Božo Despotović[1], Ivan Samardžić[2], Tihomir Marsenić[1]

WELDING OF TUBE / PIPE SYSTEMS IN BOILER PRODUCTION
ZAVARIVANJE CEVNIH SISTEMA U KOTLOGRADNJI

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Adresa autora / Author's address:
[1]Đuro Đaković , TEP d.o.o , Dr. Mile Budaka 1, Slavonski Brod, Hrvatska despotovic.bozo@gmail.com
[2]Strojarski fakultet, Trg I.B.Mažuranić 2, Slavonski Brod, Hrvatska

Ključne reči: ručni i mehanizovani procesi zavarivanja, priprema spojeva, osiguranje kvaliteta

Key words: manual and mechanized welding processes, preparing of joint, quality assurance

Abstract:
The paper describes TIG, SMAW and SAW as basic welding processes used for pipe / tube welding in boiler production. Type of base metals, joint preparing ,welding parameters and shielding gases are the most important variables which are defined in WPS. For mechanized welding processes the most important is mechanical preparation of the edges-joint. Welders and operators education and training, workshop control before, during and after welding are integral parts of the quality assurance of process.

Rezime:
U radu se opisuju TIG, REL i EPP postupak zavarivanja kao osnovni procesi zavarivanja cevnih sistema u kotlogradnji. Vrste osnovnog materijala koji se zavaruju, priprema spojeva, parametri zavarivanja kao i zaštitni gasovi pri zavarivanja su najvažnije varijable koje su definisane Uputstvima za zavarivanje. Za mehanizovane procese zavarivanja nužna je mašinska priprema žljeba za zavarivanje.
Obuka i vežbe zavarivača, radionička kontrola pre za vreme i nakon zavarivanja su sastavni dio u osiguranju kvaliteta ovih procesa.

1. INTRODUCTION

Boiler systems, regardless of operating parameters and specific design is basically a heat exchanger. Thermal energy is created by burning fuel in the combustion chamber and the media is transferred to the water which is circulating through the various pipe systems. In this way energy state of water is raised to the highest degree required to operation of steam turbines or for specific purposes.
Piping systems, as well as the basic structure of boiler components, can be divided into functional groups such as:
-evaporators.,
-superheaters of different degrees,
-reheaters,
-ecomomisers,
- air heaters,
-pipelines for various purposes,
-suporting pipes, etc.

1. UVOD

Kotlovi, bez obzira na radne parametre i specifičan dizajn su u osnovi izmjenjivač topline. Toplotna energija se stvara spaljivanjem goriva u komori za sagorevanje i medijuma koji je prenosi na vodu koja kruži kroz različite cevne sisteme. Na ovaj način energetsko stanje vode se podiže na najviši stepen potreban za rad parnih turbina ili za određene svrhe.
Cevni sistemi, kao i osnovna struktura komponenti kotla, mogu se podeliti u funkcionalne grupe, kao što su:
- isparivača
- superzagrejača različitih stepena
- međupregrejača
- ekonomajzera
- zagrejača vazduha
- cevovoda različitih namena
- nosećih (potpornih) cevi, itd.

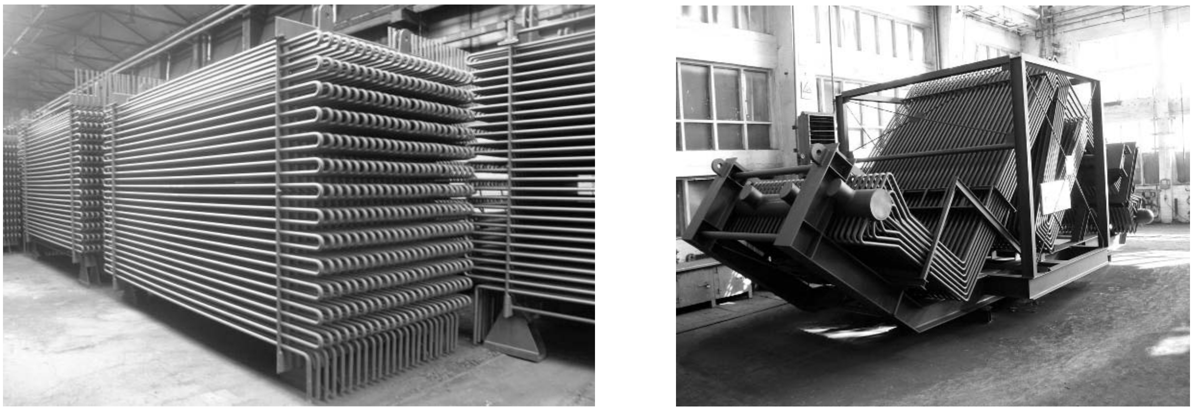


Figure 1. *Overview of typical piping system "package" pipe snake and appearance of one of the superheater*
Slika 1. *Pregled tipičnih cevnih sistema "paket" cevnih zmija i izgled jednog od pregrejača*

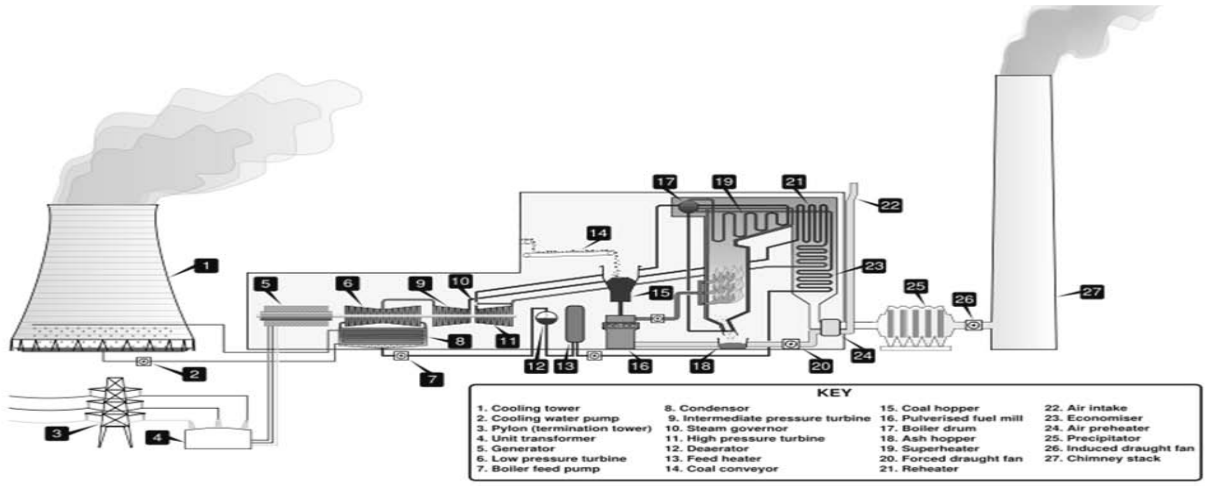


Figure 2. *Overview of the typical boiler plant with the each component names*
Slika 2. *Pregled tipičnog kotlovskog postrojenja sa nazivom svake komponente*

Each of these functional components have different operating parameters and therefore the materials incorporated in the pipe systems are different and adapted to these parameters. Permanent strength and creep resistance properties of these materials have a dominant role due to expected life of the boiler plant.

As the plants are classified in the group of pressure vessels, pressure, temperature, and creep resistance properties are the basic parameters in designing of these plants.

Regardless of the chosen design of the plant and the operating parameters welding technique is the core technology in manufacturing of complete plants and individual pipe systems.

Terminology speaking pipe systems can be classified into two different main groups. At first view there is no difference between "small pipe" (or Tube) and "large pipe" (or Pipe) . But group of tubes/pipes are defined by a separate specification, both groups are made of steel, they

Svaka od ovih funkcionalnih komponenti ima različite radne parametre, a time i ugrađene materijale u cevnim sistemima koji su različiti i prilagođeni ovim parametrima. Stalna čvrstoća i otpornost na puzanje tih materijala imaju dominantnu ulogu zbog očekivanog trajanja kotlovskog postrojenja.

S obzirom da ova postrojenja potpadaju u opremu pod pritiskom, pritisak, temperatura, i svojstva otpornosti na puzanje su osnovni parametri u konstruisanju ovih postrojenja.

Bez obzira na izabranu konstrukciju postrojenja i radne parametre, tehnika zavarivanja je srž tehnologije u proizvodnji kompletnih postrojenja i pojedinačnih cevnih sistema.

Terminološki govoreći, cevni sistemi se mogu svrstati u dve različite glavne grupe. Na prvi pogled ne postoji razlika između "malih cevi" (ili “tube”) i "velike cevi" (ili “pipe”). Ali grupa “tubes / pipes” je definisana posebnom specifikacijom, obe grupe su napravljene od čelika, istog su oblika are the same shapes and they all are used for medium flow, etc.

But there are a few significant differences (referred to same sources there are 15 differences between them). The differences are in the tolerances of the diameter and wall thickness (small pipes have significantly narrower tolerances), the differences are in terms of the design process, mechanical properties, prices, applications, etc.

Large pipes are referred to nominal outside diameter including wall thickness while the small tubes are referred differently, clearly visible in Figure 3.

i svi oni se koriste za protok medijuma, itd, ali postoji nekoliko značajnih razlika (prema istom izvoru postoje 15 razlika između njih). Razlike su u tolerancijama prečnika i debljine zida (male cevi imaju znatno uže tolerancije), razlike su u pogledu procesa konstruisanja, mehaničkih svojstava, cene, primene, itd

Velike cevi se nazivaju sa nominalnim spoljašnjim prečnikom uključujući debljinu zida, dok se male cevi različito nazivaju, jasno se vidi na slici 3.

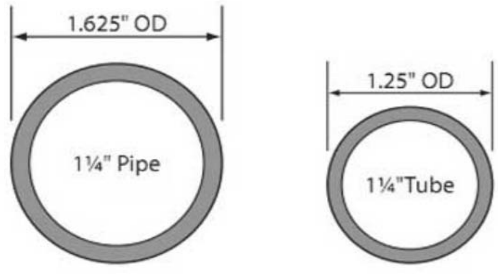


Figure 3. *Example distinctions between "large" (or "Pipe") and "small" (or "Tube") pipes size 11/4"*
Slika 3*. Primer razlike između "velikih" (ili "pipes") i "malih" (ili "tubes") cevi veličine 11/4 "*

Pipe / Tube manufacturers generally consider that the small pipes have pipe diameter of approximately 7 " and all above that are considered as large pipes .

Proizvođači malih cevi / velikih cevi generalno smatraju da male cevi imaju prečnik cevi od oko 7" i sve iznad toga se smatra velikim cevima.

2. WELDING PROCESSES

Welding sparks process as one of the first processes for pipe system welding is no more in application due to the problems with the quality of welds and corrosion in the weld zone.

SMAW and SAW welding processes are applicable to larger diameters and larger wall thicknesses and they are considered as standard well known and reliable welding procedures.

TIG welding process, hand type or mechanized type, are today dominant in technology of pipe systems welding. Manual procedure is well known and it is now the most applicable. Respecting all these known advantages of this procedure it has to be taken into consideration the fact that this process is most of all dependent on welder, his level of education, his concentration, his motivation as well as his imperfections.

There are two different types of mechanized and automated TIG welding processes:

a) tube / pipe which is welded makes rotation during welding and burner-torch is in the same position, and

b) burner-torch make rotation around the pipe

2. POSTUPCI ZAVARIVANJA

Postupak zavarivanja iskrenjem kao jedan od prvih postupaka zavarivanja cevnog sistema nije više u primeni zbog problema sa kvalitetom zavarenih spojeva i korozije u zoni zavarivanja.

Postupci zavarivanja REL i EPP važe za veće prečnike i veće debljine zida i oni se smatraju kao standardni dobro poznat i pouzdan način zavarivanja.

TIG postupak zavarivanja, ručnog ili mehanizovanog tipa, danas je dominantna tehnologija zavarivanja cevnih sistema. Ručni postupak je dobro poznat i danas se najviše primenjuje. Poštujući sve poznate prednosti ovog postupka mora se uzeti u obzir činjenica da ovaj postupak pre svega zavisi od zavarivač, njegovog nivoa obučenosti, njegove koncentracije, motivacije kao i njegove nesavršenosti.

Postoje dve različite vrste mehanizovanih i automatizovanih TIG procesa zavarivanja:

a) mala cev / velika cev koje se zavaruju, rotiraju tokom zavarivanja a gorionik/pištolj je u istom položaju, i

b) gorionik/pištolj rotira oko cevi u toku zavarivanja during welding (the path orbit shape - hence the name orbital welding).

Automated TIG welding method, 2. a)

This procedure is very reliable and stable primarily due to the constant position of the molten bath during welding. The method can be used as a single-pass and multi-pass process. Single- pass welding method is applicable to smaller diameter and wall thickness. Process requires a flat preparing of the tube ends with a minimum clearance - gap in joint preparing.

Multi-pass welding process with circuit types of joint preparation form "V" or form "U" is used for greater diameters and wall thickness. Figure 4.

(put je orbitalnog oblika - otuda i naziv orbitalno zavarivanje).

Automatizovana metoda TIG zavarivanja 2. a)

Ovaj postupak je vrlo pouzdan i stabilan, prvenstveno zbog konstantnog položaja rastopljene kupke u toku zavarivanja. Metoda se može koristiti za jedan prolaz i više prolaza. Jednoslojni način dodavanja je primjenjiv na manjim prečnicima i debljinama zida. Proces zahteva ravnu pripremu krajeva cevi sa minimalnim zazorom u pripremi spoja.

Višeslojni proces zavarivanja sa tipovima priprema spoja oblika "V" ili u obliku "U" se koristi za veće prečnike i debljine zida (slika 4).

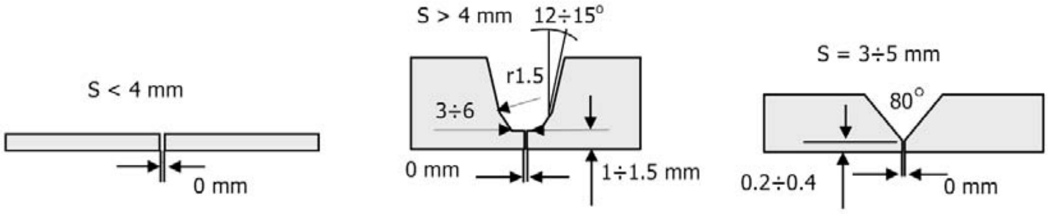


Figure 4. *Forms of joint preparation – grove for various wall thickness of tubes*

Slika 4. *Oblici pripreme spoja – žljebovi za različite debljine zida malih cevi*

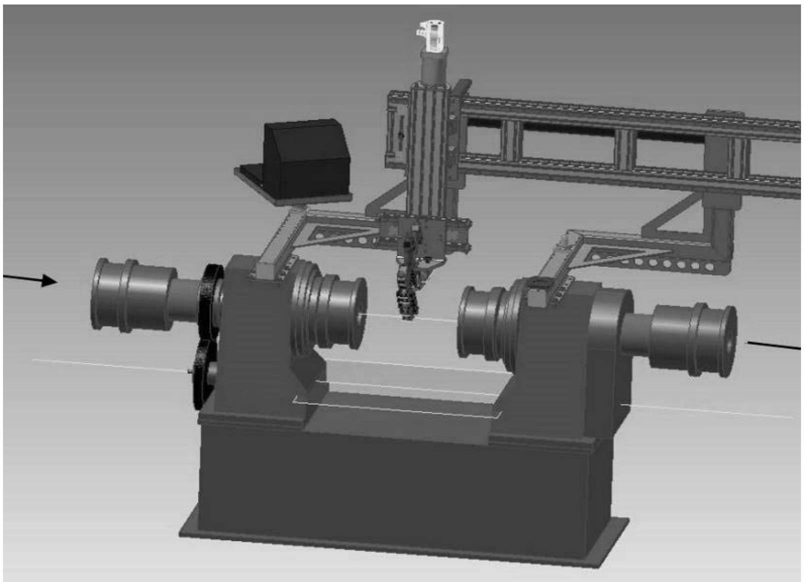


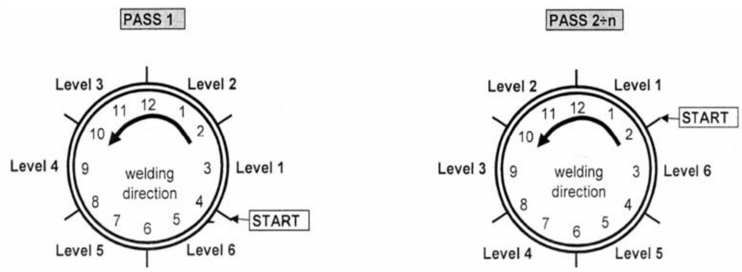
Figure 5. *Visage of the machine for automated TIP - TIG process, tube rotates during welding*

Slika 5. *Izgled mašine za automatsko TIP-TIG zavarivanje, cev rotira tokom zavarivanja*

Automated TIG welding method, 2. b) In case of welding of pipes with tight production tolerances of dimensions, chemical composition and consistent quality through the cross sections of tubes this type of welding process has the most common applications. The limiting factor is the space between tubes which must be provided for freely rotation of the welding head with the torch around the pipe.

Automatizovana metoda TIG zavarivanja 2. b) U slučaju zavarivanja cevi s uskim proizvodnim tolerancijama dimenzija, hemijskog sastava i doslednog kvaliteta kroz preseke cevi, ova vrsta zavarivanja se najčešće primenjuje. Ograničavajući faktor je prostor između cevi koji mora biti predviđen za slobodno okretanje glave za zavarivanje sa pištoljem oko cevi.

Figure 6. *Left : Manual TIG welding. Right : Automated orbital TIG welding*
Slika 6. *Levo; Ručno TIG , Desno; Automatsko orbitalno zavarivanje*



	Pass / Level Parameter	PASS 1						
		Level						
		S/T	1	2	3	4	5	6
WELDING	AMPS [A]	N/A	115	108	109	112	112	112
	WIRE [cm/min.]		50	50	50	50	50	50
	TRAV [cm/min.]		12.3	12.3	12.3	12.3	12.3	12.3
	AGC [mm]		1.65	1.65	1.65	1.65	1.65	1.65
	OSPD [s]		N/A					
	OAMP [cm/OFF]							
	I DWL [s]							
	O DWL [s]							
	AGCST [ON / OFF]		ON	ON	ON	ON	ON	ON
	LPAMP [%]		50	50	50	50	50	50
	HPT [s]		0.45	0.45	0.45	0.45	0.35	0.35
	LPT [s]		0.45	0.45	0.45	0.45	0.45	0.45
	TRST [% / OFF]		OFF	OFF	OFF	OFF	OFF	OFF
	WIRST [% / OFF]		OFF	OFF	OFF	OFF	OFF	OFF

Figure 7. *Example for orbital TIG welding : Levels - sectors of welding and welding parameters*
Slika 7. *Primer za orbitalno TIG zavarivanje; Nivoi- sektori zavarivanja i parametri zavarivanja*

3. BASE AND FILLER MATERIALS

Although today we can often meet with specific materials (eg. Ni alloy type APRI P 87) the basic materials for pipe/tube systems are standardized, classified in quality groups and proven in operation. The most common application of these systems have a special steel pipes (P 235 JRG, P 295 JRG), alloy tubes with Mo (16Mo3), alloy Cr-Mo (45 13CrMo, 11CrMo 910, P / T 23, P / T 24, ..) or microalloying elements (V, W, Ti, B, ...) as well as stainless tubes. Addition of alloying elements in production of tubes or/and thermo-mechanical preparation during the production are the methods.
to achieve mechanical, corrosion and other necessary properties of tube base materials

Filler materials by types, diameters and metallurgical aspects should be adjusted to base material which is welded.

Boiler standards cover all basic types and kinds of steels for tube / pipe production and application.

Steels are classified into quality groups as shown below.

Note: view presents only the main groups of steel.

3. OSNOVNI I DODATNI MATERIJALI

Iako danas često možemo sretati sa specifičnim materijalima (npr. tipa Ni legure APRI P 87) osnovni materijali za sisteme velikih cevi / malih cevi su standardizovani, svrstani u grupe kvaliteta i provereni u radu. Najčešću primenu ovih sistema imaju posebne čelične cevi (P 235 JRG, P 295 JRG), legirane cevi sa Mo (16Mo3), legirane sa Cr-Mo (45 13CrMo, 11CrMo 910, P / T 23, P / T 24 , ..) ili mikrolegirajućim elementima (V, W, Ti, B, ...), kao i nerđajuće cevi. Dodatak legirajućih elemenata u proizvodnji cevi i / ili termo-mehanička prerada tokom proizvodnje su metode za postizanje mehaničkih, korozionih i drugih potrebnih osobina osnovnih materijala cevi.

Dodatne materijale po vrstama, prečniku i metalurškim aspektima treba prilagoditi osnovnom materijalu koji se zavaruje.

Standardi za kotlove obuhvataju sve osnovne vrste i vrste čelika za proizvodnju malih cevi / velikih cevi i primene. Čelici su svrstani u grupe kvaliteta kao što je prikazano u nastavku.

Napomena: pregled predstavlja samo glavne grupe čelika.

Steel Group	Material designation according to CR ISO 15608:2000
1.1.	P235JRG2; P235 GH-TC1; P235 GH-TC2; P265 GH
1.2.	P295 GH; P355 GH; P355 N; 16Mo3
1.4.	X10CrAl7
3.1.	26CrMo4-2; 21CrMoV 5 7
4.2.	15NiCuMoNb 5-6-4
5.1.	13CrMo 4-5
5.2.	10CrMo 9-10; 11CrMo 9-10
6.1.	14MoV 6 3
6.2.	7CrWVMoNb 9-6; 7CrMoVTi 10-10
6.4.	X10CrMoVNb 9-1; X10CrWMoVNb 9-2; X12CrWMoVNb 12-2-2; X20CrMoV 11-1
7.1.	X10CrAl24
8.1.	X5CrNi 18-10
8.2.	X10NiCrAlTi 32-30; X5NiCrCeNb 32-27-AC66; X1NiCrMoCuNb 31-27-4

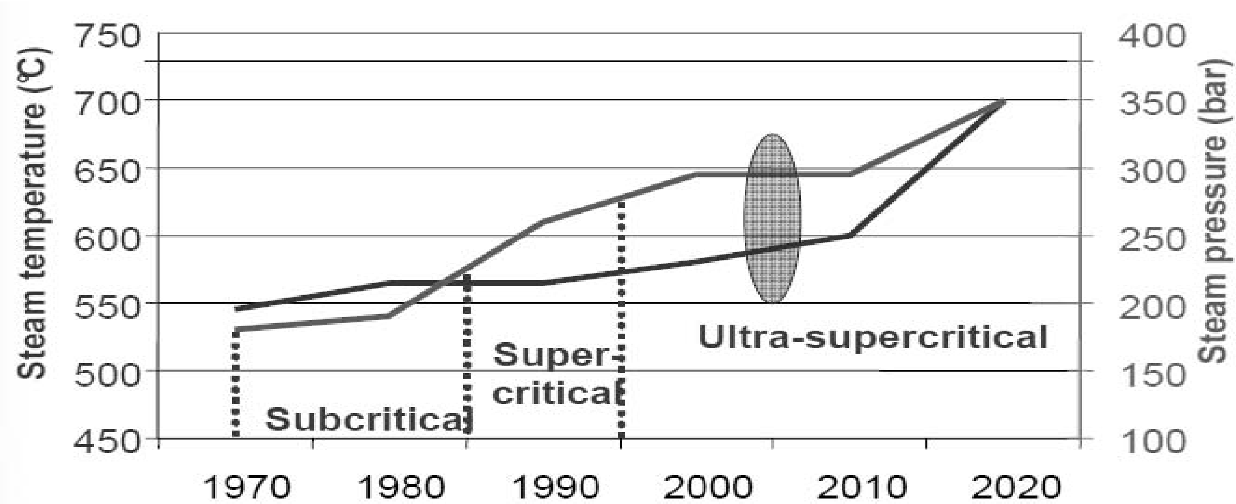


Figure 8. *Dependence of steam pressure and operating temperature of the boiler basic types of steel*
Slika 8. *Zavisnost pritiska pare i radne temperature osnovnih kotlovskih čelika*

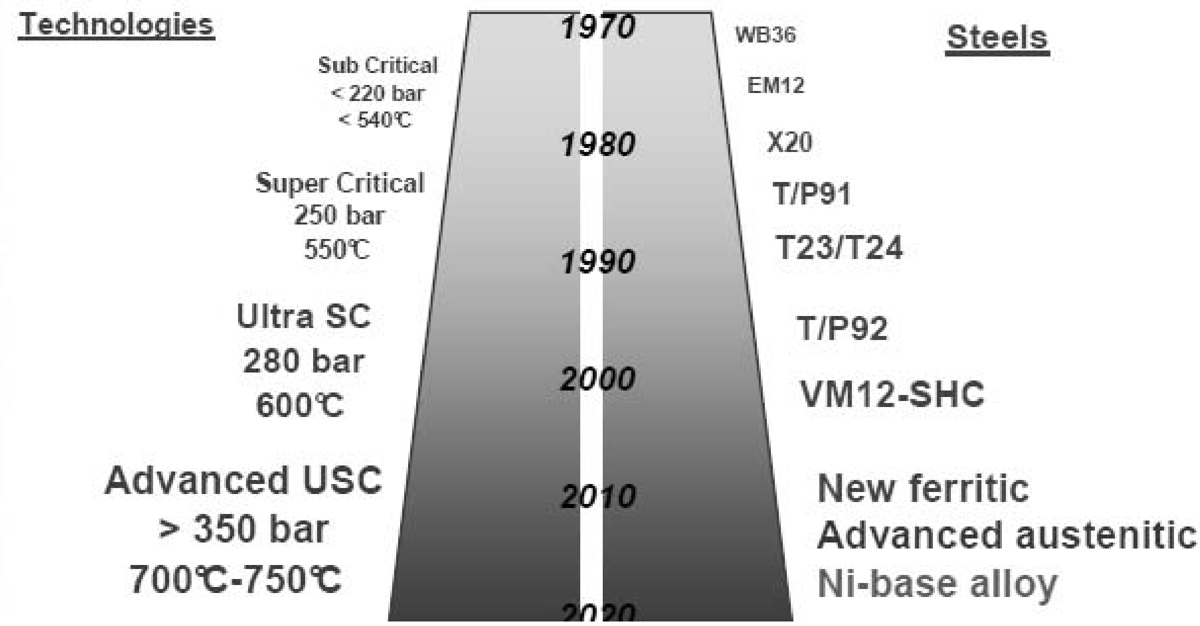


Figure 9*. Development of basic materials as a result of the development of thermal power plants*
Slika 9. *Razvoj osnovni materijala kao rezultat razvoja termoenergetskih postrojenja*

4. WELDING PARAMETERS AND SHIELDING GASSES

All important variables related to welding are defined by qualified welding specifications (WPS-s) which are based on welding procedures qualifications (WPQR-s). For manual welding process trend of defining welding parameters is to limit the parameters validity in the areas which are especially important. Therefore it is necessary to have the basic welding parameters defined for each welding pass. Welding current, run width, thickness of each pass and preheat / interpass temperatures are important variables in this case.

4. POSTUPCI ZAVARIVANJA I ZAŠTITNI GASOVI

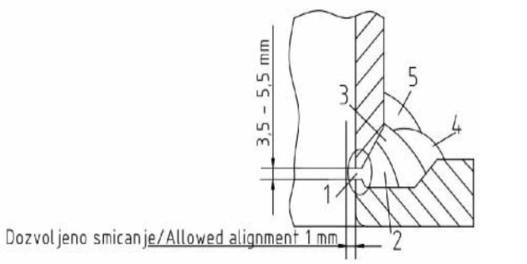
Sve važne varijable koje se odnose na zavarivanje definisane su kvalifikovanim specifikacijama zavarivanja (WPS-e) koje su zasnovane na kvalifikacijama zavarivanja (WPQR-e). Za ručne postupke zavarivanja, trend definisanja parametara zavarivanja je da se ograniči valjanost parametara u područjima koja su od posebnog značaja. Zbog toga je potrebno imati osnovne parametre zavarivanja definisane za svaki zavareni sloj. Struja zavarivanja, širina prolaza, debljina svakog prolaza i predgrevanje/međuprolazna temperatura su važne varijable u ovom slučaju.

Pojedinosti zavarivanja/ Details of welding/ Einzelheiten für das Schweissen										
WS br. WS No. WS Nr.	Slijed zav. Welding sequence Schweiss-folge	Postupak Process Prozess (EN ISO 4063)	Položaj zav. Welding pos. Schw. pos. (EN ISO 6947)	Dodatni materijal EN Filler metal EN Zusatzwerkstoff EN / Trgovačka oznaka Trade mark Handelsname	Promjer Diameter Durch-messer [mm]	Struja Current Strom-stärke [A]	=,~/ +,-	Napon Voltage Spannung [V]	Brzina zav. Travel speed Schweiss-geschw. [cm/min]	*Unos topline Heat input Wärmeeinbringung [kJ/mm] (EN 1011-1)
1	Korijen Root Wurzel	141	PF	EN ISO 21952: WZ CrMo 2 V Ti/Nb Union I P24 T-PUT	2÷2,4	70÷130	=,-	12,0÷17,9	3,5÷6,0	1,2
2	Popuna Fillpass Fullage	141	PF	EN ISO 21952: WZ CrMo 2 V Ti/Nb Union I P24 T-PUT	2÷2,4	80÷180	=,-	12,4÷19,3	4,0÷11,0	1,2
Rukovanje DM WFM - Handling Umgang mit WFM	Vidi / See / Siehe QMP 15-02		Maks. širina prolaza / Max. width of run / Max. weite von Schweissraupe [mm]	12	Maks. debljina prolaza / Max. weld thickness of run/ Max. dicke schweissraupe [mm]		2,5 (3,0)	*Prosječni unos topline /*Average heat input /*Durchschnitt Wärmeeinbringung [kJ/mm]		-

Figure 10. *Section from the WPS which defines the basic parameters of welding*
Slika 10. *Deo WPS koji definiše osnovne parametre zavarivanja*

SKETCH – WELDING SEQUENCE

Projekt / *Project* : Dablin (26.0225)
Crtež / *Dwg.* : 341.050.01; 345.050.01; 346.050.01;
Tip zavara / *Weld No.* : 1; 2; 3
Uputa za zavarivanje / *WPS* : 001-1-NW01-01; 001-1-NW02-01
Postupak zavarivanja / *Welding process* : 141
Pozicija zavarivanja / *Welding position* : PH/PB
Dimenzije / *Dimension* : Komora / *Header* Ø114,3 x 14,2mm
Cijev / *Tube* Ø48,3 x 5 / 6,3mm

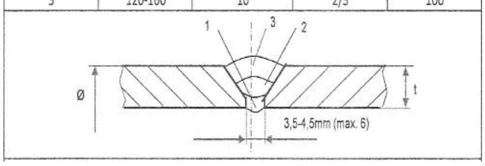


REDOSLJED I PARAMETRI ZAVARIVANJA /
WELDING SEQUENCE AND PARAMETERS

PROLAZI / *PASSES*	STRUJA ZAVARIVANJA / *WELDING CURRENT* - I [A]	ŠIRINA PROLAZA / *WIDTH OF PASS*	MEĐUPROLAZNA TEMP. / *INTERPASS TEMP.*
1.KORIJEN / *PASS (ROOT)*	140 – 180	9 mm	-
2. POPUNA / *PASS (FILLING)*	170 – 190	9 mm	150 °C
3. POPUNA / *PASS (FILLING)*	180 – 190	12 mm	150 °C
4. ZAVRŠNI / *PASS (FINAL LAYER)*	180 – 190	14 mm	350 °C
5. ZAVRŠNI / *PASS (FINAL LAYER)*	160 – 180	10 mm	350 °C

Promjer cijevi: Ø 25-76,3mm
Debljina stijenke: t 5,6-6,3mm
Položaj zavarivanja PH

Broj prolaza	Struja zavarivanja A	maksimalna širina prolaza (mm)	debljina prolaza min/max (mm)	temp. predgrijavanja ili međuprolazna °C
1	95-135	8	2,5/3,5	min 5
2	105-145	10	2/3	100
3	120-160	10	2/3	100



Promjer cijevi: Ø 48-88,9mm
Debljina stijenke: t 7,1mm
Položaj zavarivanja PH

Broj prolaza	Struja zavarivanja A	maksimalna širina prolaza (mm)	debljina prolaza min/max (mm)	temp. predgrijavanja ili međuprolazna °C
1	100-140	8	2,5/3,5	min 5
2	110-150	10	2/3	100
3	120-170	10	2/3	100
4,5	120-160	10	2/3	100

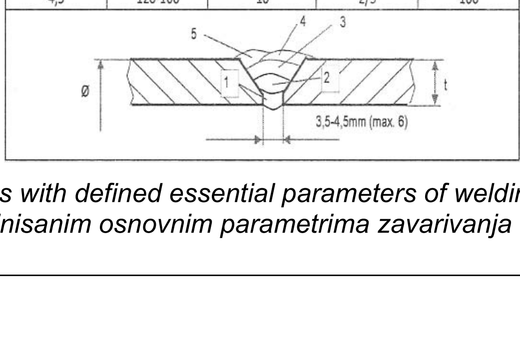


Figure 11. *Examples of appendix to WPS s with defined essential parameters of welding*
Slika11. *Primeri dodataka WPS sa definisanim osnovnim parametrima zavarivanja*

Argon and Helium are the basic primary gasses for welding and for protection of roots as secondary gasses. Small amounts of other gases are added to Ar or He for special purpose to increase the specific effects of the welding arc. Regardless of the type of the base material to be welded and the shielding gas applied in each welded joint it is understood to be good penetration in the base material. Types of protective gas election and geometry of the tungsten electrode can directly affect the depth and shape of penetration.

Argon i helijum su osnovni primarni gasovi za zavarivanje i za zaštitu korena kao sekundarnih gasova. Male količine drugih gasova dodatih Ar ili He je za posebne namene za povećanje specifičnih efekata zavarivačkog luka. Bez obzira na vrstu osnovnog materijala koji se zavaruje i zaštitni gas koji se primjenjuje u svakom zavarenom spoju, jasno da mora da se ostvari dobro uvarivanje u osnovni materijal. Izbor vrste zaštitnog gasa i geometrija volframove elektrode mogu direktno uticati na dubinu i oblik uvarivanja.

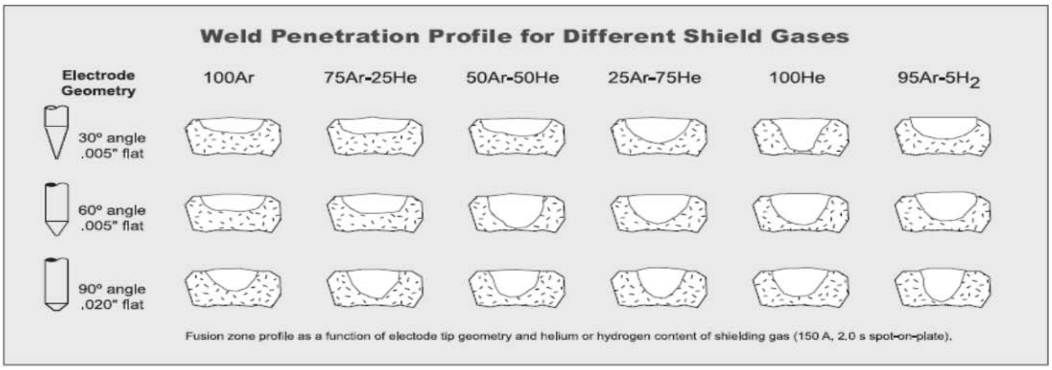


Figure 12. Depth and profile of penetration depending on shield gases and geometry od W electrode
Slika 12. Dubina i profil uvarivanja zavisno od zaštitnog gasa i geometrije W elektrode

5. PREPARATION OF WELDING GROOVE

Groove preparation for welding by machining process is recommended in all cases where it is applicable. Only for manual welding preparation can be made by hand tools. It is especially useful in cases of pre-assembly or assembly of tube / pipe systems. For automated orbital welding method tolerance of tube / pipe grooves preparing are one of the important variables and they must be controlled and maintained. Typical groove forms in case of butt welding and nozzles welding are shown in Figure 13.

5. PRIPREMA ŽLJEBA ZA ZAVARIVANJE

Priprema žljeba za zavarivanje mašinskom obradom preporučuje se u svim slučajevima u kada je to moguće. Samo kod ručnog zavarivanja, priprema može biti ručnim alatima. To je posebno korisno u slučajevima pred-montaže ili montaži sistema malih cevi / velikih cevi. Za automatsko orbitalno zavarivanje način tolerancije žljebova malih cevi / velikih cevi je jedna od važnih varijabli i oni moraju biti pod kontrolom i održavani. Tipični oblici žljeba u slučaju sučeonog zavarivanja i zavarivanja mlaznica prikazani su na slici 13.

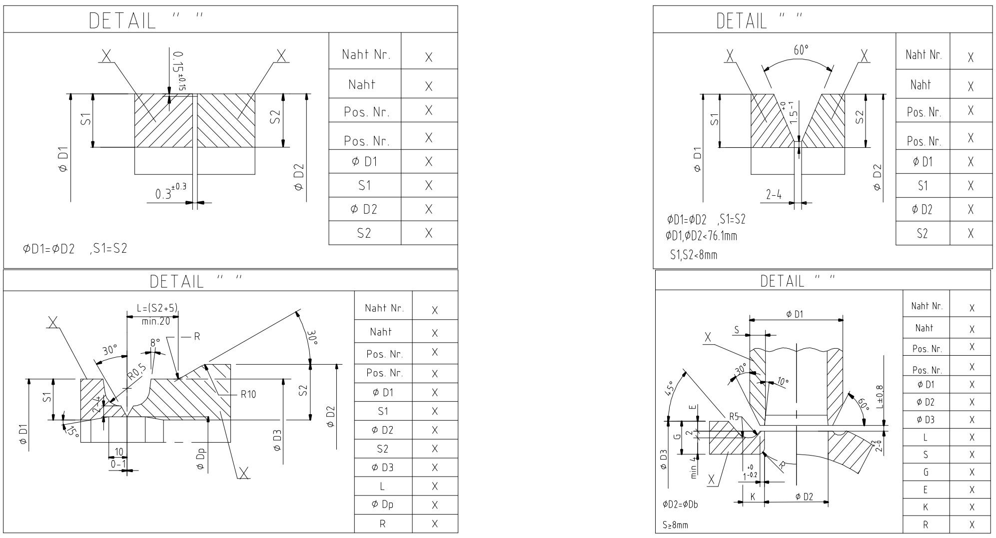


***Figure 13.** Groove forms in case of butt welding and nozzles welding*
***Slika 13. O**blici žljeba u slučaju sučeonog zavarivanja i zavarivanja mlaznica*

6. QUALITY ASSURANCE OF WELDING TUBE / PIPE SYSTEMS

Quality assurance, as well as in other processes, involves a sequence of related activities before, during and after welding. Workshop documentations for performance must contain all relevant information about any of the details of welding, applicable procedures, welding parameters, scope and methods of control including clearly defined acceptability criteria etc. Methods and controls scope of making tube / pipe systems are carried out according to norms, specifications or standards. This cods for QA of products depends on the type of product and the following norms are used for area of Europe mostly:

6. OBEZBEĐENJE KVALITETA PRI ZAVARIVANJU SISTEMA MALIH / VELIKIH CEVI

Obezbeđenje kvaliteta, kao i u drugim procesima, uključuje niz povezanih aktivnosti pre, za vreme i nakon zavarivanja. Dokumentacije radionice za izvođenje mora sadržavati sve relevantne informacije o svim detaljima zavarivanja, važećim procedurama, parametrima zavarivanja, obimu i metodama kontrole uključujući i jasno definisane kriterijime prihvatljivosti itd. Metode i obim kontrole izrade sistema malih cevi / velikih cevi se obavlja u skladu sa normama, specifikacijama ili standardima. Ovaj kod za QA proizvoda zavisi od vrste proizvoda i sledeće norme se uglavnom koriste za područje Evrope:

EN ISO 17637 (umjesto / instead EN 970 (VT metoda / method)
EN ISO 9712 (umjesto / instead EN 473 (VNDT osoblje / personnel)
EN ISO 5817 (Stupnjevi kvalitete zavara / Quality levels for welds)
EN ISO 6520-1 (Klasifikacija nepravilnosti / Classification of imperfections)
EN 12952-6 (Cjevovodni kotlovi / Water tube boilers)
EN 13480-5 (Metalni industrijski cjevovodi / Metallic industrial piping)
EN 13445-5 (Tlačne posude / Pressure vessels)
EN 1090-2 (Čelična konstrukcija / Steel structure

The space position and arrangement of welded joints are often the limiting factors in defining the method and scope of control. Figure 14.a) shows the case where access to welding and NDT is easy and without limits and b) where it is different and difficult.

Položaj i raspored zavarenih spojeva prostora često su ograničavajući faktori u definisanju načina i obima kontrole. Slika 14.a) prikazuje slučaj gde je lak i bez ograničenja pristup zavarivanju i IBR i b) gde je drugačije i teško.

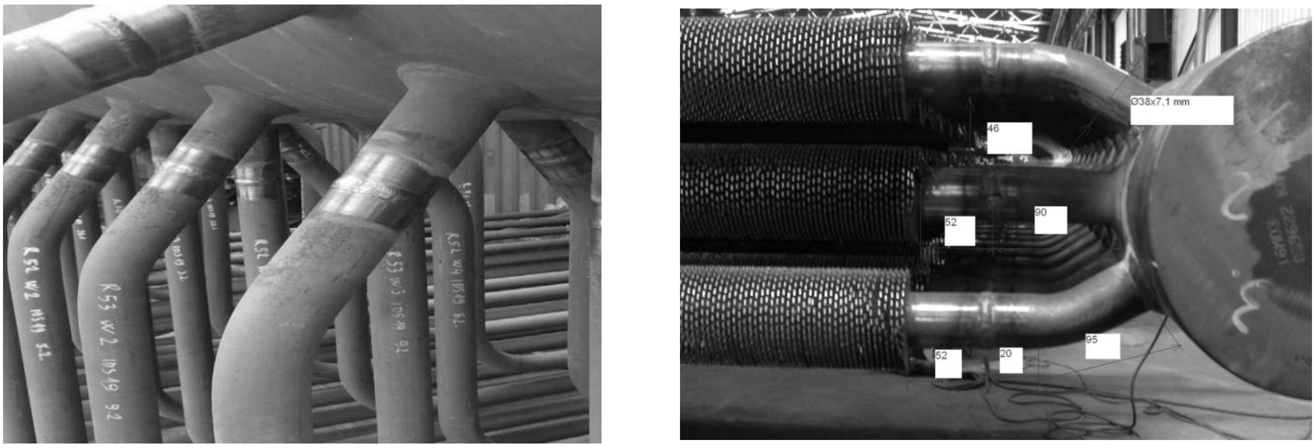


Figure 14. *a) no limits for welding and NDT and b) unfavorable location of welded joints*
Slika 14. *a) bez ograničenja za zavarivanje i IBR i b) nepovoljna lokacija zavarenih spojeva*

In this and in all other cases, the most important method of control is visual control.
Basically there are two different methods of visual control of welded joints:
a) direct visual control - inspection, applied to all surfaces, connections and parts which are visible to the eye. For this method various assisting tools can be used: comparative samples, magnify glass, tool for size measurement,for different lighting, etc., and

U ovom i u svim drugim slučajevima, najvažnija metoda kontrole je vizuelna kontrola.
U osnovi postoje dva različita načina vizuelne kontrole zavarenih spojeva:
a) direktna vizuelna kontrola - pregled, primenjuje se na sve površine, veze i delove koji su vidljivi golim okom. Za ovaj način mogu se koristiti različiti pomoćni alati: komparativni uzorci, uveličavajuća stakla, alati za merenje veličina, za različito osvetljenje, itd, i

b) indirect visual control - inspection, applicable to all cases that can't be controlled by a) method.

Direct visual inspection is well known as described.

For welded tube / pipe systems, indirect visual control is often the only way to determine the condition of welds witch are "invisible" (mostly roots of welds). Indirect visual inspection is carried out by using special control equipment as videoscope / endoscope with certain technical features appropriate for given tube/pipe systems.

One of the applicable video system - endoscope are shown in Figure 15. and has following technical characteristics:

- light guide / conductor diameter of 6.1 / 8 mm length of 2 / 4.5 / 6 mm with variable optics,
- manipulation using joystick,
- LCD display,
- microcomputer memory for storing pictures and movies
- light source for light guide,
- supplies for positioning,
- operating temperature level : - 20 ° C to + 40 ° C

b) indirektna vizuelna kontrola - pregled, primenjuje se u slučajevima koji se ne mogu kontrolisati metodom a).

Direktan vizuelni pregled je poznat kao što je već opisano. Za zavarene sisteme male cevi / velike cevi, indirektna vizuelna kontrola je često jedini način da se utvrdi stanje zavarenih spojeva koji su "nevidljivi" (uglavnom koreni zavara). Indirektni vizuelni pregled vrši se pomoću posebne opreme kao videoskop / endoskop s određenim tehničkim karakteristikama koje odgovaraju datim sistemima malih cevi / velikih cevi.

Jedan od primenljivih video sistema - endoskopa su prikazani na slici 15. i ima sledeće tehničke karakteristike:

- vodič svetla / provodnik prečnika od 6,1/8 mm dužine od 2/4,5 /6 mm sa varijabilnom optikom,
- manipulacija koristeći "joystick",
- LCD zaslon,
- mikroračunarska memorija za skladštenje slika i video zapisa
- izvor svetlosti za vodič svetla,
- zalihe za pozicioniranje,
- nivo radnih temperatura: - 20 ° C do + 40 ° C

Indirect visual examination
Compjuterized video system XL PRO–EVEREST VIT

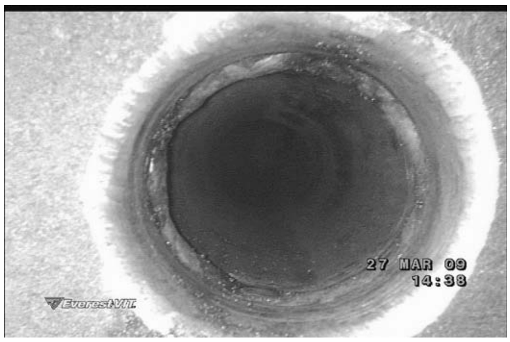


Figure 15. *Inspection of roots TIG welds: Operator in action, picture of endoscope and color image of good root welded joint*

Slika 15. *Kontrola korena TIG zavarenih spojeva; Operater u radu, slika endoskopa i kolor slika dobrog korena zavarenog spoja*

For this method of control it is extremely important education level of operator who performs the control / examination. Interpretation of types and

Za ovaj način kontrole je izuzetno važan nivo obrazovanja operatera koji obavlja kontrolu / ispitivanje. Tumačenje vrste i procene veličine estimation of sizes of the observed deviation are of exceptional importance for this method of control.

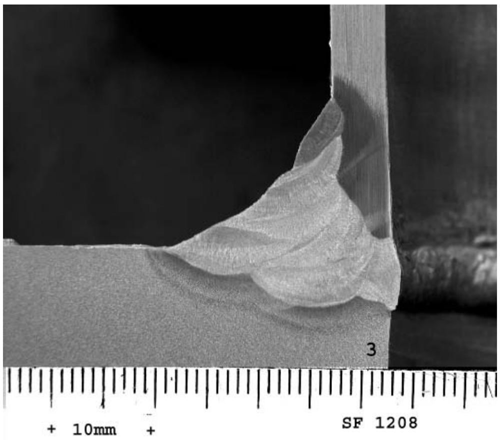
Real macro-sections of typical welded joints can be used for prescribing proper welding techniques, training of welders and education of operators for visual inspection.

Comparative control methods applied in the beginning of the production as well as NDT at the right time during the manufacturing process is very reliable way to avoid possible errors and delays in production.

posmatranog odstupanja su od izuzetnog značaja za ovu metodu kontrole.

Realni makro-preseci tipičnih zavarenih spojeva mogu se koristiti za propisivanje odgovarajuće tehnike zavarivanja, obuku zavarivača i obrazovanje operatora za vizuelnu kontrolu.

Komparativne metode kontrole se primenjuju u početku proizvodnje, kao i IBR u pravo vreme u procesu proizvodnje su vrlo pouzdan način da se izbegnu moguće greške i kašnjenja u proizvodnji.



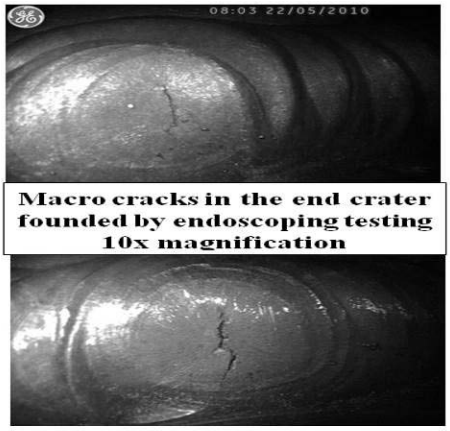
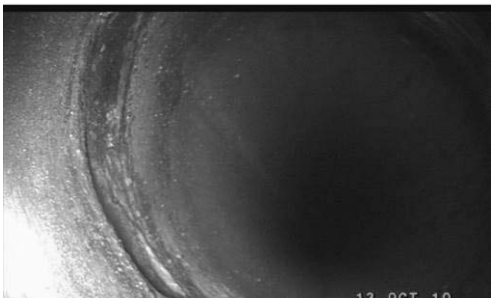


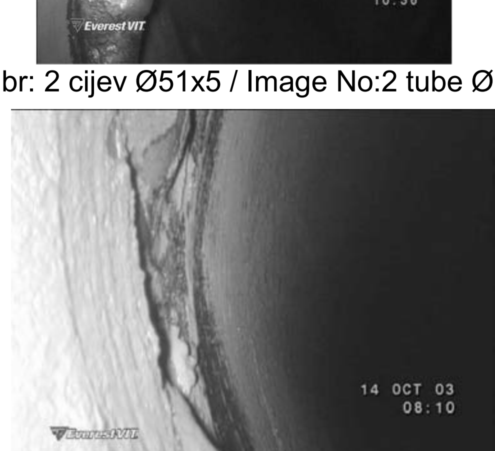
Figure 16. *Macro section of one of the typical welded joints nozzle to header and typical end crater defects excepted after welding martensitic steel*

Slika 16. *Makropresek jednog tipičnog zavarenog spoja mlaznice (nastavka) sa nosačem i tipične greške u krateru koje se javljaju posle zavarivanja martenzitnog čelika*



Slika br: 1 cijev Ø51x5 / Image No:1 tube Ø51x5

Slika br: 2 cijev Ø51x5 / Image No:2 tube Ø51x5



Slika br: 4 cijev Ø51x5 / Image No:4 tube Ø51x5

Figure 17*. Nozzle to header welded joint: typical technology - geometric defect from root side*

Slika 17. *Zavareni spoj mlaznice i nosača; tipične tehnološko-geometrijske greške sa korene strane*

6. CONCLUSION

Tendency to produce boiler plants using more and more demanding types of basic materials make welding techniques and all other applicable processes to require adequate responses to these intentions. Therefore, some of the basic processes in the preparation of tube / pipe systems as welding, heat treatment and inspection are very specific. This activities must be the object of analysis from the beginning of production planning with regards to the applicability and ability to satisfy the requirements of project.

Analyses relate primarily to the qualification of processes and personnel, existing appropriate equipment, the possibility of evidence of complete controls over the process and they ensure the traceability of all related operations.

TIG welding process, especially mechanized is dominant in the preparation of tube / pipe systems.

NDT and indirect visual controls including training of operators for this method are integral part of a complete quality assurance in production.

6. ZAKLJUČAK

Tendencija proizvodnje kotlovskih postrojenja koristi više i zahtevnije vrste osnovnih materijala koji traže od tehnike zavarivanja i svih drugih primenjenih procesa adekvatne odgovore. Stoga, neki od osnovnih procesa u pripremi sistema malih cevi / velikih cevi kao zavarivanje, termička obrada i inspekcija su vrlo specifični. Ove aktivnosti moraju biti predmet analize od početka planiranja proizvodnje u odnosu na primenljivost i sposobnost zadovoljenja zahteva projekta.

Analize se odnose prvenstveno na kvalifikacije procesa i osoblja, postojeće odgovarajuće opreme, mogućnost dokazivanja potpune kontrole nad procesom i osiguranja praćenja svih povezanih operacija.

TIG postupak zavarivanja, posebno mehanizovani je dominantan u pripremi sistema malih cevi / velikih cevi.

IBR i indirektne vizuelne kontrole uključujući obuku operatera za ovu metodu su sastavni deo kompletnog obezbeđenja kvaliteta u proizvodnji.

7. LITERATURE

7. LITERATURA

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