POWSIM

THE USER MANUAL
FOR VERSION 1.2

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NTH - Thermal Energy and Hydropower

CONTENTS

1 GENERAL INFORMATION

1.1 About *POWSIM*

POWSIM is a computer program for design calculations of steam cycles utilizing hot gas as heat source. Data for a topping gas turbine cycle can be specified in order to calculate combined cycle performance.

POWSIM is developed by Dr.ing. Olav Bolland at the Norwegian University of Science and Technology.

1.2 Computer requirements

POWSIM is supplied as an executable DOS code and runs on IBM PC-XT, AT, PS/2 or compatible with 640 K memory. A math coprosessor on 286/386 systems is strongly recommended. By the way, this was written in 1991. If you still have a 286/386 it is about time you get a new PC. A hard disk, or a network drive or a 1.44/1.2 Mb floppy disk is required.

1.3 Installation

The *POWSIM* menu system requires that the following:

For WIN95:
In the file c:\config.sys the following line must be inserted.

```
DEVICE=C:\WINDOWS\COMMAND\ANSI.SYS
```

Check whether the file ANSI.SYS exists on the directory given above.

For WIN NT:
In the file c:\winnt\system32\autoexec.nt the following lines must be inserted:

```
mode con codepage select=850
keyb no,,c:\winnt\system32\keyboard.sys
```

In the file c:\winnt\system32\config.nt the following line must be inserted:

```
device= c:\winnt\system32\ansi.sys
```

POWSIM may be run from a floppy disk, but it is recommended to install it on a hard disk. For installation on a hard disk the following procedure should be used.

Create a new directory (this is not necessary if you are upgrading to a new version, and a directory already exists). The DOS command for creating a new directory is:

```
C:\> MD POWSIM <cr>
```

Then change the current directory by using the following command:

```
C:\> CD POWSIM <cr>
```

Install *POWSIM* from the installation floppy disk by using the following command:

C:\POWSIM> COPY A:*.* <cr>

or

C:\POWSIM> COPY B:*.* <cr>

If this procedure is successful *POWSIM* is now ready to be run. Your prompt may not appear as the prompt (underlined) shown in the procedure above. To run *POWSIM* use the command:

C:\POWSIM> POWSIM <cr>

POWSIM uses two types of input files (see section 0), and one or both of these files may be written on the command line. Below are some examples of how this is done. Be sure to insert a space between the file names. Both uppercase and lowercase may be applied, but do not mix cases on the DOS command line when typing the file names. When only one file is specified, *POWSIM* uses the file from the last run for the unspecified file type. One should be aware that *POWSIM* remember the name of the input files which were used in the last run, and reads them automaticly when the program is started as shown above. Reading input files when running *POWSIM* is of course also possible (see section 0, 0 and 0).

C:\POWSIM> POWSIM filename.PGT filename.PDT <cr>

C:\POWSIM> POWSIM filename.PDT filename.PGT <cr>

C:\POWSIM> POWSIM filename.PGT <cr>

C:\POWSIM> POWSIM filename.PDT <cr>

1.4 File types

There are eight types of files with different meanings to the *POWSIM* system. These are distinguished by the file extension.

1) POWSIM.EXE
2) *.PGT
3) *.PDT
4) *.RES
5) *.XRY
6) *.HPT
7) *.HPH
8) *.PRO
9) POWSIM.LOG
10) POWSIM.DEF
11) HS.SAT

1) "POWSIM.EXE" is the executable code for the *POWSIM* program.

2) Files with the extension "*.PGT" are input files containing information about the gas turbine data that are used for two purposes in *POWSIM*.

→ information about the heat source for the steam cycle; gas temperature, gas flow rate and gas composition

→ in order to calculate combined cycle performance, the *.PGT files contain information about power output, fuel consumption and auxiliary power demand for the gas turbine(s).

This is a sequential ASCII-file, and may be edited with an editor (such as Turbo-Pascal, BRIEF or others). However, this is not recommended. If the file is to be changed outside *POWSIM*, do not remove any lines or change the succession of the lines. The information in this file can be changed most efficiently from within *POWSIM* (see sections 0 and 0).

3) Files with the extension "*.PDT" are input files containing the user supplied steam cycle input data. The content of a "*.PDT"-file may be changed with an editor, but this is not recommended. The information in this file is changed most efficiently from within *POWSIM* (see sections 0 and 0).

4) Files with the extension "*.RES" contain the computational results from a *POWSIM* calculation. This is a sequential ASCII-file, and can be printed out by any type of printer. This file may be included in any word-processing system which is able to read ASCII-files (any decent word-processing system does that !). See section 0.

5) Files with the extension "*.XRY" contain the computational results from the exergy analysis from a *POWSIM* calculation. This is a sequential ASCII-file, and can be printed out on any type of printer. This file may be included in any word-processing system which is able to read ASCII-files (see section 0).

6) Files with extension "*.HPT" are plotter files with the heat recovery TQ-diagram. This a file with a HP-GL plotter format, and can be plotted directly on any plotter accepting this format. Some laser printers accept this file format. This file may also be included in some word-processing systems (see section 0).

7) Files with extension "*.HPH" are plotter files with the steam cycle HS-diagram. This a file of the same type as described above (see section 0).

8) Files with extension "*.PRO" are gas property table files for a given gas composition. This file may be useful when gas properties are required for hand calculations (see page 44).

9) The "POWSIM.LOG"-file contains information about the frequency of using *POWSIM*. Each time the user runs *POWSIM*, a new line of text is added to the file. A text line contains information about *POWSIM* version number, date and time. This file may be deleted by the user without any concern.

10) The "POWSIM.DEF"-file contains information about colour selection from the previous run of *POWSIM*. When the user has selected foreground and background colours which he is comfortable with, these colours are used in the next *POWSIM* runs. This file also contains the name of the input files that were used when ending the last *POWSIM* run. When starting *POWSIM* these input files are automaticly retrieved, in order to enable the user to continue from the same state with respect to input values as from the last *POWSIM* run. The "POWSIM.DEF"-file must be present. If this file is deleted, *POWSIM* is unable to run.

11) The "HS.SAT"-file contain the saturation line given as a number of entropy/enthalpy-values. The file is read by *POWSIM* when plotting the steam cycle HS-diagram (see page 44).

1.5 How to work with the menues

A menu consists of a number of item lines. On the left edge of each line there is an item number. When entering a menu, the cursor appears near the bottom on the right hand side of the screen, the command prompt. In front of the cursor there is a text; "SELECT ITEM -->". The user may at this prompt type a command, and the available commands are shown in Table 1. In the upper right corner of the screen there is a user identification, date (MM/DD/YY) and time (HH:MM).

Table 1 *Commands to be used in the menues*

COMMAND	ABBREVIATION	DESCRIPTION
HELP	H	A window appears on the left hand side of the screen, displaying available commands. See text box below this table
NEW	N	The screen is cleared and the menu is refreshed.
<nr>		<nr> is the selected item number. By typing a number and then pressing <cr>, the cursor moves to the selected item line (input item) or an action is taken (action item).
ALL	A	The cursor moves the first input item and the item value may be changed and/or use <cr>. The cursor will then move to the next input item and so on.
<cr>		Leaving the menu.
STOP	STOP	*POWSIM* run is ended.

There are two types of items; action items and input items. The former type of item is used when a specific action is to be taken, such as performing a calculation, changing directory, saving input data and so on. The latter item type is used for changing an item value. When the cursor is located on an item line, the cursor can be moved to the command prompt (SELECT ITEM -->) by typing "QUIT <cr>" (or "Q <cr>").

There are three ways to end a *POWSIM* run without turning the computer off, and these are:

- type "STOP <cr>" at the command prompt
- select item 19 in the POWSIM MAIN MENU
- use CTRL-C

When using either of the two first options, the user is asked to confirm quitting *POWSIM*. Next the screen is cleared and the screen colours is set to black background and white foreground, and the system is returned to DOS. Using CTRL-C stops program execution at any time when running *POWSIM*. The screen colours will remain the same as selected from within *POWSIM*.

By typing "HELP <cr>" (or "H <cr>") at the command prompt, a help window is displayed on the left hand side of the screen. This window disappears when pressing any key, and the cursor moves back to the command prompt location.

```
HELP (H) - TO GET THIS WINDOW
NEW  (N) - REFRESH THE SCREEN
ALL  (A) - INPUT ALL ITEMS
<NR>     - INPUT ITEM <NR>
QUIT (Q) - QUIT THE ITEM INPUT
<CR>     - QUIT THE MENU
STOP     - STOP THE PROGRAM
```

Help window in the menues

1.6 Menu structure

The menu structure in *POWSIM* is shown in Figure 1 on page 7. The dotted lines in Figure 1 indicates that it possible to go from the CALCULATION & OUTPUT menu to the STEAM CYCLE INPUT, SUPPLEMENTARY FIRING and GAS TURBINE INPUT/CHECK menues.

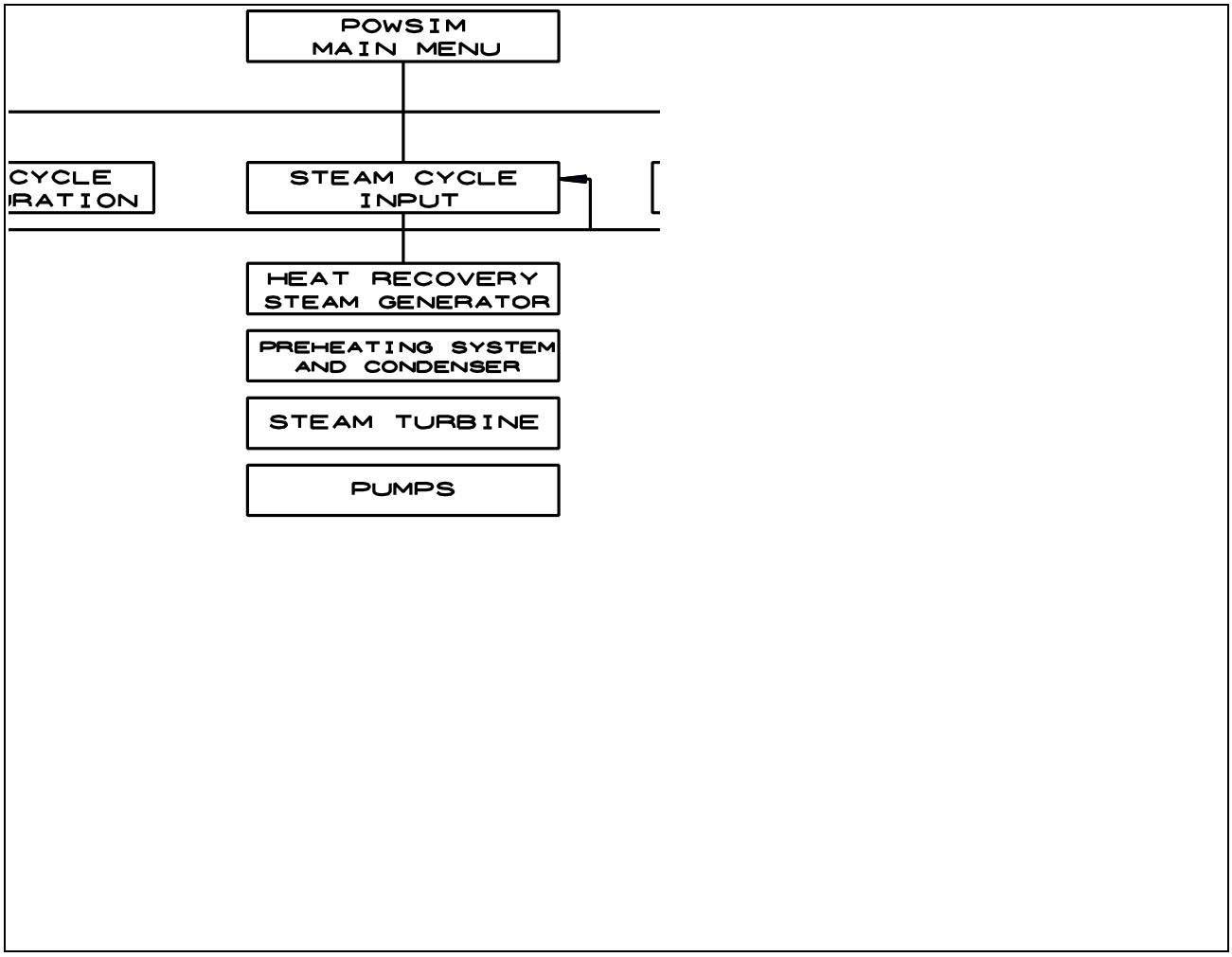

Figure 1*Menu structure in POWSIM*

2 STEAM CYCLE CONFIGURATIONS

When specifying the steam cycle in *POWSIM*, a number of configurations are allowed. These are summarized in Table 2. Flowsheet diagrams and TQ-diagrams for the valid configurations are shown on the following pages.

Supplementary firing (using CH_4) of the heat source gas (may be gas turbine exhaust, air or any other composition) can be applied.

A "***pressure level***" is here defined as a heat recovery boiler section with economiser, evaporator and superheater. *POWSIM* is regarding reheating as a pressure level. A dual-pressure steam cycle with reheating is in *POWSIM* a cycle with 3 pressure levels, though steam generation takes place at 2 pressure levels.

Table 2 *Steam cycle configurations*

NUMBER OF PRESSURE LEVELS	STEAM REHEATING	SUPERCRITICAL STEAM PRESSURE
1	NO	NO
2	NO	YES
3	YES	YES
4	YES	YES
5	YES	YES

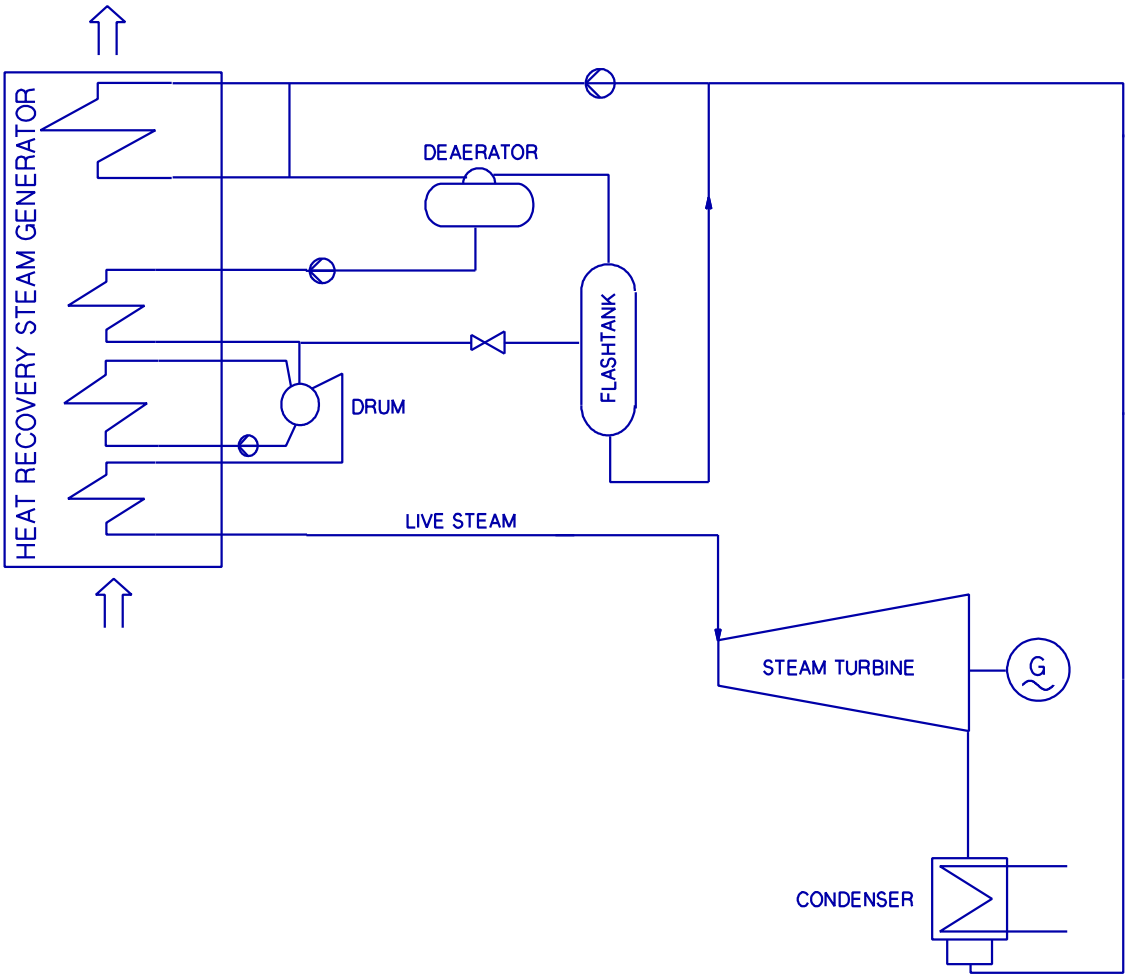

Figure 2 *Flowsheet diagram for the single pressure steam cycle*

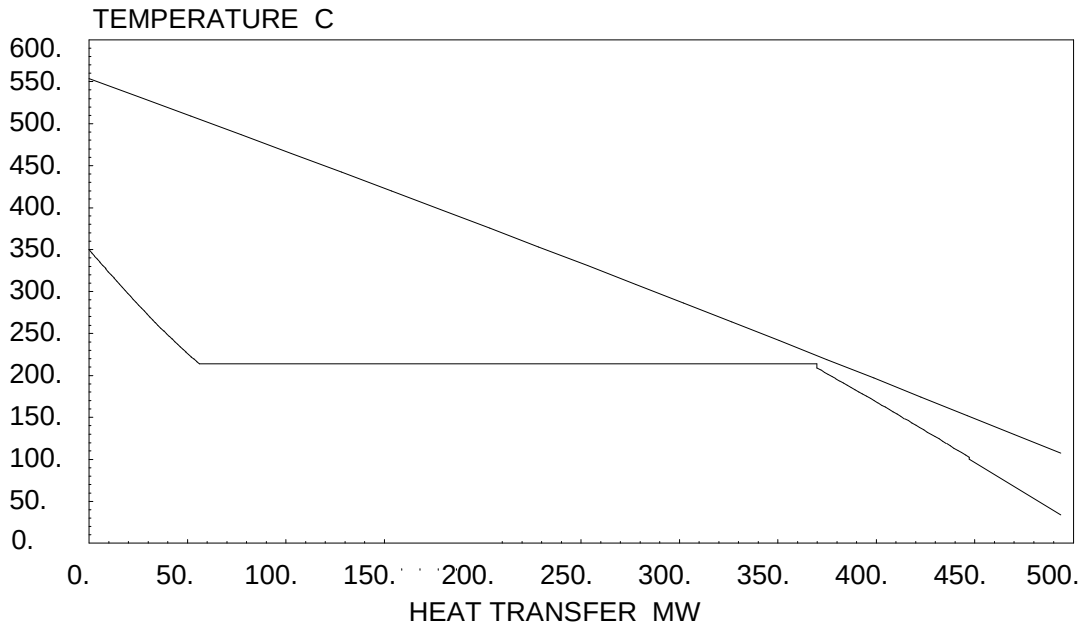

Figure 3 *TQ-diagram for the single pressure steam cycle*

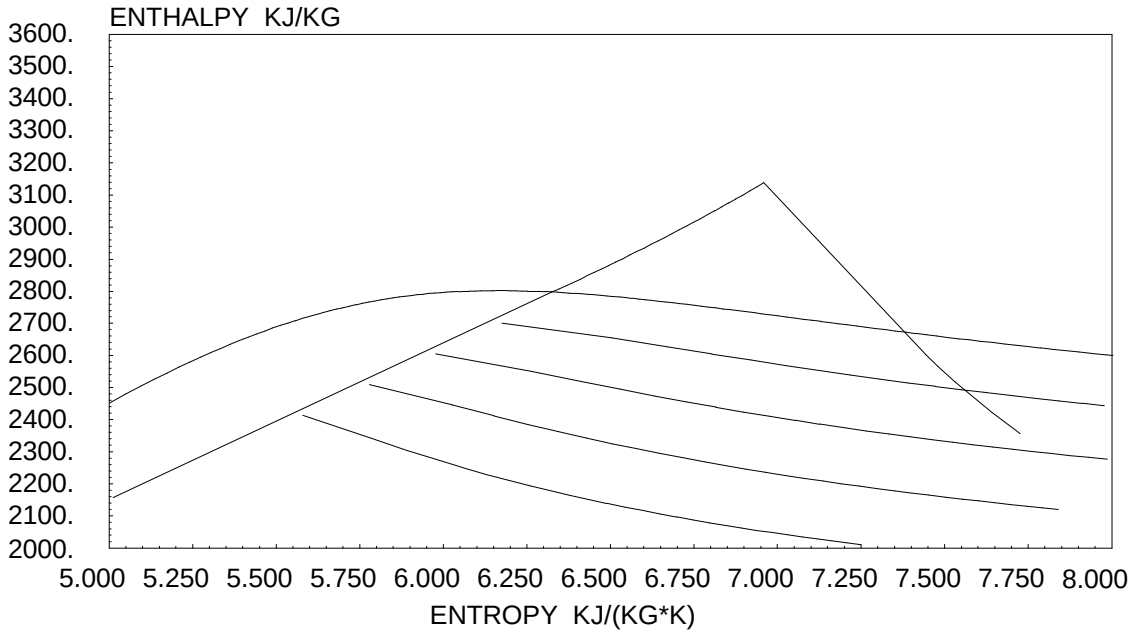

Figure 4 *HS-diagram for the single pressure steam cycle*

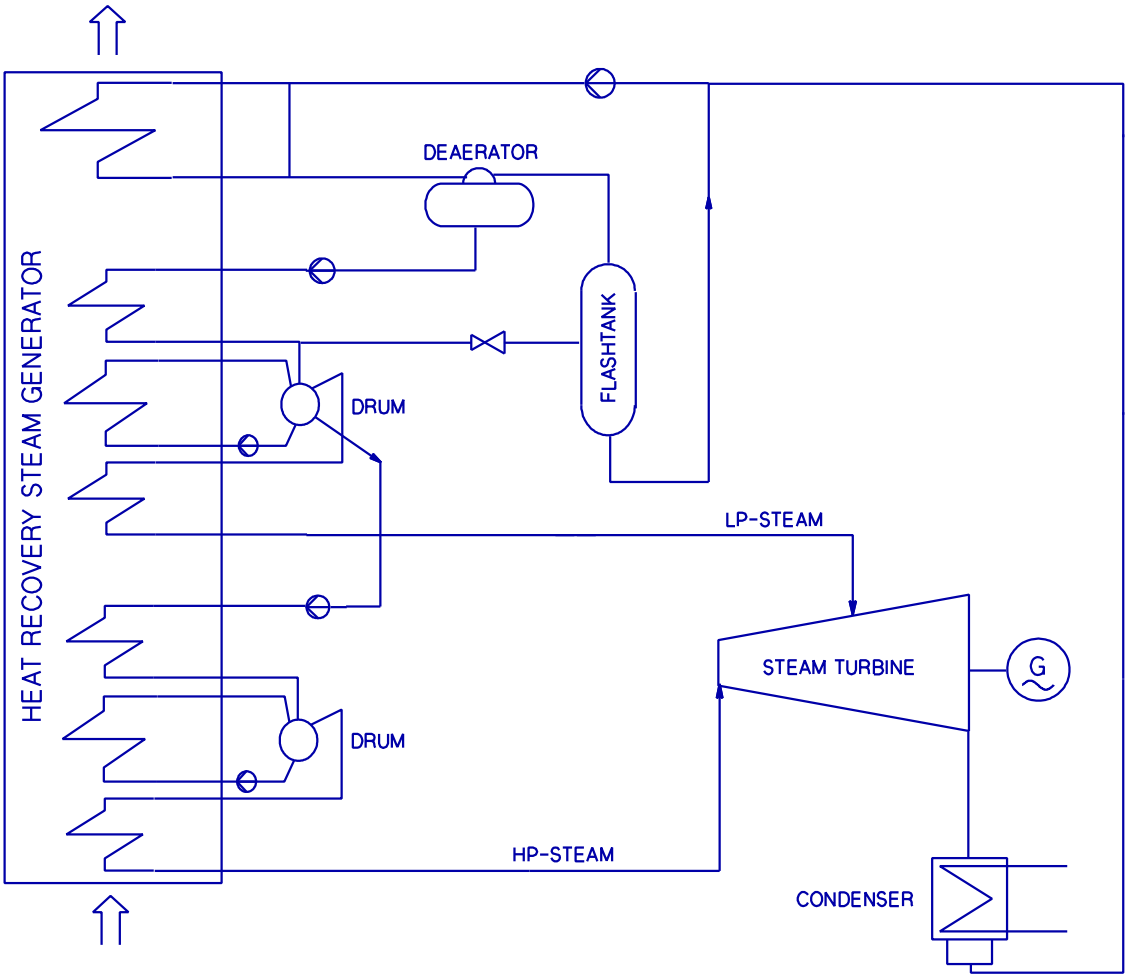

Figure 5 *Flowsheet diagram for the dual pressure steam cycle*

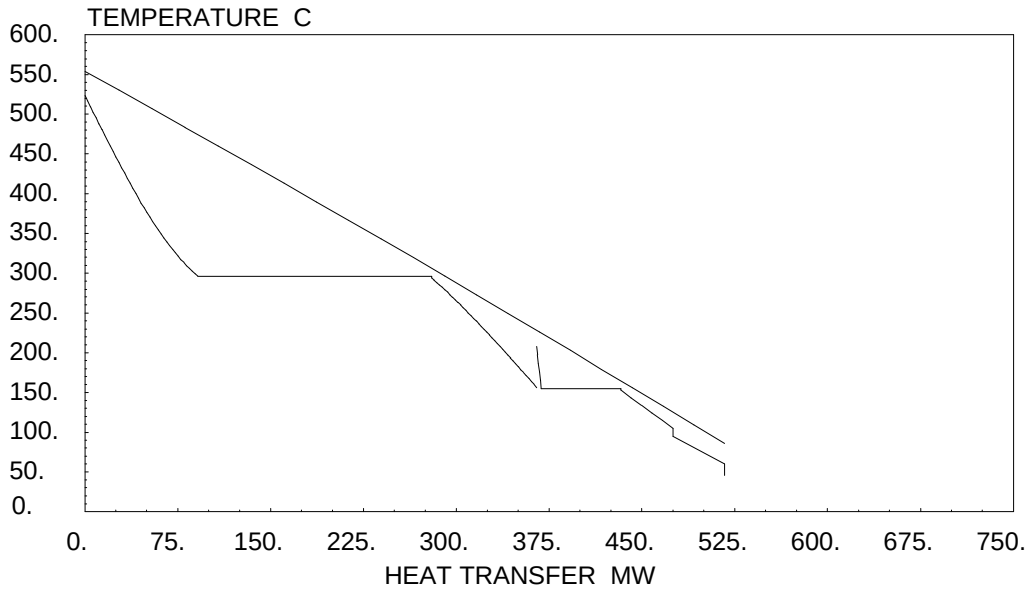

Figure 6 *TQ-diagram for the dual pressure steam cycle*

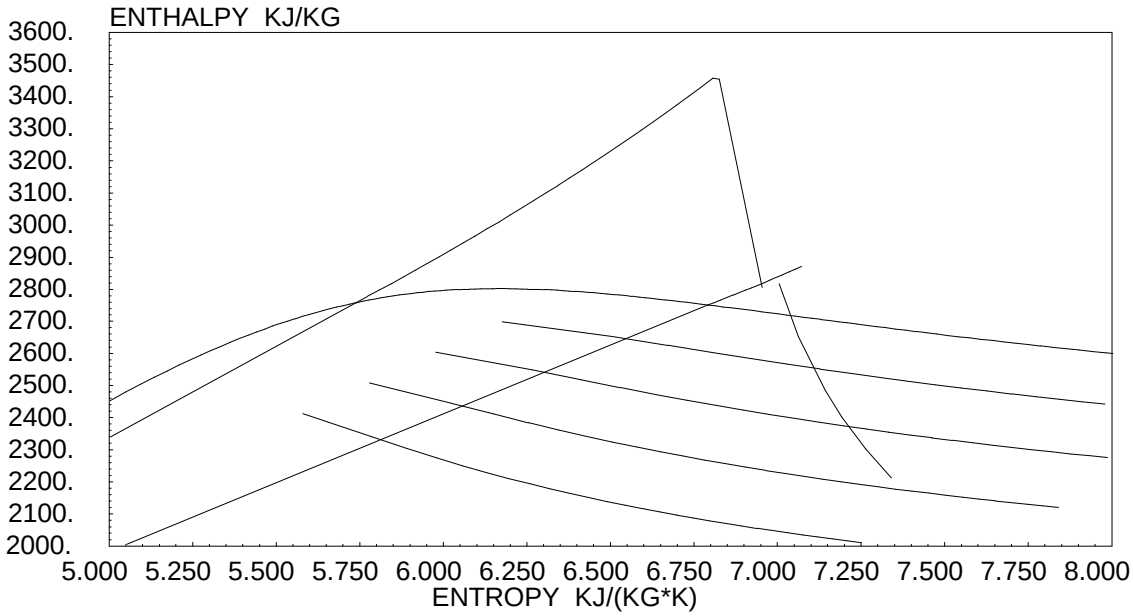

Figure 7 *HS-diagram for the dual pressure steam cycle*

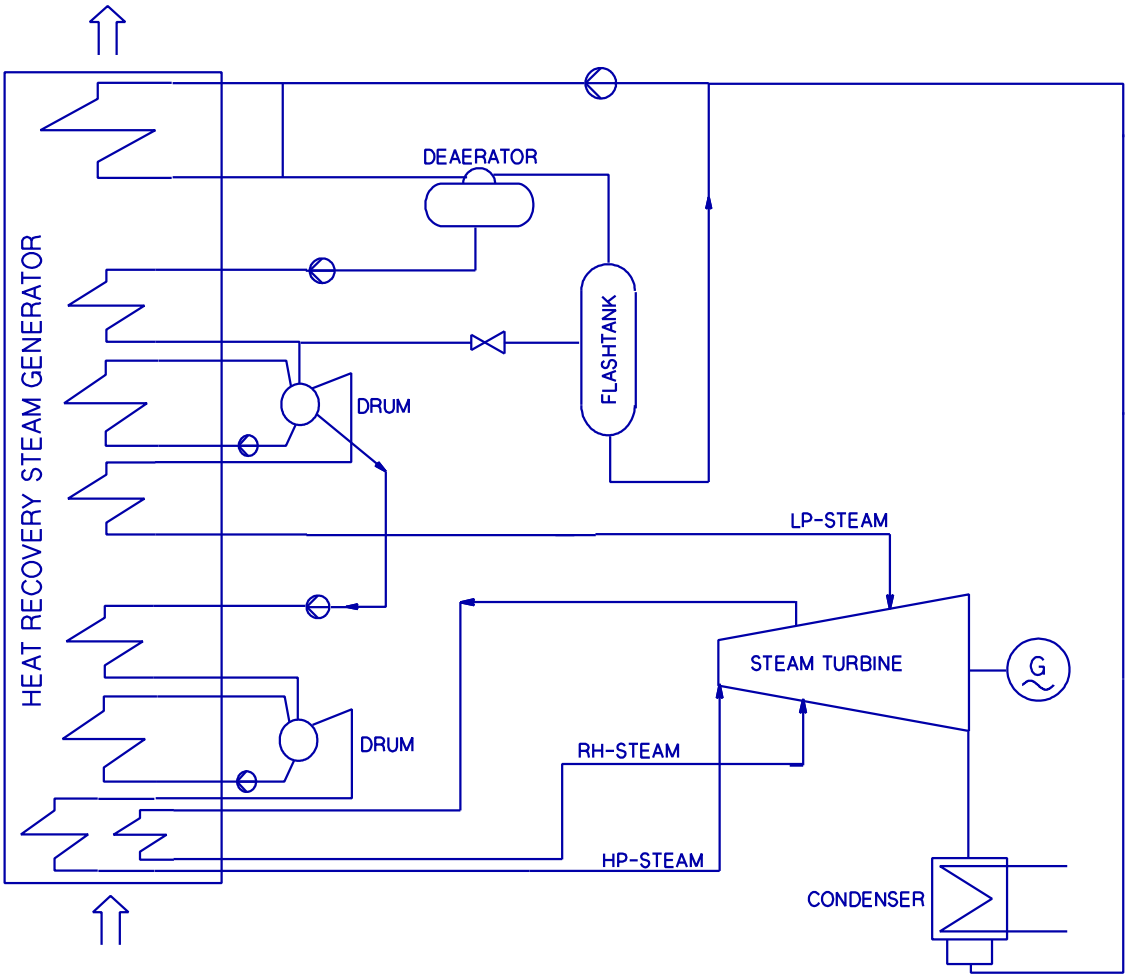

Figure 8 *Flowsheet diagram for the dual pressure reheat steam cycle*

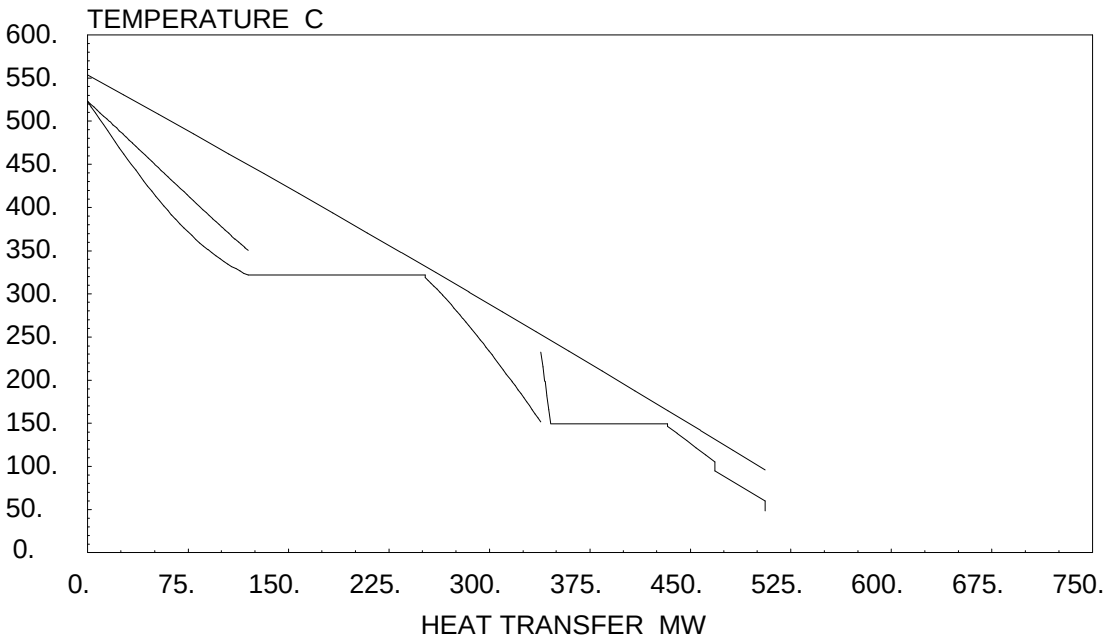

Figure 9 *TQ-diagram for the dual pressure reheat steam cycle*

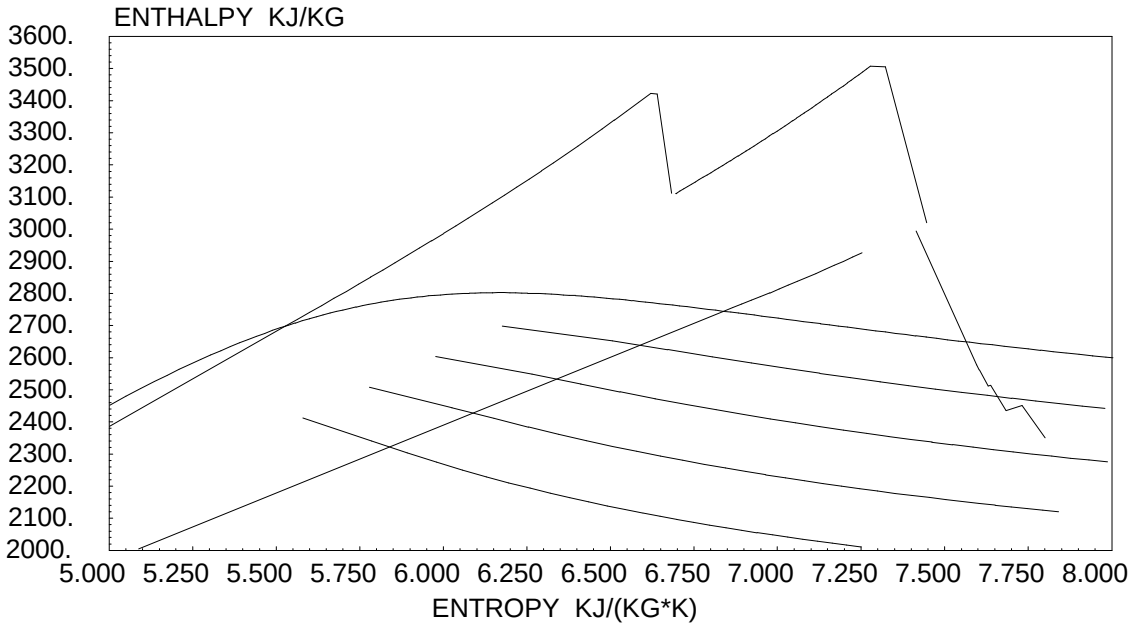

Figure 10 *HS-diagram for the dual pressure reheat steam cycle*

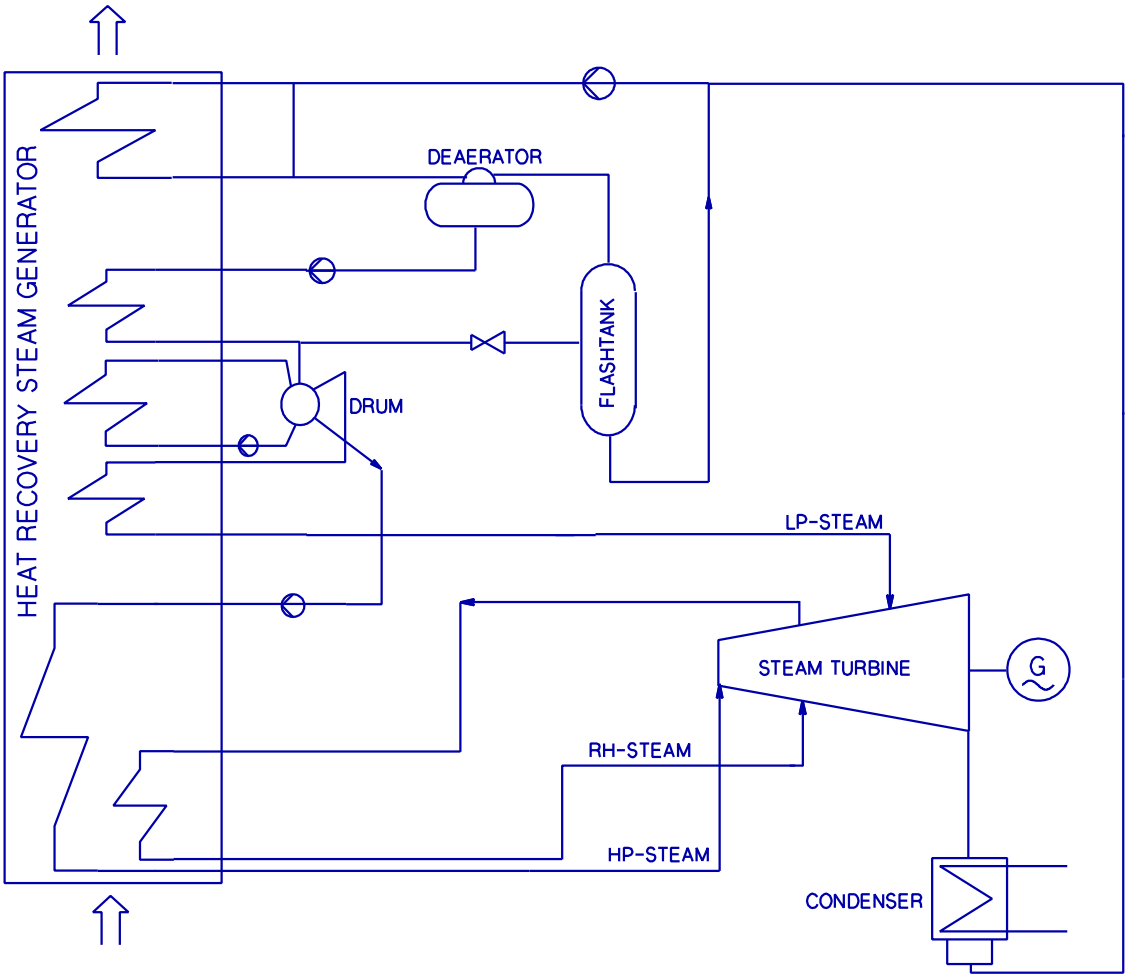

Figure 11 *Flowsheet diagram for the dual pressure supercritical reheat steam cycle*

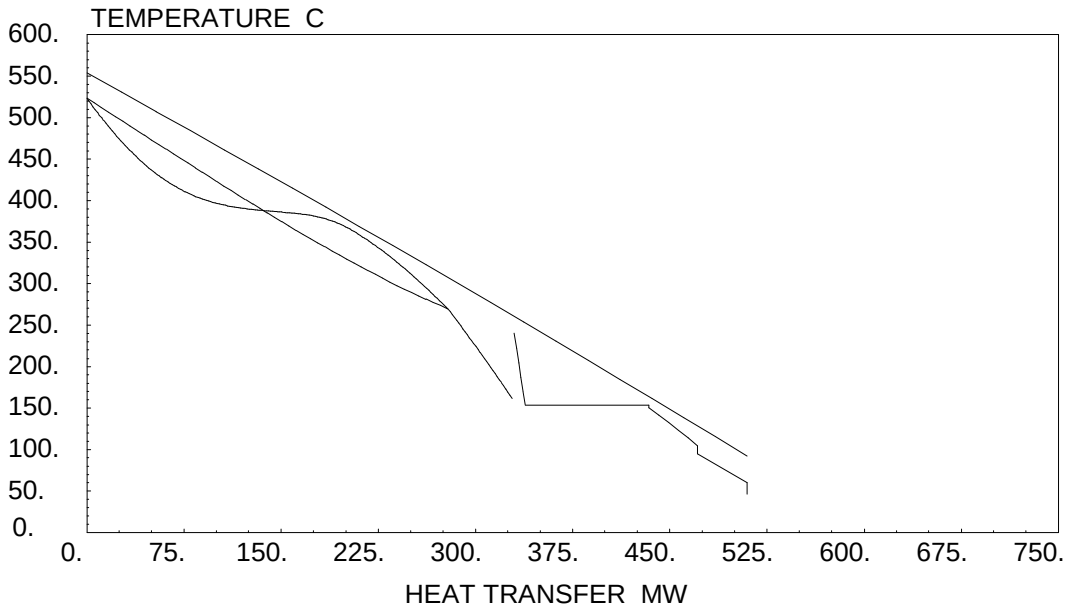

Figure 12 *TQ-diagram for the dual pressure supercritical reheat steam cycle*

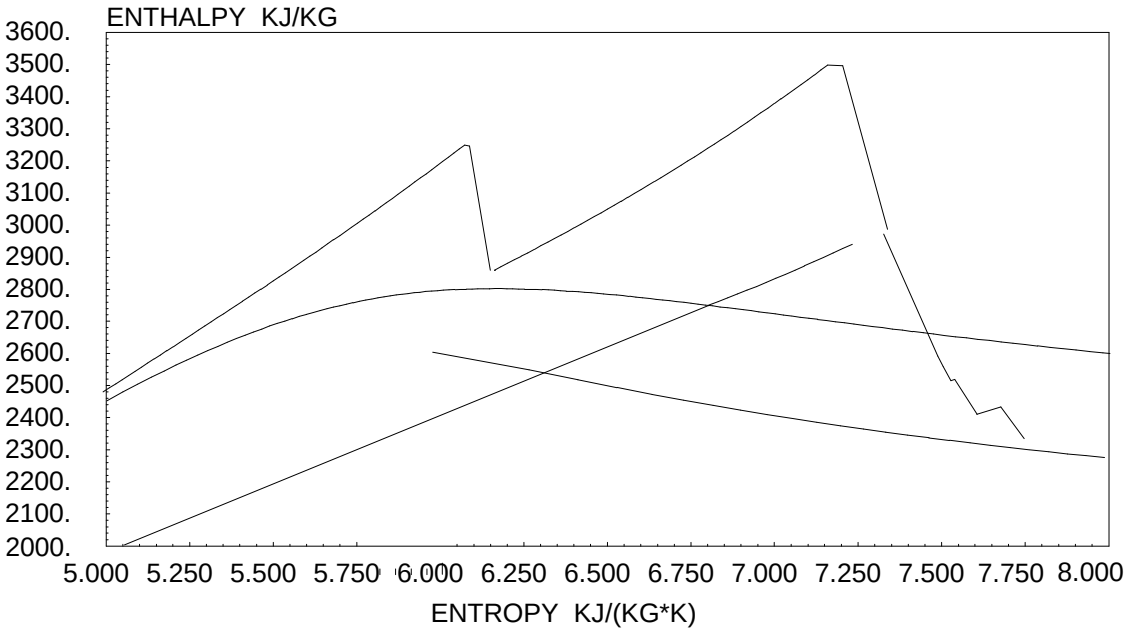

Figure 13 *HS-diagram for the dual pressure supercritical reheat steam cycle*

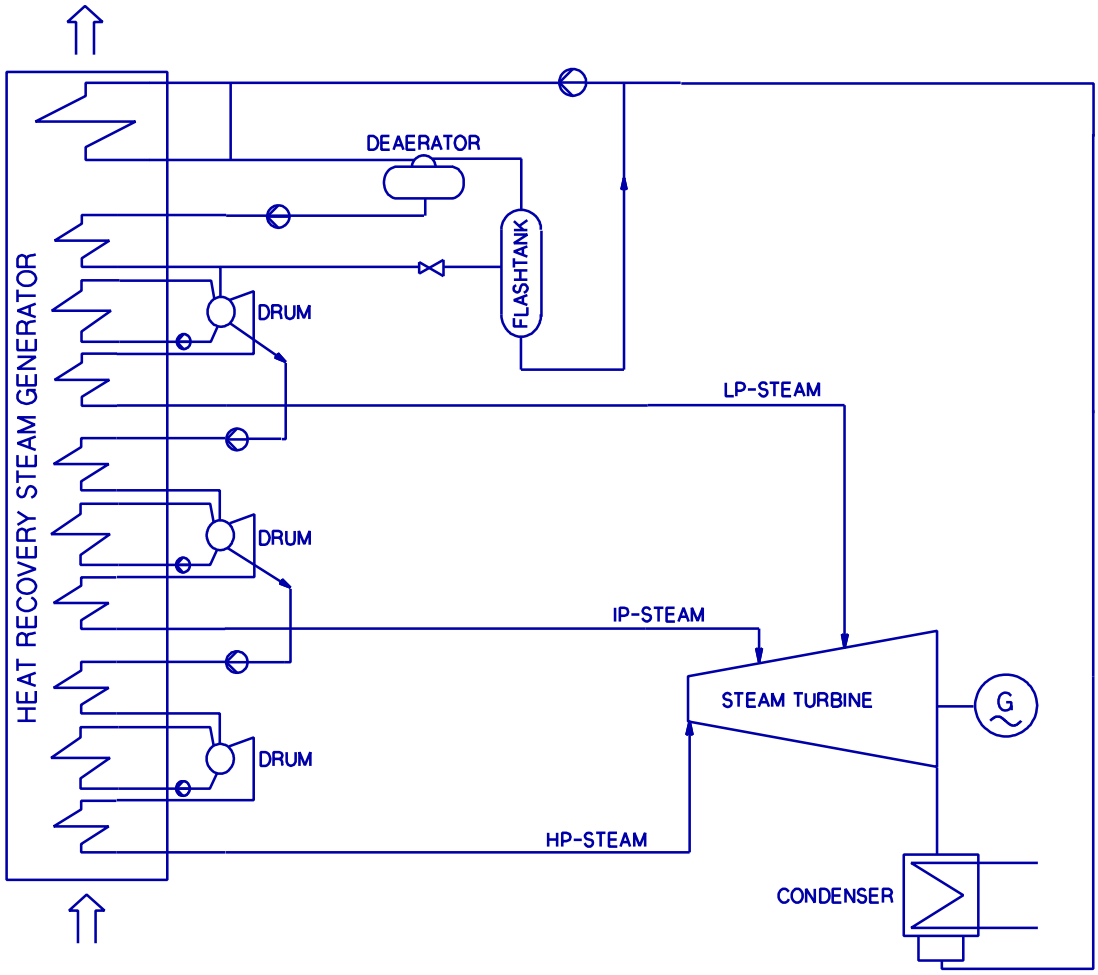

Figure 14 *Flowsheet diagram for the triple pressure steam cycle*

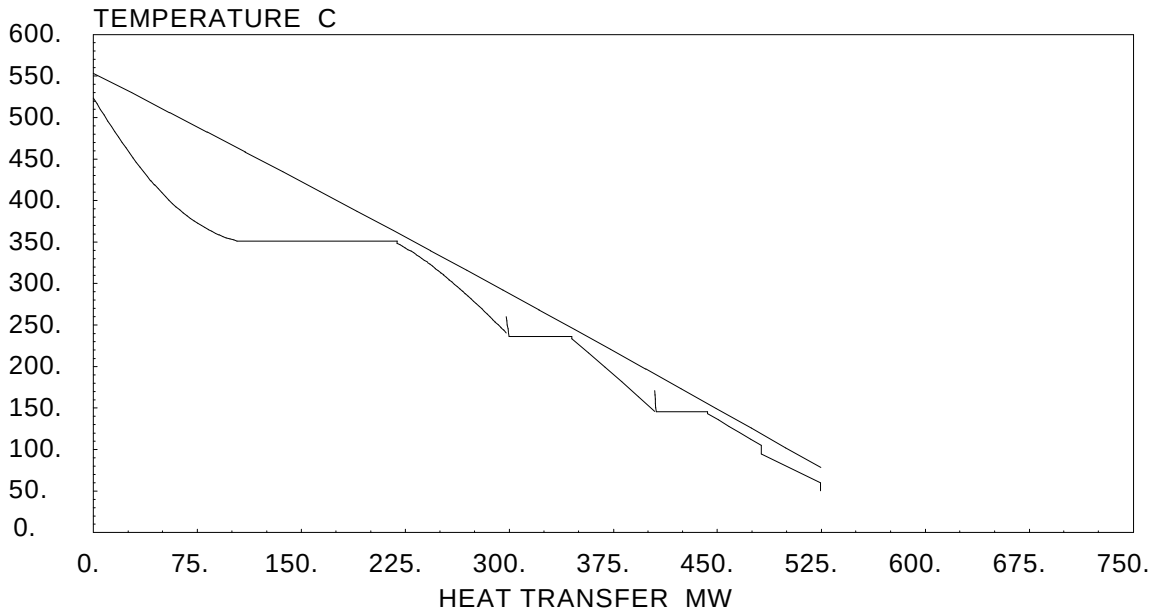

Figure 15 *TQ-diagram for the triple pressure steam cycle*

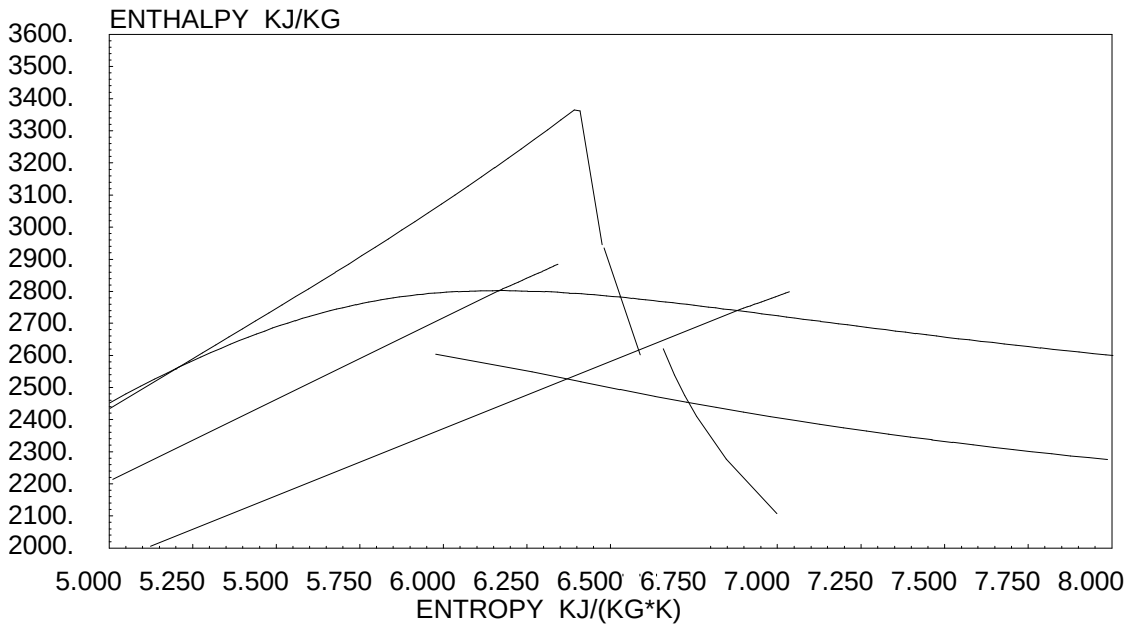

Figure 16 *HS-diagram for the dual triple pressure steam cycle*

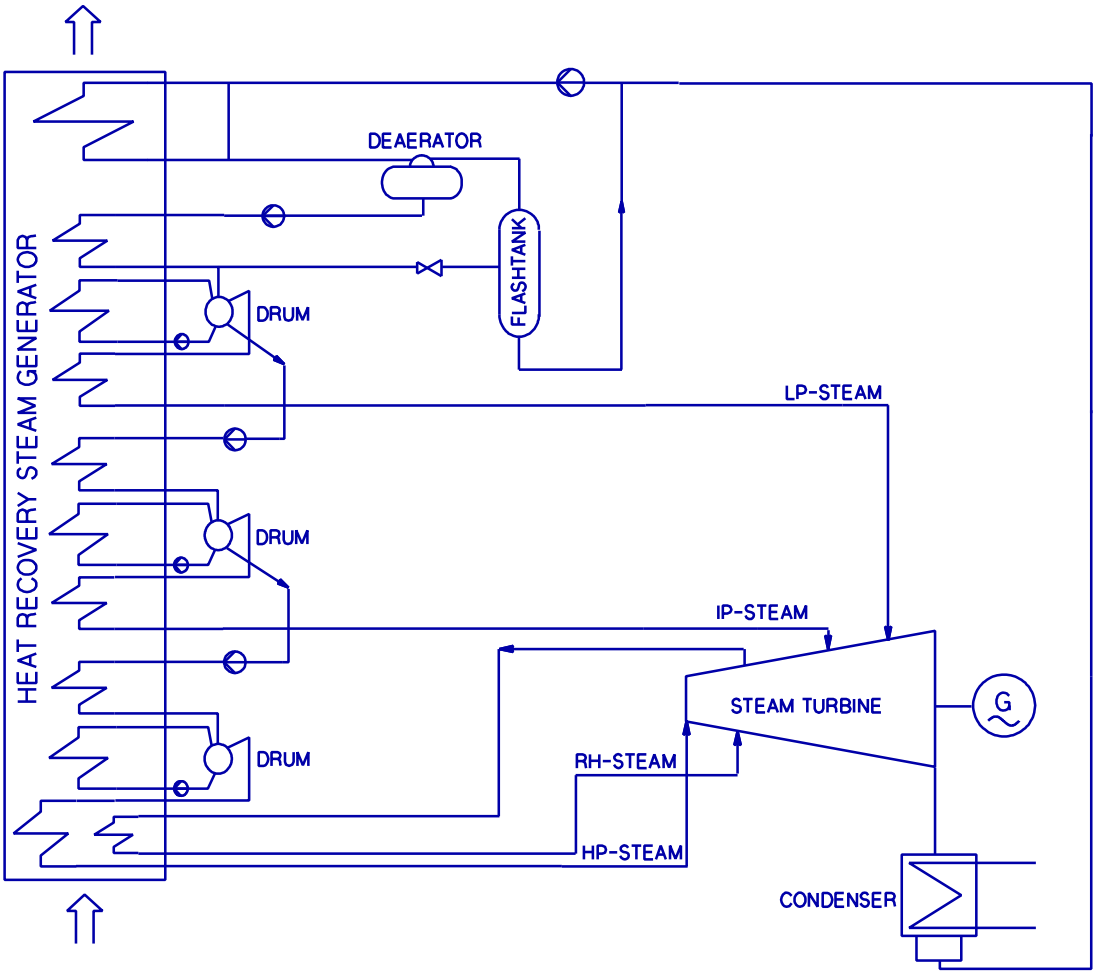

Figure 17 *Flowsheet diagram for the triple pressure reheat steam cycle*

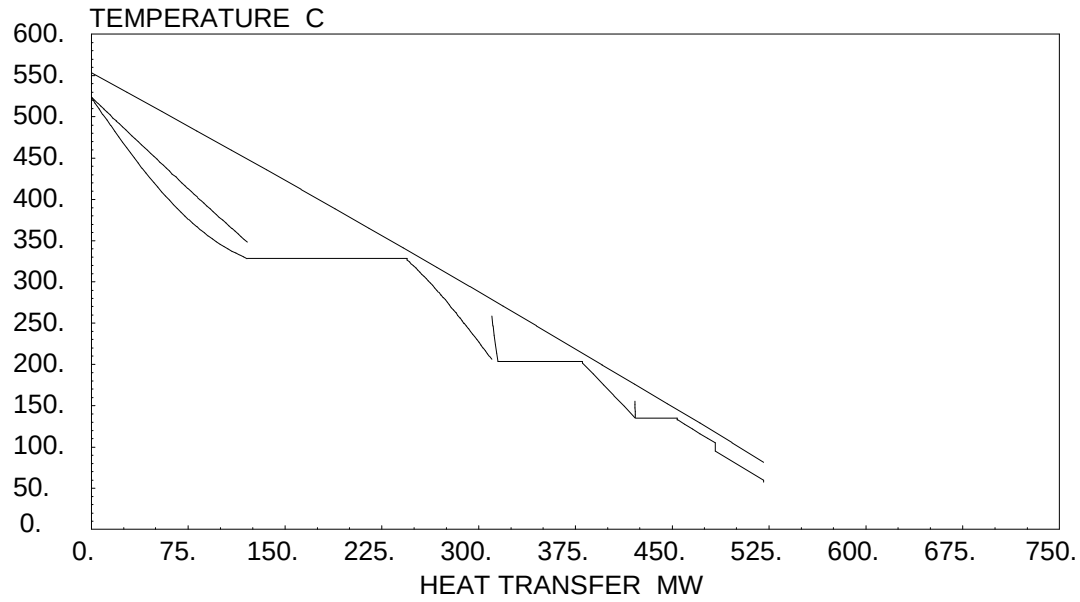

Figure 18 *TQ-diagram for the triple pressure reheat steam cycle*

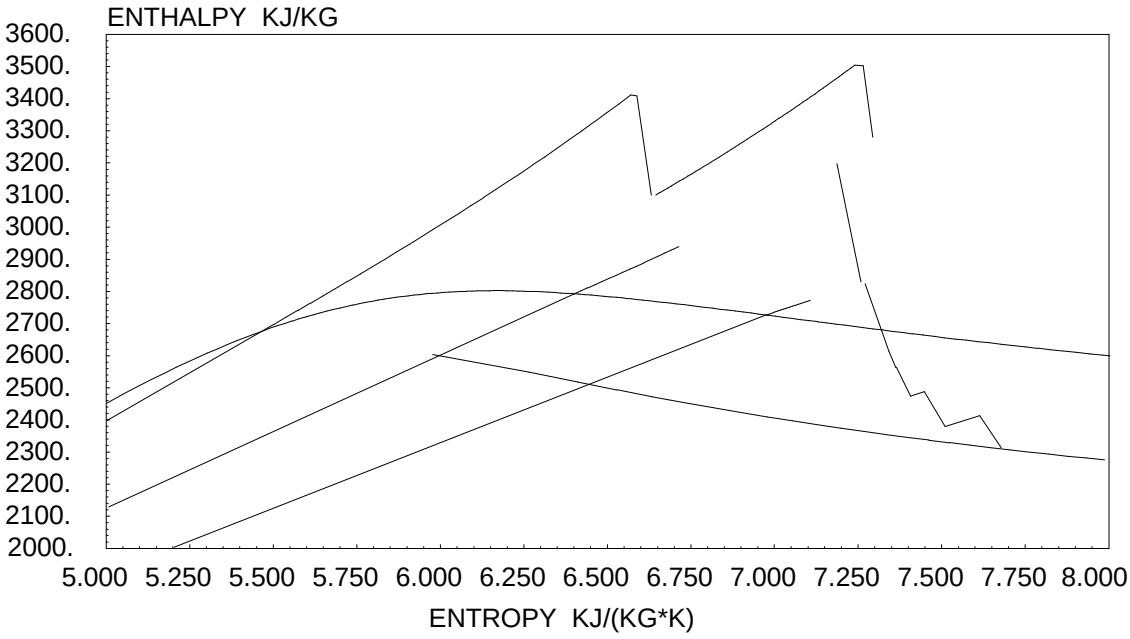

Figure 19 *HS-diagram for the triple pressure reheat steam cycle*

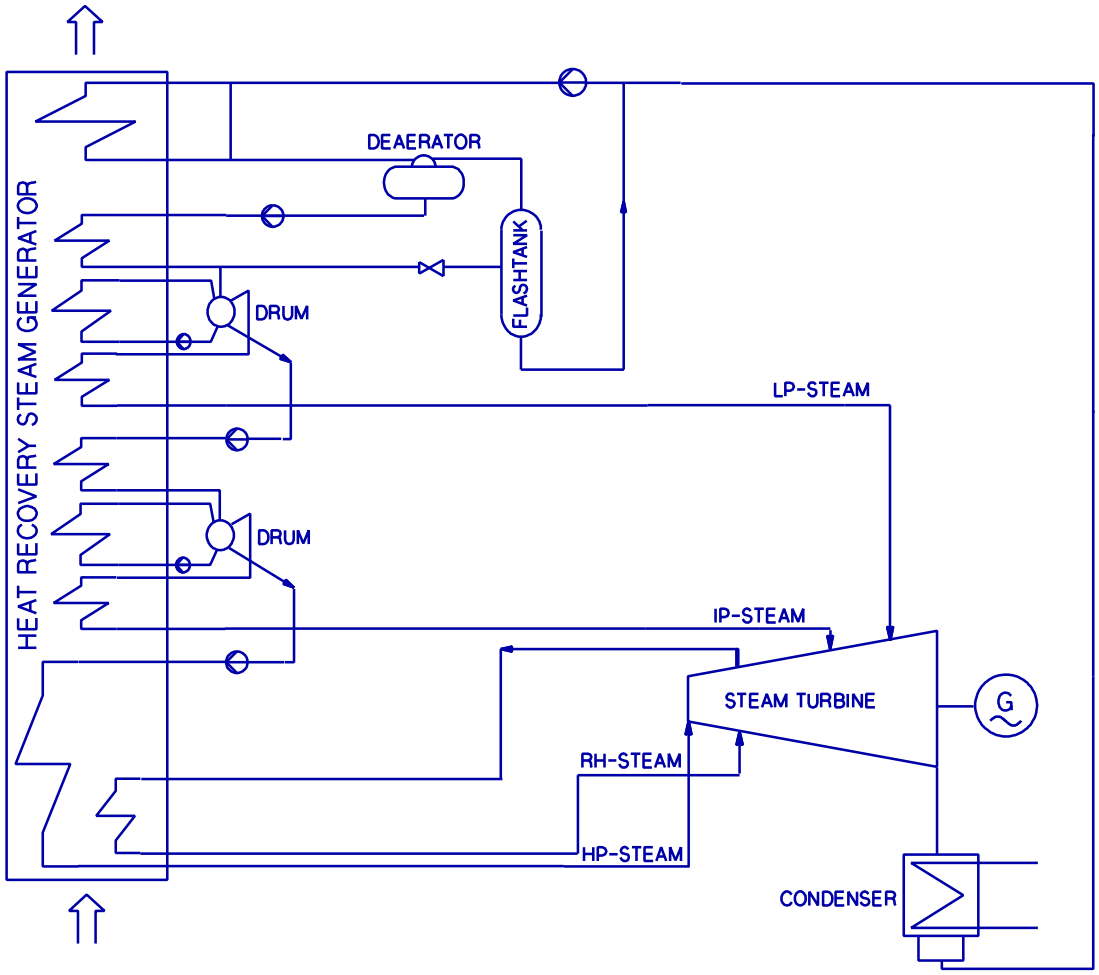

Figure 20 *Flowsheet diagram for the triple pressure supercritical reheat steam cycle*

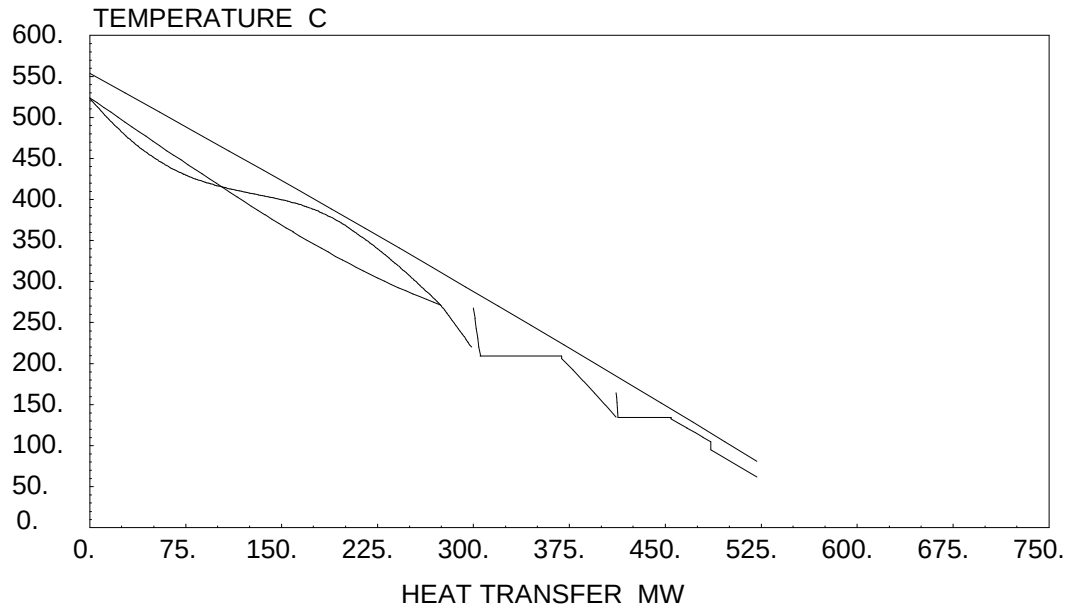

Figure 21 *TQ-diagram for the triple pressure supercritical reheat steam cycle*

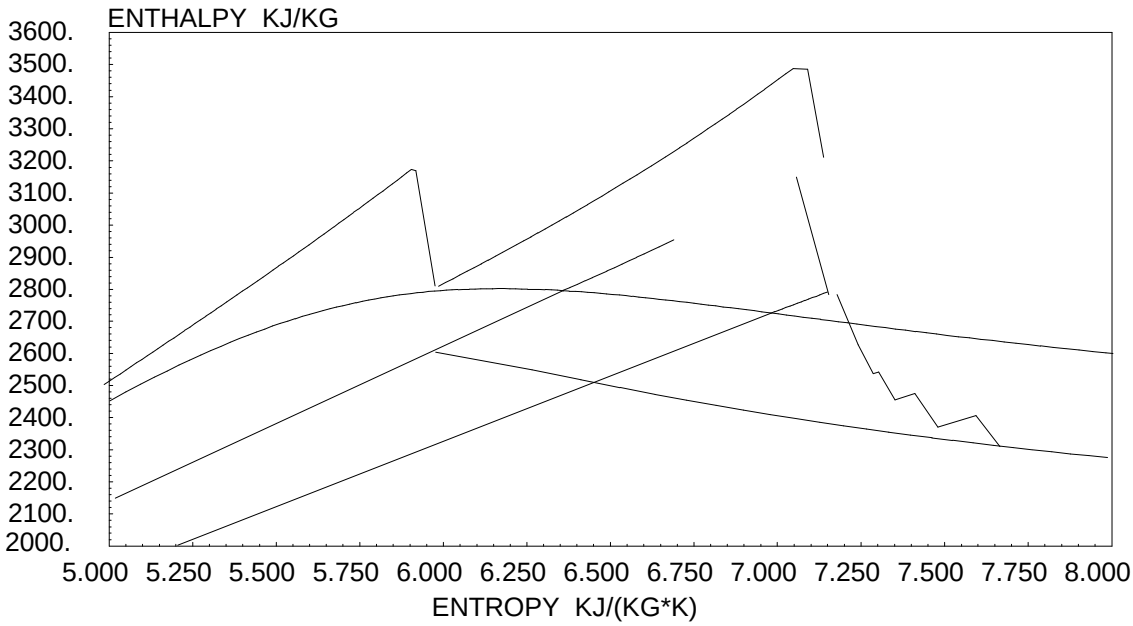

Figure 22 *HS-diagram for the triple pressure supercritical reheat steam cycle*

3 INPUT DESCRIPTION

In the following is a description given of the input required for a calculation in *POWSIM*. The different menues are described separately. The numbers which are referred to { **1)**, **2)** and so on}, are the item numbers in the menues.

The user supplied input data are in *POWSIM* separated into two categories; the gas turbine input data and the steam cycle input data. All the input data can be saved on files and retrieved later when needed. The two categories of input data are saved on separate file types (see section 1.4).

3.1 Powsim main menu

```
  POWSIM MAIN MENU    Version 1.2              Fag 66167 ITEV     02/23/94 08:28

 1  LOGICAL INPUT SEQUENCE
 2  GAS TURBINE INPUT
 3  SUPPLEMENTARY FIRING
 4  STEAM CYCLE CONFIGURATION
 5  STEAM CYCLE INPUT
 6  CALCULATION & OUTPUT
 7
 8
 9
10
11    TERMISKE KRAFTSTASJONER VCREN 1995
12
13
14
15
16  POWSIM INFORMATION
17  CHANGE DRIVE/DIRECTORY D:\POWSIM\WORK
18  COLOUR SETUP
19  QUIT THE PROGRAM
```

1) Selecting this item results *POWSIM* to choose the logical input sequence, by invoking the menues the user has to go through in order to do a cycle calculation. It is recommended to novel users of *POWSIM* to select this item to learn the proper sequence of input menues.

2) Invokes the GAS TURBINE INPUT and GAS TURBINE CHECK menues.

3) Invokes the SUPPLEMENTARY FIRING menu. The gas turbine input data must be given before *POWSIM* accept this selection.

4) Invokes the STEAM CYCLE CONFIGURATION menu. The gas turbine input data must be given before *POWSIM* accept this selection.

5) Invokes the STEAM CYCLE INPUT menu. Input data for the gas turbine and steam cycle configuration must be given before *POWSIM* accept this item to be chosen. If input data for the steam cycle configuration is not given before selecting this item, *POWSIM* invokes the STEAM CYCLE CONFIGURATION menu first and goes directly to the STEAM CYCLE INPUT menu.

6) By selecting this item, the CALCULATION & OUTPUT menu is invoked. Input data for the gas turbine and steam cycle must be given before *POWSIM* accept this item to be chosen.

7) - 15) Not used.

16) Display information about *POWSIM*: version number, date of origin, user identification and a telephone number and name to contact for help. Statistics for the use of *POWSIM* are also displayed.

17) Current directory and drive can be changed by selecting this item. *POWSIM* is able to save/retrieve files only to/from the current directory and drive (see page 25).

18) Screen colours can be selected; both foreground and background colours. When ending a *POWSIM* run the last selection of screen colours are saved on the POWSIM.DEF-file, in order to have the same screen colours for the next run of *POWSIM*.

```
                                CURRENT DRIVE          : D:
                                CURRENT DIRECTORY      : POWSIM\WORK
                                PATHNAME               : D:\POWSIM\WORK

                                NEW DRIVE              : C <cr>    (or C:)
                                NEW DIRECTORY (\..\..) : \ADMIN <cr>

                                CURRENT DRIVE          : C:
                                CURRENT DIRECTORY      : ADMIN
                                PATHNAME               : C:\ADMIN
```

Changing drive and directory (bold characters are user supplied input)

19) The user is prompted to confirm quitting *POWSIM*. By responding with "Y" the program is stopped. Any response other than "Y" will continue the *POWSIM* run. Before selecting this item, the user should ensure that the input data are saved on file. Otherwise, all input data are lost.

3.2 Gas turbine input

The gas turbine input data are checked for consistency when leaving the menu. If there are errors in the input data, the user is not allowed by *POWSIM* to leave the menu. If there are any errors, an error message is shown on the screen. When leaving this menu (without errors), the GAS TURBINE CHECK-menu is invoked directly.

```
  GAS TURBINE INPUT                                Fag 64167 ITEV     02/23/94 08:37

 1  PRESENT GAS TURBINE DATA FILE                    : v94.pgt
 2  READ NEW GAS TURBINE DATA FILE
 3
 4  GAS TURBINE NAME                                 : Siemens V94.
 5  NUMBER OF GAS TURBINES                           :            2
 6  GAS TURBINE NET POWER OUTPUT                     :   379044.000     kW
 7  FUEL MASS FLOW                                   :       21.470     kg/s
 8  GAS TURBINE AUXILIARY POWER REQUIREMENT          :      800.000     kW
 9  FUEL LOWER HEATING VALUE                         :    50056.000     kJ/kg
10
11  EXHAUST FLOW RATE                               :     1130.460     kg/s
12  EXHAUST TEMPERATURE                             :      561.400     /C (-X)
13  EXHAUST COMPOSITION    - NITROGEN         N2    :       75.800     %
14                         - ARGON            AR    :        0.000     %
15                         - CARBON DIOXIDE   CO2   :        3.100     %
16                         - OXYGEN           O2    :       14.100     %
17                         - WATER VAPOUR     H2O   :        7.000     %
18  SUM OF COMPONENTS                               :      100.000     %
19
20  CHANGE DRIVE/DIRECTORY D:\POWSIM\WORK
```

1) The name of the present gas turbine data file. This item is for information only and cannot be changed by selecting the item. If no gas turbine file is retrieved or saved, the name field is filled with dots.

2) Retrieve a gas turbine data file. When selecting this item, the screen is cleared and a two-column list of gas turbine data files (*.PGT) are displayed (if any exist). The user is asked for a file name. The file name must be given without the file extension. After typing the file name, the user is asked to confirm his choice by pressing "Y". *POWSIM* then reads the file and gives a message if it was not successful. An example of retrieving a gas turbine data file is given below.

```
                              Directory List of:  C:\POWSIM\*.PGT

                              TURBINE1.PGT     V94.PGT          GT.PGT
                              TURBINE2.PGT     ABB13E.PGT GT1.PGT
                              GEFR9E.PGT       V64.PGT

                              PRESENT FILE IN MEMORY IS: GEFR9E.PGT

                              FILE TO BE RETRIEVED (NO EXTENSION): TURBINE1 <cr>

                              RETRIEVE FILE  TURBINE1.PGT  - CONFIRM  Y/N  :  Y
```

Retrieve a gas turbine data file (bold characters are user supplied input)

3) Not used.

4) Name of gas turbine. The number of characters in the gas turbine name is restricted to 12.

5) All the input quantities given for the gas turbine is by *POWSIM* interpreted to be for one gas turbine. If the user wants to calculate a steam cycle fed by exhaust gas from multiple gas turbines, this item can be used instead of giving mass flow rates and power output for multiple gas turbines.

6) Gas turbine gross power output referred to the generator terminals. The gas turbine net power output is the value given for this item minus the auxiliary power consumption (item 8)

7) Fuel mass flow.

8) Gas turbine auxiliary power requirement.

9) Fuel lower heating value.

10) Not used.

11) Gas turbine exhaust mass flow.

12) Gas turbine exhaust temperature.

13 - 17) Exhaust gas composition (mole-fraction or volume-fraction). Input for five different gases are required: nitrogen (13), argon (14), carbondioxide (15), oxygen (16) and water vapour (17). The oxygen fraction must always be larger than zero.

18) Sum of the gas fractions given in items 13-17. This item is for information only and cannot be changed by selecting the item. The sum of the component fractions has to be 100%. An error message is displayed if the sum of components does not equal 100%.

19) Not used.

20) Change drive and directory. See explanation in section 3.1 for item 17 (page 25).

3.3 Gas turbine check

This menu looks very much like the GAS TURBINE INPUT menu. When leaving the GAS TURBINE INPUT menu this menu is invoked directly. In the following only the differences from the GAS TURBINE INPUT menu are explained. Only items 2, 3 and 20 can be selected from this menu.

```
 GAS TURBINE CHECK                                Fag 64167 ITEV     02/23/94 08:37

 1  PRESENT GAS TURBINE DATA FILE                    : v94.pgt
 2  SAVE GAS TURBINE DATA ON FILE
 3  RETURN TO GAS TURBINE DATA INPUT MENU
 4  GAS TURBINE NAME                                 : Siemens V94.
 5  NUMBER OF GAS TURBINES                           :          2
 6  GAS TURBINE NET POWER OUTPUT                     :   379044.000     kW
 7  FUEL MASS FLOW                                   :       21.470     kg/s
 8  GAS TURBINE AUXILIARY POWER REQUIREMENT          :      800.000     kW
 9  FUEL LOWER HEATING VALUE                         :    50056.000     kJ/kg
10  GAS TURBINE NET EFFICIENCY (CALCULATED)          :       35.195     %
11  EXHAUST FLOW RATE                                :     1130.460     kg/s
12  EXHAUST TEMPERATURE                              :      561.400     /C (-X)
13  EXHAUST COMPOSITION    - NITROGEN         N2     :       75.800     %
14                         - ARGON            AR     :        0.000     %
15                         - CARBON DIOXIDE   CO2    :        3.100     %
16                         - OXYGEN           O2     :       14.100     %
17                         - WATER VAPOUR     H2O    :        7.000     %
18  EXHAUST GAS MOLECULAR WEIGHT                     :       28.374     kg/kmole
19  GAS CONSTANT                                     :      293.038     kJ/(kg*K)
20  CHANGE DRIVE/DIRECTORY D:\POWSIM\WORK
```

2) Save the gas turbine input data on file. When selecting this item, the screen is cleared and a two-column list of gas turbine data files (*.PGT) are displayed (if any exist). The user is asked for a file name. The file name must be given without the file extension. After typing the file name, the user is asked to confirm his choice by pressing "Y". *POWSIM* then saves the file and gives a message if it was not successful. An example of saving a gas turbine data file is given below.

```
                                Directory List of:  C:\POWSIM\*.PGT

                                TURBINE1.PGT     V94.PGT           GT.PGT
                                TURBINE2.PGT     ABB13E.PGT GT1.PGT
                                GEFR9E.PGT       V64.PGT

                                PRESENT FILE IN MEMORY IS: GEFR9E.PGT

                                FILE TO BE SAVED (NO EXTENSION): TURBINE1 <cr>

                                SAVE FILE  TURBINE1.PGT  - CONFIRM  Y/N  : Y
```

Saving the gas turbine input data (bold characters are user supplied input)

3) Return to the GAS TURBINE INPUT menu.

10) The gas turbine net efficiency. Based on the given inputs for the gas turbine, the net efficiency is calculated. The following equation is applied to calculate this efficiency.

$$h_{GT} = \frac{P_{GT} - P_{AUX}}{mf_{GT} \; LHV} \qquad \text{Eq. (1)}$$

0_{GT} = gas turbine net efficiency (item 10)
P_{GT} = gas turbine gross power output (item 6)
P_{AUX} = gas turbine auxiliary power requirement (item 8)
mf_{GT} = gas turbine fuel mass flow (item 7)
LHV = fuel lower heating value (item 9)

18) Exhaust gas molecular weight.

19) Gas constant.

20) Change drive and directory. See explanation in section 3.1 for item 17 (page 25).

3.4 Supplementary firing

The exhaust gas leaving the gas turbine(s) can be fired in order to increase the plant power output and in some cases also increase the efficiency. Methane (CH_4) is used as fuel for this supplementary firing.

```
  SUPPLEMENTARY FIRING                          Fag 64167 ITEV     02/23/94 08:43

 1  EXHAUST GAS TEMPERATURE BEHIND GAS TURBINE     :      561.400     /C (-X)
 2  SUPPLEMENTARY FIRING TEMPERATURE               :      650.000     /C (-X)
 3  CALCULATE SUPPLEMENTARY FIRING
 4
 5  NITROGEN         (before supplementary firing) :       75.800     %
 6  ARGON                                          :        0.000     %
 7  CARBONDIOXIDE                                  :        3.100     %
 8  OXYGEN                                         :       14.100     %
 9  WATER VAPOUR                                   :        7.000     %
10  MOLECULAR WEIGHT                               :       28.374     kg/kmole
11
12  NITROGEN         (after supplementary firing)  :       75.509     %
13  ARGON                                          :        0.000     %
14  CARBONDIOXIDE                                  :        3.472     %
15  OXYGEN                                         :       13.278     %
16  WATER VAPOUR                                   :        7.741     %
17  MOLECULAR WEIGHT                               :       28.326     kg/kmole
18  SUPPLEMENTARY FIRING FUEL FLOW  (CH4)          :        4.924     kg/s
```

1) Exhaust gas temperature behind gas turbine. This item is for information only and cannot be changed by the user in this menu. This value can be changed in the GAS TURBINE INPUT menu.

2) Supplementary firing temperature. This is the desired exhaust gas temperature after the firing. The value for this item must be higher than the value for item 1. Otherwise, no calculation of the supplementary firing is performed.

3) Calculate supplementary firing. It is not necessary to choose this item before leaving the menu. The supplementary firing is calculated automaticly when doing the cycle calculation.

4) Not used.

5) - 10) Exhaust gas composition (mole fractions) and molecular weight before supplementary firing. These items are in this menu only for information and cannot be changed by the user. These values can be changed in the GAS TURBINE INPUT menu.

11) Not used.

12) - 17) Exhaust gas composition (mole fractions) and molecular weight after supplementary firing. These items are updated when choosing item 3.

18) Supplementary firing fuel flow. This is the amount of fuel that is necessary to increase the temperature of the exhaust gas from the value for item 1 to the value for item 2.

3.5 Steam cycle configuration

This menu is used to select the type of steam cycle system. If an invalid configuration is specified, an error message appears in the lower left corner of the screen, and *POWSIM* does not allow the user to leave the menu.

```
  STEAM CYCLE CONFIGURATION                      Fag 64167 ITEV     02/23/94 08:49

 1  AIR BOTTOMING CYCLE                              :           NO
 2  MAXIMUM NUMBER OF PRESSURE LEVELS                :            7
 3  NUMBER OF PRESSURE LEVELS                        :            2
 4  STEAM REHEATING                                  :           NO
 5  SUPPLEMENTARY FIRING OF GAS TURBINE EXHAUST      :          YES
 6  SUPERCRITICAL STEAM PRESSURE                     :           NO
 7  AMBIENT AIR TEMPERATURE (for exergy analysis)    :       15.000     /C (-X)
 8  AMBIENT WATER TEMPERATURE (for exergy analysis):       15.000     /C (-X)
 9  CASE NAME (maximum 12 characters)                : 2-TRYKK
10
11  READ STEAM CYCLE DATA FROM FILE
12  CHANGE DRIVE/DIRECTORY D:\POWSIM\WORK
```

1) Maximum number of pressure levels. For *POWSIM* version 1.2 the number of pressure levels is restricted to 7. This item is for information only and cannot be changed by selecting the item.

2) Number of pressure levels. In *POWSIM* the number of pressure levels is defined as the number of HRSG steam exit points feeding the steam turbine. The steam reheat is always pressure level 2. The number of pressure levels has to be greater than or equal to 1, and less than or equal to item 1.

3) Steam reheating. The user can select whether he wants to have steam reheating or not. In case of having steam reheating, item 2 has to be greater than or equal 2.

4) Supplementary firing of exhaust. Before the gas turbine exhaust (or ambient air) enters the HRSG, it is possible to increase the temperature. To be able to enter the SUPPLEMENTARY FIRING menu, this item must be "YES".

5) Supercritical steam pressure. *POWSIM* is able to calculate pressure level 1 with supercritical steam pressure (greater than 221 bar).

6) Ambient air temperature. This temperature is used for exergy calculations, and has an important meaning for calculation of stack loss.

7) Ambient water temperature. This temperature is used for exergy calculations, and has an important meaning for calculation of condenser losses. The user should be aware that if different values for item 6 and 7 are used, there will be a discrepancy between the steam cycle exergy efficiency and the steam cycle exergy losses. However, using the actual ambient air temperature for item 6 and the actual cooling water temperature for item 7 give the best picture of the stack loss and condenser losses.

8) Case name. A case identifier restricted to 12 characters may be specified. The case name will appear on plot diagrams and in the output files.

9) Not used.

10) Retrieve steam cycle data from file. When selecting this item, the screen is cleared and a two-column list of steam cycle data files (*.PDT) are displayed (if any exist). The user is asked for a file name. The file name must be given without the file extension. After typing the file name, the user is asked to confirm his choice by pressing "Y". *POWSIM* then reads the file and gives a message if it was not successful. An example of retrieving a gas turbine data file is given below.

```
                                CYCLE1.PDT        3PRS.PDT
                                CYCLE2.PDT        TEST.PDT
                                2PR.PDT           2P.PDT

                                PRESENT FILE IN MEMORY IS: CYCLE1.PDT

                                FILE TO BE RETRIEVED (NO EXTENSION):  2PR <cr>

                                RETRIEVE FILE  SLETT2.PDT  - CONFIRM  Y/N  :   Y
```

Retrieve a steam cycle data file (bold characters are user supplied input)

11) Change drive and directory. See explanation in section 3.1 for item 17 (page 25).

3.6 Steam cycle input

The STEAM CYCLE INPUT menu is the top menu for user supplied steam cycle data. Menues for different sections of the steam cycle can be invoked. The steam cycle inputs can be saved or retrieved from this menu. When leaving this menu the steam cycle data are checked for consistency and errors. The user cannot leave this menu unless *POWSIM* accepts the input data. If any changes in the steam cycle configuration have been made (STEAM CYCLE CONFIGURATION menu), the user should go through the items in this menu.

```
  STEAM CYCLE INPUT                              Fag 64167 ITEV     02/23/94 08:50

 1  FULL INPUT
 2  HEAT RECOVERY STEAM GENERATOR
 3  PREHEATING SYSTEM/FEEDWATER TANK/CONDENSER
 4  STEAM TURBINE
 5  PUMPS
 6  PRESENT FILE IN MEMORY                          : 2p.pdt
 7  RETRIEVE STEAM CYCLE DATA FROM FILE
 8  SAVE STEAM CYCLE DATA ON FILE
 9  CHANGE DRIVE/DIRECTORY D:\POWSIM\WORK
10  GAS TURBINE INPUT
```

1) Full input. The user is brought automaticly through all the menues for the steam cycle input. This is useful when giving input for a new case. Selecting this item is strongly recommended if the number of pressure levels is changed from the previous run.

2) HRSG. The menu for input of HRSG data is invoked.

3) Preheating system and condenser. The menu for input of data for the preheating system and condenser is invoked.

4) Steam turbine. The menu for input of steam turbine data is invoked.

5) Pumps. The menu for input of data for the pumps in the steam cycle is invoked.

6) The name of the present steam cycle data file. This item is for information only and cannot be changed by selecting the item. If no steam cycle data file is retrieved or saved, the name field is filled with dots.

7) Retrieve steam cycle data from file. When selecting this item, the screen is cleared and a three-column list of steam cycle data files (*.PDT) are displayed (if any exist). The user is asked for a file name. The file name must be given without the file extension. After typing the file name, the user is asked to confirm his choice by pressing "Y". *POWSIM* then reads the file and gives a message if it was not successful.

8) Save steam cycle data on file. When selecting this item, the screen is cleared and a three-column list of steam cycle data files (*.PDT) are displayed (if any exist). The user is asked for a file name. The file name must be given without the file extension. After typing the file name, the user is asked to confirm his choice by pressing "Y". *POWSIM* then saves the file and gives a message if it was not successful.

9) Change drive and directory. See explanation in section 3.1 for item 17 (page 25).

10) Invokes the GAS TURBINE INPUT and GAS TURBINE CHECK menues.

3.6.1 Heat recovery steam generator

The HRSG input sequence consists of a number of menues corresponding the number of pressure levels. There are four types of menues, though these are quite similar. The different menues are:

- → menu for subcritical pressure level (pressure level number equal 1)
- → menu for subcritical pressure level (pressure level number greater than 1)
- → menu for supercritical pressure level
- → menu for reheat pressure level

```
 HEAT RECOVERY STEAM GENERATOR                  Fag 64167 ITEV     02/23/94 08:51

 1  PRESSURE LEVEL NUMBER                            :            1
 2  NON-REHEAT PRESSURE LEVEL
 3  LIVE STEAM PRESSURE                              :       79.000     bar
 4  PINCH-POINT TEMPERATURE DIFFERENCE               :       10.000     /C (-X)
 5  SUPERHEATER HOT END TEMPERATURE DIFFERENCE        :       30.000     /C (-X)
 6  ECONOMIZER APPROACH TEMPERATURE DIFFERENCE        :        2.000     /C (-X)
 7  MAXIMUM STEAM TEMPERATURE                        :      530.000     /C (-X)
 8  SUPERHEATER PRESSURE LOSS  (-% , +bar)           :       -3.000
 9  EVAPORATOR  PRESSURE LOSS  (-% , +bar)           :       -3.000
10  ECONOMIZER  PRESSURE LOSS  (-% , +bar)           :       -3.000
11  SUPERHEATER HEAT TRANSFER COEFFICIENT            :       50.000     W/(M2*K)
12  EVAPORATER  HEAT TRANSFER COEFFICIENT            :       50.000     W/(M2*K)
13  ECONOMIZER  HEAT TRANSFER COEFFICIENT            :       50.000     W/(M2*K)
```

HRSG input menu for subcritical pressure level (pressure level number equal 1)

1) Pressure level number. This is the pressure level number for which inputs are given in this menu. This item is for information only and cannot be changed by selecting the item.

2) Non-reheat pressure level. This the description of the type of the pressure level for which inputs are given in this menu.

3) Live steam pressure. The steam pressure at the superheater exit (hot end). When selecting a pressure close up to the supercritical pressure, make sure that the pressure losses (item 8-11) does not result in a supercritical drum pressure.

4) Pinch-point temperature difference. The difference between the exhaust gas temperature and the drum temperature.

5) Superheater hot end temperature difference. The temperature difference between exhaust gas and steam at the hot end of the superheater.

6) Economizer approach temperature difference. The difference between the drum temperature and the temperature of the water at the economizer exit (hot end).

7) Maximum steam temperature. If the exhaust gas temperature at the hot end of the HRSG is very high (for example when using supplementary firing), this item can be used to set an upper limit for the steam temperature at the hot end of the superheater. This item may supersede item 5.

8-10) Pressure loss for superheater, evaporator and economizer. The pressure loss can be given as a percentage (negative number) of the live steam pressure (item 3), or as an absolute value (positive number).

11-13) Heat transfer coefficient for superheater, evaporator and economizer. The heat transfer coefficients are used for the heat transfer area calculation.

1-6) Same as above.

```
 HEAT RECOVERY STEAM GENERATOR                 Fag 64167 ITEV     02/23/94 08:54

 1  PRESSURE LEVEL NUMBER                          :            2
 2  NON-REHEAT PRESSURE LEVEL
 3  LIVE STEAM PRESSURE                            :        5.250     bar
 4  PINCH-POINT TEMPERATURE DIFFERENCE             :       10.000     /C (-X)
 5  SUPERHEATER HOT END TEMPERATURE DIFFERENCE     :       20.000     /C (-X)
 6  ECONOMIZER APPROACH TEMPERATURE DIFFERENCE     :        2.000     /C (-X)
 7
 8  SUPERHEATER PRESSURE LOSS  (-% , +bar)         :       -3.000
 9  EVAPORATOR  PRESSURE LOSS  (-% , +bar)         :       -3.000
10  ECONOMIZER  PRESSURE LOSS  (-% , +bar)         :       -3.000
11  SUPERHEATER HEAT TRANSFER COEFFICIENT          :       50.000     W/(M2*K)
12  EVAPORATER  HEAT TRANSFER COEFFICIENT          :       50.000     W/(M2*K)
13  ECONOMIZER  HEAT TRANSFER COEFFICIENT          :       50.000     W/(M2*K)
14  NUMBER OF EVAPORATOR CIRCULATIONS              :        4.000
```

HRSG input menu for subcritical pressure level (pressure level number greater than 1)

7) Not used.

8-13) Same as above.

14) Number of evaporator circulations. In the evaporator the circulated flow rate is larger than the steam quantity flow rate by a factor. This menu item appears only for the highest pressure level number (item 1).

```
  HEAT RECOVERY STEAM GENERATOR                 Fag 64167 ITEV     02/23/94 08:55

 1  PRESSURE LEVEL NUMBER                          :            1
 2  SUPERCRITICAL PRESSURE LEVEL
 3  SUPERCRITICAL STEAM PRESSURE (>221 bar)        :      250.000     bar
 4  PINCH-POINT TEMPERATURE DIFFERENCE             :       10.000     /C (-X)
 5  SUPERCRITICAL STAGE HOT END TEMP. DIFFERENCE   :       30.000     /C (-X)
 6
 7  MAXIMUM STEAM TEMPERATURE                      :      550.000     /C (-X)
 8  SUPERCRITICAL STAGE PRESSURE LOSS  (-% , +bar) :       -5.000
 9
10
11  SUPERCRITICAL STAGE HEAT TRANSFER COEFFICIENT  :       50.000     W/(M2*K)
12
13
```

HRSG input menu for supercritical pressure level

1) Same as above.

2) Supercritical pressure level. This the description of the type of the pressure level for which inputs are given in this menu.

3) Supercritical steam pressure. The steam pressure at the exit of the supercritical stage (hot end). The pressure has to be greater than 221 bar.

4) Pinch-point temperature difference. The smallest difference between the exhaust gas temperature and the supercritical steam, except for the difference at the exit of the supercritical stage (item 5).

5) Supercritical stage hot end temp. difference. The temperature difference between exhaust gas and supercritical steam at the hot end of the supercritical stage.

6) Not used.

7) Maximum steam temperature. If the exhaust gas temperature at the hot end of the HRSG is very high (for example when using supplementary firing), this item can be used to set an upper limit for the steam temperature at the hot end of the superheater. This item may supersede item 5.

8) Supercritical stage pressure loss. The pressure loss can be given as a percentage (negative number) of the live steam pressure (item 3), or as an absolute value (positive number).

9-10) Not used.

11) Heat transfer coefficient for supercritical stage. The heat transfer coefficient is used for the heat transfer area calculation.

```
  HEAT RECOVERY STEAM GENERATOR                Fag 64167 ITEV     02/23/94 08:55

 1  PRESSURE LEVEL NUMBER                        :            2
 2  REHEAT PRESSURE LEVEL
 3  REHEAT LIVE STEAM PRESSURE                   :       40.000     bar
 4
 5  REHEATER HOT END TEMPERATURE DIFFERENCE      :       30.000     /C (-X)
 6
 7  MAXIMUM REHEAT STEAM TEMPERATURE             :      560.000     /C (-X)
 8  REHEATER PRESSURE LOSS  (-% , +bar)          :       -5.000
 9
10
11  REHEATER HEAT TRANSFER COEFFICIENT           :       50.000     W/(M2*K)
12
13
```

HRSG input menu for reheat pressure level

1) Same as above.

2) Reheat pressure level. This the description of the type of the pressure level for which inputs are given in this menu.

3) Reheat live steam pressure. The steam pressure at the reheater exit (hot end).

4) Not used.

5) Reheater hot end temperature difference. The temperature difference between exhaust gas and steam at the hot end of the reheater.

6) Not used.

7) Maximum reheat steam temperature. If the exhaust gas temperature at the hot end of the HRSG is very high (for example when using supplementary firing), this item can be used to set an upper limit for the reheat steam temperature at the hot end of the reheater. This item may supersede item 5.

8) Reheater pressure loss. The pressure loss can be given as a percentage (negative number) of the reheat steam pressure (item 3), or as an absolute value (positive number).

9-10) Not used.

11) Reheater heat transfer coefficient. The heat transfer coefficient is used for the heat transfer area calculation.

3.6.2 Preheating system and condenser

```
 PREHEATING SYSTEM AND CONDENSER              Fag 64167 ITEV     02/23/94 08:56

 1  PRESSURE IN FEEDWATER-TANK                    :        1.200     bar
 2  FEEDWATER-TANK APPROACH TEMPERATURE           :       10.000     /C (-X)
 3  PRESSURE DROP PREHEATER                       :        4.000     bar
 4  PREHEATER HEAT TRANSFER COEFFICIENT           :       50.000     W/(M2*K)
 5  PRESSURE DROP BETWEEN FLASH-TANK/FEEDWATER-TANK:       0.200     bar
 6  MINIMUM FEEDWATER TEMPERATURE ENTERING HRSG   :       60.000     /C (-X)
 7  COOLING WATER ENTERING TEMPERATURE            :       15.000     /C (-X)
 8  COOLING WATER TEMPERATURE RISE                :        7.500     /C (-X)
 9  TOTAL COOLING WATER PRESSURE DROP             :       10.000     M H2O
```

1) Pressure in feedwater tank. The pressure at which deaeration takes place. It is recommended to use a value between 1 and 2 bar.

2) Feedwater-tank approach temperature. The difference between the temperature in the feedwater tank and the feedwater preheater exit (hot end) temperature. Typical values are 7-10 EC.

3) Pressure loss feedwater preheater.

4) Heat transfer coefficient for preheater. The heat transfer coefficient is used for the heat transfer area calculation.

5) Pressure loss between flash-tank/feedwater-tank. The steam needed for deaeration in the feedwater tank is supplied from a flash tank which is connected to the exit of the low pressure economizer. The steam that is flashed off is led through a pipe to the feedwater tank, and with this item the pressure loss in this pipe can be given.

6) Minimum feedwater temperature entering HRSG. If the temperature of the water entering the feedwater preheater is close to or below the exhaust gas dew point, some condensation of the exhaust gas water vapour may occur at the tube surfaces and cause corrosion. To avoid this phenomena the feedwater should be heated up to a temperature well above the exhaust gas dew point before any heat exchange with the exhaust gas. The feedwater coming from the condenser is heated up by mixing with the liquid fraction coming from the flash tank. If the temperature after this mixing is below the value specified for this item, the water from the feedwater preheater exit (hot end) is circulated to the feedwater preheater entrance (cold end). It is recommended to use a value of 60 EC. If this value is close to the stack temperature, the feedwater preheater heat transfer area becomes very large. If no preheating of the feedwater is wanted, the value for this item should be set to a very low number (for example 0 EC).

7) Cooling water entering temperature. The temperature of the cooling water entering the condenser.

8) Cooling water temperature rise. The temperature rise of the cooling water through the condenser.

9) Total cooling water pressure loss. In order to calculate the cooling water pump work, the user may specify the cooling water pressure loss in the condenser and in the cooling water ducts.

3.6.3 Steam turbine

The steam turbine expansion path is broken into a number of sections which correspond to the number of HRSG pressure levels. The steam turbine input sequence consists of a number of menues corresponding the number of pressure levels. There are three types of menues, though these are quite similar. The different menues are:

- F menu for non-reheat pressure level (except for low pressure turbine)
- F menu for reheat pressure level (pressure level number equal 2)
- F menu for low pressure turbine

```
 STEAM TURBINE INPUT                          Fag 64167 ITEV     02/23/94 08:58

1  PRESSURE LEVEL NUMBER                        :            1
2  HEAT LOSS FROM LIVE STEAM PIPE TO TURBIN     :        1.000     /C (-X)
3  PRESSURE LOSS IN LIVE STEAM PIPE TO TURBINE  :        5.000     %
4
5  STEAM FRACTION THROUGH SEALS                 :        0.300     %
6
7
8
9  ISENTROPIC EFFICIENCY                        :       92.000     %
```

Steam turbine input menu for non-reheat pressure level (except for low pressure turbine)

1) Pressure level number. This is the pressure level number for which inputs are given in this menu. This item is for information only and cannot be changed by selecting the item.

2) Heat loss from live steam pipe to turbine. This is the heat loss from the superheater exit to the steam turbine inlet. It should be noted that if a pressure loss is specified in item 3), there will be a temperature drop between the HRSG and steam turbine regardless of the heat loss. This is due to the fact that the Joule-Thompson coefficient is greater than zero for the steam conditions that are typical in this respect. The Joule-Thompson coefficient : is defined by the relation

$$m \equiv \left(\frac{\partial T}{\partial p}\right)_h \qquad \text{Eq. (2)}$$

where

T = temperature
p = pressure
h = enthalpy

3) Pressure loss in live steam pipe to turbine. The pressure loss in the pipe going from the HRSG to the steam turbine. The item value is the pressure loss in percent of the pressure at the superheater exit (hot end).

4) Not used.

5) Steam fraction through seals. The fraction of the steam fed to the steam turbine that is lost through the seals. This fraction is therefore not expanded through the turbine and does not contribute to the steam turbine work.

6-8) Not used.

9) Isentropic efficiency. Each section (or pressure level) is calculated by an individual isentropic efficiency.

```
  STEAM TURBINE INPUT                          Fag 64167 ITEV     02/23/94 08:58

 1  PRESSURE LEVEL NUMBER                        :            2
 2  HEAT LOSS FROM LIVE STEAM PIPE TO TURBIN     :        1.000     /C (-X)
 3  PRESSURE LOSS IN LIVE STEAM PIPE TO TURBINE  :       10.000     %
 4  PRESSURE DROP IN REHEAT RETURN STEAM PIPE    :        3.000     %
 5  STEAM FRACTION THROUGH SEALS                 :        0.003     %
 6
 7
 8
 9  ISENTROPIC EFFICIENCY                        :       88.000     %
```

Steam turbine input menu for reheat pressure level (pressure level number equal 2)

1-3) Same as above.

4) Pressure loss in reheat return steam pipe. After expansion through the high pressure section (pressure level 1) of the steam turbine, the steam is led through a pipe to the HRSG for reheating. The pressure loss is a percentage of the high pressure section exit pressure.

5) Same as above.

6-8) Not used.

9) Same as above.

```
  STEAM TURBINE INPUT                          Fag 64167 ITEV     02/23/94 08:58

 1  PRESSURE LEVEL NUMBER                        :            3
 2  HEAT LOSS FROM LIVE STEAM PIPE TO TURBIN     :        1.000     /C (-X)
 3  PRESSURE LOSS IN LIVE STEAM PIPE TO TURBINE  :        7.000     %
 4
 5  STEAM FRACTION THROUGH SEALS                 :        0.200     %
 6  CONDENSER PRESSURE                           :        0.040     bar
 7  LEAVING LOSS                                 :       30.000     kJ/kg
 8  NUMBER OF LP-TURBINE WATER EXTRACTIONS       :            3
 9  ISENTROPIC EFFICIENCY                        :       87.000     %
10  MECHANICAL AND GENERATOR EFFICIENCY          :       98.206     %
11  STEAM TURBINE AUXILIARY POWER FRACTION       :        0.250     %
12  TRANSFORMER EFFICIENCY                       :       99.500     %
```

Steam turbine input menu for low pressure turbine

1-3) Same as above.

4) Not used.

5) Same as above.

6) Condenser pressure. This is the back pressure of the low pressure turbine.

7) Leaving loss. The exit velocities from a low pressure turbine may be quite high. This item can be used to account for this loss.

8) Number of LP-turbine water extractions. In some cases the low pressure turbine steam exit quality may be to low and cause erosion. To avoid this problem water drainage devices may be used. *POWSIM* is able to calculate with up to three water extractions.

9) Isentropic efficiency. The low pressure turbine expansion path is broken into steps, and the efficiency is corrected for moisture when the exit quality is below that for the onset of condensation (Wilson-line). The efficiency given for this item is corrected for moisture with the following relation

$$\eta_{is} = \eta_{is,dry}\left[1-(1-x_{mean})^{c}\right] \qquad \text{Eq. (3)}$$

where

η_{is} = expansion step isentropic efficiency
$\eta_{is,dry}$ = isentropic efficiency for section (item 9)
x_{mean} = mean steam quality for the expansion step
c = efficiency moisture correction factor

10) Mechanical and generator efficiency. This item is the mechanical efficiency for the steam turbine multiplied with the generator efficiency.

11) Steam turbine auxiliary power fraction. Power demand for steam turbine oil coolers and controls.

12) Transformer efficiency. The electricity generated by the generator is usually transformed at the site of the power plant. In order to include the transformer losses in the calculation of the plant net efficiency, item 12 can be set to a value below 100 %. A typical value is 99.5 %.

3.6.4 Pumps

The look of the PUMP menu depends on the number of pressure levels and whether reheating is specified or not. Menu items with odd numbers are for isentropic efficiency and even numbers are for mechanical efficiency. In the text for the menu items for feedwater pumps there is a number ("#1", "#2" and so on). These numbers refer to the HRSG pressure levels. A reheat pressure level has no pumps, and *POWSIM* does not ask for input for any pumps for such a pressure level (see example below). There are no input items for the evaporator circulation pumps, but *POWSIM* use the efficiencies given for the feedwater pumps for the calculation of the circulation pumps.

```
 PUMPS                                          Fag 64167 ITEV     02/23/94 09:07

 1  ISENTROPIC EFFICIENCY FEEDWATER PUMP #1        :       82.000     %
 2  MECHANICAL EFFICIENCY FEEDWATER PUMP #1        :       92.000     %
 3  ISENTROPIC EFFICIENCY FEEDWATER PUMP #2        :       82.000     %
 4  MECHANICAL EFFICIENCY FEEDWATER PUMP #2        :       90.000     %
 5  ISENTROPIC EFFICIENCY FEEDWATER PUMP #3        :       82.000     %
 6  MECHANICAL EFFICIENCY FEEDWATER PUMP #3        :       90.000     %
 7  ISENTROPIC EFFICIENCY CONDENSATE PUMP          :       82.000     %
 8  MECHANICAL EFFICIENCY CONDENSATE PUMP          :       92.000     %
 9  ISENTROPIC EFFICIENCY COOLING WATER PUMP       :       82.000     %
10  MECHANICAL EFFICIENCY COOLING WATER PUMP       :       92.000     %
```

Pumps input menu

Odd numbers) Isentropic efficiency for feedwater pumps (which is also the efficiency for the circulation pumps), condensate pump and cooling water pump.

Even numbers) Mechanical efficiency for feedwater pumps (which is also the efficiency for the circulation pumps), condensate pump and cooling water pump.

3.7 Calculation & output

```
  CALCULATION & OUTPUT                          Fag 64167 ITEV     02/23/94 09:11

 1  CALCULATE CYCLE
 2  CALCULATE CYCLE & HEAT TRANSFER AREA
 3
 4
 5  COMPUTATIONAL RESULTS ON SCREEN
 6  COMPUTATIONAL RESULTS TO FILE
 7  HEAT BALANCE & EXERGY ANALYSIS ON SCREEN
 8  HEAT BALANCE & EXERGY ANALYSIS TO FILE
 9  CHECK IF SUPL. FIRING INCREASES EFFICIENCY
10  MAKE HRSG TQ-DIAGRAM PLOTTER FILE (HP-GL)
11  PLOT HRSG TQ-DIAGRAM ON SCREEN
12  PLOT HRSG TQ-DIAGRAM ON SCREEN (MANUAL INPUT)
13  MAKE Hs-DIAGRAM PLOTTER FILE (HP-GL)
14  PLOT Hs-DIAGRAM ON SCREEN
15  PLOT Hs-DIAGRAM ON SCREEN (MANUAL INPUT)
16  MAKE GAS PROPERTY TABLE
17  GAS TURBINE INPUT
18  STEAM CYCLE INPUT
```

Calculation and output menu

In order to select items 5-15 the cycle must be calculated. However, it is possible to choose items 5-16 without first having used item 1 or 2. If the cycle is not calculated, *POWSIM* does this before the action for items 5-15 is performed.

1) Calculate cycle. The cycle is normally calculated within 0.3-5 seconds and the results are shown. The results can also be viewed on the screen by selecting item 5.

2) Calculate cycle & heat transfer area. This is the same as item 1, but in addition the heat transfer area for the different HRSG sections are calculated. The calculation of the HRSG heat transfer area take some more time than the cycle calculation. The reason for this is that the different HRSG sections are calculated in small steps in order to take into the influence of variable c_P of the fluids.

3) Optimize cycle. The live steam pressures for the different HRSG sections can be optimized with respect to plant net efficiency. If supplementary firing is used, the temperature after the supplementary firing can be optimized with respect to plant net efficiency. The box below shows the input sequence for the optimization. In the box on page 43 is an example of the input sequence shown.

The optimization procedure is a search through a number of combinations of the parameters which the net efficiency is maximized for. For each parameter (live steam pressures and supplementary firing temperature if used) the user must give a range (lower to upper value) and a step value. If the user want to use a constant value for a parameter, this is simply accomplished by setting the lower value equal to the upper value. *POWSIM* does not accept a lower value that is higher than the upper value, or a step value that is higher than the difference between the lower and upper value (except if upper and lower values are equal).

The number of cycle calculations is in some cases very high and the optimization procedure then requires long time. It is, however, possible to break the optimiztion procedure by pressing "B". *POWSIM* remembers the values of the optimized parameters achieved when breaking the optimization procedure.

```
                                                    USER ID           09/05/90 20:26

OPTIMIZATION OF LIVE STEAM PRESSURES AND SUPPLEMENTARY FIRING
NUMBER OF PRESSURE LEVELS:            3

LOWER,UPPER,STEP FOR PRESSURE LEVEL #1 (115.0) : 110,120,2 <cr>              6       6
LOWER,UPPER,STEP FOR PRESSURE LEVEL #2 ( 35.0) : 30,50,2 <cr>         11     66
LOWER,UPPER,STEP FOR PRESSURE LEVEL #3 (  4.0) : 3,6,1 <cr>            4    264

TEMPERATURE BEHIND GAS TURBINE                 :  561.4
PRESENT VALUE OF SUPPL. FIRING TEMPERATURE     :  570.0
LOWER,UPPER,STEP FOR SUPPL. FIRING TEMPERATURE : 570,580,10 <cr>       2    528

NUMBER OF CALCULATIONS:       528

                                        DO YOU WANT TO REVISE INPUT ( Y/N ) :
```

Optimization input (bold characters are user supplied input)

4) Not used.

5) Computational results on screen. The results from the cycle and heat transfer area calculations are displayed. There are a number of sections for the presentation of the results, and these are:

- Main data
- Exhaust gas data
- HRSG
- Deaerator and preheating system
- HRSG heat transfer
- HRSG heat transfer area
- Steam turbine
- Pumps
- Condenser

Some of the sections are displayed on one screen page, while others are displayed on multiple pages. The user can go between any of the different sections by pressing the appropriate key. By typing H (help), the user can see which keys to use. By simply pressing <cr> the sections are displayed in the succession shown above. By typing E (exit) *POWSIM* returns to the CALCULATION & OUTPUT menu.

6) Computational results to file. The results described for item 5 are written to a file. The user is asked for a file name (no extension). *POWSIM* adds the extension *.RES to the user supplied file name. The user can specify which sections of the results to be written to the file.

7) Heat balance & exergy analysis results on screen. The results from the overall heat balance and exergy analysis are displayed. There are a number of sections for the presentation of the results, and these are:

- Heat balance for the steam cycle
  - HRSG
  - Steam turbine and condenser
- Exergy analysis for HRSG
- Exergy analysis for steam turbine
- Exergy analysis for condenser
- Exergy loss summary
- Main exergy losses sorted by size

Some of the sections are displayed on one screen page, while others are displayed on multiple pages. The user can go between any of the different sections by pressing the appropriate key (look at the bottom line on the screen). By simply pressing <cr> the sections are displayed in the succession shown above. By typing E (exit) *POWSIM* returns to the CALCULATION & OUTPUT menu.

8) Exergy analysis results to file. The results described for item 7 are written to a file. The user is asked for a file name (no extension). *POWSIM* adds the extension *.XRY to the user supplied file name.

9) Not used.

10) Make the heat recovery TQ-diagram plotter file (HP-GL). The TQ-diagram for the HRSG is written to a file with the HP-GL format. This format is accepted by many pen-plotters as well as some laser-writers. It is also possible to include this plotter file in many word-processing systems (like WordPerfect as you can see in this manual). The user is asked for a file name (no extension). *POWSIM* adds the extension *.HPT to the user supplied file name. The user is also asked to do any changes in the default values for the axis text, the heading and the scaling of the axis. The plot may be viewed on the screen before printing it to file.

11) Plot the heat recovery TQ-diagram on screen. The TQ-diagram is displayed on the screen and *POWSIM* is using default values for axis text and heading, and the axis are scaled automaticly.

12) Plot the heat recovery TQ-diagram on screen (manual input). This is the same as described for item 11, except that the user is user asked to do changes in the default values as described for item 10.

13) Make the steam cycle HS-diagram (enthalpy-entropy) plotter file (HP-GL). The HS-diagram for the steam cycle is written to a file with the HP-GL format. The user is asked for a file name (no extension). *POWSIM* adds the extension *.HPH to the user supplied file name. The user is also asked to do any changes in the default values for the axis text, the heading and the scaling of the enthalpy-axis (y-axis). The entropy-axis (x-axis) is fixed and cannot be chanced. The user is also asked if he wants to change the number of lines (0-4) with constant steam quality in the two-phase region, and if the number of lines is greater than zero *POWSIM* asks for steam quality values for each line. The plot may be viewed on the screen before printing it to file.

14) Plot the steam cycle HS-diagram on screen. The HS-diagram is displayed on the screen and *POWSIM* is using default values for axis text and heading, and the axis are scaled automaticly.

15) Plot the steam cycle HS-diagram on screen (manual input). This is the same as described for item 14, except that the user is user asked to do changes in the default values as described for item 13.

16) Make gas property gas table which is written to a file. The properties are also printed on the screen. The properties are written in columns, and the columns are: temperature [EC], local c_P $(MH/MT)_P$ [kJ/(kg*K)], integrated c_P ()H/)T) [kJ/(kg*K)], enthalpy [kJ/kg], internal energy [kJ/kg], entropy [kJ/(kg*K)] and isentropic exponent ($GAM=c_P/c_V$). *POWSIM* prompts for a file name (without extension) and adds the extension *.PRO. The user is asked for a zero point temperature, starting and ending temperature for the table and temperature step. The zero point temperature defined as the temperature at which the enthalpy, the internal energy and the entropy equal zero. At the beginning of the file the gas composition, molecular weight and gas constant is written before the table starts. The gas composition used for making this table is given in the GAS TURBINE INPUT menu (see section 0).

17) Gas turbine input. The GAS TURBINE INPUT menu is invoked.

18) Steam cycle input. The STEAM CYCLE INPUT menu is invoked.

19) Supplementary firing. The SUPPLEMENTARY FIRING menu is invoked. This menu line is visible only if supplementary firing is chosen in the STEAM CYCLE CONFIGURATION menu.

3.8 Screen colours

By selecting item 18 in the POWSIM MAIN MENU, the user can change foreground and background colour for the screen. In Table 3 are recommendations given for combinations of foreground and background colours. When ending a *POWSIM* session the last selection of screen colours are saved on the POWSIM.DEF-file, in order to have the last chosen screen colours for the next run of *POWSIM*. The user is not allowed to select same foreground and background colour, and if so, an error message is displayed. For LCD screens; use foreground=2 and background=18, or vice versa.

```
  SCREEN COLOURS                                  Fag 64167 ITEV     02/23/94 09:14

 1  2 - 9 : FOREGROUND - PRESENT CHOICE = 9
 2  BLACK
 3  RED
 4  GREEN
 5  YELLOW
 6  BLUE
 7  MAGENTA
 8  CYAN
 9  WHITE
10  11 - 18 : BACKGROUND - PRESENT CHOICE = 12
11  BLACK
12  RED
13  GREEN
14  YELLOW
15  BLUE
16  MAGENTA
17  CYAN
18  WHITE
19  SWITCH FOREGROUND AND BACKGROUND COLOUR
```

2) - 9) These items each represents a foreground colour. The colours are: black (2), red (3), green (4), yellow (5), blue (6), magenta (7), cyan (8) and white (9).

11) - 18) These items each represents a background colour. The colours are: black (11), red (12), green (13), yellow (14), blue (15), magenta (16), cyan (17) and white (18).

19) Switch between foreground and background colours.

Table 3 *Colour selection*

POWSIM COLOURS		**BACKGROUND**							
		11	12	13	14	15	16	17	18
f	2	BLACK	O	+	O	-	-	+	+
o	3	O	RED	O	-	-	-	O	+
r	4	+	-	GREEN	-	O	-	-	-
e	5	O	-	O	YELLOW	-	-	O	+
g	6	-	-	O	-	BLUE	O	+	+
r	7	-	-	-	-	O	MAGENTA	-	O
o	8	+	O	-	O	+	-	CYAN	-
und	9	+	+	-	+	+	+	-	WHITE
+ = GOOD O = ACCEPTABLE - = NOT GOOD "COLOUR" = NOT ALLOWED									