

Utility name: pn2pipefr

Purpose

pn2pipefr computes the enthalpy and mass flow rates in a pneumatic pipe of circular section without inertia, as well as the Reynolds number, gas velocity and friction factor.

Description

This utility is used to compute:

- the Reynolds number
- the mean gas velocity
- the friction factor
- the enthalpy flow rate at port 1
- the mass flow rate at port 1
- the enthalpy flow rate at port 2
- the mass flow rate at port 2
- the mass flow parameter

in a pneumatic pipe or hose of circular section from the following inputs:

- the pressure at port 1
- the temperature at port 1
- the pressure at port 2
- the temperature at port 2
- the internal diameter
- the relative roughness
- the length
- the cross sectional area

Both the diameter and cross sectional area are required:

- the diameter will be used for the friction factor calculation,
- while the cross sectional area will be used for the mass flow rate calculation.

For instance, it is then possible to model several identical pipes set in parallel by giving the diameter of each pipe and the total cross sectional area.

It is the responsibility of the calling submodel writer to ensure that these two values are consistent.

All inputs and outputs are in SI units.

If inertia dynamics in the pipe needs to be modeled, the utility function [pn2pipifr](#) should be used.

Physics and equations

- The relative roughness ϵ is calculated as the ratio of the average height of asperities to the tube diameter:

$$\epsilon = \frac{\Delta}{D_{eq}}$$

where:

- Δ is the equivalent uniform roughness of the pipe,
- D_{eq} is the equivalent diameter of the pipe.

A sampling of absolute pipe roughness Δ for new clean pipes is proposed by Binder :

Pipe material	Absolute roughness Δ
drawn brass	1.5 μm
drawn copper	1.5 μm
commercial steel	45 μm
wrought iron	45 μm
asphalted cast iron	120 μm
galvanized iron	150 μm
cast iron	260 μm
wood stave	0.2 to 0.9 mm
concrete	0.3 to 3 mm
riveted steel	0.9 to 9 mm

- The **Reynolds number** is defined as follows:

$$Re = \frac{v D}{\nu}$$

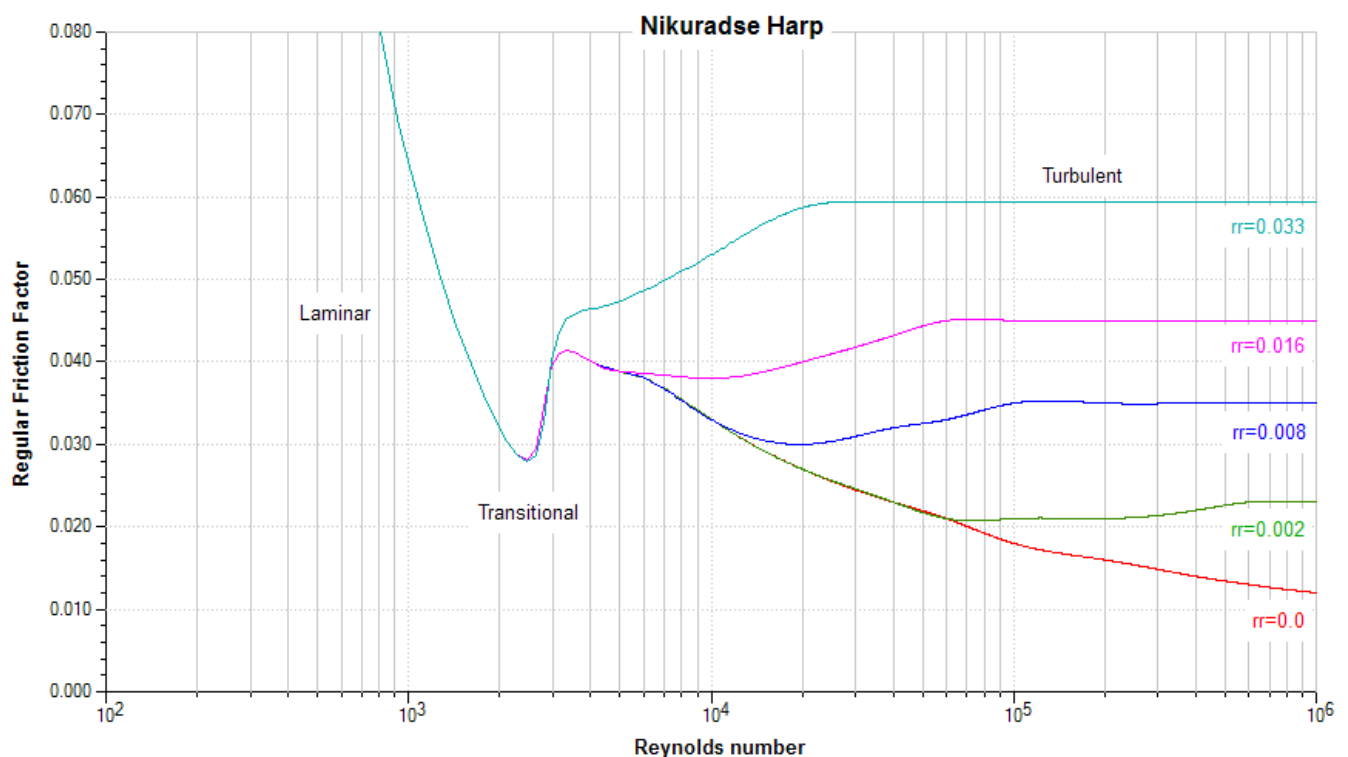
- D is the pipe internal diameter [m],
- v is the mean gas velocity [m/s],
- and ν is the gas kinematic viscosity [m²/s].

- The **regular friction factor** f_f depends on flow conditions defined thanks to the Reynolds number and the relative roughness of the pipe:

- $Re < 1e-6$, the friction factor is set to 64e6 to avoid non expected computations.
- $Re < 2500$, the flow is laminar, the friction factor is analytically computed as follows:

$$f_f = \frac{64}{Re}$$
- $Re > 2500$, the flow is turbulent, then the friction factor is extracted from the Nikuradse harp. It is both Reynolds number and relative roughness dependent during the transition phase between laminar flow conditions and fully rough turbulent flow conditions. Indeed, in fully rough hydraulic conditions, the friction factor is only dependent of the relative roughness of the pipe.

f_f is determined by a cubic spline interpolation based on a table of empirical values from as shown below:



- Knowing the friction factor allows to define an **equivalent flow coefficient** (C_q):

$$C_q = \sqrt{\frac{D}{L \cdot f}}$$

- From this flow coefficient, the **mass flow rate** is evaluated as done in the orifice model (please refer to the [pn2rcqfix](#) utility for more details):

$$\dot{m} = A \cdot C_q \cdot C_m \cdot \frac{p_{\text{up}}}{\sqrt{T_{\text{up}}}}$$

where A is the orifice area, C_m the flow parameter, p_{up} the upstream absolute pressure and T_{up} the upstream temperature.

- The **enthalpy flow rate** $\dot{h}$ [J/s] is then calculated as follows:

$$\dot{h} = \dot{m} \cdot h(p_{\text{up}}, T_{\text{up}})$$

where h is the upstream enthalpy [J/kg]. Please refer to the utility [pn2hpti](#) for detailed computations.

C call prototype

```
extern void pn2pipefr_(double *p1, double *t1, double *p2, double *t2,
    double *diam, double *rr, double *l, double *area,
    double *re, double *v, double *ff, double *dh1,
    double *dm1, double *dh2, double *dm2, double *cm,
    double *table, int *gi, int *pipeindex, int *reg2);
```

Arguments

Inputs

- ***p1***, pressure at port 1 [PaA]
- ***t1***, temperature at port 1 [K]
- ***p2***, pressure at port 2 [PaA]
- ***t2***, temperature at port 2 [K]
- ***diam***, internal diameter [m]
- ***rr***, relative roughness [null]
- ***l***, length [m]
- ***area***, internal cross sectional area [m²]
- ***gi***, gas type index

Outputs

- ***re***, Reynolds number [null]
- ***v***, mean gas velocity (sign of dm1) [m/s]
- ***ff***, friction factor [null]
- ***dh1***, enthalpy flow at port 1 [J/s]
- ***dm1***, mass flow at port 1 [kg/s]
- ***dh2***, enthalpy flow at port 2 [J/s]
- ***dm2***, mass flow at port 2 [kg/s]
- ***cm***, subsonic flow coefficient [(kg.K/J)^(1/2)]

Inputs and outputs

- ***table***, array (dimension 3) used to build interpolation tables for the current pipe/hose parameters [null]
- ***pipeindex***, index for friction factor computation
- ***reg2***, not used

Note that the variable **pipeindex** is set on the first call to **pn2pipefr_**. Its value must be preserved between calls. This is done by replacing **pipeindex** by an integer store variable such as **&ic[1]**.

Usually some part of the real store array is used for **table**. Thus **table** might be replaced by for example **&c[8]**, but it is important to ensure that the **c** array be large enough to contain 3 array elements from this address.

See also

[pn2pipifr](#), [PNL00R](#), [PNL0001](#), [PNL0002](#), [PNL0003](#), [PNL0010](#), [PNL0011](#), [PNL0012](#).