The stress in pipe when changing temperatures

Seating of pipes:
Pipes are led by the terrain either freely deposited, on concrete foundations above the terrain, or in the open trenches, and finally buried in trenches. The pipe line is firmly anchored at both ends - one ends is anchored in the foundations of the intake and the other in the foundations of the power house. Apart from these, anchorages are installed at bends and also near the expansion joints of long straight sections. Pipes in these places are equipped with ring girders make of rolled sections. Axial forces acting upon pipes are taken up by the anchors. The pipe is axially fixed to the blocks. Since the piping in these blocks is axially trapped, a dilatation piece must always be inserted between the two blocks to allow dilatation of the pipe at temperature changes. Between the anchor blocks the pipe is supported by concrete piers which take up reactions acting perpendicularly to the axis of the pipe and they permit shifting in axial direction.

The stress in pipe walls:

$$\sigma_t = E * \alpha * \Delta_t$$

σ_t	the stress in pipe walls	[MPa]
E	Young's modulus for pipe	[MPa]
α	coefficient of linear expansion of the pipe material	$[K^{-1}]$
Δ_t	temperature difference	[°C]; [K]

Young's modulus for pipe:

Pipe material	[MPa]
Steel	$2*10^5$
Cast iron	$0,7*10^5$

Coefficient of linear expansion of the pipe material:

Pipe material	$[K^{-1}]$
Steel	$1,2*10^{-5}$
Cast iron	$0,9*10^{-5}$

Temperature difference:

$$\Delta_t = t_1 - t_0$$

Δ_t	temperature difference	[°C]; [K]
t_0	Initial temperature	[°C]
t_1	Temperature after changing	[°C]

The total axial force:

$$F_t = \sigma_t * \frac{\pi}{4} * ((D_i + 2e_n)^2 - D_i^2)$$

F_t	the total axial force	[N]
σ_t	the stress in pipe walls	[MPa]
D_i	internal pipe diameter	[mm]

e_n thickness of the pipe wall [mm]

Example:
We should determine the stresses in the pipe walls, the axial force from the temperature change and calculate the maximum allowable pressure for the pipeline that is firmly anchored between the two blocks without the expansion joints. The thickness of the wall of the Type 11 flange according to EN 1092-1 will be assessed. Thickness of the walls flange be considered as non-welded joint without defects. P = 4MPa; D_i = 976mm; e_n = 20mm; flange material P235GH; $R_{p0,2T}$ = 225MPa; $R_{m/20}$ = 360MPa; t_0 = 20°C; t_1 = 50°C.

The stress calculated from the pressure:
$$\sigma_p = \frac{P * D_i}{2e_n} = \frac{4 * 976}{2 * 20} = 97{,}6MPa$$

Temperature difference:
$$\Delta_t = t_1 - t_0 = 50 - 20 = 30$$

The stress in pipe walls:
$$\sigma_t = E * \alpha * \Delta_t = 2 * 10^5 * 1{,}2 * 10^{-5} * 30 = 72MPa$$

The nominal design stress calculation cases:
$$f_d = min\left(\frac{R_{p0,2T}}{1{,}5}; \frac{R_{m/20}}{2{,}4}\right) = min\left(\frac{225}{1{,}5}; \frac{360}{2{,}4}\right) = 150MPa$$

The stress in the flange wall:
$$f_d \geq \sigma_e = \sigma_p + \sigma_t = 97{,}6 + 72 = 169{,}6MPa \rightarrow does\ not\ suit$$

The total axial force:
$$F_t = \sigma_t * \frac{\pi}{4} * ((D_i + 2e_n)^2 - D_i^2) = 72 * \frac{\pi}{4} * ((976 + 2 * 20)^2 - 976^2) = 4505797{,}9N$$

Maximal pressure:
$$P_{max} = \frac{(f_d - \sigma_t) * 2e_n}{D_i} = \frac{(150 - 72) * 2 * 20}{976} = 3{,}19MPa$$

The thickness of the flange housing does not meet the strength calculation according to the standard EN 13445-3. The EN 1092-1 standard specifies the temperature range that is fulfilled in the example, but the standard does not predict such a large axial force that can occur when designing a pipeline without expansion joint with a temperature difference of 30.
The piping system can be designed with expansion joints to prevent axial forces from changing the temperature, but the piping system may become uneconomic (expensive). Another disadvantage of the expansion joint is the non-transfer of the axial forces, so that if the expansion joint is inappropriately positioned in the duct system containing a member which forms axial forces (valve, elbow), the expansion joint may be destroyed.
No standard can in any way replace the expert opinion of the technician. The pipe system designer must determine not only the PN pressure class but also all non-pressure loads that

affect the pipeline during operation. The device must be designed for maximum load by either adjusting the appropriate material or by modifying the device dimensions (greater sheath thickness).

Literature:

Miroslav Nechleba: Vodní turbíny, jejich konstrukce a příslušenství. SNTL 1954

ČSN EN 13445-3: Unfired pressure vessels – Part 3: Design.