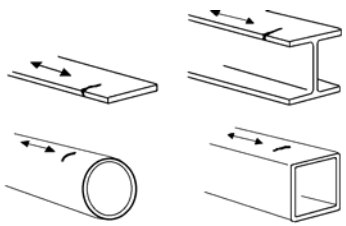
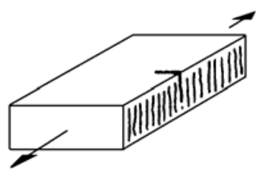
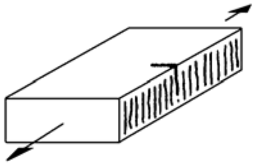
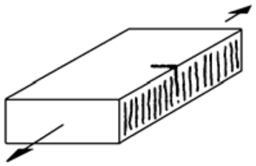
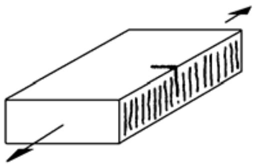
Annex G

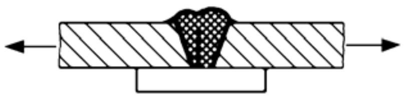
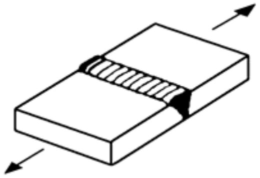
FAT Classes

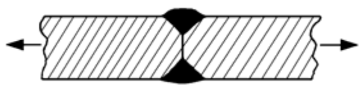
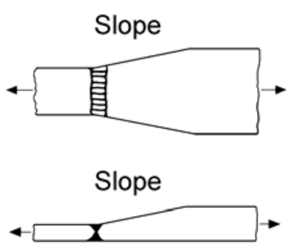
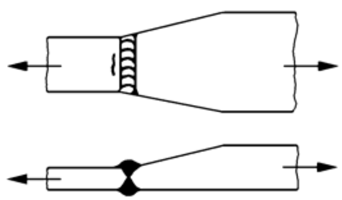
Table G.1 – Fatigue resistance values for structural details in steel and aluminium assessed on the basis of nominal stresses {Ref. ??}-MK for the rest of the tables

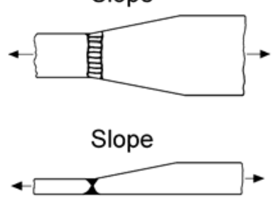
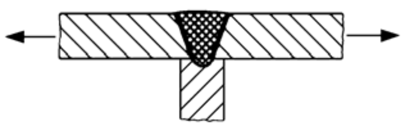
No.	Structural Detail	Description (St.= steel; Al.= aluminium)	FAT St.	FAT Al.	Requirements and Remarks
100	**Unwelded parts of a component**				
111		Rolled or extruded products, components with machined edges, seamless hollow sections. m = 5 St.: For high strength steels a higher FAT class may be used if verified by test. Al.: AA 5000/6000 alloys AA 7000 alloys	160	70 80	No fatigue resistance of any detail to be higher at any number of cycles! Sharp edges, surface and rolling flaws to be removed by grinding. Any machining lines or groves to be parallel to stresses! For high strength steels a higher FAT class may be used if verified by test.
121		Machine gas cut or sheared material with subsequent dressing, no cracks by inspection, no visible imperfections m = 3	140	---	All visible signs of edge imperfections to be removed. The cut surfaces to be machined or ground, all burrs to be removed. No repair by welding refill! Notch effects due to shape of edges have to be considered.

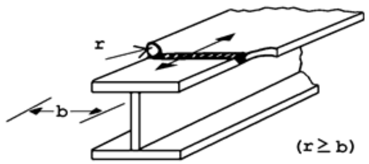
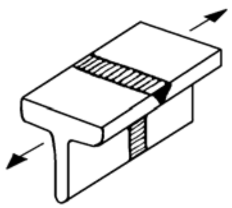
122		Machine thermally cut edges, corners removed, no cracks by inspection m = 3	125	40	Notch effects due to shape of edges have to be considered.
123		Manually thermally cut edges, free from cracks and severe notches m = 3	100	---	Notch effects due to shape of edges have to be considered.
124		Manually thermally cut edges, uncontrolled, no notch deeper than 0.5 mm m = 3	80	---	Notch effects due to shape of edges have to be considered.

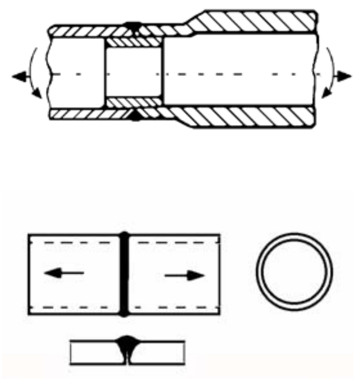
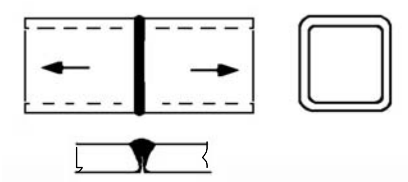
200	**Butt welds, transverse loaded**				
211		Transverse loaded butt weld (X-groove or V-groove) ground flush to plate, 100% NDE	100	40	All welds ground flush to surface, grinding parallel to direction of stress. Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Welded from both sides. No misalignment. Required quality cannot be inspected by NDE !
212		Transverse butt weld made in shop in flat position, toe angle ≤ 30°, NDE	90	36	Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Welded from both sides. Misalignment <5%
213		Transverse butt weld not satisfying conditions of 212, NDE Al.: Butt weld with toe angle ≤50° Butt welds with toe angle >50°	80	 32 25	Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Welded from both sides. Misalignment <10%

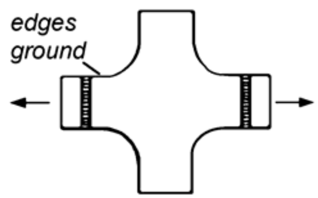
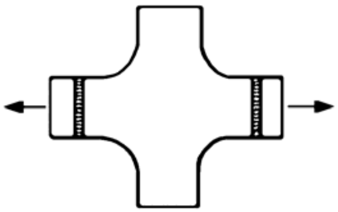
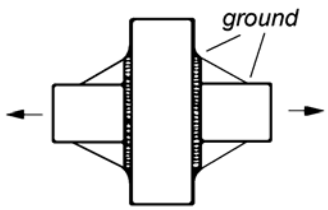
214		Transverse butt weld, welded on ceramic backing, root crack	80	28-	Backing removed, root visually inspected. Misalignment <10%
215		Transverse butt weld on permanent backing bar terminating >10 mm from plate edge, else	71 63	25 22	Misalignment <10%
216		Transverse butt welds welded from one side without backing bar, full penetration root controlled by NDE no NDE	71 36	28 12	Misalignment <10%

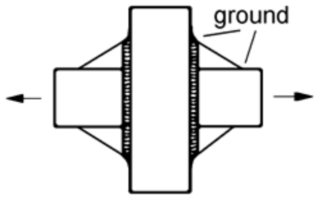
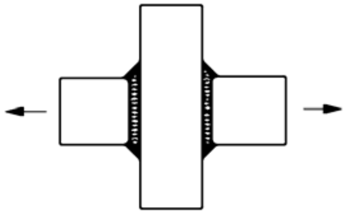
217		Transverse partial penetration butt weld, analysis based on stress in weld throat sectional area, weld overfill not to be taken into account.	36	12	The detail is not recommended for fatigue loaded members. Assessment by notch stress or fracture mechanics is preferred.
221		Transverse butt weld ground flush, NDE, with transition in thickness and width slope 1:5 slope 1:3 slope 1:2	100 90 80	40 32 28	All welds ground flush to surface, grinding paralell to direction of stress. Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Misalignment <10% Exceeding misalignment due to thickness step to be considered, see chapter 3.8.2
222		Transverse butt weld made in shop, welded in flat position, weld profile controlled, NDE, with transition in thickness and width: slope 1:5 slope 1:3 slope 1:2	90 80 72	32 28 25	Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Misalignment <10% Exceeding misalignment due to thickness step to be considered, see chapter 3.8.2

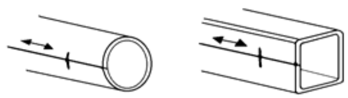
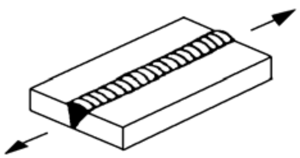
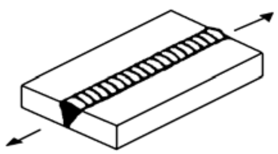
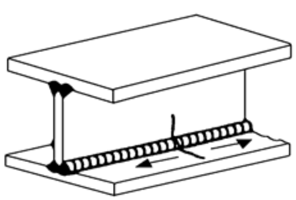
223		Transverse butt weld, NDE, with transition on thickness and width slope 1:5 slope 1:3 slope 1:2	 80 71 63	 25 22 20	Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Misalignment <10% (213 has 10% ??) Exceeding misalignments due to thickness step to be considered, see chapter 3.8.2
224		Transverse butt weld, different thicknesses without transition, Centres aligned. In cases, where weld profile is equivalent to a moderate slope transition, see no. 222	71	22	Misalignment <10% of smaller plate thickness
225		Three plate connection, root crack	71	22	Arc welds: Misalignment <10%

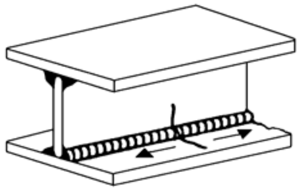
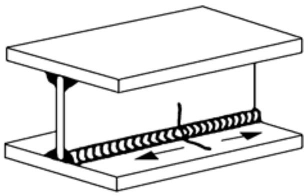
226		Transverse butt weld flange splice in built-up section welded prior to the assembly, ground flush, with radius transition, NDE	100	40	All welds ground flush to surface, grinding parallel to direction of stress. Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress.
231		Transverse butt weld splice in rolled section or bar besides flats, ground flush, NDE	80	28	All welds ground flush to surface, grinding parallel to direction of stress. Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress.

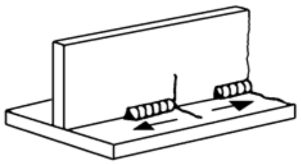
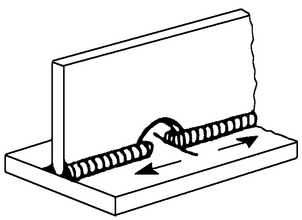
232		Transverse butt weld splice in circular hollow section, welded from one side, full penetration, root crack root inspected by NDE no NDE	 71 36	 28 12	Welded in flat position.
233	Picture is missing	Tubular joint with permanent backing	71	28	Welded in flat position.
234		Transverse butt weld splice in rectangular hollow section, welded from one side, full penetration, root crack root inspected by NDE no NDE	 56 36	 25 12	Welded in flat position.

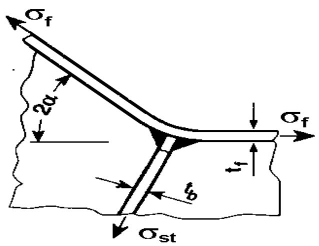
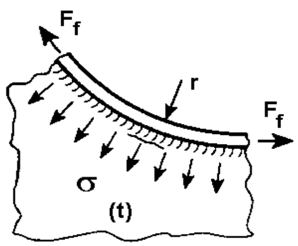
241		Transverse butt weld ground flush, weld ends and radius ground, 100% NDE at crossing flanges, radius transition.	100	40	All welds ground flush to surface, grinding parallel to direction of stress. Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Welded from both sides. No misalignment. Required weld quality cannot be inspected by NDE
242		Transverse butt weld made in shop at flat position, weld profile controlled, NDE, at crossing flanges, radius transition	90	36	Weld run-on and run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress. Welded from both sides. Misalignment <5%
243		Transverse butt weld ground flush, NDE, at crossing flanges with welded triangular transition plates, weld ends ground. Crack starting at butt weld. For crack of through going flange see details 525 and 526!	80	32	All welds ground flush to surface, grinding parallel to direction of stress. Plate edges to be ground flush in direction of stress. Welded from both sides. Misalignment <10%

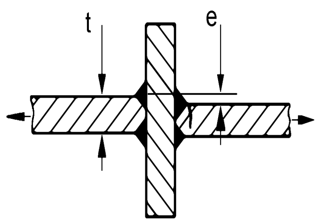
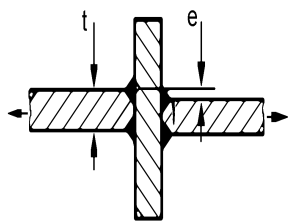
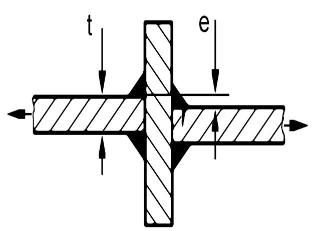
244		Transverse butt weld, NDE at crossing flanges, with welded triangular transition plates, weld ends ground. Crack starting at butt weld. For crack of through going flange see details 525 and 526!	71	28	Plate edges to be ground flush in direction of stress. Welded from both sides. Misalignment <10%
245		Transverse butt weld at crossing flanges. Crack starting at butt weld. For crack of through going flange see details 525 and 526!	50	20	Welded from both sides. Misalignment <10%
246	picture is missing !	Laser beam butt weld			

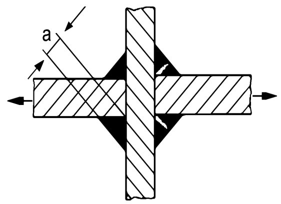
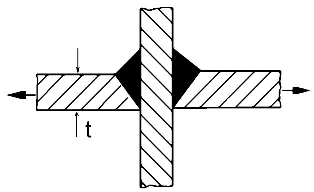
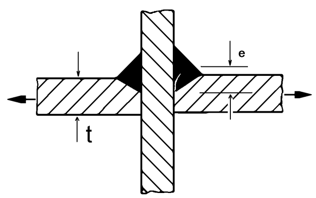
300	**Longitudinal load-carrying welds**				
311		Automatic longitudinal seam welds without stop/start positions in hollow sections with stop/start positions	125 90	50 36	
312		Longitudinal butt weld, both sides ground flush parallel to load direction	125	50	
313		Longitudinal butt weld, without stop/start positions, NDE with stop/start positions	125 90	50 36	
321		Continuous automatic longitudinal fully penetrated K-butt weld without stop/start positions (based on stress range in flange) NDE	125	50	No start-Stop position is permitted except when the repair is performed by a specialist and inspection is carried out to verify the proper execution of the weld.

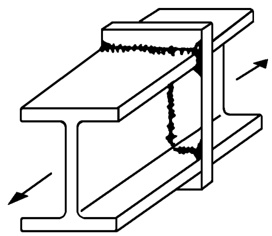
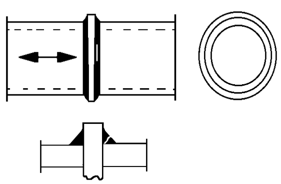
322		Continuous automatic longitudinal double sided fillet weld without stop/start positions (based on stress range in flange)	100	40	Discussion: EC3 has 112 ??
323		Continuous manual longitudinal fillet or butt weld (based on stress range in flange)	90	36	

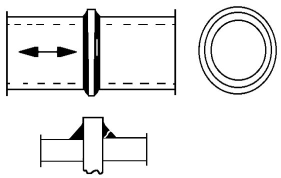
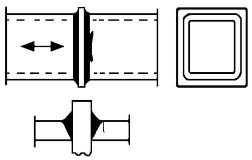
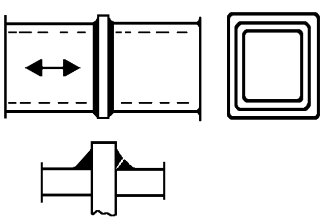
324		Intermittent longitudinal fillet weld (based on normal stress in flange **σ** and shear stress in web **τ** at weld ends). τ/σ = 0 0.0 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 0.5 - 0.6 0.6 - 0.7 > 0.7	80 71 63 56 50 45 40 36	32 28 25 22 20 18 16 14	Analysis based on normal stress in flange and shear stress in web at weld ends. representation by formula?? steel 80 cdot (1 - {Delta tau} over {Delta sigma}) but >=36 alum. 36 cdot`(1 - {Delta tau} over {Delta sigma}) but >=14
325		Longitudinal butt weld, fillet weld or intermittent weld with cope holes (based on normal stress in flange and shear stress in web at weld ends), cope holes not higher than 40% of web. τ/σ = 0 0.0 - 0.2 0.2 - 0.3 0.3 - 0.4 0.4 - 0.5 0.5 - 0.6 > 0.6	71 63 56 50 45 40 36	28 25 22 20 18 16 14	Analysis based on normal stress in flange and shear stress in web at weld ends. representation by formula steel 80 cdot`( 1 - {Delta tau} over {Delta sigma} ) but >=36  alum. 36 cdot`(1 - {Delta tau} over {Delta sigma}) but >=14

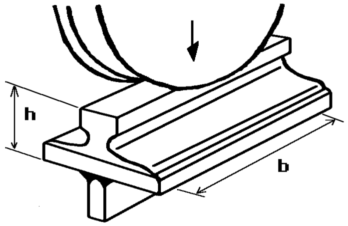
331		Joint at stiffened knuckle of a flange to be assessed according to no. 411 - 414, depending on type of joint. Stress in stiffener plate: sigma~=~sigma sub f cdot ` A sub f over {Sum A sub st}`cdot `2 cdot`sin alpha A_f = area of flange A_{St} = area of stiffener Stress in weld throat: sigma sub w ~=~ sigma sub f cdot `A sub f over {Sum A sub w} cdot `2 cdot` sin alphaA_w = area of weld throat	---	---	
332		Unstiffened curved flange to web joint, to be assessed according to no. 411 - 414, depending on type of joint. Stress in web plate: sigma~=~F sub g over {r` cdot` t}Stress in weld throat: sigma sub w ~=~F sub f over {r cdot Sum a}F_f axial force in flange t thickness of web plate a weld throat	---	---	The resulting force of Ff-left and Ff-right will bend the flange perpendicular to the plane of main loading. In order to minimize this additional stressing of the welds, it is recommended to minimize the width and to maximize the thickness of the flange. Stress longitudinally to the weld is to be considered. At additional shear, principle stress in web is to be consired (see 321 to 323)

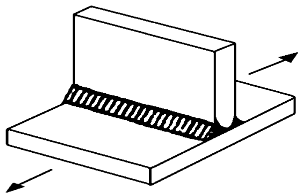
400	**Cruciform joints and/or T-joints**				
411		Cruciform joint or T-joint, K-butt welds, full penetration, no lamellar tearing, misalignment e<0.15□t, weld toes ground, toe crack	80	28	Material quality of intermediate plate has to be checked against susceptibility of lamellar tearing. Misalignment <15% of primary plate.
412		Cruciform joint or T-joint, K-butt welds, full penetration, no lamellar tearing, misalignment e<0.15t, toe crack	71	25	Material quality of intermediate plate has to be checked against susceptibility of lamellar tearing. Misalignment <15% of loaded plate.
413		Cruciform joint or T-joint, fillet welds or partial penetration K-butt welds, no lamellar tearing, misalignment e<0.15t, toe crack	63	22	Material quality of intermediate plate has to be checked against susceptibility of lamellar tearing. Misalignment <15% of loaded plate. Also to be assessed as 414

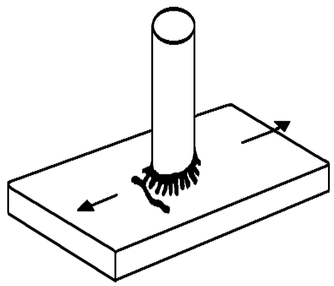
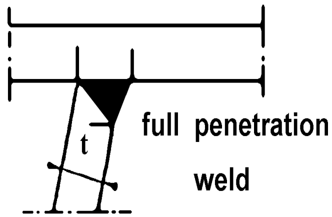
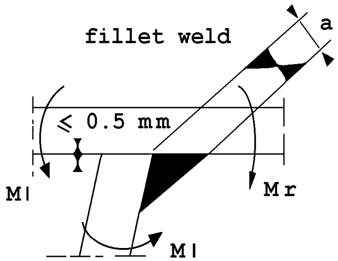
414		Cruciform joint or T-joint, fillet welds or partial penetration K-butt welds including toe ground joints, weld root crack. For a/t<=1/3	36 40	12 14	Analysis based on stress in weld throat Also to bes assessed as 413. Ratio a/t is calculated from weld throat over wall thickness
415		Cruciform joint or T-joint, single-sided arc or laser beam welded V-butt weld, full penetration, no lamellar tearing, misalignment e< 0.15□t, toe crack. Root inspected. If root is not inspected, then root crack	71 36	25 12	
416		Cruciform joint or T-joint, single-sided arc welded fillet or partial penetration Y-butt weld, no lamellar tearing, misalignment of plates e< 0.15t, stress at weld root. Penetration verified. Penetration not verified.	71 36	25 12	Analysis based on stress in weld root. Eccentricity e of plate t and weld throat midpoints to be considered in analysis. Stress at weld root: $\boldsymbol{\Delta\sigma_{w,\,root} = \Delta\sigma_{w,\,nom}(1+6e/a)}$ An analysis by effective notch stress procedure is recommended

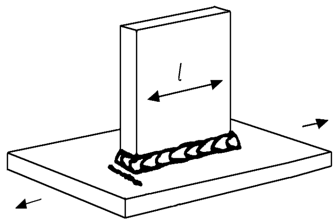
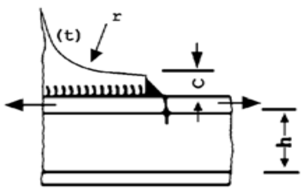
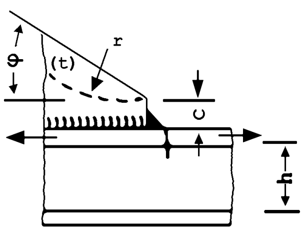
421		Splice of rolled section with intermediate plate, fillet welds, weld root crack. Analysis base on stress in weld throat.	36	12	
422		Splice of circular hollow section with intermediate plate, single-sided butt weld, toe crack wall thickness > 8 mm wall thickness < 8 mm	 56 50	 22 20	Welds NDE inspected in order to ensure full root penetration.

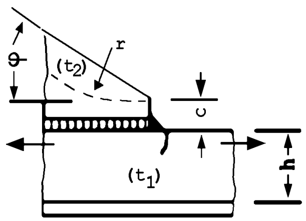
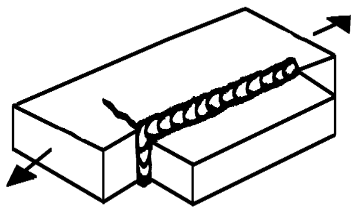
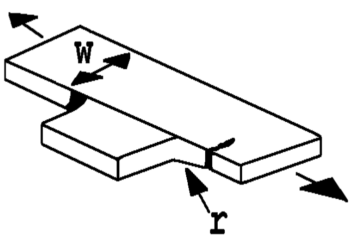
423		Splice of circular hollow section with intermediate plate, fillet weld, root crack. Analysis based on stress in weld throat. wall thickness > 8 mm wall thickness < 8 mm	45 40	16 14	
424		Splice of rectangular hollow section, single-sided butt weld, toe crack wall thickness > 8 mm wall thickness < 8 mm	50 45	20 18	Welds NDE inspected in order to ensure full root penetration.
425		Splice of rectangular hollow section with intermediate plate, fillet welds, root crack wall thickness > 8 mm wall thickness < 8 mm	40 36	16 14	

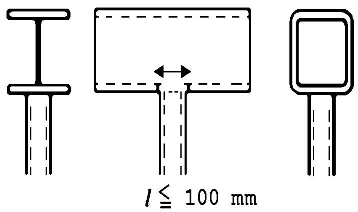
431		Weld connecting web and flange, loaded by a concentrated force in web plane perpendicular to weld. Force distributed on width b = 2h + 50 mm. Assessment according to no. 411 - 414. A local bending due to eccentric load should be considered.	---	---	Full penetration butt weld.

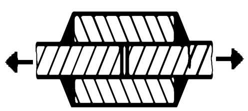
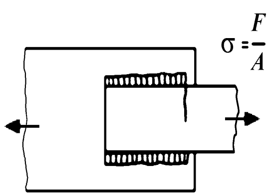
500	**Non-load-carrying attachments**				
511		Transverse non-load-carrying attachment, not thicker than main plate K-butt weld, toe ground Two-sided fillets, toe ground Fillet weld(s), as welded thicker than main plate	 100 100 80 71	 36 36 28 25	Grinding parallel to stress At one sided fillet welds, an angular misalignment corresponding to k_m = 1.2 is already covered
512		Transverse stiffener welded on girder web or flange, not thicker than main plate. K-butt weld, toe ground Two-sided fillets, toe ground fillet weld(s): as welded thicker than main plate	 100 100 80 71	 36 36 28 25	For weld ends on web principle stress to be used

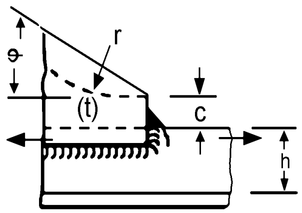
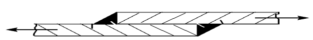
513		Non-load carrying stud as welded	80	28	
514		Trapezoidal stiffener to deck plate, full penetration butt weld, calculated on basis of stiffener thickness, out of plane bending	71	25	
515		Trapezoidal stiffener to deck plate, fillet or partial penetration weld, out of plane bending	50	16	Calculation on basis of stiffener thickness and weld throat, whichever is smaller

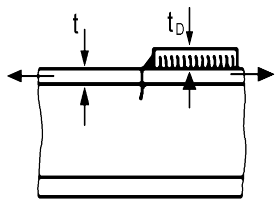
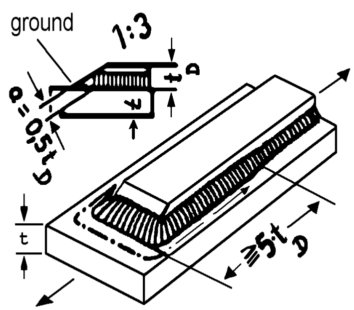
521		Longitudinal fillet welded gusset at length l l < 50 mm l < 150 mm l < 300 mm l > 300 mm	80 71 63 50	28 25 20 18	For gusset near edge: see 525 "flat side gusset" If attachment thickness < 1/2 of base plat thickness, then one step higher allowed (not for welded on profiles!)
522		Longitudinal fillet welded gusset with radius transition, end of fillet weld reinforced and ground, c < 2 t, max 25 mm r > 150 mm	90	32	t = thickness of attachment
523		Longitudinal fillet welded gusset with smooth transition (sniped end or radius) welded on beam flange or plate. c < 2 t, max 25 mm r > 0.5 h r < 0.5 h or φ < 20°	71 63	25 20	t = thickness of attachment If attachment thickness< 1/2 of base plat thickness, then one step higher allowed (not for welded on profiles!)

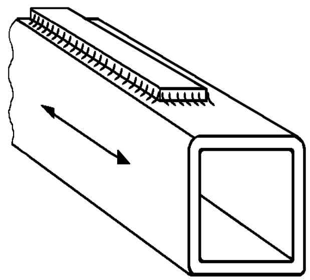
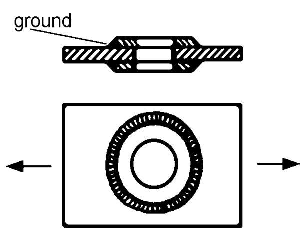
524		Longitudinal flat side gusset welded on plate edge or beam flange edge, with smooth transition (sniped end or radius). $c < 2t_2$, max. 25 mm r > 0.5 h r < 0.5 h or $\varphi < 20°$	 50 45	 18 16	t = thickness of attachment For $t_2 < 0.7\ t_1$, FAT rises 12%
525		Longitudinal flat side gusset welded on plate or beam flange edge, gusset length l: l < 150 mm l < 300 mm l > 300 mm	 50 45 40	 18 16 14	For $t_2 < 0.7\ t_1$, FAT rises 12%
526		Longitudinal flat side gusset welded on edge of plate or beam flange, radius transition ground. r>150 or r/w > 1/3 1/6 < r/w < 1/3 r/w < 1/6	 90 71 50	 36 28 22	Smooth transition radius formed by grinding the weld area in transition in order to remove the weld toe completely. Grinding parallel to stress.

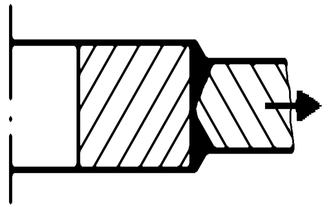
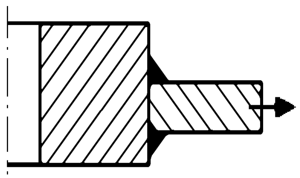
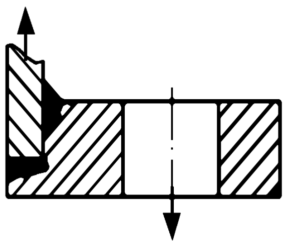
531		Circular or rectangular hollow section, fillet welded to another section. Section width parallel to stress direction < 100 mm, else like longitudinal attachment	71	28	Non load-carrying welds. Width parallel to stress direction < 100 mm.

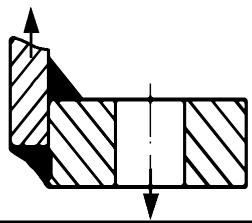
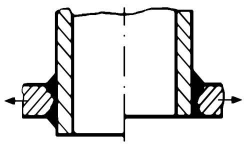
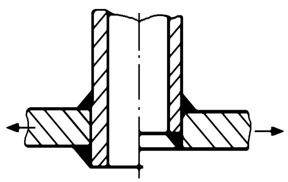
600	**Lap joints**				
611		Transverse loaded lap joint with fillet welds Fatigue of parent metal Fatigue of weld throat	 63 45	 22 16	Stresses to be calculated in the main plate using a plate width equaling the weld length. Buckling avoided by loading or design!
612		Longitudinally loaded lap joint with side fillet welds Fatigue of parent metal Fatigue of weld (calc. on max. weld length of 40 times the throat of the weld	 50 50	 18 18	Weld terminations more than 10 mm from plate edge. Buckling avoided by loading or design!

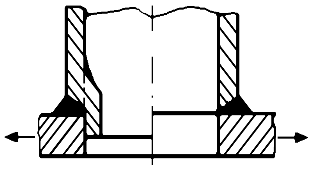
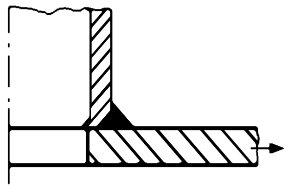
613		Lap joint gusset, fillet welded, non-load-carrying, with smooth transition (sniped end with φ < 20° or radius), welded to loaded element c<2t, but c <= 25 mm to flat bar to bulb section to angle section	 63 56 50	 22 20 18	t = thickness of gusset plate
614		Transverse loaded overlap joint with fillet welds. Stress in plate at weld toe (toe crack) Stress in weld throat (root crack)	 63 36	 22 12	Stresses to be calculated using a plate width equaling the weld length. For stress in plate, eccentricity to be considered, as given in chapters 3.8.2 and 6.3. Both failure modes have to be assessed separately.

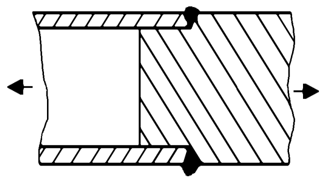
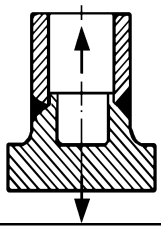
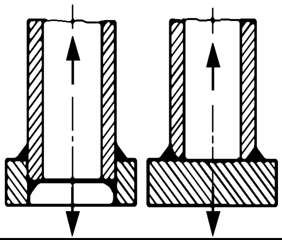
700	Reinforcements				
711		End of long doubling plate on I-beam, welded ends (based on stress range in flange at weld toe) $t_D \leq 0.8$ t 0.8 t < $t_D \leq 1.5$ t $t_D > 1.5$ t	 56 50 45	 20 18 16	End zones of single or multiple welded cover plates, with or without frontal welds. If the cover plate is wider than the flange, a frontal weld is needed. No undercut at frontal welds!
712		End of long doubling plate on beam, reinforced welded ends ground (based on stress range in flange at weld toe) $t_D \leq 0.8$ t 0.8 t < $t_D \leq 1.5$ t $t_D > 1.5$ t	 71 63 56	 28 25 22	Grinding parallel to stress direction.

721		End of reinforcement plate on rectangular hollow section. wall thickness: t < 25 mm	50	20	No undercut at frontal weld!
731		Reinforcements welded on with fillet welds, toe ground Toe as welded	 80 71	 32 25	Grinding in direction of stress! Analysis based on modified nominal stress, however, structural stress approach recommended.

800	**Flanges, branches and nozzles**				
811		Stiff block flange, full penetration weld	71	25	
812		Stiff block flange, partial penetration or fillet weld toe crack in plate root crack in weld throat	 63 36	 22 12	
821		Flat flange with > 80% full penetration butt welds, modified nominal stress in pipe, toe crack	71	25	Assessment by structural hot spot is recommended.

822		Flat flange with fillet welds, modified nominal stress in pipe, toe crack.	63	22	Assessment by structural hot spot is recommended.
831		Tubular branch or pipe penetrating a plate, K-butt welds.	80	28	If diameter > 50 mm, stress concentration of cutout has to be considered Assessment by structural hot spot is recommended.
832		Tubular branch or pipe penetrating a plate, fillet welds. Toe cracks. Root cracks (analysis based on stress in weld throat)	71 36	25 12	If diameter > 50 mm, stress concentration of cutout has to be considered Assessment by structural hot spot is recommended.

841		Nozzle welded on plate, root pass removed by drilling.	71	25	If diameter > 50 mm, stress concentration of cutout has to be considered Assessment by structural hot spot is recommended.
842		Nozzle welded on pipe, root pass as welded.	63	22	If diameter > 50 mm, stress concentration of cutout has to be considered Assessment by structural hot spot is recommended.

900	**Tubular joints**				
911		Circular hollow section butt joint to massive bar, as welded	63	22	Root of weld has to penetrate into the massive bar in order to avoid a gap perpendicular to the stress direction.
912		Circular hollow section welded to component with single side butt weld, backing provided. Root crack.	63	22	Root of weld has to penetrate into the backing area in order to avoid a gap perpendicular to the stress direction.
913		Circular hollow section welded to component single sided butt weld or double fillet welds. Root crack.	50	18	Impairment of inspection of root cracks by NDE may be compensated by adequate safety considerations (see chapter 5) or by downgrading down to 2 FAT classes.

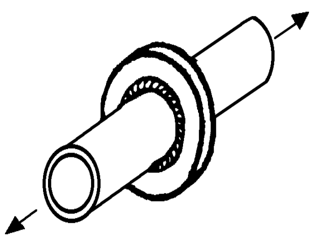
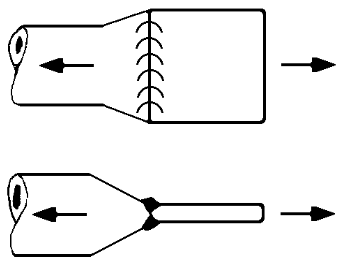
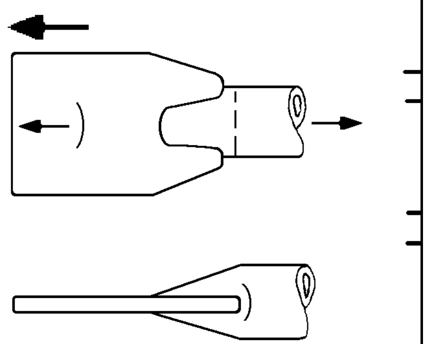
921		Circular hollow section with welded on disk K-butt weld, toe ground Fillet weld, toe ground Fillet welds, as welded	 90 90 71	 32 32 25	Non load-carrying weld.
931		Tube-plate joint, tubes flattened, butt weld (X-groove) Tube diameter < 200 mm and plate thickness < 20 mm	71	25-	
932		Tube-plate joint, tube slitted and welded to plate tube diameter < 200 mm and plate thickness < 20 mm tube diameter > 200 mm or plate thickness > 20 mm	 63 45	 18 14	

Table G.2 – Fatigue resistance values for structural details in steel on the basis of shear stress

No	Description (St.=Steel; Al.= Aluminium)	FAT St.	FAT Al.
1	Parent metal or full penetration butt welds; nr=5 down to 1E8 cycles	100	36
2	Fillet weld or partial penetration butt weld; nr=5 down to 1E8 cycles	80	28