Description of Forces Occurred in Anchor Blocks and Saddle Support:

F_1	This force is the component of the weight of pipe and enclosed water perpendicular to the pipe alignment. If there is a bend at the anchor, however, both the upstream and downstream lengths of pipe contribute separately, each force perpendicular to the centerline of the pipe segment which contributes to it.
F_2	This force is the frictional force of pipe on support piers. If the penstock moves longitudinally over support piers, a friction force on the pipe is created at each pier. A force "F_2", equal to the sum of all these forces but opposite in direction, acts on the anchor. This force exists only where one or more support piers are located between the anchor block and an expansion joint. For example, if an expansion joint is located immediately downhill of the anchor, friction forces on the downhill length of pipe will not be transmitted to the anchor block from that side. The friction coefficient, f, depends on the material against which the penstock slides and is as follows: Steel on concrete, $f = 0.60$ Steel on steel, rusty plates, $f = 0.50$ Steel on steel, greased plates or tar paper in between, $f = 0.25$
F_3	This is the force due to hydrostatic pressure within a bend. The hydrostatic pressure at a bend creates a force which acts outward for upward bends and inward if the bend is downward. This is a major force which must be considered in designing anchor blocks. However, the block size can be significantly reduced if the bend angle ($b - a$) can be minimized while fixing the penstock alignment.
F_4	This is the force due to the component of the weight of pipe parallel to the pipe alignment. On a slope, the component of the weight of the pipe which is parallel to the pipe tends to pull it downhill and exerts a force on an anchor block. The sections of pipe both upstream and downstream of an anchor block may have to be considered. The lengths 'L_{4u}' and 'L_{4d}' in the equation for the force 'F_4' acting on an anchor block are the lengths of the upstream or downstream section of the penstock which is actually to be held by that block. The upstream section may begin at the forebay or, more usually, at an expansion joint. The downstream section usually ends at an expansion joint. If the expansion joint downstream of an anchor block is located near the anchor, as it usually is, the force arising from the weight of the downhill section of pipe between the anchor and the joint is insignificant and is usually neglected. Also, the anchor block will not experience this force if the penstock is buried since the ground friction will resist this force.
F_5	This is the force that is transmitted to the anchor block due to thermally induced stresses in the absence of an expansion joint. If an exposed section of a rigid pipe does not incorporate an expansion joint, thermally induced stresses build up in the pipe and act on the anchor block. The associated force 'F_5' may push against the anchor block (with increasing temperature) or pull the anchor block (with decreasing temperature).
F_6	This is the force due to friction within the expansion joint. To prevent leaking, the packing within an expansion joint must be tightened sufficiently. However this tightening also makes it more difficult for the joint to accept any longitudinal movement of the pipe. Friction between the packing and the concentric sleeves in the expansion joint creates a force 'F_6' which opposes any expansion or contraction of the pipe. This force is dependent on pipe diameter, tightness of the packing gland and smoothness of sliding surfaces. If there is not a change in the pipe direction ($a = b$) upstream and downstream of the anchor block, the forces (from upstream and downstream expansion joints) cancel out.

F_7	This is the hydrostatic force on exposed ends of pipe in expansion joints. The two sections of penstock pipe entering an expansion joint terminate inside the joint; therefore, their ends are exposed to hydrostatic pressure, resulting in a force 'F_7' which pushes against the anchors upstream and downstream of the joint. This force usually contributes minimally to the total forces on an anchor since the ratio of pipe thickness to the diameter is low. However, this force can be significant at mild steel-HDPE joint sections (since HDPE pipes are thicker). Note that h_{total} is the total head at the expansion joint.
F_8	This force is the dynamic force at the pipe bend. At the bend, the water changes the direction of its velocity and therefore the direction of its momentum. This requires that the bend exert a force on the water. Consequently, an equal but opposite reaction force 'F_8' acts on the bend; it acts in the direction which bisects the exterior angle of the bend (same as F_3). Since velocities in penstocks are relatively low (< 5 m/s), the magnitude of this force is usually insignificant.
F_9	This is the force exerted due to the reduction of pipe diameter. If there is a change in the diameter of the penstock, the hydrostatic pressure acting on the exposed area creates a force 'F1pg' which acts in the direction of the smaller-diameter pipe. If the penstock length is long then the pipe thickness is increased with increasing head. However, the effect of changing the diameter by a few mm does not contribute significant forces and can be ignored.
F_{10}	This is the force on the anchor blocks or support piers due to the soil pressure acting on the upstream face. If there is a significant difference between the upstream and downstream buried depth $[(h_1 - h_2) > 1$ m$)]$ of the block then a force will be exerted on the anchor block due to soil pressure. In such cases, this force should be considered since it has a destabilizing effect. Note that the resultant of this force acts at 1/3 h_1.