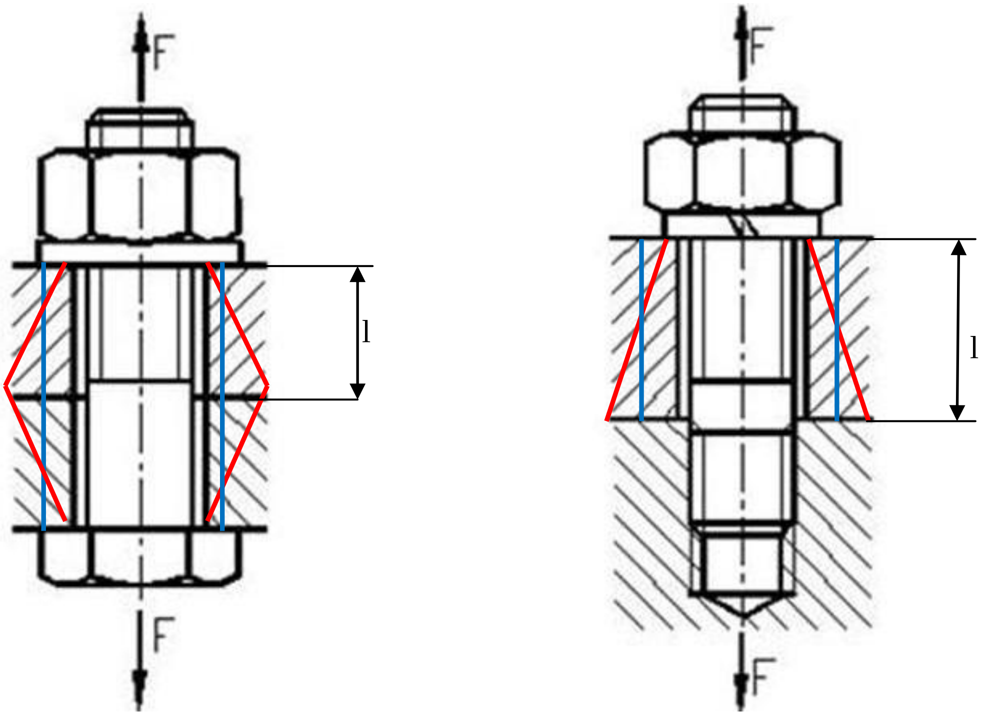
# Design of Pre-loaded screws

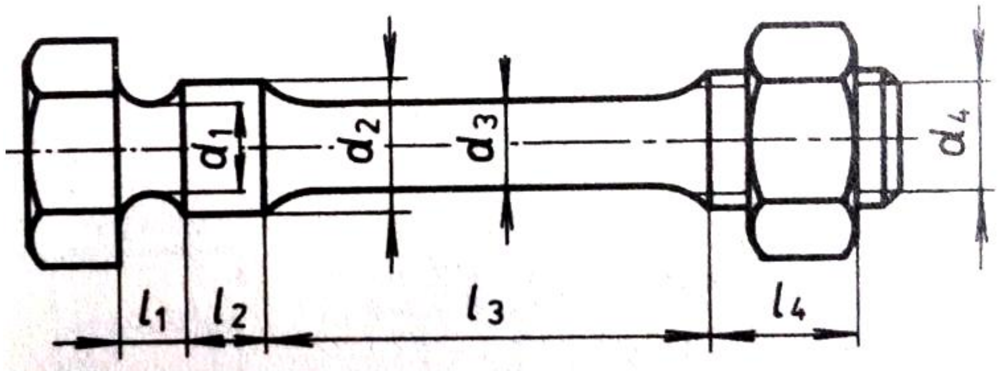
During assembly (raised), a tensile force $F_Q$ is created in the screw, which is called the Pre-loaded force. The action of this tensile force will extend the screw by the value $\Delta l_1$ and at the same time compress the connected parts by the value $\Delta l_2$ ,. According to the embodiment of the screw connection, the stress (pressure) according to FIG. The effect of screw preload is used mainly for screws that are dynamically stressed, and determining their safety is only impossible due to static stress conditions.




Determination of deformation constants of the joint
After required to raise the screw joint, due to the axis force in the screw, the screw will lengthen and the joined parts are compressed: This deformation depends on the basic dimensions of the screw and the joined parts and on the material.
Deformation constant of the screw:

$$\Delta l_1 = \frac{F.l_1}{E_1.S_1} = F.k_1 = \frac{F}{c_1}$$

A condition must apply to a screw shape consisting of different diameters and different lengths:



$$\frac{1}{c_1} = \frac{l_1}{E_1 . S_1} = \frac{1}{E_1} . \sum \frac{l_i}{S_i}$$

Deformation constant of the assembly parts:

$$\Delta l_2 = \frac{F . l_2}{E_2 . S_2} = F . k_2 = \frac{F}{c_2}$$

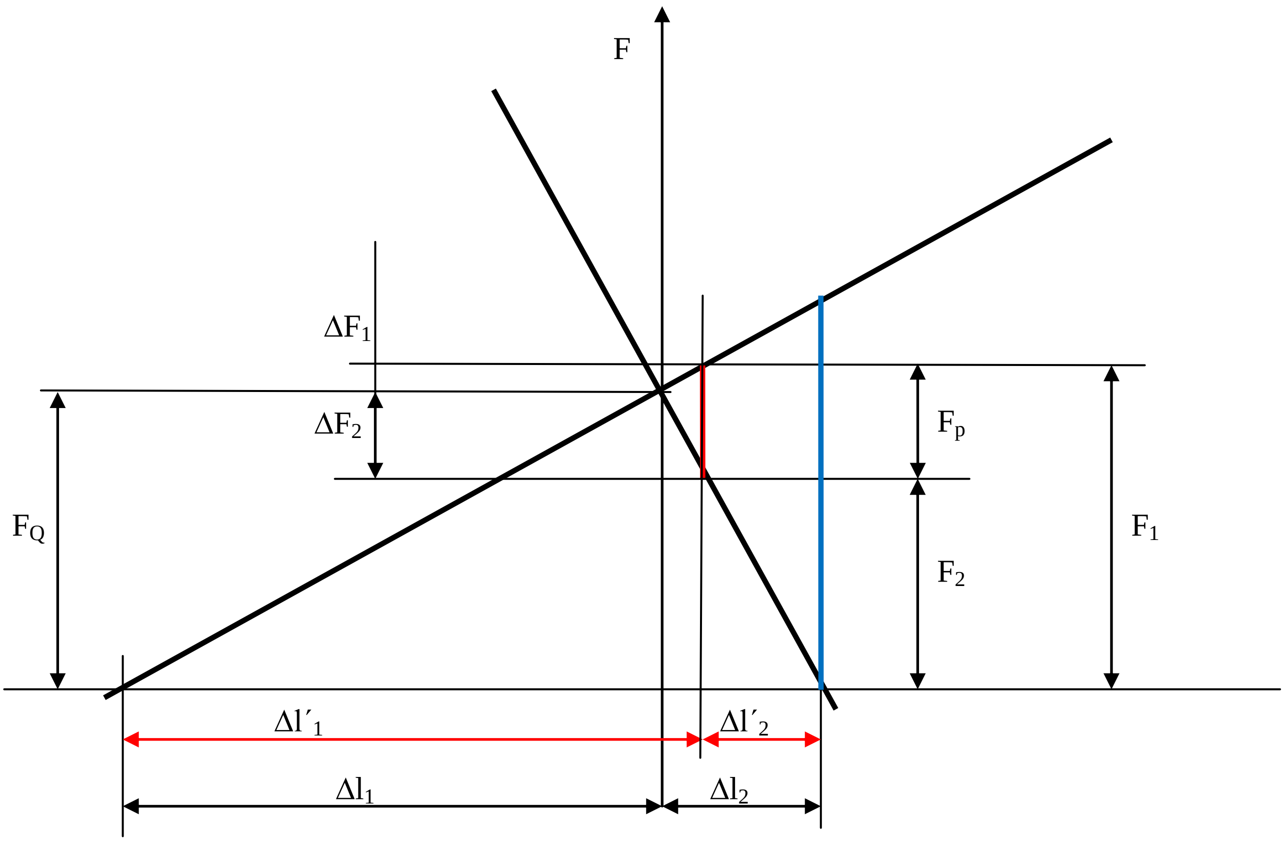
$S_2$ – the area of the intermediate ring of the deformation cylinder, by which we replace the actual deformation formations - see fig. blue and red markings

$$S_2 = \frac{\pi}{4} . [(s + l)^2 - d_0^2]$$

The condition must apply to different thicknesses and diameters of the holes of the joined materials:

$$\frac{1}{c_2} = \frac{l_1}{E_2 . S_2} = \frac{1}{E_2} . \sum \frac{l_i}{S_i}$$

Deformation diagram of a screw joint:




$\Delta l_1$ – extension of the screw due to preload
$\Delta l_2$– compression of the connected parts by effect preload
$\Delta l'_1$ – extension of the screw after loading with operation force
$\Delta l'_2$– compression of connected parts after loading by operation force

$$\Delta l_1 + \Delta l_2 = \Delta l'_1 + \Delta l'_2$$

Operation force:

$$\Delta F_1 + \Delta F_2 = F_p$$

$$\frac{F_Q}{c_1} + \frac{F_Q}{c_2} = \frac{F_1}{c_1} + \frac{F_2}{c_2}$$

Maximal force in screw:

$$F_1 = F_Q + \Delta F_1$$

Maximal force in compressed parts:

$$F_2 = F_Q - \Delta F_2$$

Increment of screw force due to operating:

$$\Delta F_1 = F_p . \frac{c_1}{c_1 + c_2} = F_p . \frac{k_2}{k_1 + k_2}$$

Increase in force in connected parts due to operation:

$$\Delta F_2 = F_p . \frac{c_2}{c_1 + c_2} = F_p . \frac{k_1}{k_1 + k_2}$$

If $\mathbf{F_2 = 0}$ and $\mathbf{F_1 = F_p}$ (blue line in the diagram) then the joint ceases to be a preloaded joint
To ensure the tightness of the joint must be $\boldsymbol{\psi > 0}$ (usually chosen from the range 0.2-1.2 in the case of piping systems, we choose a higher value)

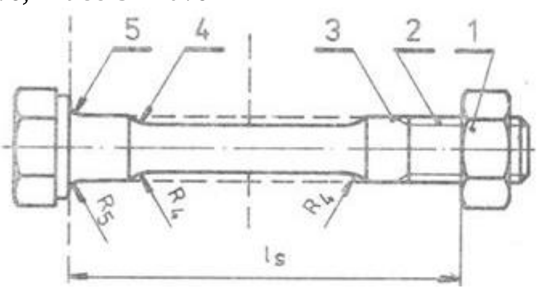
then: $F_2 = \psi \, . \, F_p$

Preloaded force in screw:

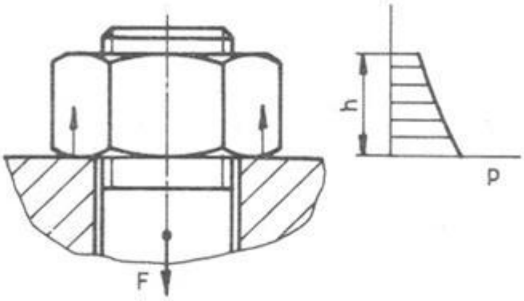
$$F_Q = F_2 + \Delta F_2 = \psi . F_p + F_p . \frac{c_2}{c_1 + c_2}$$

**Pre-loaded screw fasteners in fluctuating force operation**

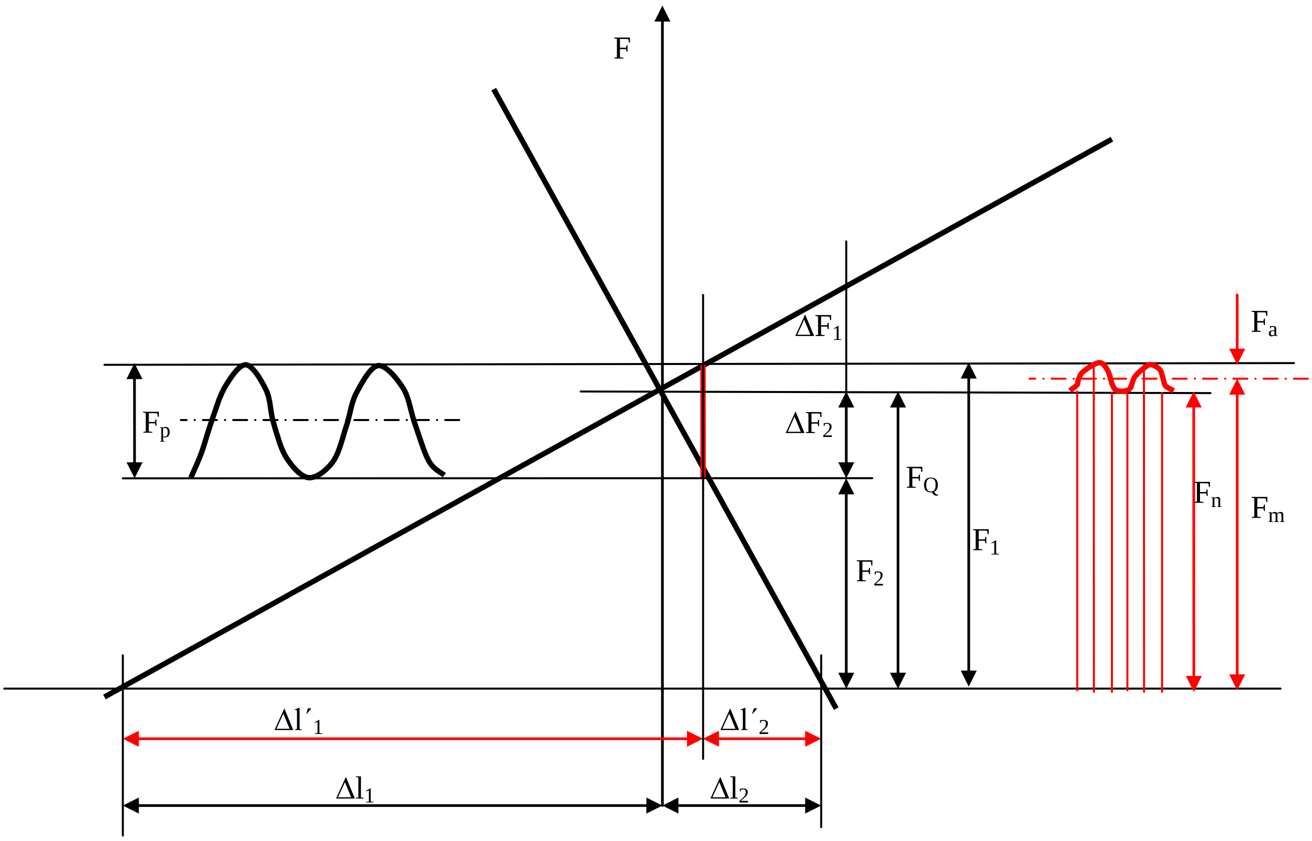
These screw connections are used in particular in cases where an increase in the service life of the screw connection is required. Usually, the aim is to ensure that the impact of a operating force of a disappearing nature is reduced, by means of a preload on the fluctuating force. Due to the variable load, fatigue stress occurs and the most probable places of failure of the actual joint were determined statistically as follows:
Place 1 -60%, Place 3 -30%, Place 5 -10%



The reason for the occurrence of fatigue fracture at the location of the first thread is the stress concentration according to FIG.




Deformation diagram of a screw joint:




At the point of probable greatest failure (first thread in the nut)

$$\sigma = \frac{F_1}{S_3}$$

$S_3$ – minimal area of thread
$F_m$ – midrange force see diagram, $F_m = F_Q + \Delta F_1 / 2$
$F_a$ – amplitude force, $F_a = \Delta F_1 / 2$
$F_h$ – maximal force
$F_n$ – minimal force, $F_n = F_Q$

Maximal stress:

$$\sigma_h = F_h / S_3$$

Minimal stress:

$$\sigma_n = F_n / S_3$$

Midrange stress:

$$\sigma_m = \frac{\sigma_h + \sigma_n}{2} = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{F_m}{S_3}$$

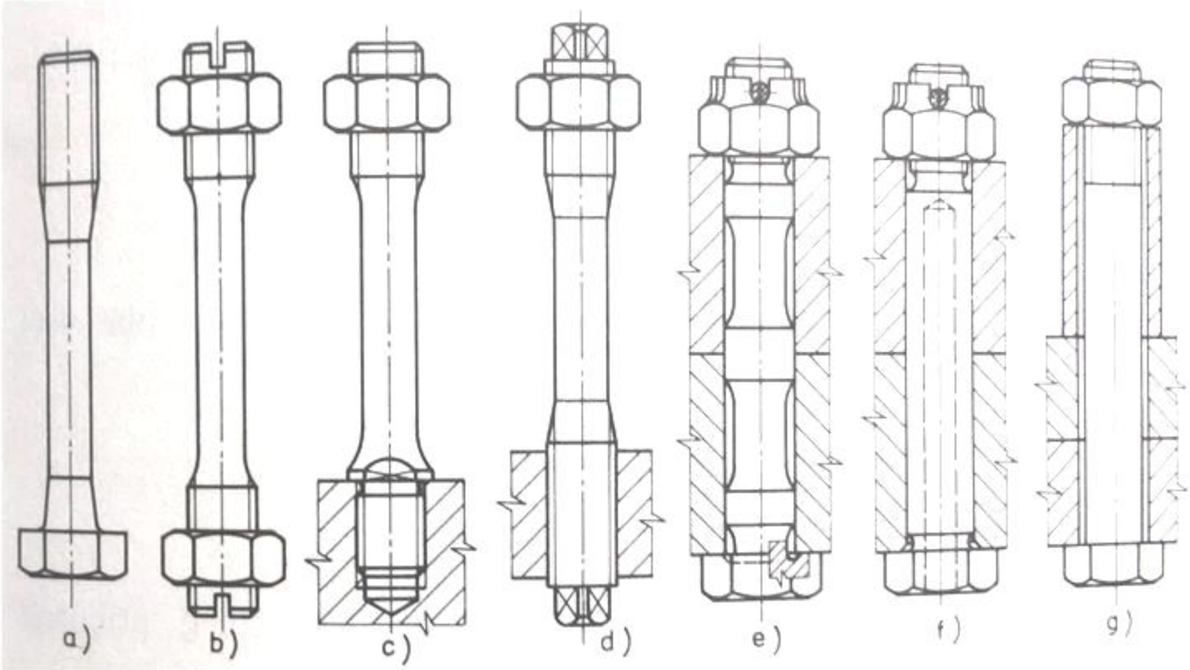
Amplitude stress:

$$\sigma_a = \frac{\sigma_h - \sigma_n}{2} = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{F_a}{S_3}$$

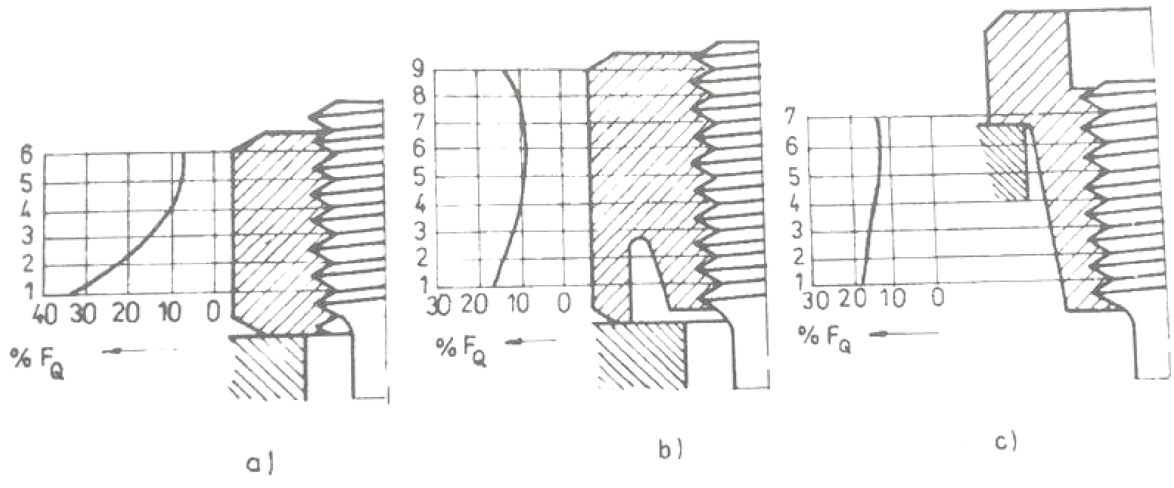
Stress Ratio:

$$r = \frac{\sigma_n}{\sigma_h}$$

As is clear from the deformation diagram of the screw, it is important that $\Delta F_1$ be as low as possible. For this reason, the screw must be as flexible as possible and the connected parts as rigid as possible. Several possibilities for solving the flexibility of the screws are shown in FIG




The deformation of the srew and the nut are the same and therefore no uneven pressure distribution occurs in the threads. In order to reduce the effects of pressure non-uniformity in the threads, it is suitable to adjust the nut according to FIG.




If the screw joint is exposed to temperatures, different deformations of the materials may occur depending on the coefficient of thermal expansion. Thermal expansion can cause a change in prestress that will affect the resulting safety value of the fasteners.