Weld inspection acc. to EN 1090-2:2018, Appendix L

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Background

- MSCE, NTH 1975 (now NTNU, Norwegian University for Technical and Natural Sciences)
- Research assistant and Institute Engineer at Institute for Steel Structures, NTH
- NPRA (Norwegian Public Roads Administration), Bridge division
- Dr.ing. A. Aas-Jakobsen AS since 1984

- Design of steel bridges
- Speciality: Design og suspension bridges
- Participated in writing Technical Specifications for Steel bridges for NPRA
- Member of Norwegian Standardisation Organization’s committee SN/K72 (mirror committe to European standarisation organisation (CEN))
- Member og Working group WG2 for the revisjon av EN 1090-2 : 2018
- Translation from English to Norwegian of EN 1090-2 : 2018

Execution classes

- The choice of execution classes (EXC) has been moved from Appendix B in EN 1090-2 to Appendix C i EN 1993-1-1:2005+**A1:2014**
- The reason for this is that execution classes shall be determined by the **designer** (and not the fabricator)

Table C.1 — Choice of execution class (EXC)

Reliability Class (RC) or Consequences Class (CC)	Type of loading	
	Static, quasi-static or seismic DCL[a]	Fatigue[b] or seismic DCM or DCH[a]
RC3 or CC3	EXC3[c]	EXC3c
RC2 or CC2	EXC2	EXC3
RC1 or CC1	EXC1	EXC2

[a] Seismic ductility classes are defined in EN 1998-1: Low = DCL; Medium = DCM; High = DCH.

[b] See EN 1993-1-9.

[c] EXC4 may be specified for structures with extreme consequences of structural failure.

NOTE 1 The National Annex may specify whether the selection of execution classes is based on reliability classes or consequences classes or both and may specify the choice in terms of the type of the structure. The National Annex may specify whether Table C.1 is to be adopted.

Execution classes

- Buildings will normally be classified in EXC2 (reliability class 2)
- Buildings in Reliability class 3, (e.g. airport buildings with many people etc.) will be placed in EXC3 (acc to Norwegian NA to NS-EN 1990)
- Bridges in Norway are to be placed in EXC3 acc. to NPRA Handbook N400 Bruprosjektering
- EXC4 is now to be specified only for «structures with extreme consequences of structural failure»

- According to Appendix C.1.2 (1) in EN 1993-1-1 the execution class may be «specified for the execution of the **works as a whole**, of an **individual component** or a **detail of a component**»
- **I recommend that the same EXC is chosen for the entire structure**
- Specifying different EXCs for individual details or welds etc. is not recommended as other requirements than weld inspection is also defined by the EXC, ref. EN 1090-2 Appendix A.3

Acceptance criteria

EN 1090-2:2018 ch. 7.6.1 **Routine requirements**

Unless otherwise specified, for EXC1, EXC2 and EXC3 the acceptance criteria for weld imperfections shall be as follows, with reference to EN ISO 5817:2014, except "Incorrect toe" (505) and "Micro lack of fusion" (401) which are not to be taken into account. Any additional requirements specified for weld geometry and profile shall be taken into account:

a) EXC1 quality level D except quality level C for "Insufficient throat" (5213);

b) EXC2 quality level C except quality level D for "Overlap" (506), "Stray arc" (601) and "End crater pipe" (2025) and quality level B for "Insufficient throat" (5213);

c) EXC3 quality level B.

NOTE Welds in connections designed according to EN 1993-1-8 generally require quality level defined for EXC2.

For EXC4 the weld shall meet the requirements of EXC3 as a minimum. Additional requirements with respect to identified welds shall be specified.

Acceptance criteria, fatigue requirements (new)

EN 1090-2:2018 ch. 7.6.2 **Fatigue requirements**

Unless otherwise specified, for welds subject to fatigue designed according to EN 1993-1-9, the execution specification shall specify the relevant acceptance criteria in terms of the detail category (DC) for the welded joint location. ☆

For EXC2, EXC3 and EXC4, in addition to the criteria specified in 7.6.1, the acceptance criteria for welds may be specified in accordance with EN ISO 5817:2014, Annex C as follows:

a) DC not exceeding 63: Quality level C 63;

b) DC above 63 and not exceeding 90: Quality level B 90;

c) DC above 90 and not exceeding 125: Quality level B 125.

The execution specification shall specify execution requirements that are necessary to comply with the execution requirements given in of EN 1993-1-9:2005, Tables 8.1 to 8.8 and/or of EN 1993-2:2006, Annex C.

☆ My interpretation is that the requirement shall be according to the detail category that is **required** from the fatigue **calculations**

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Weld inspection, ref. EN 1090-2 Ch. 12.4

Weld inspection is now devided into the following parts:

- Type testing (the first 5 joints acc. to a WPS developed from a new WPQR)
- Routine inspection and testing
- Project specific inspection and testing (if specified) (new possibility)
- Production tests of welding (if specified)

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Weld inspection

Routine inspection and testing (approximately as previously)

- 100% visual inspection
- «Supplementary NDT» acc. to table 24, **dependent on execution class, (EXC)**, with increasing extent of inspection for increasing EXC
- Table 24 has been revised so that the extent of inspection is clearly defined by the table, and no longer dependent on the usage factor (U).
- Previouly the designer had to give U in the drawings or in technical specifications (but this was seldom done)
- The routine inspection and testing is the workshops's **regular inspection** (on a yearly basis) which is the basis for the certification

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Table 24 —Extent of routine supplementary NDT

Type of weld	Shop and site welds		
	EXC1	EXC2	EXC3 [a]
Transverse butt welds and partial penetration welds in butt joints:	0 % [b]	10 %	20 %
Transverse butt welds and partial penetration welds: — in cruciform joints — in T joints	 0 % [b] 0 %	 10 % 5 %	 20 % 10 %
Transverse fillet welds [c]: with $a > 12$mm or $t > 30$ mm with $a \leq 12$mm and $t \leq 30$ mm	 0 % 0 %	 5 % 0 %	 10 % 5 %
Full penetration longitudinal welds [d] between web and top flange of crane girders	0 %	10 %	20 %
Other longitudinal welds [d], welds to stiffeners and welds specified in the execution specification as being in compression	0 %	0 %	5 %

[a] For EXC4 the percentage extent shall be at least that given for EXC3.

[b] 10 % for such welds executed in steel ≥ S420.

[c] Terms *a* and *t* refer respectively to the throat thickness and the thickest material being joined.

[d] Longitudinal welds are those made parallel to the component axis. All others are considered as transverse welds.

The execution specification may identify specific joints for inspection together with the extent and method of testing (see 12.4.2.4). This testing may be counted within the extent of routine testing as appropriate.

Weld inspection acc. to table 24 is based upon the need/wish of the workshop

- workshops are certified acc. to execution classes (EXC1, EXC2, EXC3)
- certification requires a QA system with documented weld inspections
- a regular and schematic inspection is practical for the workshop as they can plan the inspection to best suit their fabrication
- this routine weld inspection will document that the workshop has a stable quality of the welds
- for the designer, however, this may not be satisfactory, as the inspection may be random and not directed to the most important welds
- in a «worst case», no inspection of «my» structure is performed, but only on other structures in the fabrication
- the designer may therfore wish to specify the inspection in more detail

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Weld inspection dependent on EXC or not?

- Normally the **complete structure** is placed in the same EXC
- All weld of the same type will then, acc. to table 24, have the same extent of weld inspection, independent of the importance of the weld
- it is known that some workshops have reduced the EXC for some welds (in order to reduce the acceptance criteria and extent of inspection). The design responsibility is then not clear.
- The **designer** shall choose the EXC (based upon EN 1990 og EN 1993-1-1)
- The Norwegian standard committee (SN/K72) proposed to include an alternative method in order to be able to differentiate the extent of inspection and the acceptance criteria **dependent on the importance/criticality of the weld** (and independently of EXC)
- This approach is used in Norway in the Offshore standards (NORSOK-rules N-004 and M-101) and in the Technical specifications for steel structures for bridges (NPRA handbook R762, prosess 85.24)

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Weld inspection (WIC)

On this background, the Norwegian standard committee (SN/K72) therefore proposed the introduction of Weld Inspection Classes (WIC), with the following arguments:
(the text was included in Appendix L):

L.1 General

Specification of EXC may not always be sufficient alone for the differentiation of the acceptance criteria and the extent of inspection for welds /details of different importance or criticality. This may result in the following:

a) the acceptance criteria may become too onerous for welds that are not important;

b) the extent of specified inspection may become too large for welds that are not important;

c) the specified inspection may miss the critical locations.

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Project specific inspection and testing

Norway's proposal was accepted, and EN 1090-2 now has a new chapter 12.4.2.4 whith an **option** for specifying Weld Inspection Classes (WIC)

12.4.2.4 Project specific inspection and testing

For EXC1, EXC2 and EXC3, the execution specification may identify requirements for production testing and specific joints for inspection together with the extent of testing.

For EXC4 execution specification shall identify specific joints for inspection together with the extent of testing, which shall be that specified for EXC3 as a minimum.

If specified, weld inspection classes (WICs) may be used to classify specific welds for inspection, and in this respect to define the scope and percentage extent of supplementary testing and the test methods to be used according to the criticality of the weld (see Annex L for guidance). If weld inspection classes (WICs) are used, the execution specification shall be used to identify the weld inspection class (WIC) for each relevant weld.

This is a **tool** than can be used by the designer in order to describe a more specific inspection.

Selection of Weld Inspection Classes (WIC)

New Informative Annex L:

Annex L: «Guidance on the selection of weld inspection classes»

- a tool for the designer
- an attempt to obtain a common practice in different countries and environments
- guidance on the selection of welding inspection classes (WIC) is given in Table L.1

Annex L: Guidance on the selection of weld inspection classes

Table L.1 — Guidance on a method for selection of weld inspection class

Level of fatigue utilization [a]	**Consequences from failure of joint or component** [c]	**Stress in weld** [b]	**Weld Inspection Class (WIC)**
High fatigue utilization	Substantial [b]	Welds with the direction of dynamic principal stress transverse to the weld (between 45° and 135°)	WIC5
		Welds with the direction of dynamic principal stress in the direction of the weld (between −45° and +45°)	WIC4
	Not substantial [c]	Welds with the direction of dynamic principal stress transverse to the weld (between 45° and 135°)	WIC3
		Welds with the direction of dynamic principal stress in the direction of the weld (between −45° and +45°)	WIC2
No fatigue (i.e. quasi-static) or **Low** fatigue utilization	Substantial [b]	Welds with high [d] tensile stresses transverse to weld	WIC5
		Welds with low tensile stresses transverse to weld and/or high [d] shear stresses	WIC4
	Not substantial [c]	For welds in EXC3 or EXC4 with high [d] tensile stresses transverse to weld	WIC3
		All other load-bearing welds except welds in EXC1	WIC2
		Welds in EXC1 and non-load-bearing welds	WIC1

Annex L: Guidance on the selection of weld inspection classes

Table L.1 is based on the following 3 criteria:

- **fatigue** utilization**,**
- **consequence** for the structure from failure of the weld
- direction, type and level of **stress**

This is further defined in footnotes to the table:

a Low fatigue utilization means connection with calculated fatigue life longer than 4 times the required fatigue life.

b Substantial consequences means that the failure of the joint or member will entail:

— possible multiple loss of human life; and/or;
— significant pollution; and/or;
— major financial consequences.

c The consequences may be assessed as Not substantial if the structure has been provided with sufficient residual strength to meet specified accidental actions.

d High stresses are those that (quasi-)static stresse that exceed 50 % of the welds tensile or shear capacity, as appropriate. Low stresses conversely. Special consideration should also be given to the selection of WIC where the principal stress is in the through-thickness direction of the parent material.

Extent of NDT is defined by WIC in table L.2

Table L.2 — Percent extent of supplementary testing according to WIC

Weld Inspection Class (WIC)	Type of joint	RT	UT	MT/PT
WIC5	Full penetration in-line butt weld	10	100	100
	Full penetration T-butt weld	0	100	100
	Partial penetration welds with penetration depth greater than 12 mm	0	20	100
	Other partial penetration welds and all fillet welds	0	0	100
WIC4	Full penetration in-line butt weld	5	50	100
	Full penetration T-butt weld	0	50	100
	Partial penetration welds with penetration depth greater than 12 mm	0	10	100
	Other partial penetration welds and all fillet welds	0	0	100
WIC3	Full penetration in-line butt weld	0	20	20
	Full penetration T-butt weld	0	20	20
	Partial penetration welds with penetration depth greater than 12 mm	0	5	20
	Other partial penetration welds and all fillet welds	0	0	20
WIC2	Full penetration in-line butt weld	0	10	10
	Full penetration T-butt weld	0	10	10
	Partial penetration welds with penetration depth greater than 12 mm	0	5	5
	Other partial penetration welds and all fillet welds	0	0	5
WIC1	All joint types	0	0	0

Acceptance criteria

- Norway did not get sufficent support for our proposal of variation of acceptance criteria for the weld according to the WIC (i.e. a lower WIC would have given a lower acceptance criteria for the weld)
- The acceptance criteria is therefore determined by the execution class, EXC, only, as previously
- But as the **extent** of weld inspection now may be reduced for less important welds, the number of detected imperfectins will also be reduced for these welds, and therefore the extent of unnecessary repairs will be reduced. So it was acceptable for Norway.
- However, the text in Ch 7.6 Acceptance criteria has an opening for defining other acceptance critera («unless otherwise specified») :

Unless otherwise specified, for EXC1, EXC2 and EXC3 the acceptance criteria for weld imperfections shall be as follows, with reference to EN ISO 5817:2014, except "Incorrect toe" (505) and "Micro lack of fusion" (401) which are not to be taken into account. Any additional requirements specified for weld geometry and profile shall be taken into account:

Present approach for Norwegian bridges

NPRA's Handbook R762 Prosesskoden «Standard arbeidsbeskrivelse» for bridges has defined Kontrollklasser (Inspection classes) for various typical welds:

Tabell 85.24-1: Kontrollklasser

Konstruksjoner/arbeidsprosesser [1]	**Kontrollklasser**		
	1	2 [2]	3
Sveiseforbindelser			
Platebærer, buttskjøt			x
Platebærer, kilsveis/delvis buttsveis		x	
Platebærer, øvrig		x	
Stålbjelke valset, buttskjøt			x
Stålbjelke valset, kilsveis/delvis buttsveis		x	
Stålbjelke valset, øvrig		x	
Tverrkryss/vindfagverk		x	
Ståldekke, tversgående buttskjøt i kjørebaneplate med stivere			x
Ståldekke, T-forbindelse mot tverrskott			x
Stålkasse, tverrskott øvrig, side- og bunnpaneler		x	
Stålkasse, øvrig		x	
Fagverk, buttskjøt av gurt i hoved- og tverrbærer			x
Fagverk, tverrkryss/vindfagverk		x	
Fagverk, øvrig		x	
Hengestangsfeste, hengebru			x
Stagfeste, skråstagbru			x
Rørfagverk, guter, buttskjøt			x
Rørfagverk, knutepunkt			x
Rørfagverk, øvrig		x	
Boltedybler		x	
Ikke-bærende konstruksjoner	x		
Øvrige sveiser		x	

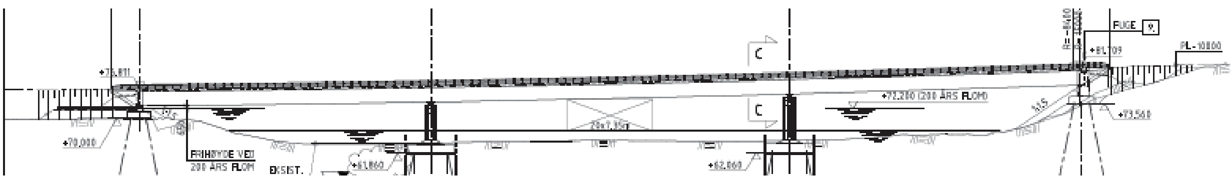
The Inspection class then defines the extent of inspection.

The handbook will hopefully adopt the system with use of WIC.

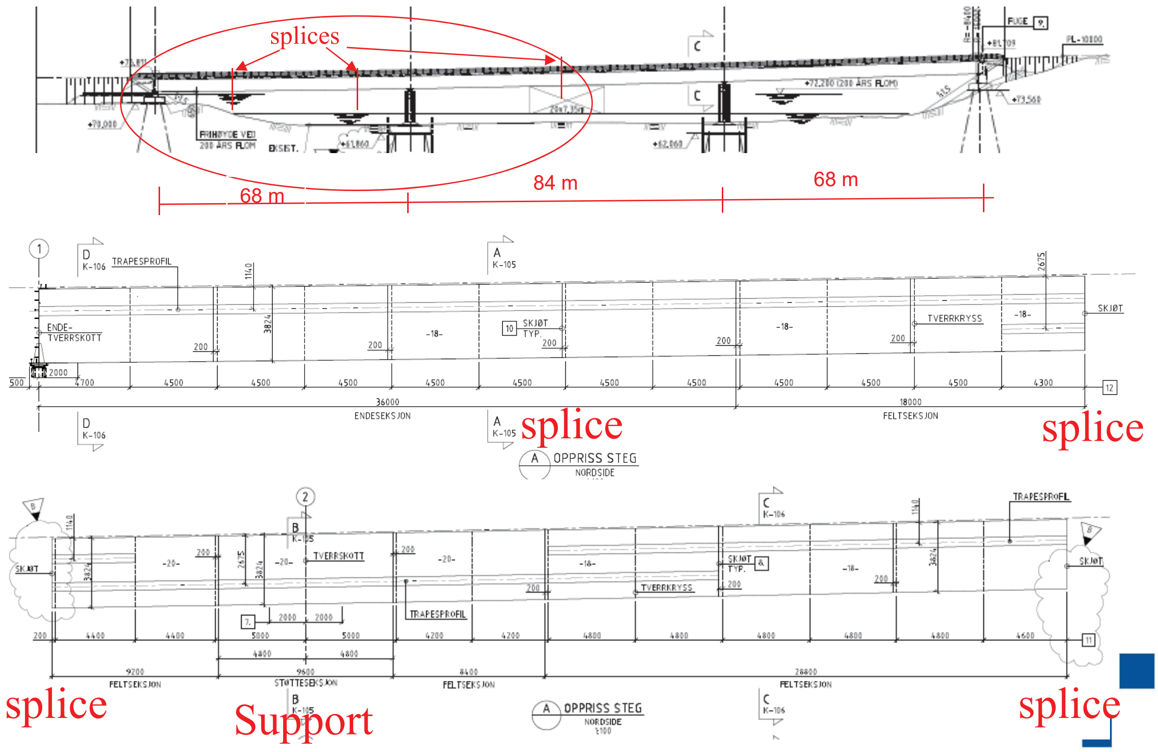
Tabell 85.24-2: Kontrollomfang

Kontroll klasse	**Forbindelsestype**	**Visuell kontroll**	**Røntgen** [7) 8)]	**Ultralyd** [4) 8) 10)]	**Magnet-pulver**
1	Alle sveise-forbindelser	100 %	-	-	stikk [5) 6)]
2	Buttsveis	100 %	5 % [1) 2)]	20 % [3)]	20 %
	T-forbindelse fullt gjennomsveist	100 %	-	20 %	20 %
	Kilsveis/delvis buttsveis	100 %	-	-	20 %
3	Buttsveis	100 %	10 % [1) 2)]	100 % [3)]	100 %
	T-forbindelse fullt gjennomsveist	100 %	-	100 % [9)]	100 %
	Kilsveis/delvis Buttsveis	100 %	-	-	100 %

EXAMPLE, COMPOSITE STEEL BRIDGE



EXAMPLE



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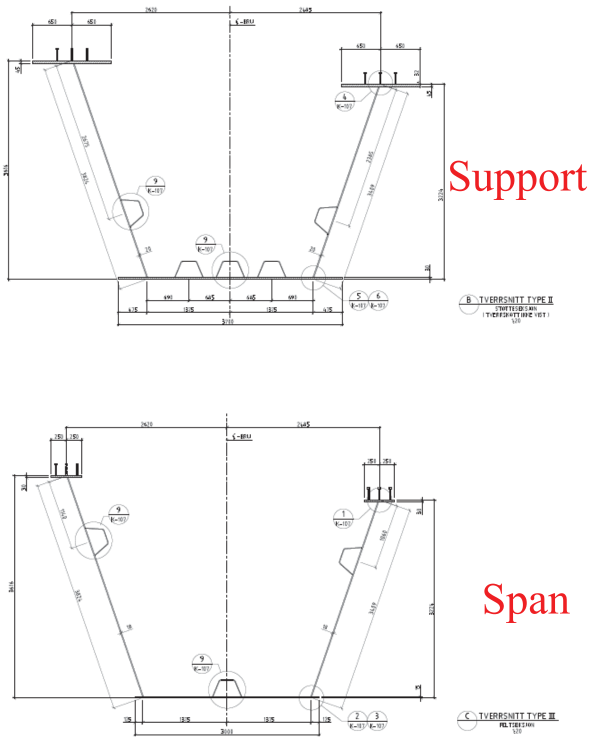
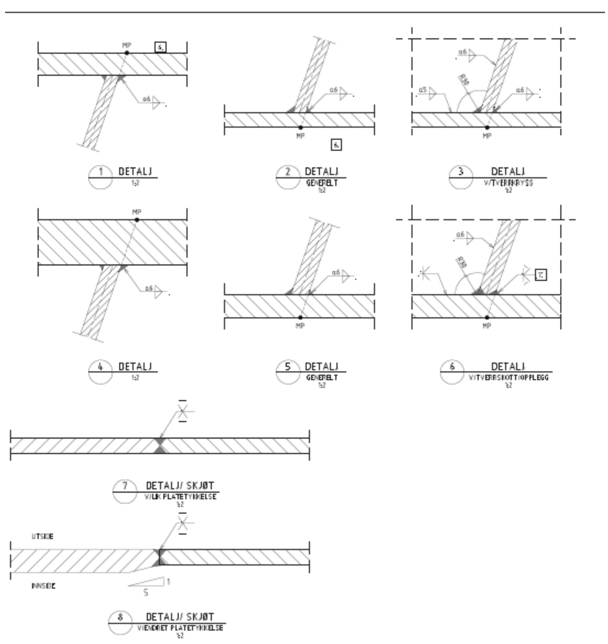
EXAMPLE





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EXAMPLE

Bridge: EXC 3 **Weld quality: B acc. to EN 5817**	**High or low fatigue utilization**	**Substantial or not substantial consequences**	**Direction of dynamic prinsipal stress**	**Direction of stress**	**WIC**	**Weld type**	**Extent of inspection %**		
							RT	UL	MPI
Splice in top flange near support	If «High»	Substantial	Transverse to weld (btw 45 deg and 135 deg		WIC 5	Full pen. butt weld	10	100	100
Splice in top flange near support	If «Low»	Substantial		Transverse to weld	WIC 5	Full pen. butt weld	10	100	100
Splice of bottom flange in span	Low ?	Substantial		Transverse to weld	WIC 5	Full pen. butt weld	10	100	100
Not use of WIC, but according to table 24							20		

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EXAMPLE

Bridge: EXC 3 **Weld quality: B acc. to EN 5817**	**High or low fatigue utilization**	**Substantial or not substantial consequences**	**Direction of dynamic prinsipal stress**	**Direction of stress**	**WIC**	**Weld type**	**Extent of inspection %**		
							RT	UL	MPI
Longitudinal weld btw. flange and web	If «High»	Not substantial	In direction of weld (btw. +45 deg and – 45 deg)		WIC 2	Fillet			5
Longitudinal weld btw. flange and web	If «Low»	Not substantial		In direction of weld	WIC 2	Fillet			5
Not use of WIC, but according to table 24							5		

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THANK YOU FOR
YOUR ATTENTION

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