4 EXAMPLES

Summary of the examples

	Mat.	Prof.	Exposure	Protection	Options1	Options2
Ex. 1:	Alum	Box	Fully exp.	Fully prot.	Fire exp. *a)*	Protection
Ex. 2:	Alum	Box	Partly exp.	Fully prot.	Fire exp. *b)*	Protection
Ex. 3:	Alum	Box	Partly exp.	Fully prot.	Fire exp. *c)*	Protection
Ex. 4:	Alum	Box	Partly exp.	Partly prot.	Fire exp. *d)*	Protection
Ex. 5:	Alum	I-prof	Partly exp.	Partly prot.	Fire exp. *e)*	Protection
Ex. 6:	Alum	I-prof	Partly exp.	Partly prot.	Displ. lim.	Temp. dep
Ex. 7:	Steel	Pipe	Partly exp.	Unprotected	User source	Radiation
Ex. 8:	Steel	Pipe	Partly exp.	Unprotected	User source	Radiation
Ex. 9:	Steel	I-prof	Fully exp.	Unprotected	User source	Temp. hist.
Ex. 10:	Steel	I-prof	Fully exp.	Unprotected	User source	Temp. hist.
Ex. 11:	Steel	I-prof	Partly exp.	Unprotected	User source	Temp. hist.
Ex. 12:	Steel	I-prof	Partly exp.	Unprotected	User source	Temp. hist.
Ex. 13:	Steel	I-prof	Partly exp.	Unprotected	Radiation	Temp. hist.
Ex. 14:	Steel	Pipe	Fully exp.	Unprotected	Kameleon	Static ana.
Ex. 15:	Steel	Pipe	Fully exp.	Unprotected	Kameleon	Temp. sim.

1. Introduction

1.1 General information

This manual contains some examples that describe the method for fire analysis by use of FAHTS and USFOS.
FAHTS and USFOS are interlinked. Both are needed for a fire analysis of a structure. The output from FAHTS is input for USFOS.

The FAHTS input can be given in one or two files. In this manual all input are separated in a *Control file* and a *Structure file*. (See Figure 1.1-1 for a *Structure file*.)

The input contains information about the heat source, thermal parameters for the structure and insulation, the structure with node numbers, co-ordinates, elements, cross-section geometry and mechanical loads. It is not necessary to give commands with default values if the default value is suitable.

The output includes an out file Figure 1.1-2(short version), which contains a summary of the input and the temperature analysis done by FAHTS. The results include Time, Accumulated energy, Max heat input and Max/Min temperature after each load step. Another output is the *Beltemp file*, Figure 1.1-3, which includes the temperature increment of the elements for each load step of the fire load.

Some of the files shown in this introduction chapter are not included in the examples. This is because they take up too much space, and because they have no importance to this manual.

Filenames used in the examples:

File type:	**File name:**
FAHTS Control file	fahts.fem
USFOS Control file	usfos.fem
FAHTS out file	resf.out
USFOS out file	resu.out
Structure file	stru.fem

```
HEAD            Structure file

                 Single beam
'---------------------------------------------------------------------------
'               ELEMENT AND NODE NUMBERS
'---------------------------------------------------------------------------
'               * Node co-ordinates. Boundary conditions *
'               Node ID    X       Y       Z       Boundary code
'                                                x  y z  rx  ry  rz
 NODE               1    0.000   0.000   0.0     1  1 1  1   0    0
 NODE               2    2.200   0.000   0.0
 NODE               3    4.400   0.000   0.0     0  1 1  1   0    0
'
'
'               * Element numbers and node numbers. Geometry ID  *
'               Elem_ID   np1     np2   material   geom  lcoor  ecc1  ecc2
 BEAM              12      1       2       1        10
 BEAM              23      2       3       1        10

'---------------------------------------------------------------------------
'               CROSS-SECTION GEOMETRY
'---------------------------------------------------------------------------
'               Geom_ID    H     T-side  T-bott  T-top   Width
 BOX               10    0.300   0.008   0.008   0.008   0.200
'
'---------------------------------------------------------------------------
'               LOAD CASES
'---------------------------------------------------------------------------
'               Load_case Node_ID  Fx      Fy      Fz
 NODELOAD           1       2       0       0     -1.0E4
'
'
'               Load_case  AccX   AccY    AccZ
 GRAVITY             2      0      0     -9.81
```

Figure 1.1-1: Structure file for FAHTS and USFOS, ***stru.fem***.

```
                       **********************************
                       ******* F   A   H   T   S  *******
                       **********************************

              ======   A N A L Y S I S    P A R A M E T E R S   ======

                  F A H T S temperature simulations
                    Single beam, box cross-section
                             Example No. 1

                 Number of nodal points                =     3
                 Number of elements                    =     2
              +++++
          FAHTS
           Step       Time      Accum.       Max heat      Max         Min
            no.                 energy        input       temp.       temp.
                       (s)       (J)          (W/m2)     (degr C)    (degr C)
             1       36.00    6.338E+04    1.13E+03       16.0        14.9
             2       72.00    2.972E+05    2.62E+03       19.4        15.3
             3      108.00    7.562E+05    4.69E+03       26.2        16.5
             4      144.00    1.455E+06    6.45E+03       36.4        19.1
             5      180.00    2.371E+06    8.18E+03       49.9        23.3
             6      216.00    3.405E+06    8.39E+03       65.0        29.2
             7      252.00    4.441E+06    8.29E+03       80.0        36.5
             8      288.00    5.478E+06    8.49E+03       94.8        44.9
             9      324.00    6.515E+06    8.38E+03      109.4        53.9
            10      360.00    7.548E+06    8.57E+03      123.8        63.2
            11      396.00    8.579E+06    8.45E+03      138.0        72.7
            12      432.00    9.609E+06    8.64E+03      151.9        82.5
            13      468.00    1.064E+07    8.51E+03      165.6        92.8
            14      504.00    1.165E+07    8.39E+03      178.9       103.3
            15      540.00    1.266E+07    8.56E+03      191.9       113.7
            16      576.00    1.366E+07    8.44E+03      204.8       124.0
            17      612.00    1.464E+07    8.31E+03      217.3       134.4
```

*Figure 1.1-2: Out file from FAHTS analysis****, resf.out***.

```
'                     ****************************
'                     ** Temperature increments  **
'                     **       calculated        **
'                     **           by            **
'                     **       F A H T S         **
'                     ****************************
'             load case   time
 LCASETIM         4       360.0
'
'             load_case  element     Mean        Gradient      Gradient
'                 no     number   temperature     Y-dir        Z-dir
'                                 (increment)   (increment)  (increment)
 BELTEMP          4        12       103.722       -.088        -171.821
 BELTEMP          4        23       103.722       -.088        -171.818
'
'             load_case   time
 LCASETIM         5       720.0
'
'             load_case  element     Mean        Gradient      Gradient
'                 no     number   temperature     Y-dir         Z-dir
'                                 (increment)   (increment)   (increment)
 BELTEMP          5        12       117.532       -.274         -79.993
 BELTEMP          5        23       117.532       -.274         -79.984
'
'             load_case   time
 LCASETIM         6      1080.0
'
'             load_case  element     Mean        Gradient     Gradient
'                 no     number   temperature      Y-dir        Z-dir
'                                 (increment)   (increment)  (increment)
 BELTEMP          6       12      100.828        -.516        -9.241
 BELTEMP          6       23      100.827        -.516        -9.225
```

*Figure 1.1-3: Beltemp file from FAHTS analysis****, resf_beltemp.fem****.*

The *Beltemp file* from FAHTS is one of the input files for USFOS. Other input for USFOS is in this manual separated in two files, a *Control file* and a *Structure file*. Before running USFOS it can be smart checking out file and inspecting in XFOS. USFOS gives a *Status file*, an out file and a raf-file. The *Status file* (see Figure 1.1-4) contains a short summary of the results from USFOS. Among other things, time before yield and plastic hinge, and utilization of the beam.
The USFOS .out file contains a summary of the input and a list of displacement and reaction forces for each load step.
The raf-file contains all the information needed for a view in XFOS. This is not a legible file.

```
         --- U S F O S   A N A L Y S I S  S T A T U S ---

               U S F O S progressive collapse analysis
                   Single beam, box cross-section
                           Example No. 1

                        Input files:
                                     usfos.fem
                                      stru.fem
                                  res_beltemp.fem

Number of nodal points               :                         3
Number of elements                   :                         2

                                                                 Time
First yield at                       :                         1146.413
First plastic hinge at               :                         1206.374
No buckling detected
Exceeding utilization threshold of   :     1.10 at :           1207.094
Max number of negative pivot element :        1 at :           1207.094
Analysis terminated at               :                         1207.094

                --    Yielding Status    --
Elem ID  Position   Cross sect.                              Time
                    utilization
   12     node 2        .83                                    1146.413
   13     node 1        .83                                    1146.413

                --    Plastic hinge Status   --
Elem ID  Position   Cross sect.                           Time
                    utilization
   12     node 2       1.00                                    1206.374
   23     node 1       1.00                                    1206.734

                -- Elements Exceeding utilization of   1.10  --
Elem ID  Position   Cross sect.                                  Time
                    utilization
   23     node 1       1.11                                    1207.094

      ----- E N D   A N A L Y S I S   S T A T U S -----
```

Figure 1.1-4: Status-file from USFOS, ***resu_status.text***.

It's important to write input files in an orderly way, to obtain a good readability. This makes it easier to find errors and correct them, and it's easier to see what the file contains.
Space is used as the only dividing sign. The number of spaces is of no importance. It's therefore possible to line up the numbers under each other.
Please note that the program reads character by character, and a command lasts until a new command is given.

It is possible to write explanations to the commands and make "headings" as long as one of the comment characters are put in front. See USFOS User's Manual. The program will ignore the text behind these characters. The command characters used in the examples in this manual are mostly " **'** " and " **!** ".

1.2 Basic commands

This chapter contains information about some of the basic FAHTS commands.
The commands are also explained in the FAHTS User's Manual.
It is very important to write a command only once, if it's said so in the manual. If a command is given more than one time, and are changed a bit, this can lead to an analysis error.

HEAD:
This command is written in the FAHTS and USFOS input files. It makes room for three lines of text identifying the analysis. The three lines will be repeated in some of the output files.

```
HEAD            U S F O S progressive collapse analysis
                             Single beam
                                 HUP
```

Figure 1.2-1: HEAD command.

MOVIEPRI:
By writing this command the storing of the temperature analysis model and the temperature result at the specified time increments are switched **ON**. This makes it possible to inspect the structure by XFOS before running USFOS.

SHAPFACT:
By writing this command shape factor calculations are switched ON. Radiation between temperature elements belonging to the same FEM structural element is included. (Radiation inside tubes).

TEMPMESH:
Specifies the temperature mesh refinement of the profile. Note that this command is overridden by the MESH… commands. See FAHTS User's Manual for details.

```
'               n_length  n_circ
 TEMPMESH           2       16
```

Figure 1.2-2: TEMPMESH command.

MESHBOX:
Specifies the temperature mesh refinement for box cross-sections. See FAHTS User's Manual for details.

```
'----------------------------------------------------------------------
'             PROFILE MESH
'----------------------------------------------------------------------
'               n_length n_side   n_top   n_bott
 MESHBOX            2       8       4        4
```

Figure 1.2-3: MESHBOX command.

MESHIPRO:
Specifies the temperature mesh refinement for I cross-sections. See FAHTS User's Manual for details.

```
'------------------------------------------------------------------------
'              PROFILE MESH
'------------------------------------------------------------------------
'                  n_length n_web  n_top n_bott  elem_id  elem_id  elem_id
 MESHIPRO              8      1      2     2
 MESHIPRO              8      6      6     6      1112      111      212
```

Figure 1.2-4: MESHIPRO command.

MESHPIPE:
Specifies the temperature mesh refinement for pipe cross-sections. See FAHTS User's Manual for details.

There are six possible ways to define a thermal "load". These are:
FIREINT:
Specifies that the environmental temperature and radiation are read from the FIREINT result database. See examples with exposure set to FIREINT.

HCFIRE:
Specifies that the environmental temperature field follows the standard hydrocarbon fire temperature development defined by NPD. See examples with option Fire exposure a), b), c), d) and e).

ISOFIRE:
Specifies that the environmental temperature field follows the standard ISO temperature development, as specified in the ISO-834.

USERFIRE:
The user specifies a radiating source used for simplified fire scenarios, which may be constant (hist = 1), or vary as a function of time, according to the specified time history. See examples with the option Radiation.

USERTEMP:
The user specifies the environmental level, which may be constant (hist = 1), or vary as a function of time, according to the specified time history. See examples with the option Temp.history.

USERJET:
The user specifies a jet source used for simplified fire scenarios, which may be constant (hist = 1), or vary as a function of time, according to the specified time history. See FAHTS User's Manual.

TEMPSIM:
This command MUST be supplied.
The command TEMPSIM contains information about the duration of the fire, the number of time steps to be used, and time between saving of results. The last number tells that a new load case is written to file every 900 sec (in Figure 1.2-5). The temperature results are saved to the *Beltemp file*, see Figure 1.1-3.

```
                 F A H T S  temperature simulation
                        Beam  + Column

'------------------------------------------------------------------
'             ANALYSIS TIME AND TEMPERATURE STEPS
'------------------------------------------------------------------
'               end-time (s)  nstep     resinc (s)
 TEMPSIM         10800.0       300       900.0
```

Figure 1.2-5: TEMPSIM command.

THERMPAR:
This command MUST be supplied.
Specifies the thermal properties of the materials used in the structure. See figure below.

INSIDPAR:
Specifies the thermal properties of the material inside hollow members. See figure below.

INSULPAR:
Specifies the thermal properties of the insulation used to protect structural members. See figure below.

ELMINSUL:
Specifies the elements, which should have the actual insulation. See figure below.

```
'------------------------------------------------------------------
'             THE MATERIAL'S AND INSULATION'S THERMAL PARAMETERS
'------------------------------------------------------------------
'               * Thermal parameters of the material *
'               id  rho (kg/m3)  c (J/kgK)  k (W/mK)  emiss
 THERMPAR        1    2700.0      896.0     200.0    0.20
'
'               * Thermal parameters of the inside material *
'               id  rho (kg/m3)  c (J/kgK)
 INSIDPAR        1     1.273       0.7
'
'               * Thermal parameters of the insulation *
'               insul-ID  type   K (W/m2K)  emiss
 INSULPAR           1      1.0      10.0     0.8
'
'               * Elements with insulation *
'               insul_ID  Elem1  Elem2 ....
 ELMINSUL           1
```

Figure 1.2-6: Thermal parameters.

2. Examples of use

2.1 Single beam exposed to fire and protected on four sides.

Key words:

Ex. 1: Alum Box Fully exp. Fully prot. Fire exp. a) *Protection*

Material:	Aluminium AA 6082-T6. Property reduction due to increased temperature, according to Eurocode 1999 Part 1-2.
Structure:	Single beam, aluminium, mid span force, full exposure, full protection.

This example shows the definition of the exposure and the protection of a profile. The beam is modelled with two elements, as shown in Figure 2.1-1.

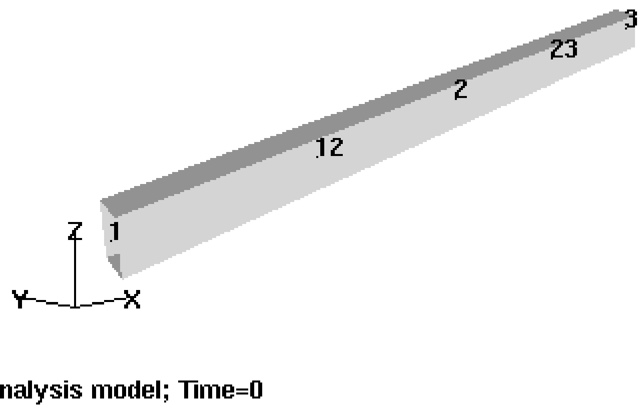


Figure 2.1-1: Structural model with node and element numbers.

Beam length	:	4.400 m	
Profile width	:	0.200 m (width)	
height	:	0.300 m (height)	
thickness	:	0.008 m (thickness)	
Yield stress	:	σ = 255 MPa	Aluminium AA 6082-T6
Youngs modulus	:	E = 70000 MPa	Aluminium
Mid span force	:	100 kN	
Fire load	:	HC-fire	

Similar beams are used in the three following examples, but with different fire exposure and protection. The *Control files* are therefore only included in their totality in this example. In the following examples only the parts of the *Control files* that are changed are included.

Problem:
Beam with full exposure, and protection on all sides.

Solution:
No specification of exposure and protection, means that the entire cross-section is exposed to the heat source, and protected. This is to simplify the writing of the *Control file*.

```
HEAD            F A H T S temperature simulations
                  Single beam, box cross-section

 LIN_RULE       2
 SHAPFACT       ! Calculation of section factor is on.
 MOVIEPRI       ! Results from FAHTS can be shown in XFOS.
'-------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'-------------------------------------------------------------------------
 HCFIRE         ! Hydrocarbon fire.
'
'               * Initial temperature in the fire compartment *
'               initemp
 INITEMP         15.0
'
'               * Exposure time *
'               end-time (s)  nstep    resinc (s)
 TEMPSIM          3600        100        360
'-------------------------------------------------------------------------
'               THE MATERIAL'S AND INSULATION'S THERMAL PARAMETERS
'-------------------------------------------------------------------------
'               * Thermal parameters of the material *
'               id  rho (kg/m3)  c (J/kgK)  k (W/mK) emiss
 THERMPAR        1    2700.0      896.0     200.0    0.20
'
'               * Thermal parameters of the inside material *
'               id  rho (kg/m3)  c (J/kgK)
 INSIDPAR        1     1.273       0.7
'
'               * Thermal parameters of the insulation *
'               insul-ID  type   K (W/m2K)  emiss
 INSULPAR           1      1.0      10.0     0.8
'
'               * Elements with insulation *
'               insul_ID  Elem1  Elem2 ....
 ELMINSUL           1                      ! All elements have insulation.
'
'------------------------------------------------------------------------
'               PROFILE MESH
'------------------------------------------------------------------------
'               n_length n_side   n_top   n_bott
 MESHBOX            2       8      4       4
```

*Figure 2.1-2: FAHTS Control file****, fahts.fem***.

```
HEAD            U S F O S progressive collapse analysis
                             Single beam
                                 HUP
'
 DETEROFF
 CMAXSTEP       1200 ! Increasing from default 512 to 1200.
'
 XFOSFULL       ! All data are saved for view in XFOS.
'
'------------------------------------------------------------------------
'               LOAD HISTORY AND DEFORMATION CONTROL
'------------------------------------------------------------------------
'               * Load history specification with load and deformation *
'               nloads   npostp  mxpstp    mxpdis
 CICYFOS           10      100       1         1
'               lcase lfact mxld   mxdisp  nstep  minstp
                  2    1.0   1.0    0.0      10   0.001  ! Gravity.
                  1    1.0   2.0   -0.250   100   0.001  ! Node load.
                  4    0.02  1.0   -0.250   200   0.001  ! Fahts Fire Load
                  5    0.02  1.0   -0.250   200   0.001  ! Fahts Fire Load
                  6    0.02  1.0   -0.250   200   0.001  ! Fahts Fire Load
                  7    0.02  1.0   -0.250   200   0.001  ! Fahts Fire Load
                  8    0.02  1.0   -0.250   200   0.001  ! Fahts Fire Load
'
'               * Specification for deformation control of the structure *
'               ncnods
 CNODES           1
'               nodex idof  dfact
                  2     3     1
'------------------------------------------------------------------------
'               MATERIAL PROPERTIES
'------------------------------------------------------------------------
'               mat_no  E-mod      poiss    yield    density  therm.exp
 MISOIEP           1   70000.0E6    0.3    255.0E6    2700.0    2.3E-5
'
'------------------------------------------------------------------------
'               REDUCTION CURVES OF MATERIAL PROPERTIES
'------------------------------------------------------------------------
'               mat_no  dep_E   dep_Yield
 USERTDEP         1       1         2
'
'               curve_no   Temp  Red    ! Reduction curve of E-modul
 TEMPDEPY          1        20   1.0
                            50   0.99
                           100   0.97
                           150   0.93
                           250   0.78
                           200   0.86
                           250   0.78
                           300   0.68
                           350   0.54
                           400   0.40
                           550   0.0
'
'               curve_no    Temp  Red   ! Reduction curve of yield
 TEMPDEPY           2       20   1.0
                           100   1.0
                           150   0.79
                           200   0.65
                           250   0.38
                           300   0.20
                           350   0.11
                           550   0.0
```

*Figure 2.1-3: USFOS Control file, **usfos.fem**.*

```
                  *********************************
                  ******* F   A   H   T   S *******
                  *********************************

                     Version 3.1 / Release 98-03-09
                             S I N T E F

                       - Analysis initiated at -
                          98-06-15   15:48:42
                         Licenced to : SINTEF

       ======   A N A L Y S I S    P A R A M E T E R S   ======

                 F A H T S temperature simulations
                   Single beam, box cross-section

                Number of nodal points                =     3
                Number of elements                    =     2
                Minimum Accepted Temperature          :     -273.00
                Maximum Accepted Temperature          :     3000.00

         FAHTS
          Step      Time     Accum.       Max heat      Max         Min
           no.               energy        input       temp.       temp.
                     (s)      (J)          (W/m2)     (degr C)    (degr C)
             1      36.00   8.250E+04    1.13E+03       16.0        16.0
             2      72.00   3.780E+05    2.62E+03       19.5        19.4
             3     108.00   9.549E+05    4.68E+03       26.2        26.2
             4     144.00   1.832E+06    6.41E+03       36.5        36.5
             5     180.00   2.980E+06    8.10E+03       50.0        50.0
             6     216.00   4.273E+06    8.25E+03       65.2        65.1
             7     252.00   5.566E+06    8.09E+03       80.4        80.3
             8     288.00   6.855E+06    8.22E+03       95.5        95.4
             9     324.00   8.142E+06    8.05E+03      110.7       110.5
            10     360.00   9.425E+06    8.18E+03      125.7       125.6
             -
            90    3240.00   5.164E+07    9.15E+02      623.8       618.0
            91    3276.00   5.168E+07    9.00E+02      624.3       618.5
            92    3312.00   5.173E+07    8.85E+02      624.8       619.0
            93    3348.00   5.177E+07    8.71E+02      625.3       619.5
            94    3384.00   5.181E+07    8.58E+02      625.8       619.9
            95    3420.00   5.184E+07    8.46E+02      626.2       620.4
            96    3456.00   5.188E+07    8.35E+02      626.6       620.8
            97    3492.00   5.191E+07    8.24E+02      627.0       621.1
            98    3528.00   5.194E+07    8.13E+02      627.3       621.5
            99    3564.00   5.197E+07    8.04E+02      627.7       621.8
           100    3600.00   5.199E+07    7.94E+02      628.0       622.1
```

*Figure 2.1-4: Extract of FAHTS out file**, resf.out**.*

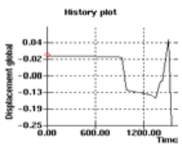


Figure 2.1-5: The global displacement history.

2.2 Single beam exposed to fire on three sides.

Key words:

Ex. 2: Alum Box Partly exp. Fully prot. Fire exp. b) *Protection*

Material: Aluminium AA 6082-T6. Property reduction due to increased temperature, according to Eurocode 1999 Part 1-2.

Structure: Single beam, aluminium, mid span force, 3-side exposure, full protection.

Similar beam as in the previous example, but different fire exposure.

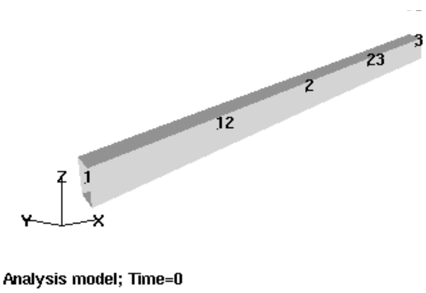


Figure 2.2-1: Model of the structure, with node- and element numbers.

Figure 2.2-2: The global displacement history.

Problem:

Beam partly exposed to fire; three sides. The top is not exposed. Full protection. Different from default values.

Solution:

EXP_BOX contains information about which sides of the profiles that are exposed to fire and which sides that are protected by use of insulation.

0 = not exposed, or not protected.

1 = exposed at the "outside" of the profile, or protected at the "outside" of the profile.

2 = exposed at the "inside" of the profile, or protected at the "inside".

3 = (1+2) exposed both "inside" and "outside", or protected both "inside" and "outside".

Because the profile in this example is a box, it will not be exposed or protected on the "inside". If the box-profile is filled with something different than air, this will be taken account for in the INSIDPAR command. See Basic commands.

```
HEAD            F A H T S temperature simulations
                  Single beam, box cross-section
                                                  +
'------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'------------------------------------------------------------------------
 HCFIRE         ! Hydrocarbon fire.
'
'                 * Exposure *          * Passive fire protection *
'                 top  L  R   bott         top    L  R  bott
 EXP_BOX           0   1  1    1            1     1  1   1
```

Figure 2.2-3: Control file for FAHTS, ***fahts.fem***.

```
                 **********************************
                 ******* F   A   H   T   S *******
                 **********************************
                    Version 3.1 / Release 98-03-09
       FAHTS
       Step       Time      Accum.       Max heat      Max         Min
        no.                 energy        input       temp.       temp.
                   (s)       (J)          (W/m2)     (degr C)    (degr C)
         1        36.00   6.338E+04    1.13E+03        16.0        14.9
         2        72.00   2.972E+05    2.62E+03        19.4        15.3
         3       108.00   7.562E+05    4.69E+03        26.2        16.5
         -
        98      3528.00   4.609E+07    2.69E+03       578.7       513.5
        99      3564.00   4.614E+07    2.68E+03       579.2       514.2
       100      3600.00   4.619E+07    2.66E+03       579.7       514.9

========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.2-4: Extract of FAHTS out file**, resf.out**.*

2.3 Single beam exposed to fire on one side.

Key words:

Ex. 3: Alum Box Partly exp. Fully prot. Fire exp. c) *Protection*

Material: Aluminium AA 6082-T6. Property reduction due to increased temperature, according to Eurocode 1999 Part 1-2.

Structure: Single beam, aluminium, mid span force, 1-side exposure, full protection.

Similar beam as in the two previous examples, but different fire exposure.

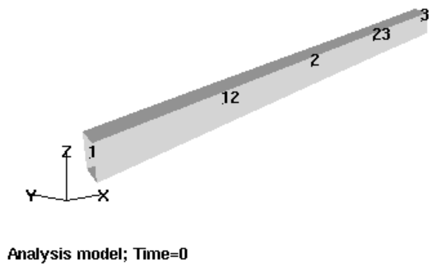


Figure 2.3-1: Structural model, with node- and element numbers.

Figure 2.3-2: The global displacement history.

```
HEAD            F A H T S temperature simulations
                  Single beam, box cross-section
                                                +
'-------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'-------------------------------------------------------------------------
 HCFIRE         ! Hydrocarbon fire.
'
'                 * Exposure *          * Passive fire protection *
'                 top  L  R   bott        top    L  R  bott
 EXP BOX           1   0  0    0           1     1  1   1
```

*Figure 2.3-3: Control file for FAHTS, **fahts.fem**.*

```
                    **********************************
                    ******* F   A   H   T   S *******
                    **********************************
          FAHTS
          Step        Time      Accum.        Max heat     Max          Min
           no.                  energy         input       temp.        temp.
                      (s)        (J)           (W/m2)     (degr C)     (degr C)
           1         36.00    5.804E+03     1.13E+03       15.9         14.8
           2         72.00    5.432E+04     2.63E+03       18.9         14.6
           -
          99       3564.00    1.769E+07     7.79E+03      286.5        180.7
         100       3600.00    1.778E+07     7.77E+03      287.5        181.7

  ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.3-4: Extract of FAHTS out file, **resf.out**.*

2.4 Single beam exposed to fire and protected on three sides.

Key words:

Ex. 4: Alum Box Partly exp. Partly prot. Fire exp. d) *Protection*

Material: Aluminium AA 6082-T6. Reduction of material properties due to increased temperature, according to Eurocode 1999 Part 1-2.

Structure: Single beam, aluminium, mid span force, 3-side exposure, 3-side insulation.

Similar beam as in the three previous examples, but different fire exposure and insulation.

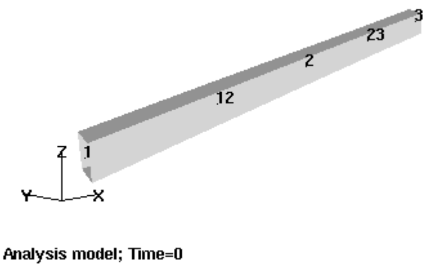


Figure 2.4-1: Model of the beam, with node- and element numbers.

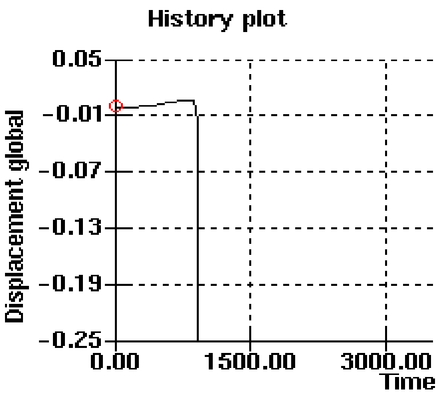


Figure 2.4-2: The global displacement history.

```
HEAD            F A H T S temperature simulations
                  Single beam, box cross-section
'------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'------------------------------------------------------------------------
 HCFIRE         ! Hydrocarbon fire.
'
'                 * Exposure *         * Passive fire protection *
'                 top  L  R   bott       top    L  R  bott
 EXP_BOX           0   1  1    1          0     1  1    1
```

*Figure 2.4-3: Control file for FAHTS**, fahts.fem**.*

```
                   **********************************
                   ******* F   A   H   T   S  *******
                   **********************************
        FAHTS
         Step      Time      Accum.       Max heat      Max         Min
          no.                energy        input       temp.       temp.
                    (s)       (J)          (W/m2)     (degr C)    (degr C)
            1      36.00   6.400E+04    1.13E+03       16.0        15.0
            2      72.00   2.985E+05    2.62E+03       19.4        15.4

           99    3564.00   4.462E+07    3.14E+03      562.2       493.3
          100    3600.00   4.465E+07    3.13E+03      562.5       493.6
  ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.4-4: Extract of FAHTS out file**, resf.out**.*

2.5 Single beam exposed to fire on three sides.

Key words:

Ex. 5: Alum I-prof Partly exp. Partly prot. Fire exp. e) *Protection*

Material: Aluminium AA 6082-T6. Reduction of material properties due to increased temperature, according to Eurocode 1999 Part 1-2.

Structure: Single beam, aluminium, I-profile, mid span force, 3-side exposure, 3-side insulation.

Similar beam as in the four previous examples, except from different profile, fire exposure and insulation.

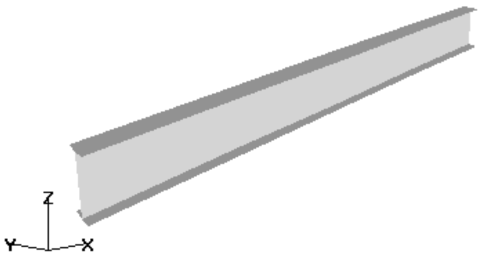


Figure 2.5-1: Model of the beam, with node- and element numbers.

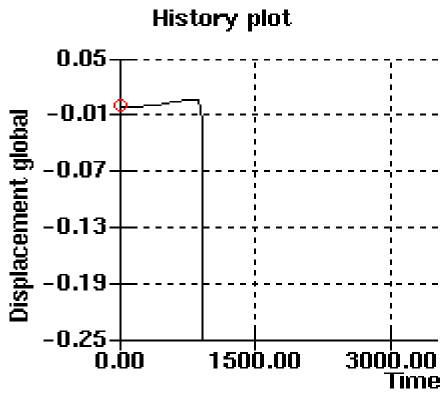


Figure 2.5-2: The global displacement history.

Problem:

Beam with I-profile. Partly exposed and partly protected.

Solution:

Since this is an I-profile it has an "inside" and an "outside". EXP_IPRO tells that the top of the profile is exposed and protected on the "inside", but not on the "outside". The web and the bottom are exposed and protected on both the "inside" and the "outside".

For the web of an I-profile the numbers 2 and 3means the same; protected, or exposed on both sides. 1 is not an option for the web, because it has no "outside".

```
'---------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'---------------------------------------------------------------------------
HCFIRE          ! Hydrocarbon fire.
'
'                 * Exposure *                * Passive fire protection *
'                 top      web      bott            top      web      bott
EXP_IPRO           2        3        3               2        3        3
'
'               * Initial temperature in the fire compartment *
'               initemp
INITEMP          15.0
'
'               * Exposure time *
'               end-time (s)     nstep   resinc (s)
TEMPSIM            3600          100       360
```

Figure 2.5-3: Control file for FAHTS, ***fahts.fem****.*

```
                  **********************************
                  ******* F   A   H    T    S ******
                  **********************************
                     Version 3.1 / Release 98-03-09
                     Licenced to : SINTEF

        ======   A N A L Y S I S    P A R A M E T E R S   ======

          FAHTS
           Step      Time     Accum.       Max heat      Max         Min
            no.               energy        input       temp.       temp.
                      (s)      (J)          (W/m2)     (degr C)    (degr C)
             1       36.00   1.235E+05    2.34E+03       16.5        15.2
             2       72.00   5.497E+05    5.31E+03       21.6        16.5
             3      108.00   1.404E+06    9.43E+03       30.8        20.8
             4      144.00   2.775E+06    1.29E+04       44.3        30.2
             5      180.00   4.720E+06    1.88E+04       61.0        47.3
             6      216.00   7.012E+06    2.01E+04       79.3        69.0
             7      252.00   9.338E+06    2.14E+04       97.5        91.4
             8      288.00   1.170E+07    2.27E+04      118.4       110.8
             9      324.00   1.411E+07    2.37E+04      141.3       129.2
            10      360.00   1.655E+07    2.44E+04      164.5       147.7
             -
            91     3276.00   1.065E+08    3.20E+03      967.8       892.2
            92     3312.00   1.066E+08    3.17E+03      970.4       892.6
            93     3348.00   1.068E+08    3.13E+03      973.0       893.0
            94     3384.00   1.070E+08    3.10E+03      975.5       893.5
            95     3420.00   1.072E+08    3.07E+03      977.9       893.9
            96     3456.00   1.073E+08    3.05E+03      980.2       894.3
            97     3492.00   1.075E+08    3.02E+03      982.4       894.6
            98     3528.00   1.076E+08    2.99E+03      984.6       895.0
            99     3564.00   1.078E+08    2.96E+03      986.7       895.3
           100     3600.00   1.079E+08    2.94E+03      988.8       895.7

    ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.5-4: Extract of FAHTS out file, **resf.out.***

2.6 Beam with displacement limitation and temp. dependant material properties.

Ex. 6: Alum I-prof Partly exp. Partly prot. Displ. lim. Temp. dep.

Material: Aluminium AA 6082-T6. Reduction of material properties due to increased temperature, according to Eurocode 1999 Part 1-2.
Structure: Single beam, aluminium, I-profile, mid span force, 3-side exposure, 3-side insulation.

Same beam as in the previous example.
This example shows the use of displacement limitation and temperature dependent material properties given by the user.

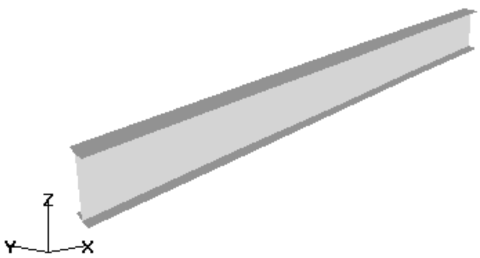


Figure 2.6-1: Model of the beam, with node- and element numbers.

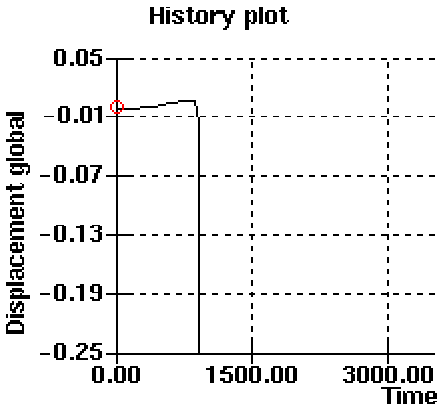


Figure 2.6-2: The global displacement's development over time.

Problem:
Partly exposed beam, with partly protection. Find time and temperature for a max displacement of 250 mm. The temperature dependent reduction of the material properties, is user defined.

Solution:
The condition for max displacement 250 mm, is given in the factor for ***mxdisp*** in CICYFOS. The max displacement is given in meters in the Z-direction for this specific beam.
The temperature dependency defined by the user is given in USERTDEP and TEMPDEPY. USERTDEP specifies the identity of the material the reduction apply to, and the identity of the reduction curves for each material property. In TEMPDEPY the reduction curves are given as co-ordinates. The reduction in this example is given as a factor. This factor is multiplied with the material property given in MISOIEP (in USFOS *Control file*).

```
HEAD          Fire capacity of single aluminium beam
                         USFOS analysis
                           I-profile
'
DETEROFF
CMAXSTEP      1200
XFOSFULL
'-----------------------------------------------------------------------
'             LOAD HISTORY AND DEFORMATION CONTROL
'-----------------------------------------------------------------------
'              nloads   npostp  mxpstp    mxpdis
CICYFOS          10      100       1         1
'              lcase lfact mxld   mxdisp  nstep  minstp
                  2   1.0   1.0     0.0      10   0.001  ! Gravity.
                  1   1.0   2.0   -0.250    100   0.001  ! Nodelaod.
                  4   0.02  1.0   -0.250    200   0.001  ! Fahts Fire Load
                  5   0.02  1.0   -0.250    200   0.001  ! Fahts Fire Load
                  6   0.02  1.0   -0.250    200   0.001  ! Fahts Fire Load
                  7   0.02  1.0   -0.250    200   0.001  ! Fahts Fire Load
'
'             ncnods
CNODES           1
'             nodex  idof  dfact
                 2     3     1
'-----------------------------------------------------------------------
'             MATERIAL PROPERTIES
'-----------------------------------------------------------------------
'             matno   E-mod      poiss    yield    density  Therm. exp
MISOIEP         1   70000.0E6    0.3    255.0E6    2700.0  2.3E-5
'
'              * Temperature dependent property reduction *
'              matno    Dep E   Dep Yield
USERTDEP         1       1         2
'
'              curve_id  Temp   Red   ! Dependency of E-mod
TEMPDEPY         1         20   1.0
                           50   0.99
                          100   0.97
                          150   0.93
                          200   0.86
                          250   0.78
                          300   0.68
                          350   0.54
                          400   0.40
                          550   0.0
'
'              curve no  Temp   Red   ! Dependency of Yield
TEMPDEPY           2       20   1.0
                          100   1.0
                          150   0.79
                          200   0.65
                          250   0.38
                          300   0.20
                          350   0.11
                          550   0.0
```

Figure 2.6-3: USFOS Control file, ***usfos.fem****.*

2.7 Cantilever beam fully exposed to fire.

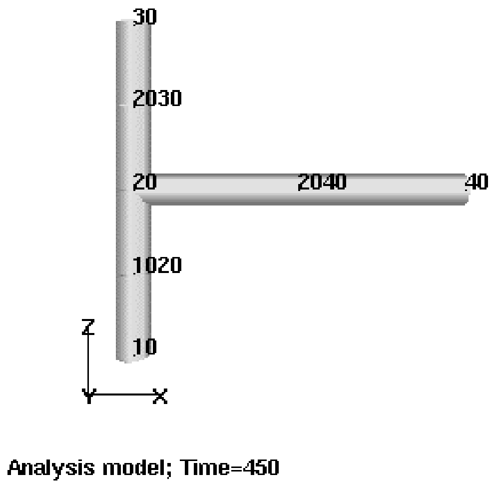
Key words:

Ex. 7: Steel Pipe Partly exp. Unprotected User source Radiation

Material: Steel.
Structure: Cantilever beam, nodal force in node 40, full exposure, not insulated.

This example shows the use of user defined radiation fields.

The structure is modelled with three elements as shown in Figure 2.7-1.



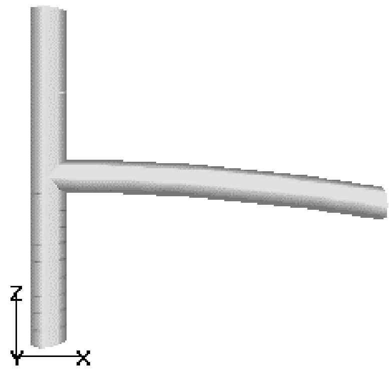


Figure 2.7-1: Structural model with node and element numbers.

Figure 2.7-2: Deformed model.

Column length	:	10.000 m
Diameter (outer)	:	1.100 m
Thickness	:	0.020 m
Beam length	:	10.000 m
Diameter (outer)	:	1.000 m
Thickness	:	0.020 m
Yield stress	:	σ = 248 MPa
Youngs modulus	:	E = 210000 MPa
Nodal force, node 40	:	10 kN
Fire load	:	User defined radiation field

Problem:
Structure with perpendicular radiation on the cantilever beam.
The structure is exposed to radiation intensity of 10000 W/m^2, which is constant.

Solution:
USERFIRE describes the problem by giving:
- constant exposure; history = 0,
- where the source is located; with X-coord. = 5 m, Y-coord. = 0 m and Z-coord. = 10000 m,
- intensity at radius distance from the source; 10000 W/m^2, and
- reference radius from the source used to define the intensity; 10000 m.

By setting a big distance, the rays, when they reach the structure, are almost parallel, and thereby perpendicular to the beam.
The distance from the source to the structure is equal to the radius distance for the intensity. Thereby, the intensity at the structure is 10000 W/m^2.
Because the thermal elongation on top of the beam is bigger than under, the end of the beam will bent down. When the underside gets hotter and the temperature increment through the cross-section is reduced, the beam will bend up again and straighten out a bit.

```
HEAD
               F A H T S  temperature simulation
                       Beam  + Column
'
MOVIEPRI       ! Override default mesh refinement.
SHAPFACT       ! Shape factor calc. is switched on.
'              n_length  n_circ
TEMPMESH           2       16
'
'-------------------------------------------------------------------------
'              USER DEFINED FIRE
'-------------------------------------------------------------------------
'                history   x    y     z     ref_intensity   ref_radius
USERFIRE            0      5   0.0  10.0E3    10000.0         10.0E3
'
'-------------------------------------------------------------------------
'              ANALYSIS TIME AND TEMPERATURE STEPS
'-------------------------------------------------------------------------
'              end-time (s)  nstep     resinc (s)
TEMPSIM         10800.0       300       900.0
'
'-------------------------------------------------------------------------
'              THE MATERIAL'S THERMAL PARAMETERS
'-------------------------------------------------------------------------
'              id     rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss
THERMPAR       10000    7850.0      500.0      50.0     0.8
```

*Figure 2.7-3: FAHTS Control file****, fahts.fem****.*

```
 HEAD           FAHTS example : Column and cantilever beam
                              U S F O S
                SINTEF  div  of  Structural  Engineering
'-------------------------------------------------------------------------
'               AMOUNT OF INPUT AND OUTPUT PRINTED TO FILE
'-------------------------------------------------------------------------
'               inpri    outpri  termpri
 CPRINT           1        1        1
'-------------------------------------------------------------------------
'               LOAD HISTORY AND DEFORMATION CONTROL
'-------------------------------------------------------------------------
'               nloads   npostp   mxpstp   mxpdis
 CUSFOS          30        15      1.00     0.05
'               lcomb    lfact    mxld     nstep     minstp
                  4        0.5      1.0      15        0.05
                  5        0.5      1.0      15        0.05
                  6        0.5      1.0      15        0.05
                  7        0.5      1.0      15        0.05
                  8        0.5      1.0      15        0.05
                  9        0.5      1.0      15        0.05
                 10        0.5      1.0      15        0.05
                 11        0.5      1.0      15        0.05
                 12        0.5      1.0      15        0.05
                 13        0.5      1.0      15        0.05
'
'               ncnods
 CNODES           1
'               nodex    idof     dfact
                 40        3        1.
'-------------------------------------------------------------------------
'               INELASTIC MATERIAL PROPERTIES
'-------------------------------------------------------------------------
'               matno    E-mod    poiss    yield    density    therm. exp.
 MISOIEP        10000  210000.0E6   0.3    248.E6   7850.0       1.4E-05
```

*Figure 2.7-4: USFOS Control file**, usfos.fem**.*

```
                    **********************************
                    ******* F   A   H   T   S  *******
                    **********************************

                       Version 3.1 / Release 98-03-09
                               S I N T E F

                 F A H T S  temperature simulation
                        Beam  + Column


                Number of nodal points                =    17
                Number of elements                    =    16
                Minimum Accepted Temperature          :     -273.00
                Maximum Accepted Temperature          :     3000.00

         FAHTS
          Step      Time      Accum.       Max heat      Max         Min
           no.                energy        input       temp.       temp.
                     (s)       (J)          (W/m2)     (degr C)    (degr C)
            1       36.00   2.864E+06     7.85E+03       23.7        19.9
            2       72.00   5.724E+06     7.82E+03       27.4        19.9
            3      108.00   8.578E+06     7.80E+03       31.0        19.8
            4      144.00   1.143E+07     7.77E+03       34.6        19.8
            5      180.00   1.427E+07     7.75E+03       38.3        19.8
            6      216.00   1.710E+07     7.72E+03       41.8        19.7
            7      252.00   1.993E+07     7.70E+03       45.4        19.7
            8      288.00   2.275E+07     7.67E+03       48.9        19.7
            9      324.00   2.556E+07     7.64E+03       52.5        19.6
           10      360.00   2.837E+07     7.61E+03       56.0        19.6
           -
           -
           -
          290    10440.00   4.057E+08     8.24E+02      323.6        18.9
          291    10476.00   4.061E+08     8.22E+02      323.6        18.9
          292    10512.00   4.066E+08     8.19E+02      323.7        18.9
          293    10548.00   4.070E+08     8.17E+02      323.7        18.9
          294    10584.00   4.074E+08     8.15E+02      323.8        18.8
          295    10620.00   4.078E+08     8.13E+02      323.8        18.8
          296    10656.00   4.082E+08     8.11E+02      323.9        18.8
          297    10692.00   4.086E+08     8.09E+02      323.9        18.8
          298    10728.00   4.091E+08     8.06E+02      323.9        18.8
          299    10764.00   4.095E+08     8.04E+02      324.0        18.8
          300    10800.00   4.099E+08     8.02E+02      324.0        18.8
    ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

Figure 2.7-5: Extract of FAHTS out file, ***resf.out***.

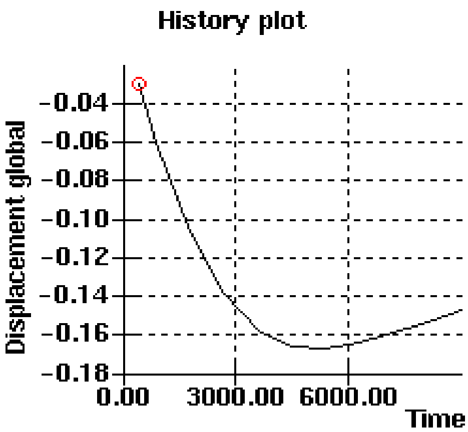


Figure 2.7-6: The global displacement's development over time.

2.8 Cantilever beam exposed to two radiation sources.

Ex. 8: Steel Pipe Partly exp. Unprotected User source Radiation

Material: Steel.
Structure: Cantilever beam, nodal force in node 40, full exposure, not insulated.

Similar structure as in the previous example.
This example shows the use of user defined radiation fields.

The structure is modelled with three elements (with refinement) as shown in Figure 2.8-1.

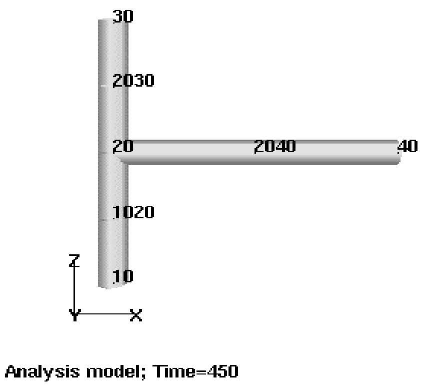


Figure 2.8-1: Model of the structure, with node- and element numbers.

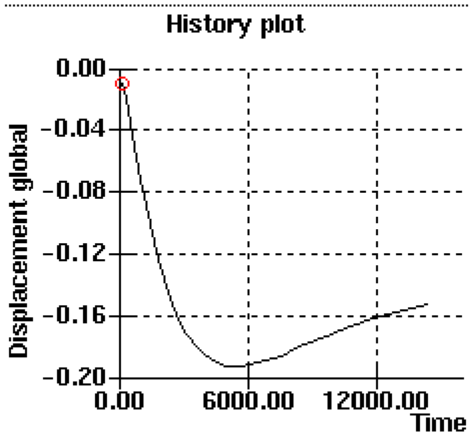


Figure 2.8-2: The global displacement history.

Column length	:	10.000 m
Diameter (outer)	:	1.100 m
Thickness	:	0.020 m
Beam length	:	10.000 m
Diameter (outer)	:	1.000 m
Thickness	:	0.020 m
Yield stress	:	σ = 248 MPa
Youngs modulus	:	E = 210000 MPa
Nodal force, node 40	:	10 kN
Fire load	:	User defined radiation field

Problem:
Two radiation sources, one is constant, the other is time dependent.

Solution:
Defines two sources with different time histories. The constant heat source is defined by giving it a ***hist_id*** 0. This tells that the source is constant. The reference intensity of the USERFIRE with ***hist_id*** 100 is set to 1.0. This is because the intensity is given in the TIMEHIST command. The ***ref_intensity*** factor is multiplied with the ***factor*** from TIMEHIST and the result is the total intensity at the given time.

```
HEAD
                F A H T S  temperature simulation
                        Beam  + Column
'--------------------------------------------------------------------------
'               USER DEFINED FIRE
'--------------------------------------------------------------------------
'                hist_id   x    y      z     ref_intensity   ref_radius
USERFIRE            0      5   0.0  10.0E3   10000.0          10.0E3
USERFIRE          100      5   0.0  10.0E3       1.0          10.0E3
'
'                hist_id  Type  time   factor
TIMEHIST          100      1     0.0     0.0
                               300.0     0.0
                               720.0   800.0
                              1020.0  1700.0
                              1200.0  1550.0
                              1500.0  1400.0
                              1980.0  1300.0
                              2100.0  1000.0
                              2700.0   250.0
                              3600.0   150.0
                              7200.0   100.0
                             10800.0     0.0
                             14400.0     0.0
```

*Figure 2.8-3: FAHTS Control file****, fahts.fem****.*

```
                 **********************************
                 ******* F   A   H    T    S ******
                 **********************************
                    Version 3.1 / Release 98-03-09
                            S I N T E F
        FAHTS
        Step      Time      Accum.       Max heat      Max          Min
         no.                energy        input       temp.        temp.
                   (s)       (J)          (W/m2)     (degr C)     (degr C)
          1      144.00   1.145E+07    7.85E+03        34.7         19.8
          2      288.00   2.286E+07    7.75E+03        49.2         19.6
          3      432.00   3.429E+07    7.83E+03        63.5         19.6
          4      576.00   4.591E+07    7.92E+03        77.8         19.6
          5      720.00   5.771E+07    8.00E+03        92.1         19.7
          6      864.00   6.976E+07    8.18E+03       106.5         19.9
          7     1008.00   8.215E+07    8.33E+03       121.1         19.9
          8     1152.00   9.455E+07    8.07E+03       135.5         19.8
          9     1296.00   1.066E+08    7.78E+03       149.2         19.8
         10     1440.00   1.184E+08    7.48E+03       162.2         19.8
          -
         91    13104.00   4.347E+08    6.94E+02       326.6         18.7
         92    13248.00   4.356E+08    6.92E+02       326.7         18.7
         93    13392.00   4.365E+08    6.89E+02       326.8         18.6
         94    13536.00   4.374E+08    6.87E+02       326.8         18.6
         95    13680.00   4.382E+08    6.84E+02       326.9         18.6
         96    13824.00   4.390E+08    6.82E+02       327.0         18.6
         97    13968.00   4.398E+08    6.80E+02       327.0         18.6
         98    14112.00   4.406E+08    6.78E+02       327.1         18.6
         99    14256.00   4.413E+08    6.76E+02       327.2         18.6
        100    14400.00   4.420E+08    6.74E+02       327.2         18.6

 ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.8-4: Extract of FAHTS out file****, resf.fem****.*

2.9 Simple portal frame.

Key words:

Ex. 9: Steel I-prof Fully exp. Unprotected User source Temp. hist.

Material:	Steel.
Structure:	Simple frame, nodal forces in nodes 11 and 12, distributed load on the beam, temperature rise in the environment. Not protected.

This example shows the use of user defined constant temperature history.

The structure is modelled with elements as shown in Figure 2.9-1.

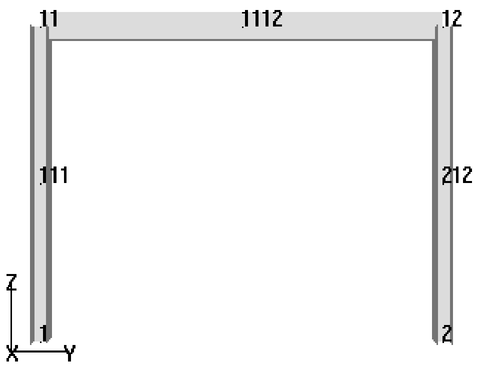


Figure 2.9-1: Structural model.

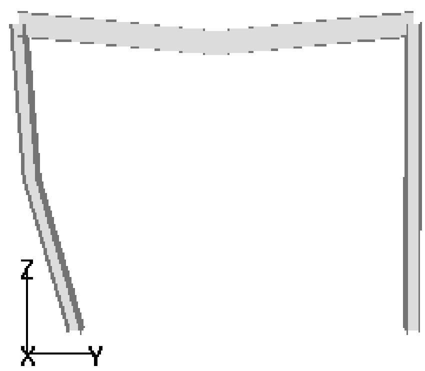


Figure 2.9-2: Deformed model.

Column	length	:	3.500 m
	ight	:	0.206 m
	width	:	0.204 m
Beam	length	:	5.500 m
	height	:	0.304 m
	width	:	0.165 m

Yield stress	:	σ = 275 MPa
Youngs modulus	:	E = 205000 MPa

Nodal forces:

node 11:	500 kN
node 12:	500 kN

Distributed force

beam	:	25.4 kN/m

Heat source	:	User defined temperature history

Problem:
Constant temperature in the environment around the structure.

Solution:
USERTEMP describes the number of the temperature/time history to be used, ***hist_id*** = 0 (constant time history). The ***field_temp*** is set to 600 Celsius degrees, which is the temperature in the environment.

```
HEAD           F A H T S  temperature simulation

                     Simple Portal Frame
MOVIEPRI
'--------------------------------------------------------------------------
'              TYPE OF FIRE AND EXPOSURE
'--------------------------------------------------------------------------
'              initemp
INITEMP         20.0
'                 hist_id     field_temp
USERTEMP            0            600
'--------------------------------------------------------------------------
'              ANALYSIS TIME AND TEMPERATURE STEPS
'--------------------------------------------------------------------------
'              end-time (s)      nstep     resinc (s)
TEMPSIM          7200.0            50        120.0
'--------------------------------------------------------------------------
'              THE MATERIAL'S THERMAL PARAMETERS
'--------------------------------------------------------------------------
'              mat_id  rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss  convection
THERMPAR         1      7850.0      450.0      54.0      0.8       20
'
'              mat_id   rho(kg/m3)  c (J/kgK)  k (W/mK)   dummy     dummy
INSIDPAR         1        1.273       0.7        0.0       0.0       0.0
```

*Figure 2.9-3: FAHTS Control file****, fahts.fem***.

```
HEAD           Portal Frame
               U S F O S  progressive collapse analysis
               NUS/ SINTEF Structural Engineering
TMPLOCON       1
BANANA
STEELTDEP      ! Temperature dependent material properties, reduction.
'              rest.  xfos  out-file
CSAVE            0    -10     -50
'--------------------------------------------------------------------------
'              LOAD HISTORY AND DEFORMATION CONTROL
'--------------------------------------------------------------------------
'              nloads   npostp   mxpstp   mxpdis
CUSFOS          10       100      1.00     0.05
'              lcomb    lfact    mxld     nstep     minstp
                 1       0.5      1.0      10        0.01 ! Dead weight
                 4       0.05     1.0      100       0.01 ! Fire load
                 5       0.05     1.0      100       0.01 ! Fire load
                 6       0.02     1.0      100       0.01 ! Fire load
                 7       0.01     1.0      100       0.01 ! Fire load
                 8       0.01     1.0      100       0.01 ! Fire load
                 9       0.01     1.0      100       0.01 ! Fire load
                10       0.01     1.0      100       0.01 ! Fire load
                 -
                 -
                23       0.01     1.0      100       0.01 ! Fire load
'
'              ncnods
CNODES           1
'              nodex    idof     dfact
                11        1        1.
                11        2        1.
                11        3        1.
'--------------------------------------------------------------------------
'              INELASTIC MATERIAL PROPERTIES
'--------------------------------------------------------------------------
'              matno    E-mod    poiss    yield     density    therm. exp.
MISOIEP          1   205000.0E6   0.3    275.0E6     7850        1.4E-05
```

*Figure 2.9-4: USFOS Control file****, usfos.fem***.

```
                  **********************************
                  ******* F   A   H    T    S ******
                  **********************************
                    Version 3.1 / Release 98-03-09
                             S I N T E F

        FAHTS
         Step       Time      Accum.        Max heat      Max          Min
          no.                 energy         input       temp.        temp.
                     (s)       (J)           (W/m2)     (degr C)     (degr C)
           1      144.00   8.437E+07    7.53E+04       434.7        257.2
           2      288.00   1.537E+08    5.59E+04       709.6        513.5
           3      432.00   1.777E+08    1.67E+04       750.8        667.0
           4      576.00   1.583E+08   -2.14E+04       664.3        526.9
           5      720.00   1.406E+08    1.85E+04       595.2        472.2
           6      864.00   1.473E+08    2.80E+04       604.7        560.3
           7     1008.00   1.590E+08    1.06E+04       667.1        582.6
           8     1152.00   1.585E+08    3.52E+03       633.7        609.1
           9     1296.00   1.520E+08   -2.60E+03       613.1        550.0
          10     1440.00   1.517E+08    1.31E+04       601.0        564.2
           -
          41     5904.00   1.545E+08    4.38E+01       600.0        599.9
          42     6048.00   1.545E+08    2.69E+01       600.1        600.0
          43     6192.00   1.545E+08    4.69E-02       600.1        600.0
          44     6336.00   1.545E+08   -1.63E-02       600.0        600.0
          45     6480.00   1.545E+08    1.19E+01       600.0        599.9
          46     6624.00   1.545E+08    1.77E+01       600.0        600.0
          47     6768.00   1.545E+08    8.95E-02       600.0        600.0
          48     6912.00   1.545E+08    9.22E-03       600.0        600.0
          49     7056.00   1.545E+08   -2.65E-03       600.0        600.0
          50     7200.00   1.545E+08    8.95E+00       600.0        600.0
 ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

Figure 2.9-5: Extract of result file from FAHTS analysis, ***resf.out***.

2.10 Simple portal frame.

Key words:

Ex. 10: Steel I-prof Fully exp. Unprotected User source Temp. hist.

Material:	Steel.
Structure:	Simple frame, nodal forces in nodes 11 and 12, distributed load on the beam, temperature rise in the environment. Not protected.

This example shows the use of user defined temperature history.

The structure is modelled with elements as shown in Figure 2.10-1.

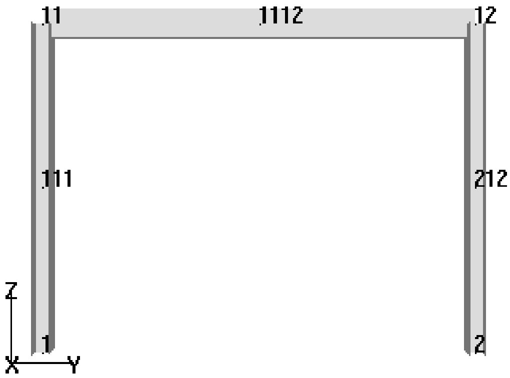


Figure 2.10-1: Structural model.

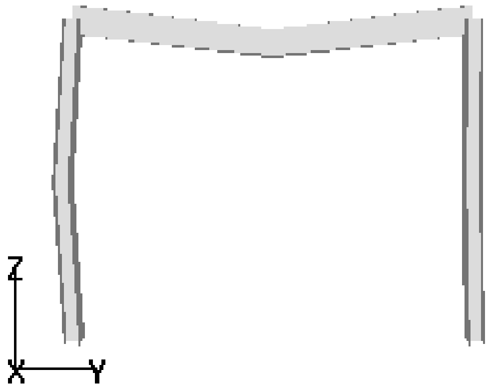


Figure 2.10-2: Deformed model.

Column	length	:	3.500 m
	height	:	0.206 m
	width	:	0.204 m
Beam	length	:	5.500 m
	height	:	0.304 m
	width	:	0.165 m
Yield stress		:	σ = 275 MPa
Youngs modulus		:	E = 205000 MPa
Nodal forces:			
	node 11:		500 kN
	node 12:		500 kN
Distributed force:			
	beam	:	25.4 kN/m
Heat source		:	User defined temperature history

Problem:
Increasing temperature in the environment around the structure.

Solution:
USERTEMP describes the number of the temperature/time history to be used, ***hist_id*** = 100, and a factor, ***field_temp***, to be multiplied with the ***factor*** from TIMEHIST to give the temperature. The ***field_temp*** factor is set to 1.0 in this example because the ***factor*** in TIMEHIST describes the temperature in Celsius degrees. This is the recommended way to do it, because of the readability.

TIMEHIST sets the variation of the temperature over time for the specific history. The factor ***Type*** defines the type of points on the curve that are used. The number 1 defines discreet points.
USERTEMP can be extended if the heat source only affects a part of the structure. See the following example.

```
HEAD           F A H T S  temperature simulation

                     Simple Portal Frame
MOVIEPRI
'--------------------------------------------------------------------------
'              TYPE OF FIRE AND EXPOSURE
'--------------------------------------------------------------------------
'              initemp
INITEMP         20.0
'
'                hist_id    field_temp
USERTEMP           100           1.0
'
'                hist_id  Type       time     factor
TIMEHIST           100      1         0.0      20.0
                                   1500.0     697.0
                                   2160.0     734.0
                                   2940.0     697.0
                                   4560.0     514.0
                                  12960.0      20.0
                                 100000.0      20.0
'--------------------------------------------------------------------------
'              ANALYSIS TIME AND TEMPERATURE STEPS
'--------------------------------------------------------------------------
'              end-time (s)      nstep     resinc (s)
TEMPSIM         14400.0           200       360.0
'--------------------------------------------------------------------------
'              THE MATERIAL'S THERMAL PARAMETERS
'--------------------------------------------------------------------------
'              mat_id  rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss  convection
THERMPAR          1      7850.0      450.0      54.0      0.8       20
'
'              mat_id   rho(kg/m3)  c (J/kgK)  k (W/mK)   dummy     dummy
INSIDPAR          1        1.273       0.7         0.0      0.0       0.0
```

*Figure 2.10-3: FAHTS Control file, **fahts.fem**.*

```
 HEAD           Portal Frame
                U S F O S  progressive collapse analysis
                NUS/ SINTEF Structural Engineering
 TMPLOCON       1
 BANANA
 STEELTDEP      ! Temperature dependent material properties, reduction.
'               rest.  xfos  out-file
 CSAVE            0    -10     -50
'--------------------------------------------------------------------------
'               LOAD HISTORY AND DEFORMATIONCONTROL
'--------------------------------------------------------------------------
'               nloads   npostp   mxpstp   mxpdis
 CUSFOS          10       100      1.00     0.05
'               lcomb    lfact    mxld     nstep     minstp
                  1       0.5      1.0      10        0.01 ! Dead weight
'
                  4       0.05     1.0      100       0.01 ! Fire load
                  5       0.05     1.0      100       0.01 ! Fire load
                  6       0.02     1.0      100       0.01 ! Fire load
                  7       0.01     1.0      100       0.01 ! Fire load
                  8       0.01     1.0      100       0.01 ! Fire load
                  9       0.01     1.0      100       0.01 ! Fire load
                 10       0.01     1.0      100       0.01 ! Fire load
                 11       0.01     1.0      100       0.01 ! Fire load
                 12       0.01     1.0      100       0.01 ! Fire load
                 13       0.01     1.0      100       0.01 ! Fire load
'
'               ncnods
 CNODES           1
'               nodex    idof     dfact
                 11       1        1.
                 11       2        1.
                 11       3        1.
'--------------------------------------------------------------------------
'               INELASTIC MATERIAL PROPERTIES
'--------------------------------------------------------------------------
'               matno    E-mod    poiss    yield     density    therm. exp.
 MISOIEP          1   205000.0E6   0.3    275.0E6     7850        1.4E-05
```

*Figure 2.10-4: USFOS Control file, **usfos.fem**.*

```
                    **********************************
                    ******* F   A   H    T    S ******
                    **********************************

          FAHTS
           Step      Time      Accum.       Max heat      Max         Min
            no.                energy        input       temp.       temp.
                      (s)       (J)          (W/m2)     (degr C)    (degr C)
             1       72.00   4.624E+05    1.65E+03        22.3        21.2
             2      144.00   1.859E+06    3.35E+03        29.2        25.2
             3      216.00   4.190E+06    5.05E+03        40.2        32.1
             4      288.00   7.443E+06    6.76E+03        55.3        42.1
             5      360.00   1.162E+07    8.52E+03        74.2        55.3
             6      432.00   1.673E+07    1.03E+04        96.9        71.8
             7      504.00   2.280E+07    1.22E+04       123.6        91.8
             8      576.00   2.985E+07    1.42E+04       154.2       115.3
             9      648.00   3.789E+07    1.62E+04       188.6       142.4
            10      720.00   4.694E+07    1.83E+04       226.8       173.3
             -
           190    13680.00   2.827E+06   -3.53E+02        33.6        26.2
           191    13752.00   2.529E+06   -3.06E+02        32.3        25.4
           192    13824.00   2.264E+06   -2.65E+02        31.1        24.6
           193    13896.00   2.027E+06   -2.29E+02        30.0        24.0
           194    13968.00   1.816E+06   -1.98E+02        29.1        23.5
           195    14040.00   1.628E+06   -1.72E+02        28.2        23.0
           196    14112.00   1.459E+06   -1.49E+02        27.4        22.6
           197    14184.00   1.309E+06   -1.29E+02        26.7        22.3
           198    14256.00   1.174E+06   -1.12E+02        26.0        22.0
           199    14328.00   1.054E+06   -9.69E+01        25.5        21.7
           200    14400.00   9.458E+05   -8.40E+01        24.9        21.5

  ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.10-5: Extract of result file from FAHTS analysis, **resf.out**.*

2.11 3 Bay and 3 Storey frame.

Key words:

Ex. 11: Steel I-prof Partly exp. Unprotected User source Temp. hist.

Material:	Steel.
Structure:	3 Bay x 3 Storey frame, nodal forces on top of the columns, distributed load on all horizontal elements, heat source placed on the first floor in the first bay. Not protected.

This example shows the use of user defined temperature history, and the heat source location.

The structure is modelled as shown in Figure 2.11-1.

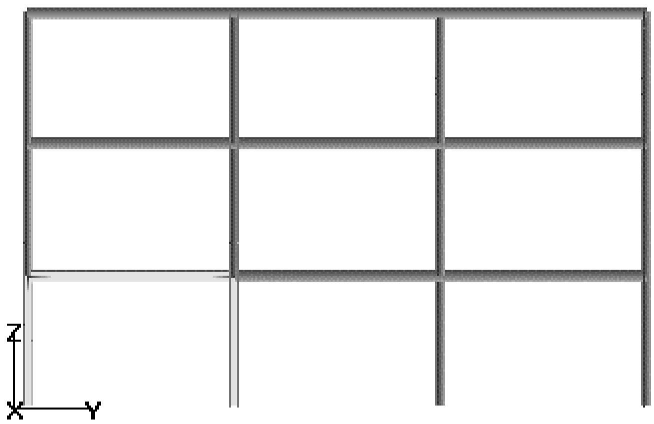


Figure 2.11-1: Structural model.

Column	length	:	3.500 m
	height	:	0.206 m
	width	:	0.204 m
Beam	length	:	5.500 m
	height	:	0.304 m
	width	:	0.165 m

Nodal forces:

end columns	:	75 kN
mid columns	:	151 kN

Distributed forces:

all horizontal elements: 25.4 kN/m

Heat source : User defined temperature history

Problem:
3 Bay x 3 Storey frame, with heat source on ground level in first bay.

Solution:
This example is similar to the previous, except from a few new conditions in the USERTEMP command.
Gas_Abs is always set to 1.0.
The next conditions define which part of the structure that is exposed to the heat. There are three ways to do this, and they are described in the FAHTS User's Manual. The command is called LIMITMOD, but can be integrated in USERTEMP, as in this example.
The ***Lim_Type*** can be 1, -1, 2, -2, 3 or -3. For more information about the difference here, see FAHTS User's Manual.
In this example the ***Lim_Type*** is 1. I.e., the part of the structure, which is of interest with respect on temperature distribution, is extracted from the structure with a box defined by two points. When ***Lim_Type*** is set to 1, all the elements on the inside of the box are included in the transient heat transfer analysis.
The next numbers are the co-ordinates of the two points of the box. To obtain a good readability of the *Control file*, the co-ordinates of the second point are written under the co-ordinates of the first point.

If the heat source is radiation, the command LIMTFIRE is used to extract a part of the structure. See USFOS User's Manual.

```
HEAD           3 Bay x 3 storey frame, Partly Exposed.
               F A H T S  temperature simulation
               NUS/SINTEF Structural Engineering
MOVIEPRI
'-------------------------------------------------------------------------
'              PROFILE MESH
'-------------------------------------------------------------------------
'              n_length n_web  n_top n_bott
MESHIPRO          8      1       2     2
MESHIPRO          8      6       6     6   1112  111 212
'-------------------------------------------------------------------------
'              HEAT SOURCE
'-------------------------------------------------------------------------
'              initemp
INITEMP         20.0
'
'              hist_id  field_temp  Gas_Abs  Lim_Type    x     y     z
USERTEMP       100        1.0        1.0        1     -1.0  -1.0  -1.0
                                                       1.0   5.6   3.6
'
'              hist_id  Type    time    factor
TIMEHIST         100      1       0.0     20.0
                               1500.0    697.0
                               2160.0    734.0
                               2940.0    697.0
                               4560.0    514.0
                              12960.0     20.0
                             100000.0     20.0
'-------------------------------------------------------------------------
'              EXPOSURE AND PROTECTION
'-------------------------------------------------------------------------
'                        * Exposure  *     * Passive Fire Protection *
'              Geo_Typ   top  Web  bott           top  Web  bott
EXP_ELEM         2        2    3    3              0    0     0
'              List of elements
               1112   ! Floor Beam, first floor, first bay
'
'                        * Exposure  *      * Passive Fire Protection *
'              Geo_Typ   top  Web  bott           top  Web  bott
EXP_ELEM         2        3    3    2              0    0     0
'              List of elements
                111   ! First bay, column to the left
'
'                        * Exposure  *      * Passive Fire Protection *
'              Geo_Typ   top  Web  bott            top  Web  bott
EXP_ELEM         2        2    3    3               0    0     0
'              List of elements
                212   ! First bay, column to the right
'-------------------------------------------------------------------------
'              ANALYSIS TIME AND TEMPERATURE STEPS
'-------------------------------------------------------------------------
'              end-time (s)  nstep     resinc (s)
TEMPSIM         7200.0       200        360.0
'-------------------------------------------------------------------------
'              THE MATERIAL'S THERMAL PARAMETERS
'-------------------------------------------------------------------------
'              id    rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss   convection
THERMPAR        1      7850.0      450.0      54.0       0.8       20
THERMPAR        2      7850.0      450.0      54.0       0.8       20
'
'              id    rho(kg/m3)  c (J/kgK)  k (W/mK)   dummy     dummy
INSIDPAR        1        1.273      0.7       0.0        0         0
```

*Figure 2.11-2: FAHTS Control file, **fahts.fem**.*

```
               **********************************
               ******* F   A   H    T    S ******
               **********************************

                  Version 3.1 / Release 98-03-09
                          S I N T E F

                    - Analysis initiated at -
                     98-06-25   09:28:25
                    Licenced to : SINTEF

    FAHTS
     Step      Time     Accum.       Max heat      Max         Min
      no.               energy        input       temp.       temp.
                (s)      (J)          (W/m2)     (degr C)    (degr C)
       1       36.00   9.663E+04    8.11E+02       20.7        20.0
       2       72.00   3.870E+05    1.64E+03       22.8        19.8
       3      108.00   8.698E+05    2.46E+03       26.3        19.6
       -
     198     7128.00   8.572E+07    1.03E+04      450.2         2.1
     199     7164.00   8.520E+07    1.02E+04      447.8         2.1
     200     7200.00   8.469E+07    1.01E+04      445.3         2.0

======== F A H T S  A N A L Y S I S  C O M P L E T E D  =======
```

Figure 2.11-3: Extract of FAHTS out file, ***resf.out****.*

2.12 9 Bay and 3 Storey frame.

Ex. 12: Steel I-prof Partly exp. Unprotected User source Temp. hist.

Material: Steel.
Structure: 9 Bay x 3 Storey frame, nodal forces on top of all columns, distributed load on all horizontal elements, heat source placed on the second floor in bay No 5. Partly protected.

This example shows the use of user defined temperature history.
The structure is modelled with nodes as shown in .

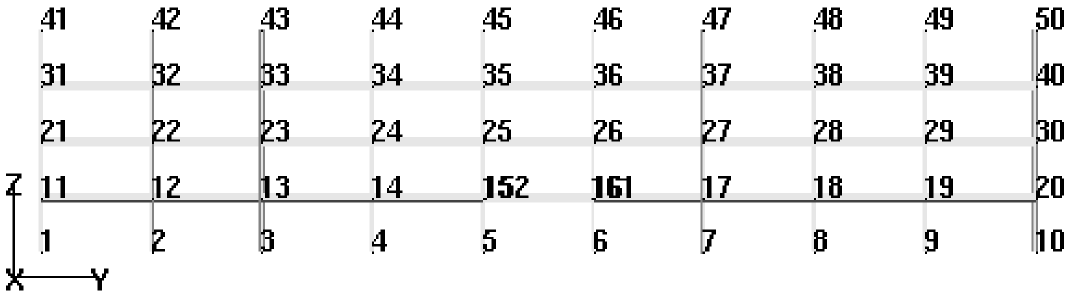


Figure 2.12-1: Structural model.

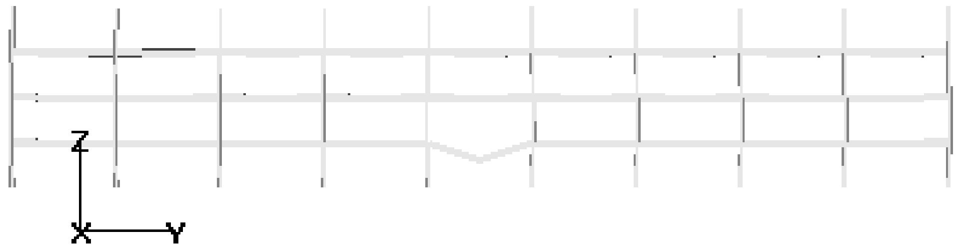


Figure 2.12-2: Deformed model.

Column	length	:	3.600 m
	height	:	0.276 m
	width	:	0.261 m
Beam	length	:	8.000 m
	height	:	0.602 m
	width	:	0.228 m

Yield stress : σ = 275 MPa
Youngs modulus : E = 205000 MPa

Nodal forces:
node 41 and 50: 475.2 kN
node 42-49 : 950.4 kN

Distributed forces:
on all beams : 59.4 kN/m

Heat source : User defined temperature history

Problem:
9 Bay x 3 Storey frame. Several different heat sources with temperature/time-histories.

Solution:
Each heat source must be described with a USERTEMP commando line and a time history, TIMEHIST.
Each source gets an identification number, which is equal for the commands, USERTEMP and TIMEHIST.
The sources are defined in the same way as the source in the previous example.

```
HEAD          9 Bay x Four storey frame, Partly Exposed.
              F A H T S  temperature simulation
              NUS/SINTEF Structural Engineering
'
MOVIEPRI
GLVIEW
'------------------------------------------------------------------------
'             PROFILE MESH
'------------------------------------------------------------------------
'             n_length n_web  n_top n_bott
MESHIPRO        8       1       2     2
'------------------------------------------------------------------------
'             HEAT SOURCE
'------------------------------------------------------------------------
'             initemp
INITEMP        20.0
'
'               hist field_temp Gas_Abs  Lim_Type    x     y     z
USERTEMP         31       1.0     1.0        1     -1.0  15.0  3.5
                                                    1.0  25.0  7.3
'
'               hist field_temp Gas_Abs  Lim_Type    x     y     z
USERTEMP         41       1.0     1.0        1     -1.0  23.0  3.5
                                                    1.0  33.0  7.3
'
'               hist field_temp Gas_Abs  Lim_Type    x     y     z
USERTEMP         51       1.0     1.0        1     -1.0  31.0  3.5
                                                    1.0  41.0  7.3
'
'               hist field_temp Gas_Abs  Lim_Type    x     y     z
USERTEMP         61       1.0     1.0        1     -1.0  39.0  3.5
                                                    1.0  49.0  7.3
'
'               hist field_temp Gas_Abs  Lim_Type    x     y     z
USERTEMP         71       1.0     1.0        1     -1.0  47.0  3.5
                                                    1.0  57.0  7.3
'
'                 id  Type   time     factor
TIMEHIST          31   1       0.0      20.0
                            4000.0      20.0
                            5500.0     697.0
                            6160.0     734.0
                            6940.0     697.0
                            8560.0     514.0
                           16960.0      20.0
                          100000.0      20.0
TIMEHIST          41   1       0.0      20.0
                            2000.0      20.0
                            3500.0     697.0
                            4160.0     734.0
                            4940.0     697.0
                            6560.0     514.0
                           14960.0      20.0
                          100000.0      20.0
TIMEHIST          51   1       0.0      20.0
                            1500.0     697.0
                            2160.0     734.0
                            2940.0     697.0
                            4560.0     514.0
                           12960.0      20.0
                          100000.0      20.0
```

```
'
'                 id  Type   time     factor
 TIMEHIST         61   1       0.0      20.0
                            2000.0      20.0
                            3500.0     697.0
                            4160.0     734.0
                            4940.0     697.0
                            6560.0     514.0
                           14960.0      20.0
                          100000.0      20.0
'
'                 id  Type   time     factor
 TIMEHIST         71   1       0.0      20.0
                            4000.0      20.0
                            5500.0     697.0
                            6160.0     734.0
                            6940.0     697.0
                            8560.0     514.0
                           16960.0      20.0
                          100000.0      20.0
'--------------------------------------------------------------------------
'               ANALYSIS TIME AND TEMPERATURE STEPS
'--------------------------------------------------------------------------
'               end-time (s)  nstep     resinc (s)
 TEMPSIM         7200.0       200        360.0
'--------------------------------------------------------------------------
'               THE MATERIAL'S THERMAL PARAMETERS
'--------------------------------------------------------------------------
'                 id    rho(kg/m3)  c (J/kgK)  k (W/mK)  emiss   convection
 THERMPAR          1      7850.0      450.0      54.0      0.8       20
 THERMPAR          2      7850.0      450.0      54.0      0.8       20
 THERMPAR       1000      7850.0      450.0      54.0      0.8       20
'
'                 id    rho(kg/m3)  c (J/kgK)  k (W/mK)   dummy     dummy
 INSIDPAR          1        1.273      0.7       0.0        0         0
'
'                 id     type   K   Emiss
 INSULPAR         10      1    5.0   0.8
'--------------------------------------------------------------------------
'               EXPOSURE AND PROTECTION
'--------------------------------------------------------------------------
'               Insulation_ID
 ELMINSUL         10             1121  1222  1323  1424  1525
                                 1626  1727  1828  1929  2030
```

Figure 2.12-3: FAHTS Control file, ***fahts.fem****.*

```
HEAD           9 Bay x 3 Storey frame
               U S F O S  progressive collapse analysis
               NUS/SINTEF Structural Engineering
TMPLOCON       1
BANANA
STEELTDEP      ! Temperature dependent material properties
DETEROFF       ! Determinant check switched off
CMAXSTEP       2000
'
'              rest.  xfos  out-file
CSAVE            0    -25     -50
'----------------------------------------------------------------------
'              LOAD HISTORY AND DEFORMATION CONTROL
'----------------------------------------------------------------------
'              nloads   npostp   mxpstp   mxpdis
CUSFOS          10       100      1.00     0.05
'              lcomb    lfact    mxld     nstep     minstp
                 1       0.1      3.0      50        0.01  ! Dead weight
                 4       0.04     1.0      100       0.01  ! Fire load
                 5       0.04     1.0      100       0.01  ! Fire load
                 6       0.04     1.0      100       0.01  ! Fire load
                 7       0.04     1.0      100       0.01  ! Fire load
                 8       0.04     1.0      100       0.01  ! Fire load
                 9       0.04     1.0      100       0.01  ! Fire load
                10       0.04     1.0      100       0.01  ! Fire load
                11       0.04     1.0      100       0.01  ! Fire load
                12       0.04     1.0      100       0.01  ! Fire load
                13       0.04     1.0      100       0.01  ! Fire load
                14       0.04     1.0      100       0.01  ! Fire load
                15       0.04     1.0      100       0.01  ! Fire load
                16       0.04     1.0      100       0.01  ! Fire load
                17       0.04     1.0      100       0.01  ! Fire load
                18       0.04     1.0      100       0.01  ! Fire load
                19       0.04     1.0      100       0.01  ! Fire load
                20       0.04     1.0      100       0.01  ! Fire load
                21       0.04     1.0      100       0.01  ! Fire load
                22       0.04     1.0      100       0.01  ! Fire load
                23       0.04     1.0      100       0.01  ! Fire load
'              ncnods
CNODES           1
'              nodex    idof     dfact
                35        2        1.
                35        3        1.
                36        2        1.
                36        3        1.
'-----------------------------------------------------------------------
'              INELASTIC MATERIAL PROPERTIES
'-----------------------------------------------------------------------
'              matno    E-mod    poiss    yield    density    therm. exp.
MISOIEP          1   205000.0E6   0.3    275.0E6     7850       1.4E-05
MISOIEP          2   205000.0E6   0.3    275.0E6     7850       1.4E-05
''
'                    X    Y    Z    Mx    My   Mz
MREF           1000  99   99   99   99   1002  99  ! Non linear Flexible Connection
```

*Figure 2.12-4: USFOS Control file, **usfos.fem**.*

```
                  **********************************
                  ******* F   A   H   T   S ******
                  **********************************

       FAHTS
        Step       Time      Accum.        Max heat      Max          Min
         no.                 energy         input       temp.        temp.
                    (s)       (J)           (W/m2)     (degr C)     (degr C)
          1       36.00    1.761E+05     8.11E+02        20.4         20.0
          2       72.00    8.611E+05     1.64E+03        21.6         19.8

        199     7164.00    2.301E+09     1.36E+04       799.8        -13.9
        200     7200.00    2.292E+09     1.34E+04       795.8        -12.4
  ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.12-5: Extract of FAHTS out file, **resf.out**.*

2.13 Arched framework exposed to radiation and heat increment.

Key words:

Ex. 13: Steel   I-prof   Partly exp.   Unprotected   Radiation   Temp. hist.

Material: Steel.
Structure: Arched framework, exposed to both radiation and environmental temperature increment, not protected.

This example shows the use of a combination of user defined temperature histories and radiation.

The structure is modelled as shown in Figure 2.13-1.

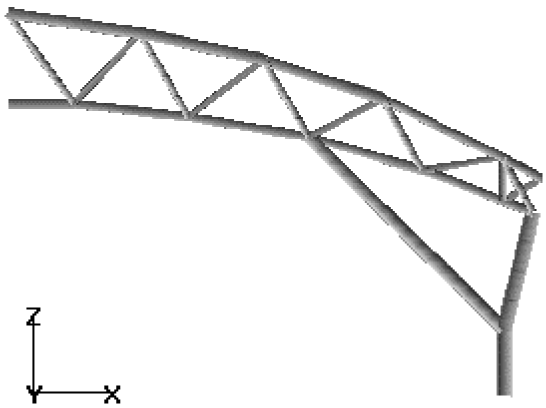


Figure 2.13-1: Structural model.

Yield stress : σ = 275 MPa
Youngs modulus : E = 205000 MPa

Heat source : User defined radiation and temperature history

Problem:
Structure with both increasing environmental temperature, and radiation.
Several sources.

Solution:
Define all radiation sources like in 2.8, and all temperature sources like in 2.12.
In this example, also the radiation sources are time dependent. This is defined in the same way as temperature fields, by giving a factor for the variation of the intensity over time. The ***ref_intensity*** factor from USERFIRE is multiplied with the ***factor*** from TIMEHIST, and results in the total intensity at the given time.

```
HEAD            F A H T S  temperature simulation
                Tuas Checkpoint, SINGAPORE
                Car Fire Simulations
MOVIEPRI
'               N_Lengt nside ntop nbot
MESHIPRO           4      1     2    2
'-------------------------------------------------------------------------
'               HEAT SOURCE
'-------------------------------------------------------------------------
'               initemp
INITEMP          30.0
'                 hist_id    x      y      z      ref_intensity    ref_radius
USERFIRE           1000     11     -1      1           0.2             0.4
USERFIRE           1005     16     -1      1           0.2             0.4
USERFIRE           1010     11      1      1           0.2             0.4
USERFIRE           1010     16      1      1           0.2             0.4
'
'                 hist_id field_temp Gas_Abs Lim_Type x1   y1   z1   x2  y2 z2
USERTEMP           100      100       1.0
USERTEMP           100      300.0     1.0        1     4   -5    0   22   5  20
USERTEMP           100      600.0     1.0        1     8   -5    0   20   5   7
USERTEMP           100      550.0     1.0        1     9   -5    7   18   5  20
'
'                 hist_id  Type   time      factor
TIMEHIST           100      1       0.0       0.0
                                  300.0       0.8
                                  720.0       1.0
                                 1980.0       0.7
                                 2100.0       0.3
                                 2700.0       0.1
                                 3600.0       0.0
                                 7200.0       0.0
TIMEHIST          1000      1       0.0     800.0E3
                                  300.0    1700.0E3
                                  720.0    1250.0E3
                                 1020.0    1400.0E3
                                 1200.0    1300.0E3
                                 1500.0    1750.0E3
                                 1980.0    1000.0E3
                                 2100.0     500.0E3
                                 2700.0     250.0E3
                                 3600.0     150.0E3
                                 7200.0     100.0E3
TIMEHIST          1005      1       0.0     800.0E3
                                  300.0    1700.0E3
                                  720.0    1250.0E3
                                 1020.0    1400.0E3
                                 1200.0    1300.0E3
                                 1500.0    1750.0E3
                                 1980.0    1000.0E3
                                 2100.0     500.0E3
                                 2700.0     250.0E3
                                 3600.0     150.0E3
                                 7200.0     100.0E3
TIMEHIST          1010      1       0.0     800.0E3
                                  300.0    1700.0E3
                                  720.0    1250.0E3
                                 1020.0    1400.0E3
                                 1200.0    1300.0E3
                                 1500.0    1750.0E3
                                 1980.0    1000.0E3
                                 2100.0     500.0E3
                                 2700.0     250.0E3
                                 3600.0     150.0E3
                                 7200.0     100.0E3
'--------------------------------------------------------------------------
'               ANALYSIS TIME, TEMPERATURE STEPS AND THERMAL PARAMETERS
'--------------------------------------------------------------------------
'               end-time (s)  nstep     resinc (s)
TEMPSIM         1800.0         50        360.0
'
'                mat_id rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss  convection
THERMPAR           1     7850.0      450.0      54.0       0.8       20
'
'                mat_id  rho(kg/m3)  c (J/kgK)  k (W/mK)  dummy     dummy
INSIDPAR           1        1.273      0.7       0.0       0.0       0.0
```

*Figure 2.13-2: FAHTS Control file, **fahts.fem**.*

```
                 ***********************************
                 ******* F   A   H    T    S ******
                 ***********************************

       FAHTS
        Step       Time      Accum.        Max heat       Max          Min
         no.                 energy          input       temp.        temp.
                    (s)       (J)           (W/m2)      (degr C)     (degr C)
          1        36.00  -1.144E+06     3.25E+03         32.3         28.8
          2        72.00   3.323E+06     6.69E+03         38.1         28.0
          3       108.00   1.387E+07     1.05E+04         47.6         27.6
          4       144.00   3.097E+07     1.49E+04         61.3         27.5
          5       180.00   5.523E+07     2.00E+04         79.5         27.7
          6       216.00   8.746E+07     2.60E+04        103.1         28.2
          7       252.00   1.286E+08     3.31E+04        132.9         29.0
          8       288.00   1.799E+08     4.15E+04        169.7         30.1
          9       324.00   2.383E+08     4.45E+04        211.5         31.2
         10       360.00   2.978E+08     4.40E+04        253.7         32.5
          -
         41      1476.00   8.384E+08     1.99E+03        583.5         70.1
         42      1512.00   8.321E+08     1.88E+03        579.4         71.1
         43      1548.00   8.256E+08     1.62E+03        575.0         71.9
         44      1584.00   8.188E+08     1.39E+03        570.4         72.7
         45      1620.00   8.118E+08     1.20E+03        565.6         73.4
         46      1656.00   8.046E+08     1.05E+03        560.6         74.0
         47      1692.00   7.972E+08     9.14E+02        555.5         74.6
         48      1728.00   7.897E+08     7.95E+02        550.3         75.0
         49      1764.00   7.821E+08     6.85E+02        545.1         75.4
         50      1800.00   7.743E+08     5.80E+02        539.8         75.7

 ========    F A H T S    A N A L Y S I S    C O M P L E T E D    ========
```

*Figure 2.13-3: Extract of result file from FAHTS analysis, **resf.fem**.*

2.14 Single frame exposed to pool fire placed between columns.

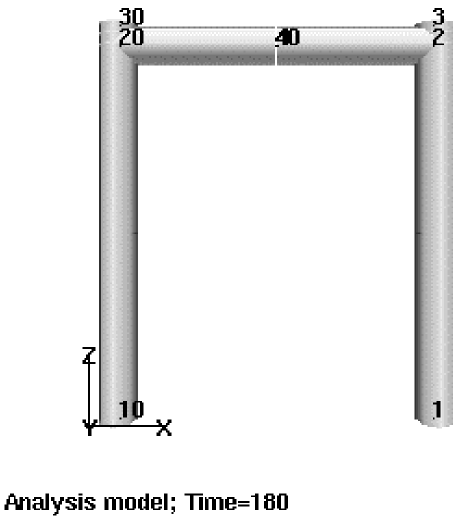
Key words:

Ex. 14: Steel Pipe Fully exp. Unprotected Kameleon Static ana.

Material: Steel.
Structure: Single frame, node load in node 40, full exposure, unprotected.
The two horizontal elements are not connected at the middle.

This example shows structures with thermal expansion.

The frame is modelled with nodes as shown in Figure 2.14-1.



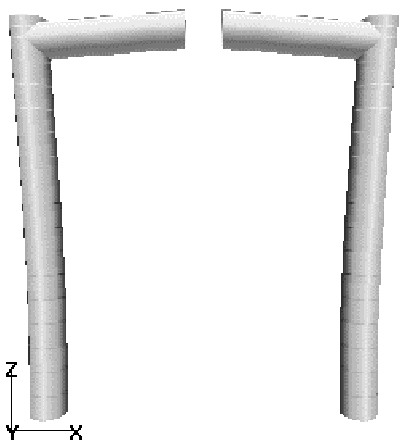


Figure 2.14-1: Structural model with node and element numbers.

Figure 2.14-2: Deformed model.

Column length	:	9.990 m
Diameter (outer)	:	1.000 m
Thickness	:	0.020 m
Beam length	:	7.960 m
Diameter (outer)	:	1.000 m
Thickness	:	0.020 m
Yield stress	:	$\sigma =$ 248 MPa
Youngs modulus	:	E = 210000 MPa
Fire load	:	From FIREINT database

Problem:
Beam not connected at the middle.

Solution:
Four nodes; 20, 40, 4 and 2 defines the beam. A beam not connected at the middle will have to be composed of the two elements 20-40 and 4-2. There is no connection between the nodes 40 and 4, and the beam is therefore not connected at the middle. The frame will be free to expand because of the increasing temperature, and will not obtain any inner forces or stress.

```
HEAD


'
 SESAM
'
'--------------------------------------------------------------------------
'               NODAL DATA
'--------------------------------------------------------------------------
'               node-id    x         y          z           boun.cond.
'                                                       ix iy iz irx iry irz
 NODE              10     -3.99      0.0       0.01      1  1  1   1   1   1
 NODE              20     -3.99      0.0       9.45
 NODE              30     -3.99      0.0       9.99
 NODE              40     -0.01      0.0       9.45
'
 NODE               1      3.99      0.0       0.01      1  1  1   1   1   1
 NODE               2      3.99      0.0       9.45
 NODE               3      3.99      0.0       9.99
 NODE               4      0.01      0.0       9.45
'
'               load-case   node-no    Fx       Fy      Fz       Mx    My   Mz
 NODELOAD           1         40       0.0      0.0  -1000.0
'
'---------------------------------------------------------------------------
'               ELEMENT DATA
'---------------------------------------------------------------------------
'                 elem-ID   np1    np2   mater   geom  lcoor
 BEAM               1020     10     20   10000   100     1
 BEAM               2030     20     30   10000   100     1
 BEAM               2040     20     40   10000   100     1
'
 BEAM                 12      1      2   10000   100     1
 BEAM                 23      2      3   10000   100     1
 BEAM                 24      2      4   10000   100     1
'
'                 lco-no     dx     dy     dz
 UNITVEC            1     -1000.0   0.0  100.0
'
 REFINE             8      1020     12
 REFINE             5      2040     24
'
'---------------------------------------------------------------------------
'               CROSS-SECTION DATA
'---------------------------------------------------------------------------
'               geo_no     Do      Thick
 PIPE             100     1.000    0.020
'
'---------------------------------------------------------------------------
'               MATERIAL PROPERTIES
'---------------------------------------------------------------------------
'               mat_no   E-mod       Poiss
 MISOSEL         10000  210000.0E6   0.3
```

*Figure 2.14-3: Structure file, **stru.fem**.*

```
HEAD            F A H T S  temperature simulation
                       Beam  + Column
                        TUBE - profile
 SHAPFACT       ! Shape factor calc. is switched on.
'
 MOVIEPRI       ! Override default mesh refinement.
'--------------------------------------------------------------------------
'               TYPE OF FIRE AND EXPOSURE
'--------------------------------------------------------------------------
 FIREINT        ! Fire scenario from FIREINT database.
'
'               initemp
 INITEMP         10.0
'--------------------------------------------------------------------------
'               ANALYSIS TIME AND TEMPERATURE STEPS
'--------------------------------------------------------------------------
'               end-time (s)  nstep     resinc (s)
 TEMPSIM         3600.0        100       360.0
'--------------------------------------------------------------------------
'               THERMAL PARAMETERS OF MATERIAL AND INSULATION
'--------------------------------------------------------------------------
'                 id    rho(kg/m3)  c (J/kgK)  k (W/mK)   emiss
 THERMPAR       10000    7850.0      500.0      50.0      0.8
'
'               id    rho(kg/m3)  c (J/kgK)
 INSIDPAR        1        1.273      0.7
```

*Figure 2.14-4: FAHTS Control file, **fahts.fem**.*

```
HEAD            FAHTS example : Simple tubular frame, no connection mid span
                              U S F O S
                SINTEF  div  of  Structural  Engineering
'
'--------------------------------------------------------------------------
'               AMOUNT OF INPUT AND OUTPUT PRINTED TO FILE
'--------------------------------------------------------------------------
'               inpri    outpri  termpri
 CPRINT           1        1        1
'--------------------------------------------------------------------------
'               LOAD HISTORY AND DEFORMATION CONTROL
'--------------------------------------------------------------------------
'               nloads    npostp   mxpstp   mxpdis
 CUSFOS           30        15      1.00     0.05
'               lcomb     lfact    mxld     nstep     minstp
                   4       0.5      1.0      15        0.05
                   5       0.5      1.0      15        0.05
                   6       0.5      1.0      15        0.05
                   7       0.5      1.0      15        0.05
                   8       0.5      1.0      15        0.05
                   9       0.5      1.0      15        0.05
                  10       0.5      1.0      15        0.05
                  11       0.5      1.0      15        0.05
                  12       0.5      1.0      15        0.05
                  13       0.5      1.0      15        0.05
'
'               ncnods
 CNODES            1
'               nodex     idof     dfact
                  40        3        1.
'
'--------------------------------------------------------------------------
'               MATERIAL PROPERTIES
'--------------------------------------------------------------------------
'               matno    E-mod     poiss    yield    density    therm.exp.
 MISOIEP        10000  210000.0E6   0.3     248.E6   7850.0       1.4E-05
```

*Figure 2.14-5: USFOS Control file, **usfos.fem**.*

```
                 **********************************
                 ******* F   A   H   T   S  *******
                 **********************************
         FAHTS
          Step      Time      Accum.       Max heat     Max         Min
           no.                energy        input       temp.       temp.
                     (s)       (J)          (W/m2)     (degr C)    (degr C)
            1       36.00   1.194E+05     2.00E+03      10.9         9.7
            2       72.00   2.384E+05     2.00E+03      11.8         9.5
            3      108.00   3.567E+05     1.99E+03      12.6         9.3
            -
           98     3528.00   1.527E+08     2.94E+03     186.9         8.7
           99     3564.00   1.536E+08     2.93E+03     187.4         8.8
          100     3600.00   1.546E+08     2.91E+03     187.9         8.9
```

Figure 2.14-6: Extract of FAHTS out file, ***resf.out****.*

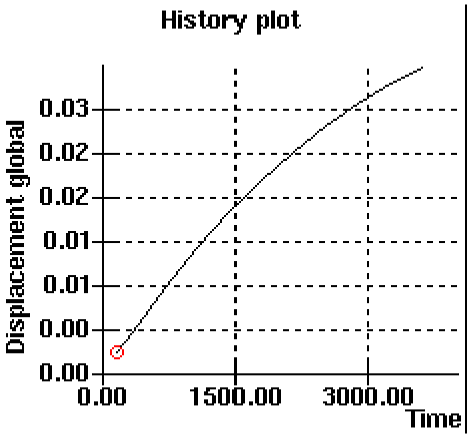


Figure 2.14-7: The global displacement's development over time.

2.15 Single frame exposed to pool fire placed between columns.

Key words:

Ex. 15: Steel   Pipe   Fully exp.   Unprotected   Kameleon   Temp. sim.

Material: Steel.
Structure: Single frame, full exposure, unprotected.

Similar structure as in the previous example, except from the two horizontal elements, which are connected at the middle.

This example shows structures with thermal expansion.
The frame is modelled with nodes as shown in Figure 2.15-1.

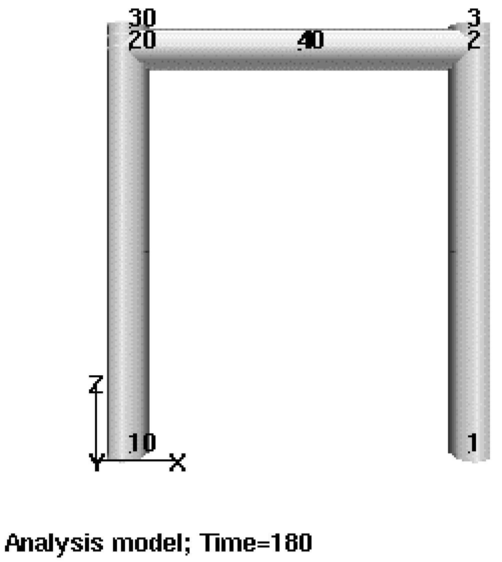


Figure 2.15-1: Structural model with node and element numbers.

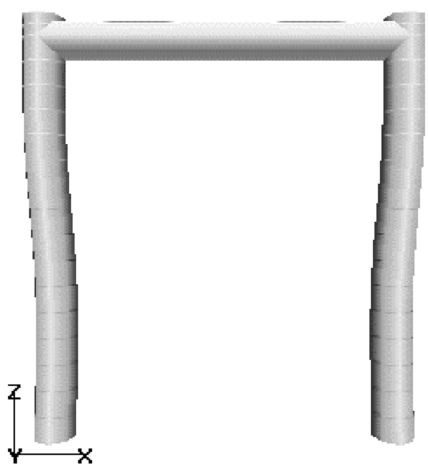


Figure 2.15-2: Deformed model.

Problem:
Simple frame, beam connected at the middle.

Solution:
Define elements between the nodes 2 and 40 instead of 2 and 4. This gives a continuos beam.

When the beam is connected at the middle, the frame will not be able to expand freely. This will lead to great inner forces and stress in the frame.

```
'
'------------------------------------------------------------------------
'              ELEMENT DATA
'------------------------------------------------------------------------
'                elem-ID  np1    np2    mater    geom  lcoor    ecc1  ecc2
 BEAM              1020     10     20    10000    100     1
 BEAM              2030     20     30    10000    100     1
 BEAM              2040     20     40    10000    100     1
'
 BEAM                12      1      2    10000    100     1
 BEAM                23      2      3    10000    100     1
 BEAM                24      2     40    10000    100     1
```

Figure 2.15-3: Structure file for USFOS and FAHTS, ***stru.fem****.*

```
                  **********************************
                  ******* F   A   H   T   S  *******
                  **********************************
        FAHTS
        Step        Time      Accum.        Max heat       Max          Min
         no.                  energy         input         temp.        temp.
                     (s)       (J)          (W/m2)       (degr C)     (degr C)
          1        36.00    1.861E+06     1.80E+04        14.8          9.8
          2        72.00    5.390E+06     1.78E+04        24.4          9.6
          3       108.00    8.876E+06     1.74E+04        33.5          9.4
          -
         98      3528.00    1.794E+08     3.19E+03       195.4          9.9
         99      3564.00    1.804E+08     3.17E+03       195.8          9.9
        100      3600.00    1.814E+08     3.16E+03       196.2          9.9
```

*Figure 2.15-4: Extract of FAHTS out file****, resf.out****.*

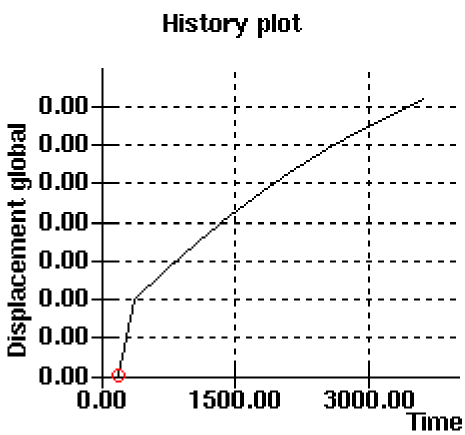


Figure 2.15-5: The global displacement's development over time.