HEAT EXCHANGER MASS CALCULATION

`STHEmass.m`	approximate heat exchanger mechanical sizing for cost estimation purposes
`getFOB.m`	cost estimation

STHEmass

Calculates heat exchanger dimensions and mass using simplified 1996 Finnish pressure vessel code. For academic purposes only. **DISCLAIMER**: The authors do not guarantee correct bug-free calculation, no usefulness for any purpose is even implied, and **no liability** for any outcome from the use of these codes is accepted.

The codes are provided in the hope it may be useful to some, and can be freely used and modified for any academic purpose, by citing:

Saari J; Suikkanen H; Mendoza-Martinec C; Hyvärinen J. *Optimization of natural circulation district heating reactor primary heat exchangers.* Energies **2023**, x, xxxx. doi: xxxx

SYNTAX

```
result = STHEmass(HXdata,Fixed,outputfname,TEMA,plotti)
```

- `HXdata` Structure containing heat exchanger thermal design output
- `Fixed` Structure containing fixed parameters for sizing
- `outputfname` Character string containing output file name
- `TEMA` Heat exchanger TEMA type. Only few common options available.
- `plotti` Selection output options

DESCRIPTION

Function `STHEmass` calculates heat exchanger approximate mass according to simplified 1996 Finnish pressure vessel code for cost estimation purposes in academic optimization studies. (i.e. this is NOT an up-to-date or complete mechanical sizing software, and is not to be used for anything but theoretical optimization studies for academic purposes.)

If shell thickness is given as input (`HXdata.s_sh`), the sufficiency of this for designated design conditions is checked and insufficiency reported. By default, this is not known, but calculated as one of the outputs.

There is currently no allowance made for using different materials for different parts of the heat exchanger other than tubes. Tube dimensions are not checked or sized; mechanical sizing of all other parts than tubes is done using the same material, whose properties are defined as part of input structure `Fixed`.

The following components are considered and sizing is performed:

Component	Method	Sizing and standard
Shell	Sizing	SFS-2611 (internal pressure) SFS-2862 (external pressure – elastic and nonelastic buckling)
Channel shell	Sizing	SFS-2611 (internal pressure) SFS-2862 (external pressure – elastic and nonelastic buckling)
Channel cover	Sizing	SFS-2615 (flange attachment assumed)
Channel tube pass division plate	Fixed	No sizing, constant thickness s = 16 mm
Tubesheet	Sizing	SFS-2774
Flanges	Approximate	No sizing, polynomial estimates for flange dimensions as a function of shell diameter
Baffle plates	Fixed	No sizing, fixed thickness from `HXdata` input struct
Sealing strips	Fixed	No sizing, fixed thickness (same as baffle thickness)
Tie rods & spacers	Fixed	No sizing, fixed diameter d = 12.5 mm

For condenser dimensions, provisions are made for additional components to be considered. These were used for Saari et al.(2022), but omitted from this code. Trough was used only in Saari et al.(2014), where some tubes were submerged in condensate a drain cooler trough for subcooling.

Air vent	Fixed	Air / non-condensable gas suction tube
Air cooler baffle	Fixed	A cover plate to block direct steam flow path from turbine to air vent. Thickness = baffle thickness
Trough	Fixed	A trough separating drain cooler section tubes. See Saari et al.(2014) from ECOS-2014 (Turku, June 2014)

Input variables

`HXdata` – output from heat exchanger thermal sizing algorithm

Data Types: structure

The structure contains a number of fields, originating from heat thermal exchanger sizing algorithm. These are listed in the following:

Field	Data type	Description
s_sh	Floating point	**OPTIONAL**: Shell thickness [m] default: not present, calculated from other dimensions, material properties, and design pressures if present: checked for sufficiency in calculation.
Npasses	Positive integer	Number of tube-side passes [-]
do_mm	Floating point	Tube outside diameter [mm]
s_mm	Floating point	Tube wall thickness [mm]
P_mm	Floating point	Tube pitch [mm]
D_OTL	Floating point	Tube bundle diameter to outer tube limit [m]
D_ShIn	Floating point	Shell inside diameter [m]
LStraight	Floating point	straight tube in pass including part covered by baffles, but not by tubesheet [m]
NtbPerPass	Positive integer	Number of tubes per pass [-]
N_bfls	Positive integer	Number of baffle plates [-]
N_HolesPerBaffle	Positive integer	Number of holes per baffle plate [-]
A_BflFr	Floating point	Frontal area of a baffle plate, after cutting the window, but before drilling the holes [m^2]
StripPairs	Floating point	Number of sealing strip **pairs** at shell side
SStripWidth	Floating point	Width of sealing strip [m] (thickness = that of a baffle)
s_bfl	Floating point	Thickness of baffle plates (and s.strips) [m]

`Fixed` – fixed parameters

Data Types: structure

The structure contains a large number of fields from heat exchanger sizing algorithm; these are listed in the following

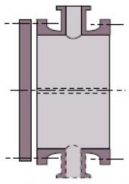
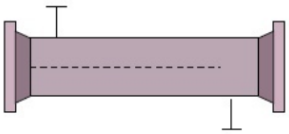
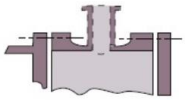
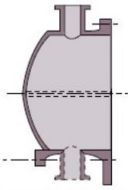
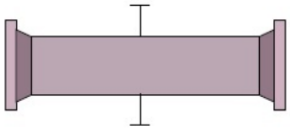
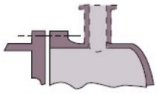
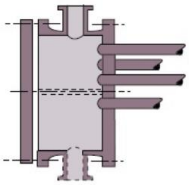
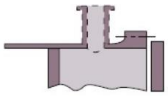
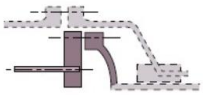
Field	Data type	Description
metalprops	Structure	Structure containing material properties
sizingdata	Structure	Structure containing design pressures
metalprops.rho	Floating point	material density [kg/m^3]
metalprops.c1	Floating point	corrosion allowance [mm] optional, default 3.0 mm
metalprops.c2	Floating point	manufacturing tolerance [mm] opt., default 2.0 mm
metalprops.Et	Floating point	Young's modulus (mod.of elasticity) [N/mm^2]
metalprops.nyy	Floating point	Poisson's ratio [-]
metalprops.sigmal	Floating point	calculation strength [N/mm^2]
metalprops.nk	Floating point	safety factor, elastic buckling [-]
metalprops.n	Floating point	safety factor, non-elastic buckling & internal pressure [-]
sizingdata.ptbmax	Floating point	tube-side maximum pressure [MPa(g)]
sizingdata.shbmin	Floating point	shell-side minimum pressure [MPa(g)]
sizingdata.shbmax	Floating point	shell-side maximum pressure [MPa(g)]

`TEMA` – type of heat exchanger according to TEMA classification

Data Type: a string of 3 characters

Examples: `STHEmass(~,~,'dummySTHE','AEL',0)`: conventional fixed-tubesheet STHE
`STHEmass(~,~,'dummycondensr','AXU',0)`: typical for U-tube steam condensers

Specifies the type of heat exchanger with 3-character code, see table below for interpretation. Note that many more TEMA head and shell types exist, only a few common ones are implemented, and of these only A/0 – E/X – L/M/T/U/0 have been subjected to even rudimentary validation/verification as it is.

1st character: Front-end head types	**2nd character: Shell types**	**3rd character: Rear-end head types**
`A`:  Flanged, removable cover	`E`:  One-pass shell	`L`:  Fixed tubesheet (equivalent to front-end head type `A`.)
`B`:  Bonnet (Integral cover)	`X`:  Cross-flow shell (typically used for condensers)	`M`:  Fixed tubesheet (equivalent to front-end head type `B`.)
`C`:  Integral with tubesheet		`N`:  Fixed tubesheet (equivalent to front-end head type `C`.)
`0`: No front head or channel – only for Saari et al. (2023) DH SMR primary heat exchangers		`T`:  Pull-through floating head (for shell-side access)
		`U`:  U-tube bundle (no rear head)
		`0`: None – same as front-end '`0`'

`outputfname` – output file name

Data Type: character string

Example: `STHEmass(~,~,'STHEdimensions.txt',~,1)`

Specifies output file name for a text output. Only relevant if `plotti` is set at value greater than `0`.

`plotti` – to print or not to print an output file

Data Type: scalar

Example: `STHEmass(~,~,'dummyname',~,0)`

Specifies whether a text file output is generated. If set at `0` or negative, no file is created, but a value for `outputfname` must still be provided.

Output variables

`results` – structure containing complete result data

Data Type: structure

A structure containing all output data. These are listed in the following:

Field	Data type	Description
`L_tot`	Floating point	Heat exchanger total length [m]
`D_tot`	Floating point	Heat exchanger diameter (flange diam. if present) [m]
`m_tot`	Floating point	Heat exchanger total mass [kg]
`m_sh`	Floating point	Mass of shell [kg]
`m_tb`	Floating point	Mass of heat transfer tubes [kg]
`m_bfl`	Floating point	Mass of baffle plates [kg]
`m_ts`	Floating point	Mass of tubesheet [kg]
`m_ch`	Floating point	Mass of channels (both channels, including shell, cover, and possible tube-side pass division plate(s) [kg]
`m_flng`	Floating point	Mass of flanges [kg]
`m_other`	Floating point	Mass of all other components: tie rods, spacers, sealing strips, and (in condensers) air vent pipe and related baffles, and (if subcooling sect.) condensate trough [kg]
`s_bfl`	Floating point	Baffle plate thickness [m]
`s_tbplate`	Floating point	Tubesheet thickness [m]
`s_fChannelcover`	Floating point	Front-head channel cover thickness [m]
`s_fChannelcover`	Floating point	Rear-head channel cover thickness [m]
`s_channelshell`	Floating point	Channel shell thickness [m]

s_shell	Floating point	Heat exchanger shell thickness [m]
L_shell	Floating point	Heat exchanger shell length [m]
L_tbTot	Floating point	Total tube length (incl.that in tubesheet, baffles) [m]
L_fhead	Floating point	Length of front-end head [m]
L_rhead	Floating point	Length of rear-end head [m]
s_TbPassDivPlate	Floating point	Tube-side pass division plate thickness [m]
L_drill_Bfl	Floating point	Total drilling length through baffle plates [m]
L_drill_Ts	Floating point	Total drilling length through tubesheet(s) [m]
D_ShO	Floating point	Shell outer diameter [m]
D_ShIn	Floating point	Shell inside diameter [m]
D_Flng	Floating point	Front-head channel diameter [m]
D_ChIn	Floating point	Rear-head channel diameter [m]
LStraight	Floating point	Tube straight length (incl.that in tubesheet, baffles) [m]
do	Floating point	Tube outside diameter [m]
fock	Positive integer	Successful calculation and acceptable result? 1 – failed to calculate and/or unacceptable design 0 – succesful calculation and acceptable design
StripPairs	Positive integer	Number of sealing strip **pairs** [-]
SStripWidth	Positive integer	Tube outside diameter [-]
NtbPerPass	Positive integer	Number of tubes **per pass** [-]