start up temperature of this composition (°C) superior to the startup temperatures of the cards TX14 - TX16.
15	WPRR	= -1.: Field of power density results from VSOP. It will be normalized to QNORM (card TX3). ≥ 0.: Power density of this composition. (W/cm^3)
16	ALP	= 0.: No effect. > 0.: Heat transfer coefficient in fluid zones ($W/cm^2/°K$) (only when IFTV = 1). **Note:** ALP ≃ 0.5: Temperature at the boundary close to that of this fluid zone. ALP ≃ 0.01: Temperature at the boundary close to that of the adjacent zone.

Cards TX11, TX12 only when BEM = "HET" on card TX10.

Card TX11 Format (2E10.3,I5)

1	HEPS	> 0.: Void fraction in the pebble bed. = 0.: Default value = 1 - RHO (on card TX10).
2	HKUG	Diameter of the spherical fuel element. (cm)
3	NHZON	Number of radial mesh intervals in the sphere. (≤ 5)

I = 1,NHZON cards TX12.

Card TX12 Format (E10.3,2I5,E10.3)

1	DI(I)	Inner diameter of the Ith radial mesh interval. (cm) **Caution:** I = 1 ... counts from the outer shell towards the inner!
2	NH1(I)	Id.no. of temperature dependent thermal conductivity (see IFLT on card TX10).
3	NH2(I)	Id.no. of temperature dependent heat capacity (see IFWKT on card TX10).
4	XFW(I)	Shielding factor of the power density in the Ith shell (in the fuel shells normally = 1.).

Card TX13 only when NTVAR > 0 on card TX10.

Card TX13 Format (14F5.2)

1	TKV(I)	Temperature. (°C)
2 .	ZEIV(I) I = 1,NTVAR	Time. (h)

Card TX14		Format (2I5,6E10.3 / 7E10.3)
1	IPOLI	= 0: Linear interpolation of temperature input of cards TX16. = 1: Logarithmic interpolation (radial).
2	IE	= 0: Drop reading of cards TX15, TX16. > 0: Number of radial mesh points for startup temperature input.
3 .	RE(I), I = 1,IE	Radial mesh points for startup temperature input on cards TX16. Continuation cards according to given FORMAT.

Cards TX15 - TX16 only when IE > 0 on card TX14.

Card TX15		Format (2I5,6E10.3 / 7E10.3)
1	IPOLN	= 0: Linear interpolation of temperature input of cards TX16. = 1: Logarithmic interpolation (axial).
2	NE	Number of axial mesh points for startup temperature input.
3 .	PHE(I), I = 1,NE	Axial mesh points for startup temperature input on cards TX16. Continuation cards according to given FORMAT.

One card TX16 for each of the N = 1,NE axial mesh points.

Card TX16		Format (7E10.3)
1 : IE	T(I,N), I = 1,IE	Startup temperature at mesh point I,N.

Card TX17		Format (I6,2I3,5E12.5)
1	MZNORM	= 0: No effect. > 0: Start the time counting from the present THERMIX-restart.
2	MC2	= 0: No effect. > 0: Read card TX18 with definition of Thermix-compositions for time dependent output of the "heat storage".
3	NGEOM	Data set no. of CITATION geometry input as prepared in BIRGIT (normally 37).
4	CIZET0	Difference between the axial zero points of CITATION and THERMIX.
5	SIG	= 0.: Default value = 1. > 0.: Factor to be multiplied with the explicitely evaluated decay heat function.
6	RL	Avg. power density. (MW/m^3)
7	SM	Avg. heavy metal content per fuel element (incl. graphite spheres). (g/sphere)
8	BURN	Avg. burnup of spent fuel. (MWd/kg_{HM})

Card TX18 only when MC2 > 0 on card TX17.

Card TX18		Format (3I1)
1 : KMAX	IKO(I), I = 1,KMAX	"Heat storage" id.-no. to which the heat of THERMIX-composition I shall be added up. Possible "heat store" id.numbers: 5, 6, 7, 8, 9.

Card TX19		Format (5E12.5,E10.3,2I1)
1	DELTAT	Desired temperature interval (ΔT) for the numerical integra-

		tion inside the fuel elements (°C). Up to 200 intervals are possible between TU and TO.
2	TU	Lowest surface temperature of fuel elements.
3	TO	Highest temperature at center of the fuel elements.
4	WRIT	≥ 0.: Program uses standard data of the thermal conductivity as a function of fast neutron dose and temperature. > 0.: Various test output of temperature integration inside of the fuel elements. < 0.: Thermal conductivity as a function of fast neutron dose and temperature will be given on the cards TX20-TX23.
5	R0	= 0.: No effect. > 0.: Inner radius of the fuel matrix (if shell ball is considered).
6	A0	Initial enrichment of the fuel. (%)
7	ISTANZ	= 0: No effect. > 0: Punch T and relative fuel matrix volume in the corresponding ΔT averaged over the total core.
8	IFUGRA	= 0: Fuel element temperature calculation by direct integration. > 0: Fuel element temperature calculation from THERMIX.

Cards TX20 - TX23 only when WRIT < 0. on card TX19.

Card TX20		Format (12I6)
1	NSCH	Number of different functions of the thermal conductivity. (≤ 2)
2 .	KTEM(N), N=1,NSCH	Number of temperature mesh points for which the thermal conductivity will be given. (≤ 10)
. .	LFAD(N), N=1,NSCH	Number of fast neutron dose mesh points for which the thermal conductivity will be given. (≤ 10)

For each thermal conductivity function one set of cards TX21 - TX23.

Card TX21		Format (6E12.5)
1 .	TSTUE(K), K = 1,KTEM	Temperature mesh points.

Card TX22		Format (6E12.5)
1 .	DSTUE(L), L = 1,LFAD	Mesh points of fast neutron dose.

For each of the LFAD mesh points of the fast neutron dose one card TX23.

Card TX23		Format (6E12.5)
1 .	WLSTUE(K), K = 1,KTEM	Thermal conductivity at the temperature mesh points. (W / cm / °C)

Card KX1		Format (5E10.3,4I5)
1	EPSI1	> 0.: Relative criterion of convergency for gas temperature. = 0.: Default value = 1.E-5
2	EPSI2	> 0.: Criterion of convergency for mass flow. = 0.: Default value = 0.01
3	OVM1	> 0.: Extrapolation factor for iterations on mass flow (every 10 iterations an extrapolation is provided with 1 + OVM1). = 0.: Default value = 0.5
4	OVM2	> 0.: Relaxation factor for iterations on mass flow. = 0.: Default value = 1.0
5	EPSI4	> 0.: Relative criterion of convergency of the avg. gas tem-

		perature in the outer iterations between gas temperature and mass flow. = 0.: Default value = 0.02
6	ITM1	> 0: Maximum number of iterations for gas temperature. = 0: Default value = 100
7	ITM2	> 0: Maximum number of iterations for mass flow. = 0: Default value = 200
8	ITM3	> 0: Maximum number of outer iterations between gas temperature and mass flow. = 0: Default value = 5

Card KX2		Format (5E10.3,4I5)
1	DKUG	> 0.: Diameter of the spheres. (cm) = 0.: Default value = 6.0
2	EPSI	> 0.: Void fraction in the core. = 0.: Default value = 0.39
3	CP	> 0.: Specific heat capacity of the gas. (J/Kg/°K) = 0.: Default value = 5195.
4	PRAN	> 0.: Prandtl-constant of the gas. = 0.: Default value = 0.66
5	DRUCK	> 0.: Pressure of the gas. (bar)
6	IFZDR	= 0: Pressure of the system is constant. = 2: Pressure changes according to temperature. Gas inventory is constant.

One card KX3 for each of the KONVEK compositions as defined on the first set of cards TX9.

Card KX3		Format (5I6,7E6.0)
1	KR	Id.no. of this composition.

2	IFBQ	= 0: When IFTV = -1 on card TX10. Convective heat source is computed in the meshes of this composition. = -1: No convective heat source evaluation (e.g. in voids).
3	IFBR	Type of composition: = 0: No gas streaming. = 1: Pebble bed. = 2: Vertical pipes. (≤ 8) = 5: Horizontal void (no more than one mesh over its thickness).
4	IFZST	= 0: No time dependent mass flow. = 1: Given by input on cards KX4, KX5. = 2: Mass flow according to conservation law.
5	IFZTF	= 0: No time dependent gas inlet temperature. = 1: Given by input on cards KX4, KX5.
6	PVOR	> 0.: Pressure at beginning of iterations. (bar) = -1.: Pressure = pressure of the gas (see DRUCK on card KX2).
7	XKON	Additional pressure drop relative to computed pressure drop over the length of the channel (only when IFBR = 2). (1/cm)
8	ALPHA	> 0.: Coefficient of heat transition between gas and solid material (W/cm^2K). In pebble beds α is internally calculated, use ALPHA = 1. as an internal multiplication factor. = 0.: Internal calculation of α. In voids (IFBR = 5) use α = 0.
9	EPSIL	Volumetric fraction of void in this composition.
10	DHYD	Hydraulic diameter (cm). Only when IFBR ≥ 2.
11	STZUK	Source of mass flow. (kg/s)
12	TFLVOR	Temperature of inlet gas. (°C)

Cards KX4, KX5 only when at least one of the IFZST and/or IFZTF = 1 on cards KX3.
Up to 100 time steps can be defined by cards KX5. Linear interpolation is provided between the time steps.

Card KX4		Format (4I10)
1	IZK1	Number of compositions with time dependent input of mass flow and/or gas inlet temperature. (≤ 3)
2 .	IZKOM(I), I = 1,IZK1	Id.no. of the I-th composition.

Card KX5		Format (8F9.3)
1	ZVOR	> 0.: Time. (min) = 0.: End of the input of cards KX5.
2	ZDR	Pressure. (bar)
3	ZST(I)	Source of mass flow of the composition no. IZKOM(I). (kg/s) (Only when IFZST(I) = 1).
4 . .	ZTF(I) I = 1,IZK1	Temperature of inlet gas of the composition no. IZKOM(I). (°C) (Only when IFZTF(I) = 1).