Welding process for oil pan block of ship engine

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1.Prepare a literature review of the welding process and fundamentals of propulsion engines for ships

2.Establish a welding procedure for oil pan block and create a welding map

3.Evaluate the quality of the welds

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KOU, Sindo. Welding metallurgy [online]. 2nd ed. Hoboken, N.J: Wiley-Interscience, c2003 [cit. 2013-11-19].
BENATAR, Avraham. Welding. Munich: Hanser Publishers, c2001, 128 s. ISBN 1-56990-333-6.
NĚMEC, Milan, Jan SUCHÁNEK a Jan ŠANOVEC. Základy technologie I. 2., přeprac. vyd. V Praze: České vysoké učení technické, 2011, 159 s. ISBN 978-80-01-04867-2.

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ABSTRAKT

Tato bakalářská práce se zabývá svařováním olejové vany pro lodní motor. Teoretická část je rozdělena na dvě hlavní části. V první části jsou popsány lodní motory a jejich rozdělení a druhá část je zaměřena na svařování, metody svařování, typy svarů a nedestruktivní zkoušení.

Praktická část je přímo zaměřena na svařování olejové vany pro lodní motor B35:40V16AG.Pro samotný proces svařování byla vytvořena svařovací mapa a pro svařovací personál byl navrhnut svařovací plán.Na závěr praktické části byly navrženy protokoly pro nedestruktivní zkoušení.

Klíčová slova: lodní motor, metody svařování, MAG svařování

ABSTRACT

This bachelor's thesis is engaged with the welding of oil sumps for marine engines. The theoretical part is divided into two main parts. The first part of this dissertation describes the marine engines and their sorting, the second part of this dissertation is focused on the welding, welding methods, types of welds and non-destructive testing.

The practical part is directly aimed at the welding of oil sumps for marine engines B35:40V16AG. The welding map was created for own it's welding process and there was proposed a welding plan for the welding personal. In the end of practical part there were suggested the protocols for non-destructive testing

Keywords: Marine engine, welding methods, MAG welding

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I hereby declare that the print version of my Bachelor's thesis and the electronic version of my thesis deposited in the IS/STAG system are identical.

CONTENTS

INTRODUCTION

The welding is an irreplaceable technology in many industrial branches and can not be replaced by another method of undemountable connections in many cases. It is used in the machinery industry, in electrical engineering , engineering constructions, and many other branches.

The welding is defined as the undemountable connection of two metal parts using heat and melting temperatures of a given material or pressure deformation of parts. The welding can proceed with or without the filler material.

The bachelor's thesis deals with different methods of welding. We have chosen the method of MAG (metal active gas), for the welding of oil sumps to a ship's engine block. This method belong to most widespread welding methods during the production of strucural steel constructions, machinery equipment, pressure tanks and piping.

The practical part of the bachelor's dissertation is aimed directly at the welding of oil sumps to the ship engine blocks. There were documents created especially for the mentioned ship tank. These documents will serve for welders during the welding and for the welding personal (welding technologist, and inspector, and workshop inspector) for the following checking.

Among these documents belong WPS (welding procedure specification), welding map, reports from NDT, requirements for welding, principles of quality welds.

I. THEORY

1 SHIP ENGINES ROLLS-ROYCE

These engines operate in commercial and military vessels, cruise ships and fishing boats and in support vessels for the offshore oil industry. Rolls-Royce engines also equip offshore installations, power stations and pipelines for industrial and land-based municipal applications.

For the marine market Rolls-Royce can offer the Bergen C25:33L, B32:40L, and the B32:40V engines. These models come as 6, 8, 9, 12, and 16 cylinder engines, with power outputs from 1,9MW up to 8MW operating on Marine Diesel Oil or Heavy Fuel Oil. In addition we offer gas engines for marine mechanical or gas-electric drive.

Engine platforms are the Bergen C26:33L, B35:40L and B35:40V, with power outputs from 1,4MW to 9,4MW.

General conditions for marine engines

Marine liquid fuel engine - Ratings are according to ISO 3046-1, at maximum 45°C ambient air temperature and maximum 32°C sea water temperature. Specific fuel oil consumption is based on MDO with a net calorific value of 42,7 MJ/kg and no engine driven pumps. For each engine driven pump, there is a need to add 0,5%.

Emissions - The marine diesel engines comply with the requirements of the IMO Tier II without any external cleaning system. IMO Tier III is met by the use of a Selective Catalytic Reactor (SCR) system. The marine gas engines comply with IMO Tier III with no need for a SCR system.

Heavy fuel oil operation - The engines are designed for operation on heavy fuel oil with viscosity up to 700 cSt at 50°C ISO 8217 RMK77. Ratings will be specified subject to type of application.

Marine gas engine - The marine gas engines give the following reductions in emissions compared with diesels IMO Tier II: 92% NOx, net 22% greenhouse gases and close to zero SOx and particulate matter. Marine gas engine ratings are according to ISO 3046-1, at maximum 45°C ambient air temperature and maximum 32°C sea water temperature. Specific fuel gas consumption excluding engine driven pumps is based on reference natural gas with Methane number above 70 and net calorific value of 36 MJ/nm3.

If there are engine driven pumps, add 0,5% for each pump. Gas feed temperature is 20-40°C. Minimum gas feed pressure to Gas Regulating Unit to be 4,5 barg.[6]

Engine range

1. Diesel engines & generator sets
2. Gas engines & generator sets
3. Marine Gas turbines

Diesel engines & generator sets

Medium-speed Bergen diesel engine portfolio comprises established and newly developed models in the 1.440 to 8.000kW power range.

Benefits – Reliability, fuel efficiency, emissions and ease of maintenance are key design goals.[6]

Diesel engine range
1. Bergen B32:40 diesel engine
2. Bergen B32:40 diesel generator set
3. Bergen C25:33 diesel engine
4. Bergen C25:33 diesel generator set

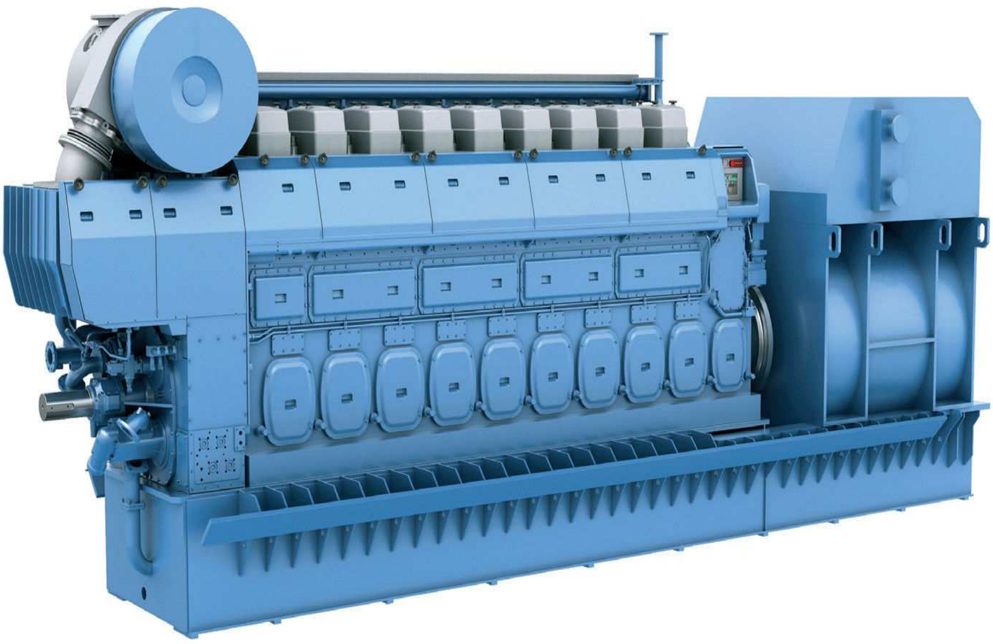


Fig. 1 Bergen diesel generator set

Gas engines & generator sets

Bergen gas engines are particularly robust, with a high degree of reliability and long intervals between overhaul. The lean-burn principle delivers high efficiency coupled with reduced exhaust emissions and low specific energy consumption. Today the compact and robust Bergen gas engine range is available for powers from 1,460 to 7,000kW.[6]

Gas engine range

1. Bergen C26:33 gas engine
2. Bergen C26:33 gas generator set
3. Bergen B35:40 gas engine
4. Bergen B35:40 gas generator set

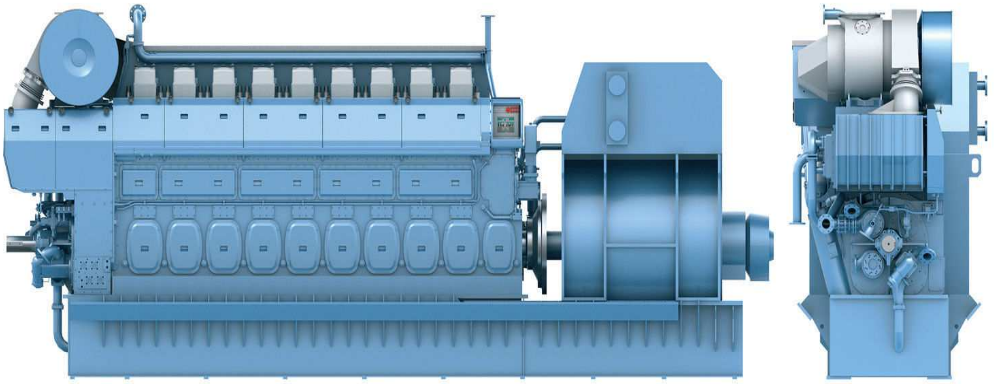


Fig. 2 Bergen gas generator set

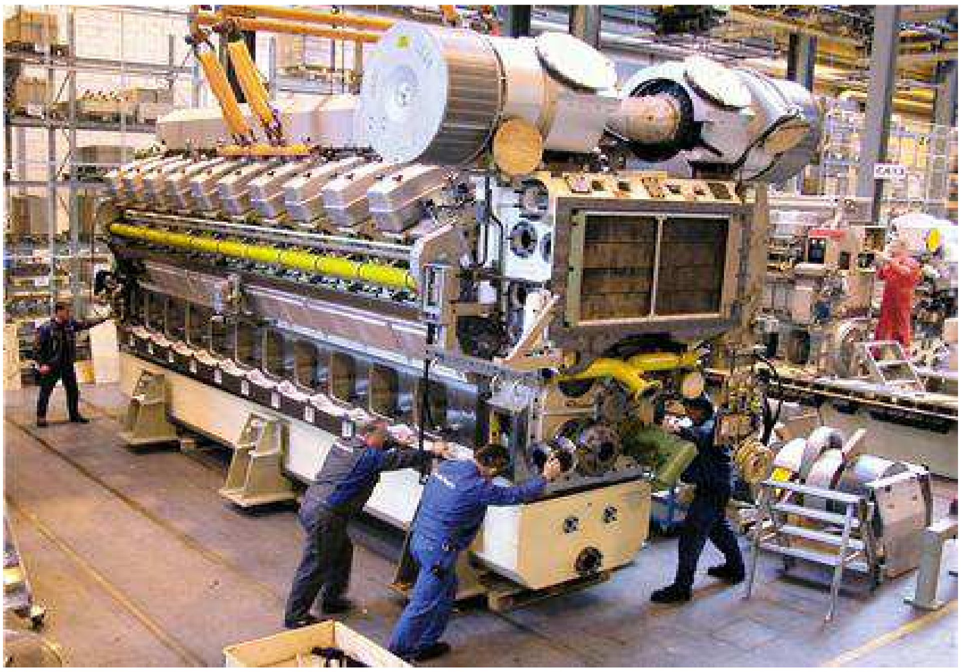


Fig. 3 Bergen B35:40 gas engine

Marine gas turbines

The gas turbine range delivers powers from 3.9 to 40MW.The MT30 has now been selected to power the Royal Navy's new aircraft carriers.

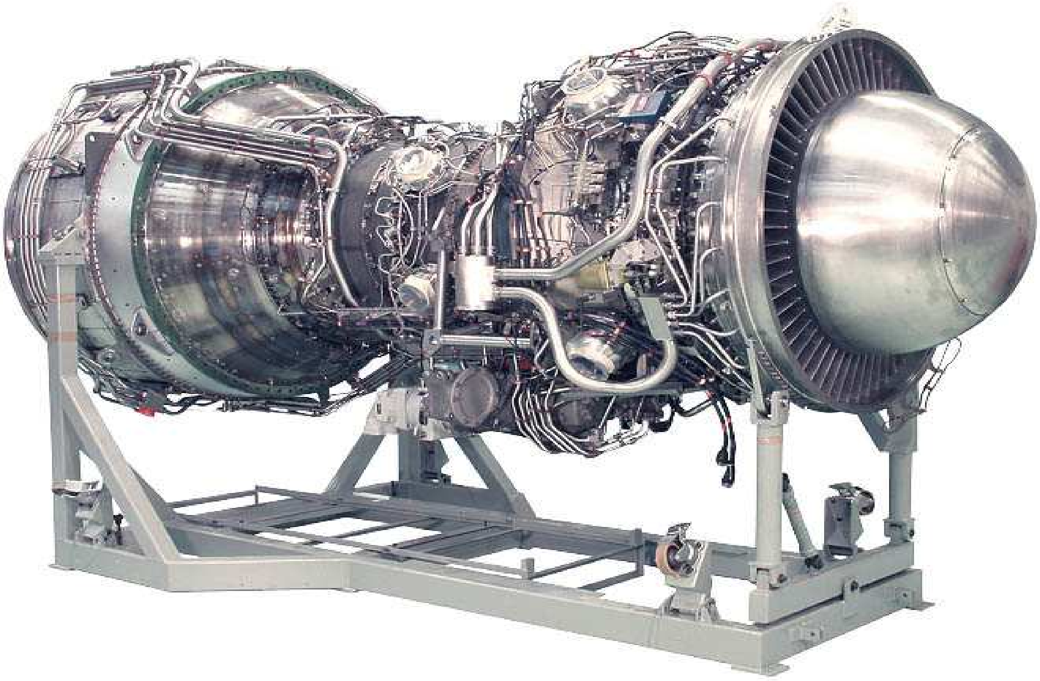


Fig. 4 Marine gas turbine – MT heritage model

Fig. 5 Marine gas turbine – MT 30

1.1 Gas engine B35:40V 16AG

Rolls-Royce was one of the first company which started research over gas engine for maritime. Their new power unit, engine B35 is one of the most modern type in world.

Engine B35 is next generation in Bergen B-series power units. Previous one was diesel engine B32 which achieved worldwide success.

The new B-gas engine is a medium-speed, spark-ignited lean-burn unit designed to produce up to 9,4MW of electrical power giving customers more energy and greater cost-effectiveness than anything else of its type on the market. It will be available in 12, 16 and 20 cylinder versions.

The design has been driven by stringent requirements for lower exhaust emissions, highest possible electrical and heat recovery efficiency coupled with extreme reliability.

The B-gas sets new standards both in power and efficiency in the 720-750rpm class.

Decisive features are the enlarged cylinder volume and optimised combustion technology, which ensures class leading performance.[6]

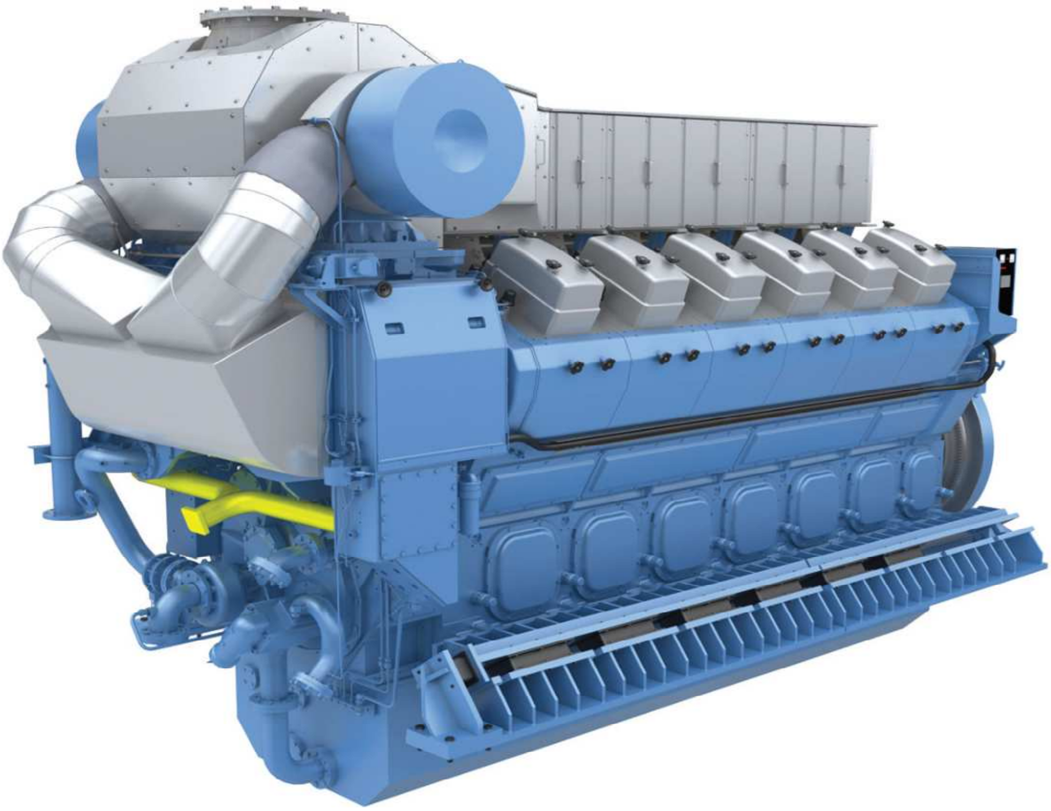


Fig. 6 Gas engine B35:40V 16AG

In model B35 Rolls-Royce company used a lot of components from its “bigger brother” for example: main hull and air turbine. Main reason for implementation of Bergen B-gas engines was upcoming update to Marpol convention, Tier III that is about to bring in new limit of NOx and COx emission in exhaust. Through the application of gas, Bergen B35 engine emission is limited exactly to Tier III norms without necessity of using filters. System of engine B35 working is based on air, which is pressed into air receiver by first stepturbo-charger. Later it go to prechamber, where air is mixed with small portion of gas. In cylinder, when piston goes up in compression stroke, dense portion of gas is pressed. This portion allows to make explosion in cylinder. Later exhaust goes through exhaust system into turbo-charger.

What is so impressive about this engine?At first, antechamber with the two-steps combustion system reducing notably consumption. Another advantage is possibility of using a lean fuel mixture. Secondly, turbochargers with variable turbine geometry (VTG) delivering precise airflow and the solid-state ignition with individual cylinder timing and diagnostics that ensures optimum efficiency. This link is extremely effective in process of air flow and overall engine working process. Using this two inventions makes power unit more ecological and cheaper.

Marine gas engine ratings are according to ISO 3046-1, at maximum 45°C ambient air temperature and maximum 32°C sea water temperature. Specific fuel gas consumption excluding engine driven pumps is based on reference natural gas with Methane number above 70 and net calorific value of 36 MJ/nm. If there are engine driven pumps, add 0,5% for each pump. Gas feed temperature is 20-40°C. Minimum gas feed pressure to Gas Regulating Unit to be 4,5 barg.[6]

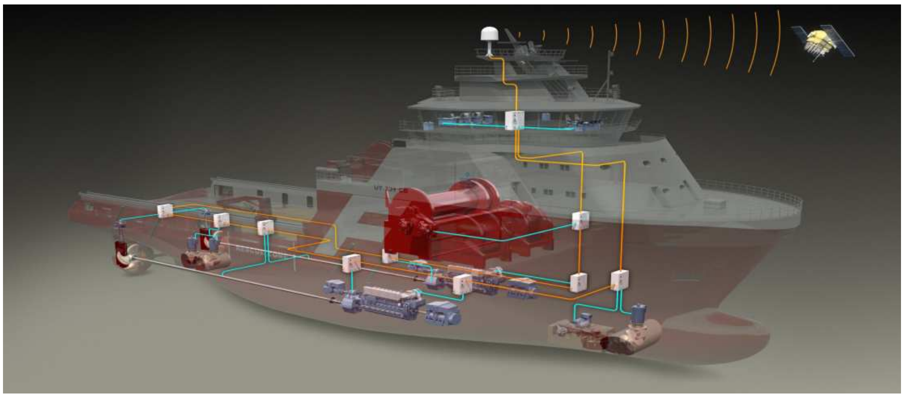


Fig. 7 Model of ship with engine

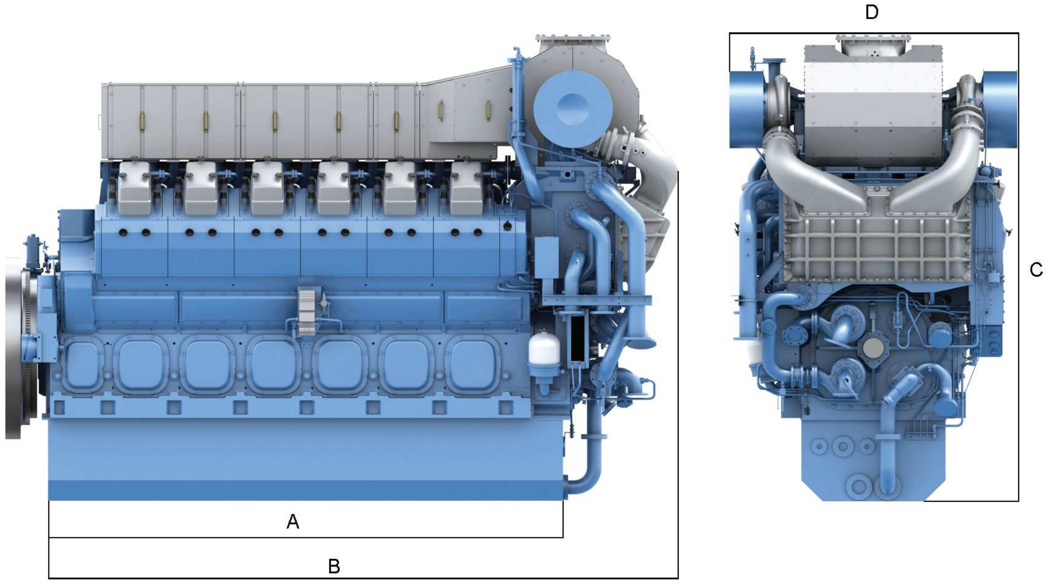


Fig. 8 Principal dimensions of gas engine B35 40V 16AG

Tab. 1 Principal dimensions of gas engine B35:40V 16AG

Engine type	**A**	**B**	**C**	**D**	**Weight dry engine**
B35:40V16PG	6200	7870	4150	2920	62900

Tab. 2 Technical dates for the Rolls-Royce B-engine at 750rpm

Engine type		**B35:40V16PG**
Number of cylinder		16
Engine speed	r/min	750
Mean piston speed	m/s	10
Maximum continuous rating	(MCR) kW	7700
Mean effective pressure	(BMEP) bar	20
Specific energy consumption	kj / kWh	7270
Specific lubricating oil consumption	g/kWh	0.4
Cooling water temp. engine outlet	°C	90

Benefits

- compact and powerful
- exceptionally low emissions of Nox, CO2, SOx and particles
- High efficiency, above 50,3%
- Low fuel and lub oil consumption
- Approved by DNV for marine applications
- Optimum response at all engine load points (VTG – Variable Turbo Geometry)
- Stable frequency, no oil contamination
- Super silent resilient mounting, designed for single bearing alternators

Main parts of Gas engine B35:40V 16AG

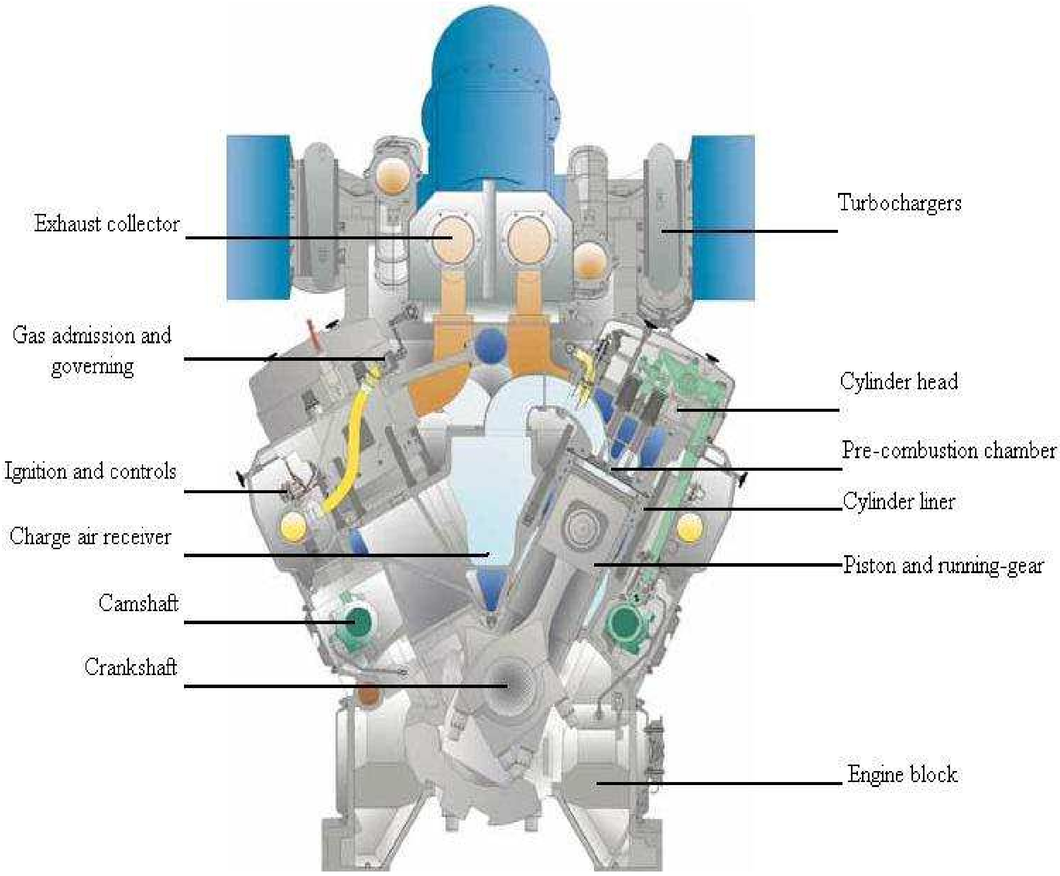


Fig. 9 Main parts of gas engine B35:40V 16AG

Exhaust collector - Single-pipe MPC type, optimised for high efficiency and reliable operation

Gas admission and governing - The combination of a separate admission valve with an adjustable flow control valve ensures quick governing response and easy cylinder balancing.

Charge air receiver - This generous charge air receiver ensures low pressure losses, dampens-out pressure fluctuations and provides good and equal air supply to each cylinder.

Ignition and controls - The B-gas engines ignition system exploits solid-state technology and provides individual timing and diagnosis for each cylinder, plus adjustable energy level. The ignition system works alongside a knock-detection system that monitors and adjusts each cylinder individually.

Camshaft - This has a simple, reliable design with individual cams shrunk on to a precision ground and segmented shift. Cams can be changed individually.

Crankshaft - This is a single forging of specially alloyed steel. Identical to the B32:40 crankshaft, it complies with all marine classification rules. Its timing-gear drive is at the flywheel end.

Engine block - This advanced mono-block structure is high precision case in nodular iron for maximum strength and easy of repair. It contains charge air, cooling water and lube oil and drain channels.

Turbochargers - The B-gas engine has two turbochargers, mounted back-to-back with one exhaust outlet. They have variable turbine geometry for ease and precision of air-flow control. This provides a simple and very efficient system that adjusts easily to varying operating or ambient conditions.

Cylinder head - Developed from the very successful B32:40 engine design, this features specially modified new ports, gas admission valves, special firing pressure indicators, a modified cooling bore layout and different flame deck machining.

Pre-combustion chamber - This small pre-combustion chamber of special heat-resistant steel is located centrally in the cylinder and optimised to ensure even and rapid distribution of ignition energy to the entire combustion space.

Cylinder liner - This is a development of the latest engine design using optimised materials, wall thickness and cooling-bore layout for gas operation.

<u>Piston and running-gear</u> **-** This well-proven steel/aluminium composite design features a special gas engine combustion bowl that ensures good cooling. Piston rings and cuff ring are all developed specifically for gas operation. The connecting rod is identical to the successful B32:40 design.[6]

Flow diagram of gas engine

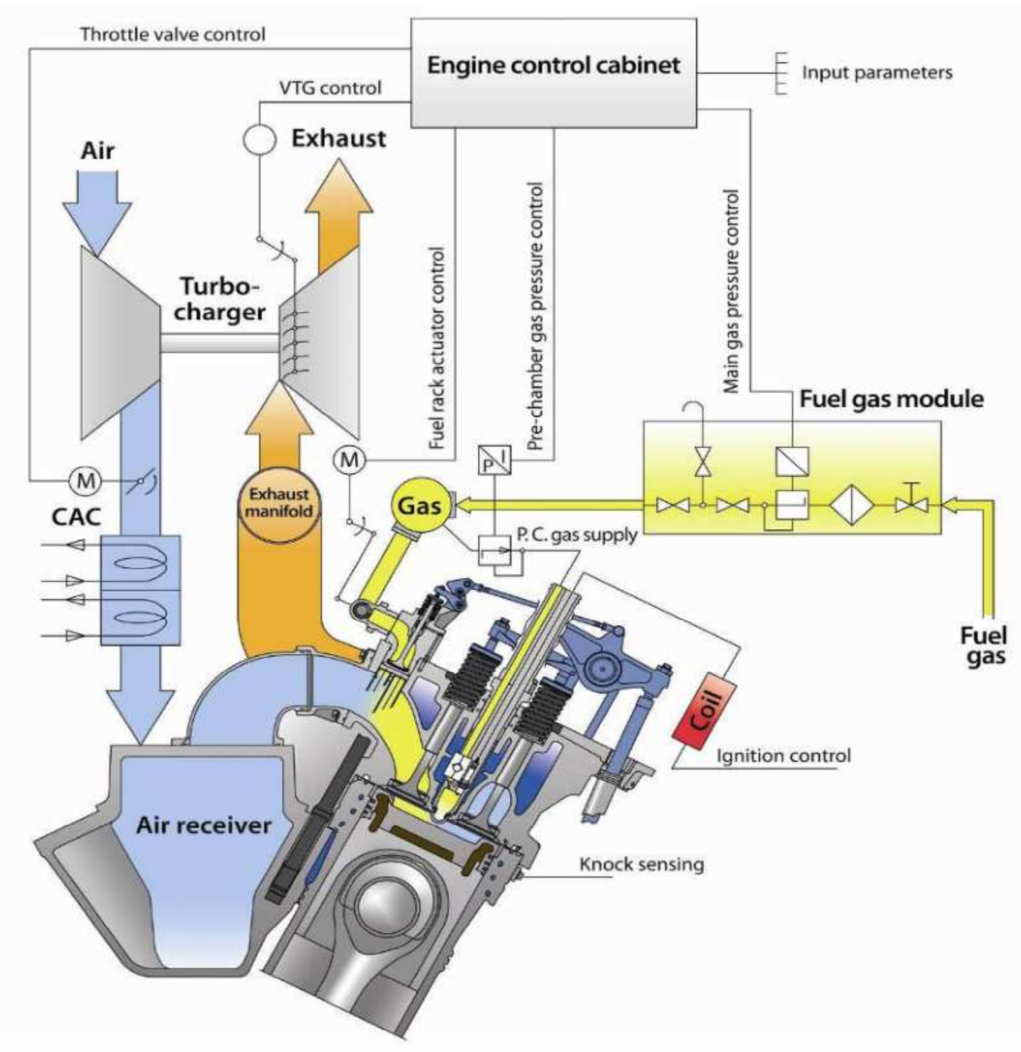


Fig. 10 Flow diagram of gas engine B35 40V 16AG

Fig. 11 History engine exhaust emission

Lean-burn technology

B gas engine use lean-burn technology with combination with Variable Turbine Geometry (VTG). By developing a suitable strong ignition source and an optimised pre-chamber, the gas-air mixture in the cylinder can affectively be “leaned-out “to ensure much improved engine performance. These improvements include higher efficiency, lower emissions (particularly of nitrous oxides) and significantly increased specific power.[6]

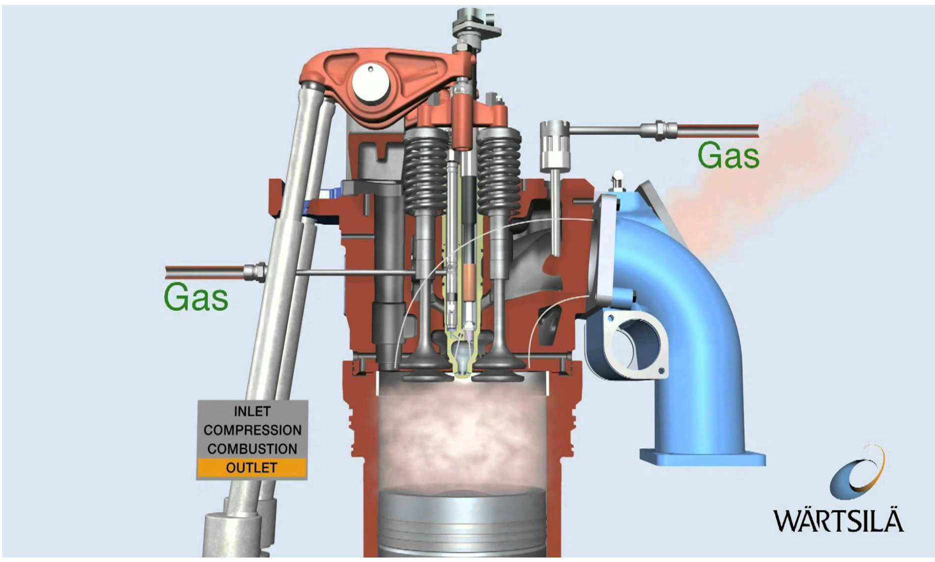


Fig. 12 Lean-burn technology

2 WELDING

The welding belongs to un-demountable connections, whereas the connection of the parts follows as a result of supply of certain quantity of energy to the connection place of parts. The supplied energy is either in form of heat (welding in the liquid status) or in form of kinetic energy (welding in rigid status), eventually their combination.

The major part of the welded joints is formed by metallurgical processes, when there follows the local melting of basic and filler material.

Two basic features but distinguish considerably the welding from common metallurgical processes. This is especially the fact that both, the welded surfaces as well as the filler material subject to the melting together and further more this is a local matter that causes heat non-homogeneity in the welded part.

With the fusion welding it concerns a micro-metallurgical process, during which a small quantity of metal is fused. The condition for success is a short-term and concentrated supply of heat energy so that a heat spread due to the heat conductivity of metals would be avoided if at all possible.

The result of this process is then the occurrence of local structural changes and furthermore an occurrence of internal stresses and then eventually deformation.[5]

2.1 Methods of welding

We divide the welding according to the way of creation of connection and further according to the mechanization grade.

according to method connection

– welding in liquid status

– welding in rigid status

– other methods of welding

according to kind of mechanization

- Manual welding (MA)
- Semiautomatic welding (SA)
- Mechanized welding (ME)
- Automatic welding (AU)
- Robotic welding (RO)
-

Manual welding (MA) – welding by the welding torch, gun or electrode holder.

Fig. 13 Demonstration of manual welding

Semiautomatic welding (SA) - Manual welding with equipment which automatically control one and more of the welding conditions.

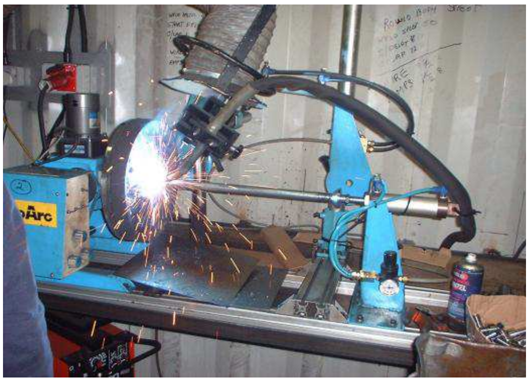


Fig. 14 Demonstration of semiautomatic welding

Mechanized welding (ME) - Requires manual adjustment of the equipment controls in response to visual observation, with welding torch, gun or electrode holder by a mechanical device.

Fig. 15 Demonstration of mechanized welding

Automatic welding (AU) - Requires only occasional or no observation of the welding and no manual adjustment of the equipment controls.

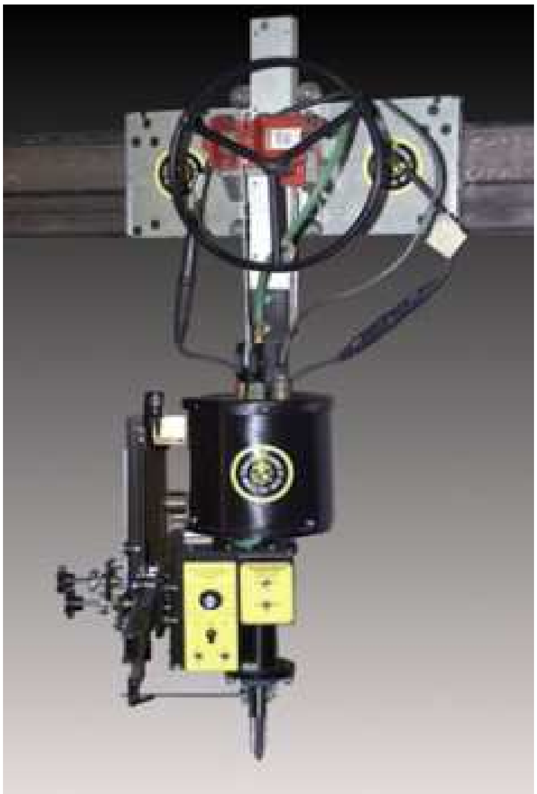


Fig. 16 Demonstration of automatic welding

Robotic welding (RO) - Welding that is performed and controlled by robotic equipment[3]

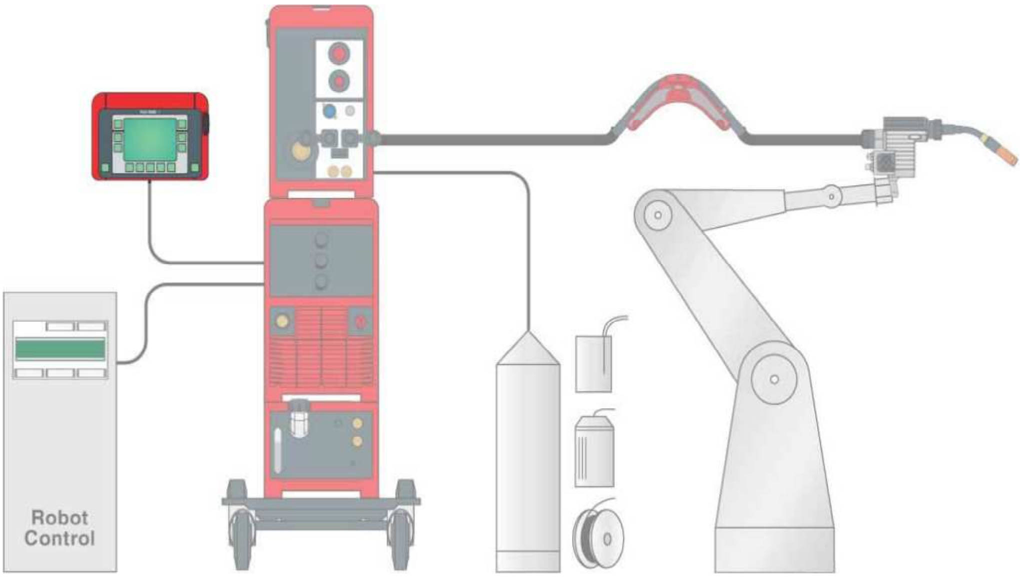


Fig. 17 Demonstration of robotic welding

2.1.1 Main methods of welding

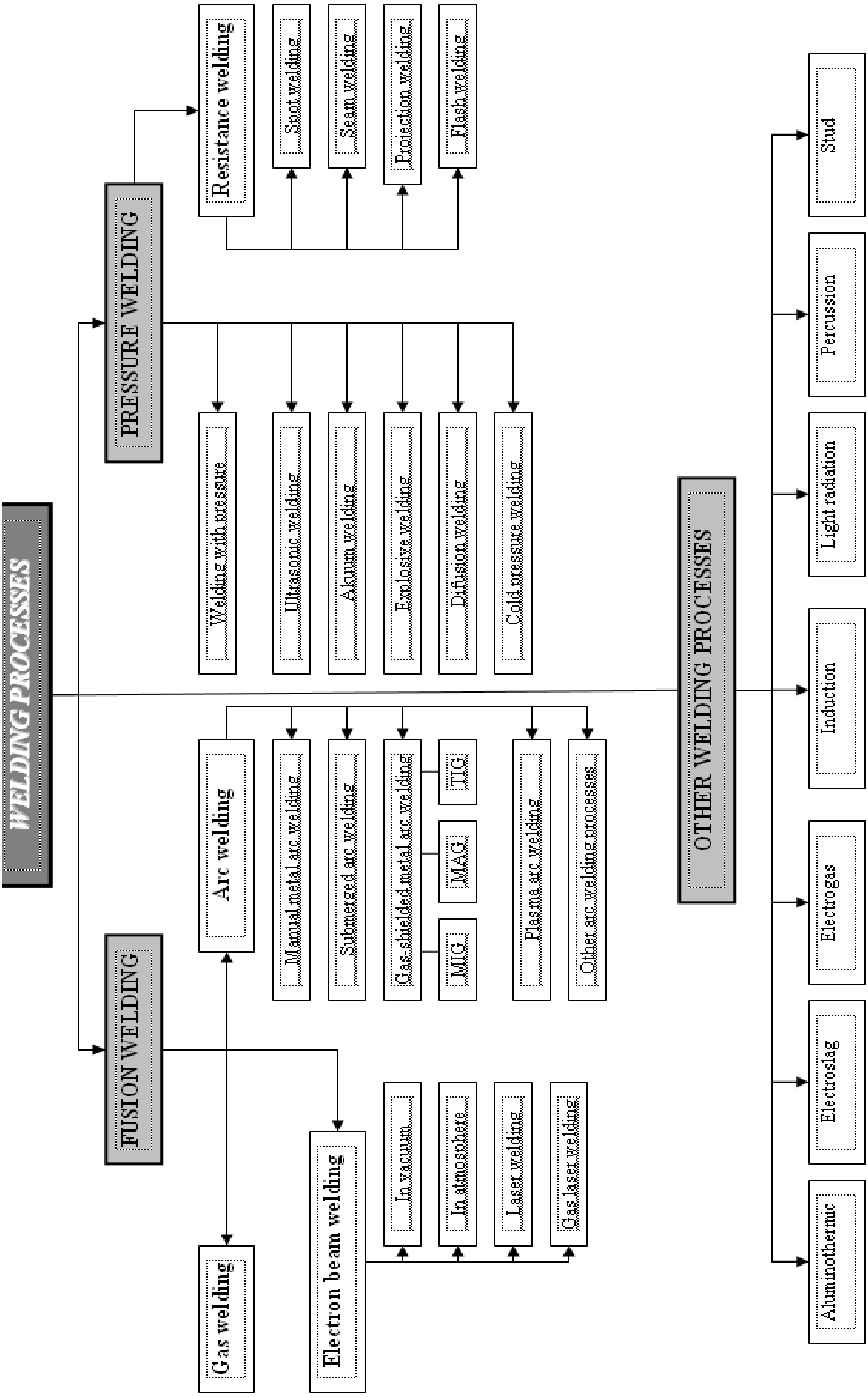


Fig. 18 Division of welding process [3]

Arc welding

With the arc welding, an electric arc burning between the electrode and welded material is used like a heat source. It follows the fusion of electrode metal and fusion of basic material surface.

The fused melted electrode metal passes through the arc column into the molten bath and there will arise a welded joint by connection with fused basic materials.

The arc welding has got a number of modifications (coated electrode welding, submerged-arc welding, shielded metal-arc welding) and it is most widely used technology for connections made by welding. [1]

Tab. 3 Main methods arc welding

Method No.	**Title of method welding**
1	Arc welding
111	Manual metal arc welding **– MMA welding**
12	Submerged arc welding
121	Submerged arc welding with one wire electrode
13	Gas-shielded metal arc welding
131	Metal inert gas welding **– MIG welding**
135	Metal akuum gas welding **– MAG welding**
141	Tungsten inert gas welding **– TIG welding**
15	Plasma arc welding
18	Other arc welding processes

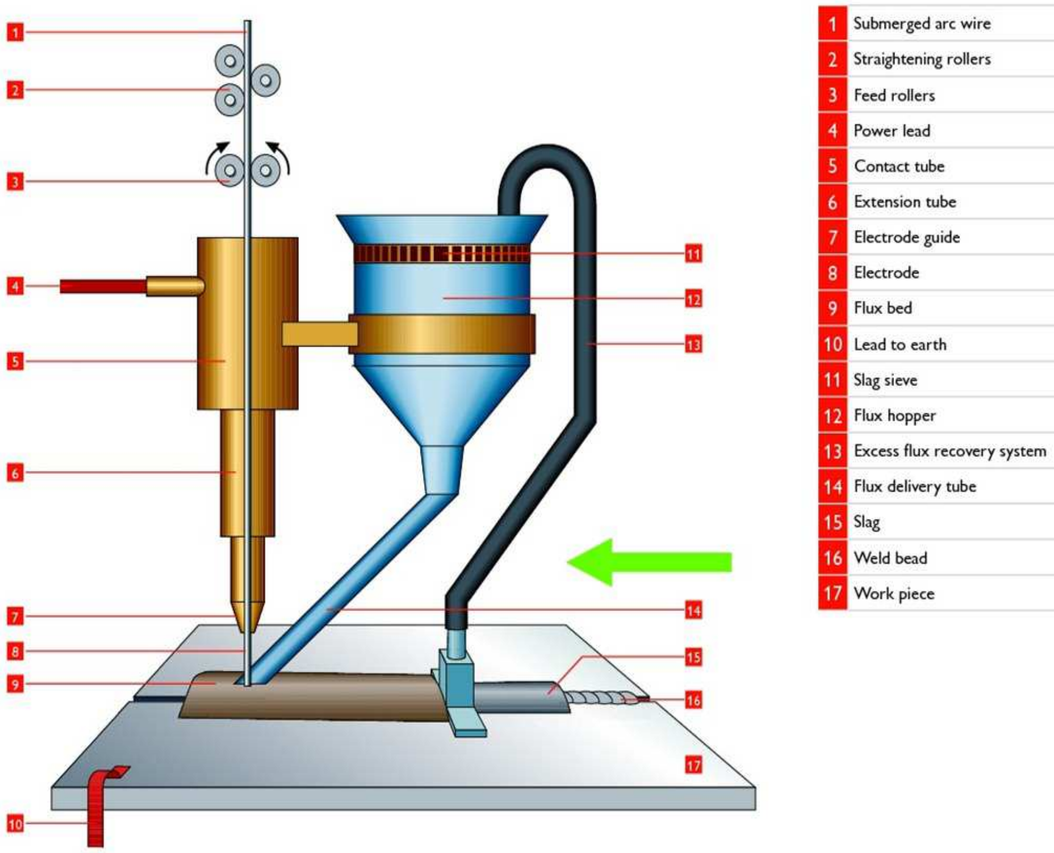


Fig. 19 Submerged arc welding with one wire electrode (method 121)

Fig. 20 Demonstration from welding submerged arc welding

Tab. 4 Marking arc welding EURO / USA

Method	Method acc. to EN ISO 4063	European marking	American marking ASME
Manual metal arc welding	111	MMA	SMAW
Submerged arc welding	12	SAW	SAW
Metal inert gas welding	131	MIG	GMAW
Metal akuum gas welding	135	MAG	GMAW
Tungten inert gas welding	141	TIG	GTAW

Resistance welding

The connection arises during the passage of electric current through pressed welded parts and it uses a known effect that heat arises during the passage of electric current through the conductor.

Due to the electrical resistance in place of jointing, the material will fuse and a metallurgical connection will be formed.[1]

Tab. 5 Main methods resistance welding

Method No.	**Title of method welding**
2	Resistance welding
21	Spot welding
22	Seam welding
23	Projection welding
24	Flash welding

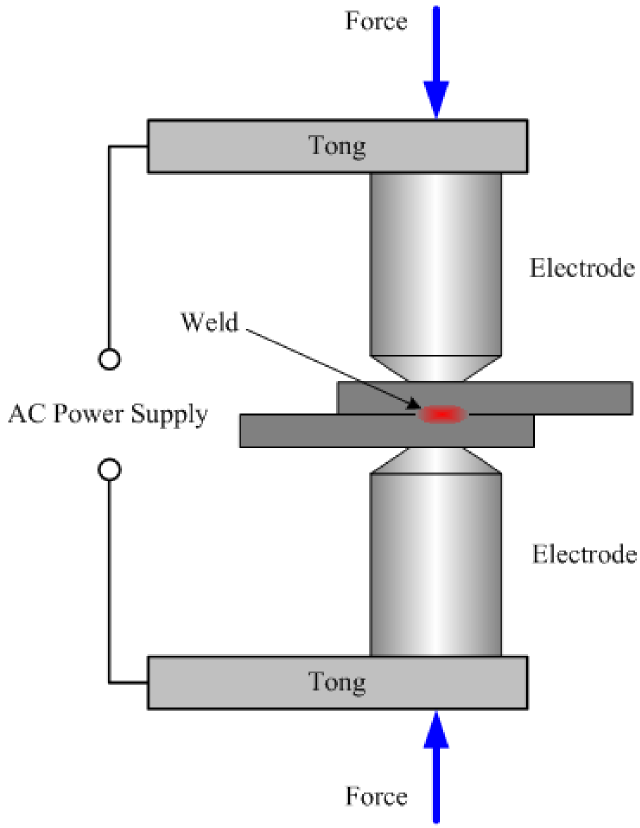


Fig. 21 Diagram of resistance spot welding (method 21)

Gas welding

This is a process of fusion welding of materials using the heat energy incurred by the combustion of a mixture of oxidizing and combustible gas in a special burner. Oxygen is used as an oxidizing gas, less commonly the air.

The acetylene is most often used like a combustible gas, further hydrogen, bottled gas, town coal-gas, methane and MAPP (methyl – acetylene – propane).[3]

Tab. 6 Main methods of gas welding

Method No.	Title of method welding
3	Gas welding
31	Oxy-fuel gas welding
311	Oxy-acetylene welding

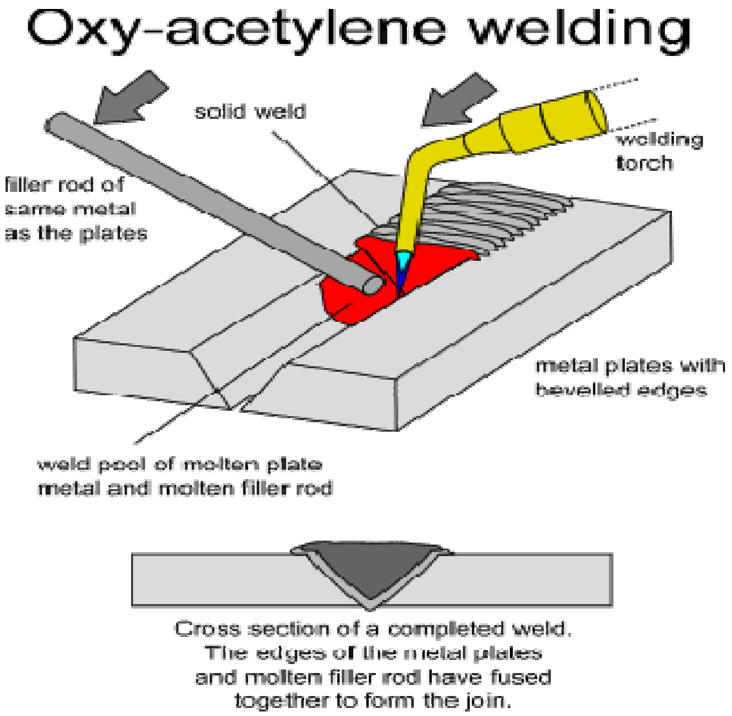


Fig. 22 Demonstration of oxy-acetylene welding

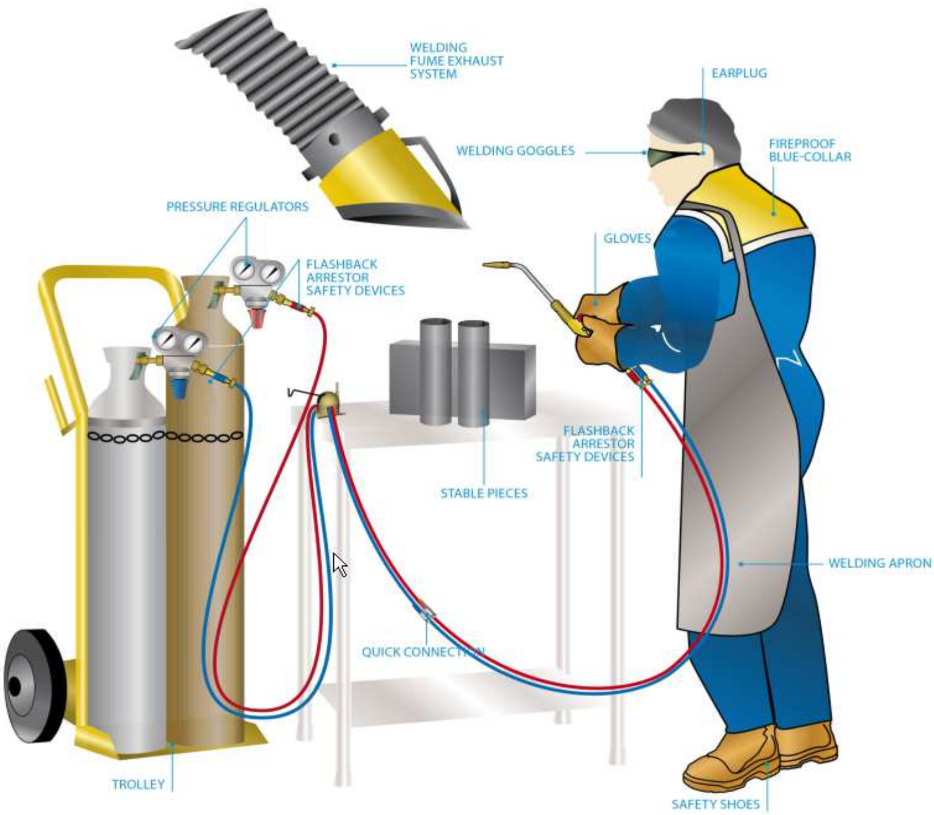


Fig. 23 Correct and safety oxy-gas welding station

Welding with pressure

Can be done in warm and cold conditions too.We can deduce an pressure force by different way (simple force application, explosion, ultrasound, mechanical power etc.).[1]

Tab. 7 Main methods of pressure welding

Method No.	Title of method welding
4	Welding with pressure
41	Ultrasonic welding
42	Friction welding
441	Explosive welding
45	Diffusion welding
48	Cold pressure welding

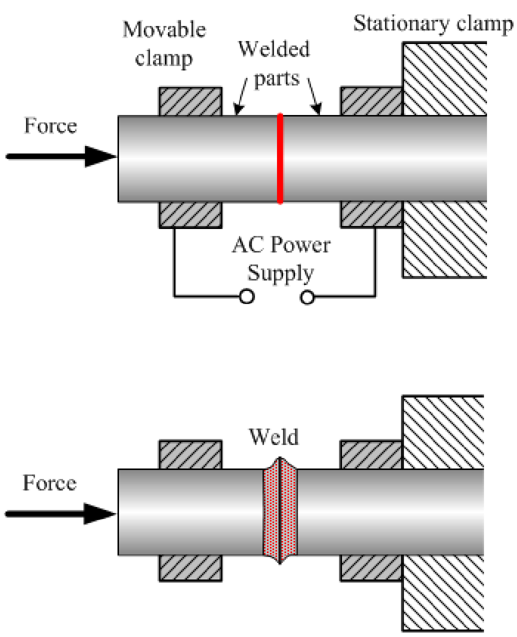


Fig. 24 Demonstration of pressure welding

Electron beam welding

The welding by a beam of rays is a process of fusion welding, during which the kinetic energy of quickly flying electrons and photons is changed to heat energy upon the drop on the surface of welded material.[1]

Tab. 8 Main methods of electron beam welding

Method No.	Title of method welding
51	Electron beam welding
511	Electron beam welding in vacuum
512	Electron beam welding in atmosphere
52	Laser welding
522	Gas laser welding

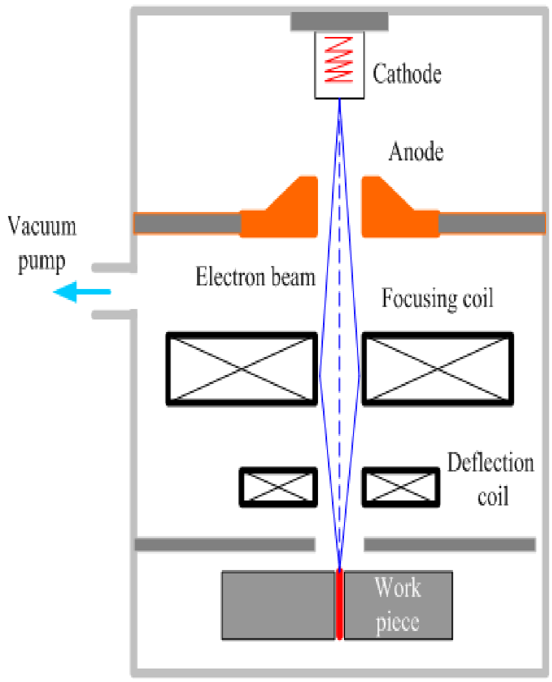


Fig. 25 Demonstration of electron beam welding

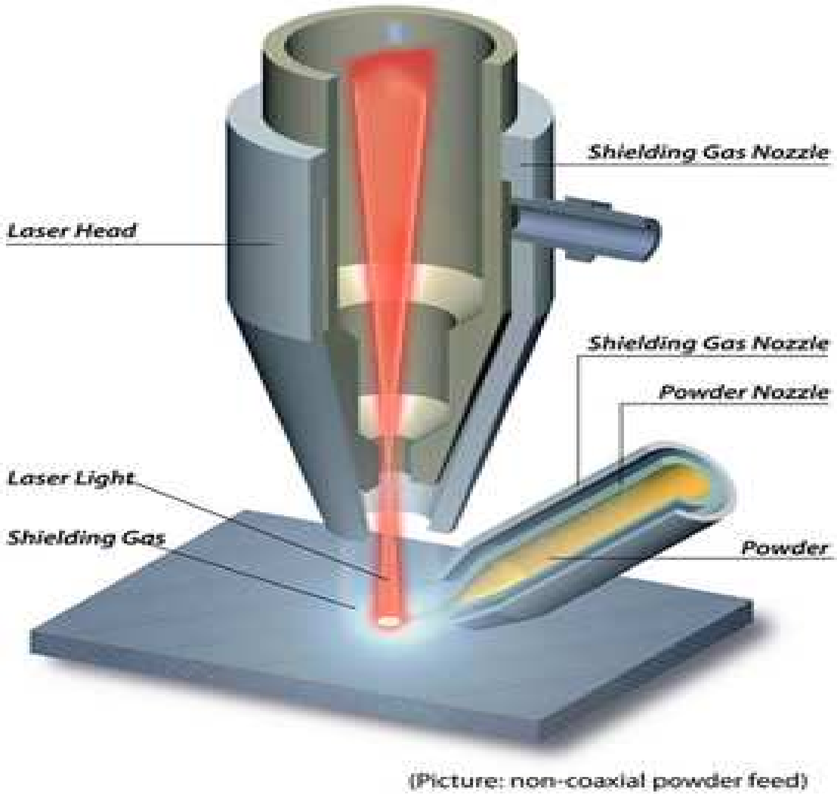


Fig. 26 Demonstration of laser welding

Other welding processes

Tab. 9 Main methods of other welding processes

Method No.	Title of method welding
7	Other welding processes
71	Aluminothermic welding
72	Electroslag welding
73	Electrogas welding
74	Induction welding
75	Light radiation welding
77	Percussion welding
78	Stud welding

2.1.2 Manual metal arc welding – MMA (method 111)

As a versatile and simple process, MMA welding has become established in many steel processing sectors. Due to its minimal equipment requirements, the process speaks for itself. Thanks to the fact that it is highly portable, especially on building (construction) sites.

The wind-sensitive shielding gas is not required, so further more that point is in its favour. Despite of the low-costs for its applicability, high-quality working results can be achieved. Innovations in welding power source technology make it possible to work with the stable arc, even in unfavourable conditions or when the mains cable is long.

Principle

Similarly as with MIG/MAG welding, in the MMA welding the electrode fulfils a dual function of arc carrier and consumable filler material as well. In MMA welding, the electrode is referred to as filler rod or rod electrode. The heat from the arc melts the core wire of the filler rod and the base metal. At the same time, the filler rod casing acts as a gas bell jar and layer of slag to protect the heated workpiece surface from chemical reactions with the surrounding air.

This maintains the strength and the durability of the welded metal. The filler rod is connected to one pole on the power source via the welding cable and electrode holder. The earth connection runs via the workpiece terminal and earthing cable to the other pole on the power source. The pole that represents the welding potential depends on the type of rod electrode being used.

Rutile electrodes are mostly welded at the power sources negative pole, whereas basic electrodes are mainly used at the positive pole. Under certain conditions, rutile electrodes are also suitable for alternate current welding with simple welding transformers and no current rectifier. Other characteristic features of rutile electrodes include easy weldability, even weld seam and spray transfer.

In addition to large drop transfer, basic electrodes on the other appear to incorporate moisture, and thereby causing pores in the weld metal in its undried state. Advantages include weldability in several positions and very good mechanical properties of the weld metal.

A further type of electrode is the cellulose electrode. In addition to spray transfer, cellulose electrodes have a very deep fusion penetration, good mechanical strength, and are suited to all welding positions, including vertical down seam.

Disadvantages include difficult weldability and the generation of a substantial amount of smoke. Furthermore, these electrodes are not suitable for all types of power sources.[4]

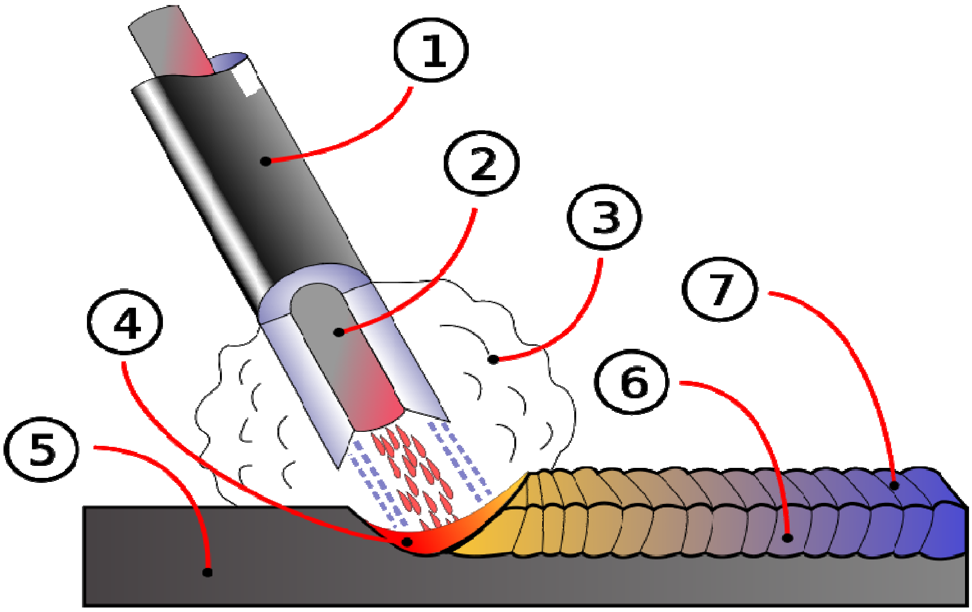


Fig. 27 Diagram of manual metal arc weldig – MMA welding

1 – Electrode, 2 – Inside electrode, 3 – Shield gas, 4 – Fusion, 5 – Base metal,

6 – Weld metal, 7 – Slag

Application

With the exception of aluminium, MMA welding is suitable for almost all metals.

The process is not limited only to workshops, but makes its presence felt outdoors, on construction sites and even under water. As a counterweight to relatively low welding speed and a lack of mechanisation of the process are the low equipment costs, easy handling and low noise of direct current welding. When welding is finished, there may well be a layer of slag to remove, yet this provides optimum protection for the metallurgical structure of material.

Advantages

- Flexibility of welding, possibility to weld in any environment
- Easy manipulation and setting
- Low purchase costs and low cost of operation

Disadvantages

- Impossibility of mechanisation
- Moderate welding speed
- Necessity to remove the slag after welding

Summary

Moderate welding speed and a lack of mechanisation limit of course the MMA welding with regard to productivity. From a technological and metallurgical perspective, this process provides very good conditions for optimum welding results, especially when the latest generation of inverter power sources provides a very quiet and stable arc, which is an essential prerequisite for optimum welding results. MMA welding comes into its own for portable use on construction sites, as well as in the manufacture of components that require minimal welding.[4]

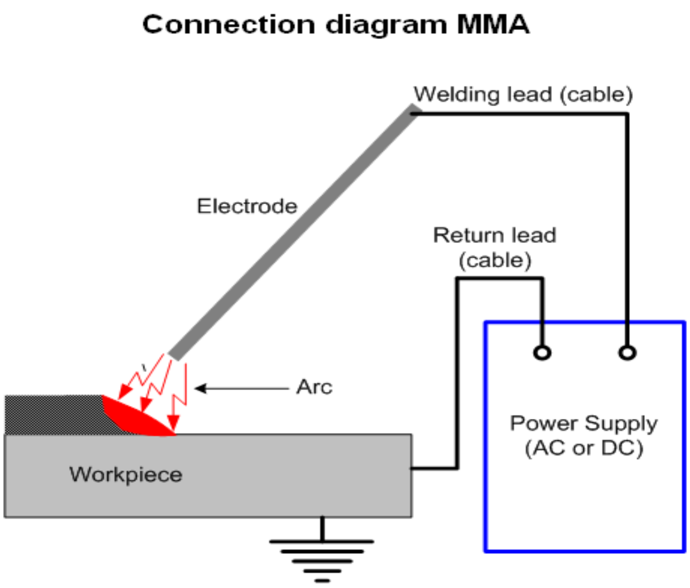


Fig. 28 Connection diagram MMA welding

Fig. 29 Welding of rolled steel by method MMA

Fig. 30 Welding of pipe by method MMA

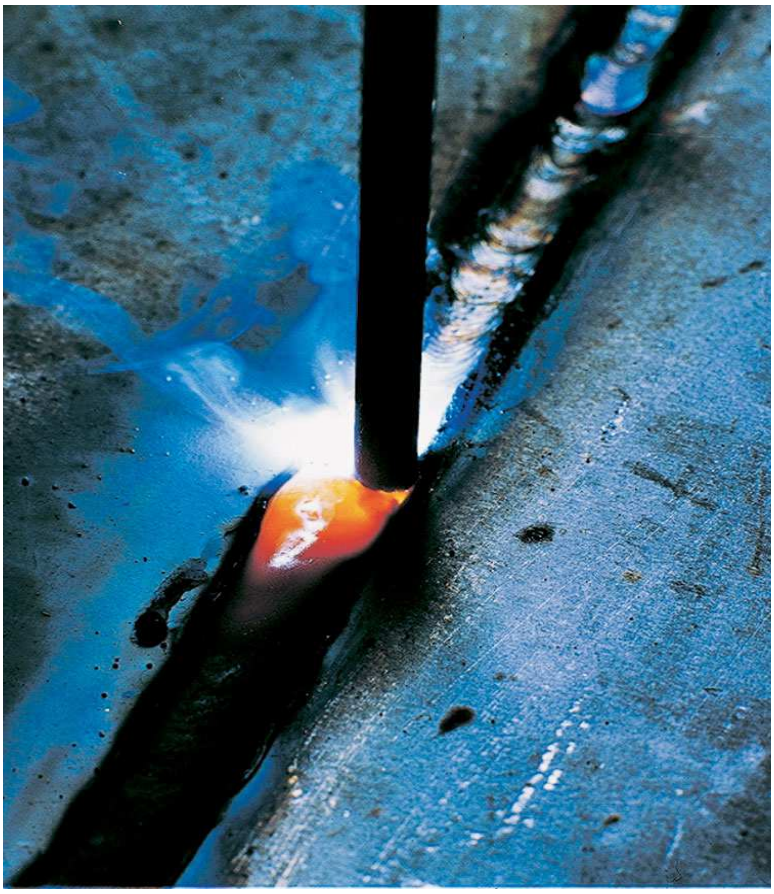


Fig. 31 Detailed demonstration of MMA welding

2.1.3 MIG/MAG welding

In MIG/MAG welding, the consumable metal electrode is both filler material and arc carrier. The “endless” filler wire is fed via two or four drive rollers into the welding torch, where the current is transferred at the so-called contact tube.

The free wire end is concentrically surrounded by a gas nozzle. The shielding gas that flows out prevents chemical reactions between the hot workpiece surface and the surrounding air. This maintains the strength and durability of the weld metal. Inert and active gases can be used as shielding gases. This is why we refer to metal inert gas (MIG) welding and metal active gas (MAG) welding.

In addition to the arc behaviour and deposition rate, the shielding gas is also partly responsible for the material transfer and shape of the weld seam. The inert gases mostly used are argon and helium, plus their compounds. The term “inert” comes from the Greek, meaning “inactive”. Inert gases are suited to practically all metals, and especially aluminium and copper, but not steel. Active gases are mainly argon-based inert gas compounds, yet also contain some oxygen or carbon dioxide, and are comparatively reactive. Active gases are suited to stainless, high-alloy steels, as well as to unalloyed and low-alloy steels. With some limitations, even carbon dioxide on its own is suited to unalloyed or low-alloy steels as an active gas.

Flux cored wires can also be used as an alternative to the shielding gases, with their casing that evaporates in the arc, thereby creating a shielding gas environment. Flux cored wires also ensure reliable gas shielding where there are draughts.[2]

If it can be said that to begin with, the MIG/MAG process proved itself highly useful for rationalised welding of unalloyed and low-alloy structural steels, today it can be best put to use for aluminium alloys and high-quality structural steels, thanks to the pulsed arc technique. Characteristic of the pulsed arc technique is the controlled material transfer. In the ground current phase, the energy supply is reduced to such an extent that the arc is still only just stable and the surface of the workpiece is preheated. The main current phase uses a precise current pulse for targeted droplet detachment. An unwanted short circuit with simultaneous droplet explosion is ruled out, as is uncontrolled welding spatter.

Regardless of the type of arc, MIG/MAG displays significant advantages over other welding processes. These include good deposition rate, deeper fusion penetration, simple handling and total mechanisation, in addition to high productivity.[7]

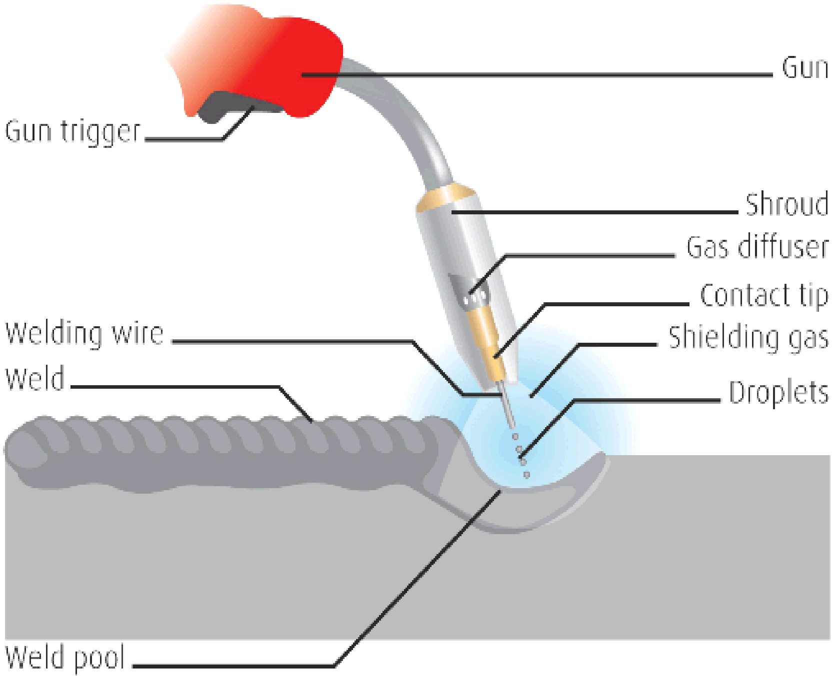


Fig. 32 MIG welding process

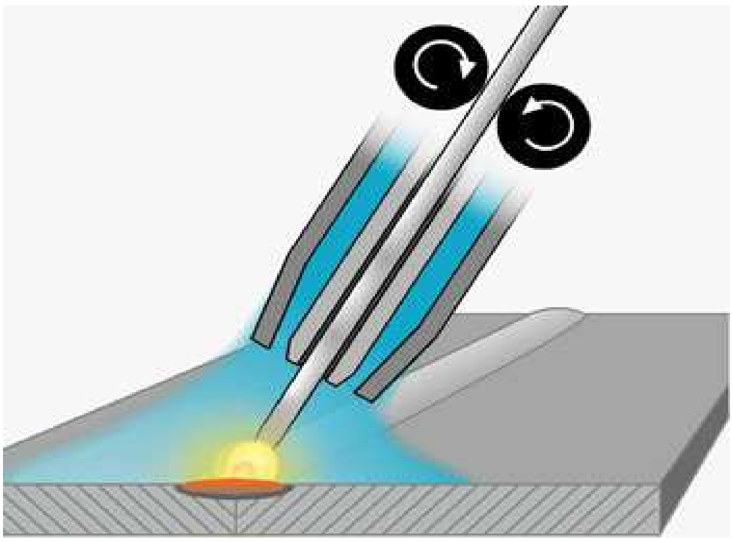


Fig. 33 MIG/MAG process

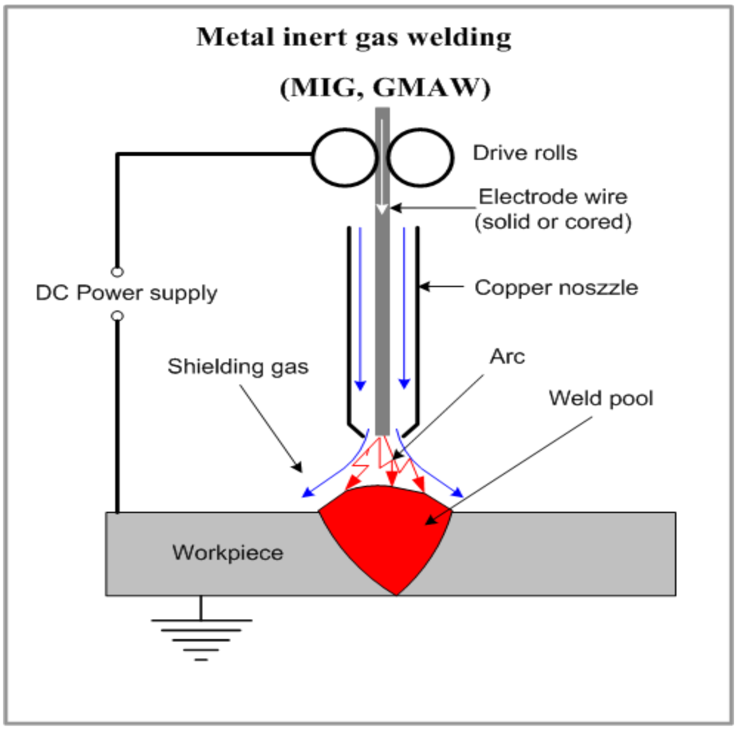


Fig. 34 Connection of MIG/MAG welding

2.2 Weld joints and weld types

Weld joints – Welding has are five basic types of weld joints.

Butt joint
T-joint
Lap joint
Corner joint
Edge joint

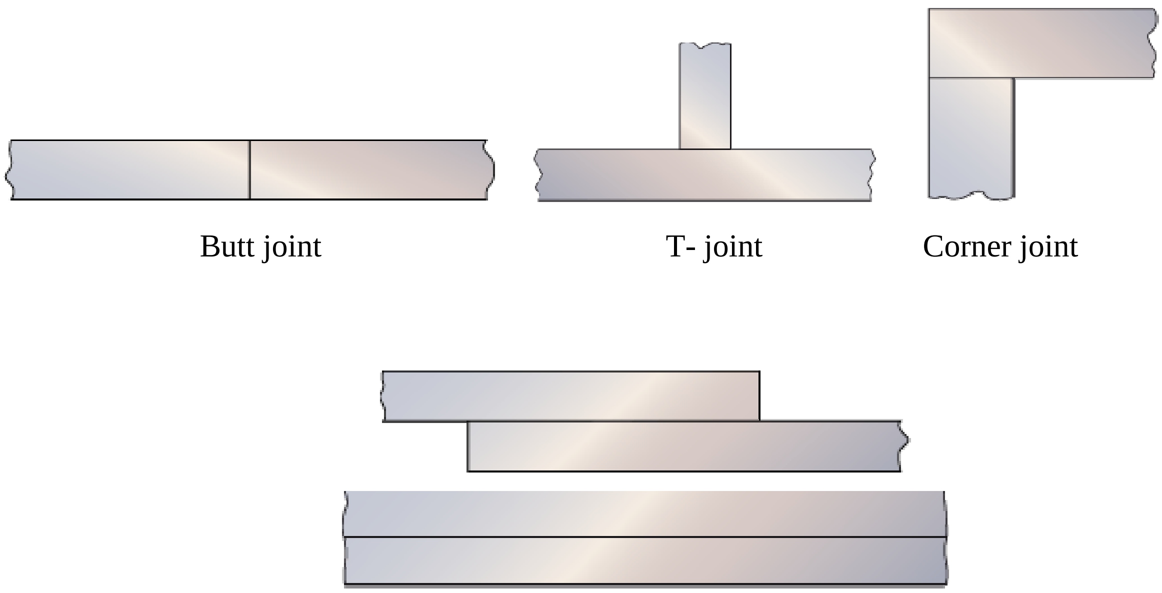


Fig. 35 Types of welds

Joint preparation

Weld joints may be initially prepared in a number of ways.

For example: Shearing, Casting, Forging, Machining, Stamping, Filling, Routing, Oxyacetylene cutting (thermal cutting process), Plasma arc cutting, Grinding.

Preparation of welding seam edges must be relevant to welding method, thickness of the base material, and identification in drawings (rule ČSN EN ISO 9692-1).

Preparation of edges for those parts of the steel structure that are under dynamic load must be carried out by metal cutting, oxygen or laser cutting (in the case of the oxygen method, the seam edges must be ground to expose the metal core).[1]

Weld Types

There are various types of welds than can be made in each of the basic joints.

<u>Fillet weld</u>

This is the most commonly used weld. The fillet weld is so named because of its cross-sectional shape.

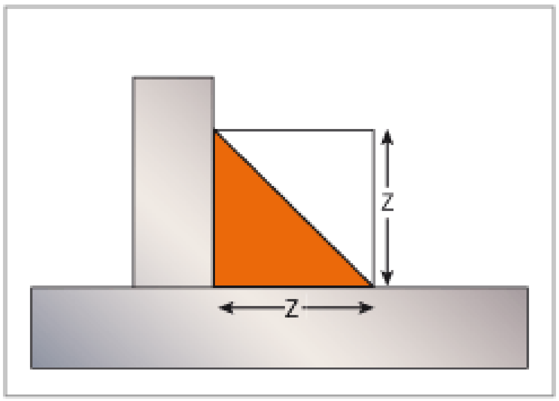


Fig. 36 Fillet weld

<u>Groove weld</u>

This is the second most popular weld. It is defined as a weld made in the groove between two members to be joined. The groove weld is regarded as being in the joint. There are a few main basic groove weld designs, and they can be used as single or double welds.

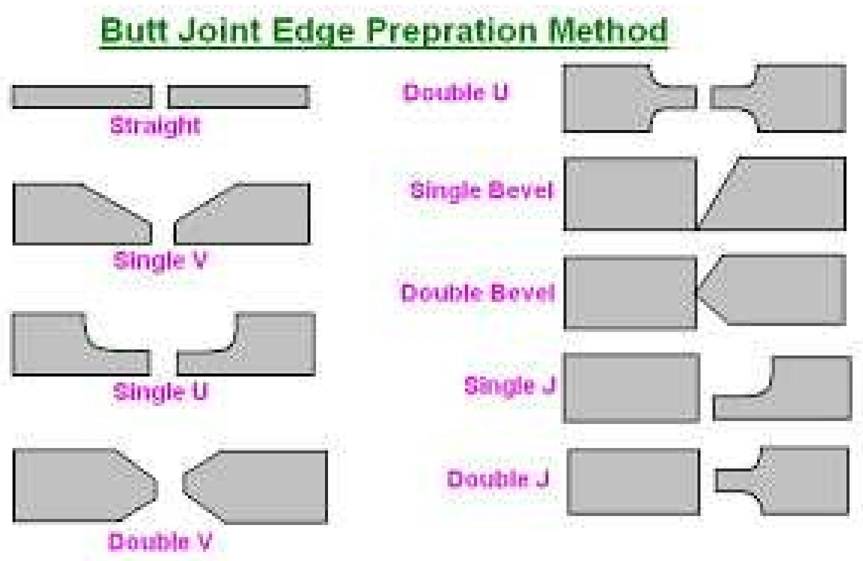


Fig. 37 Butt weld

Back or backing weld - This is a special weld made on the back side or root side of a previous weld. The root of the original weld is gouged, chipped, or ground to sound metal before backing weld is made. This will improve the quality of the weld joint by assuring complete penetration.

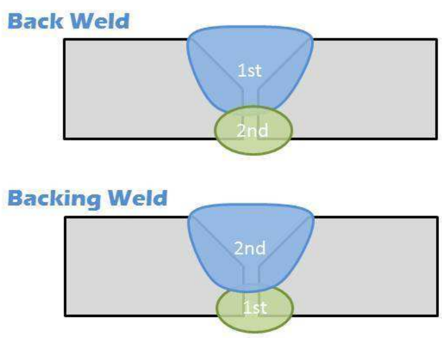


Fig. 38 Back or backing weld

Plug or slot weld - These are made using prepared holes. They are considered together since the welding symbol to specify them is the same. If the hole is round , it is plug weld; if it is elongated, it is a slot weld.

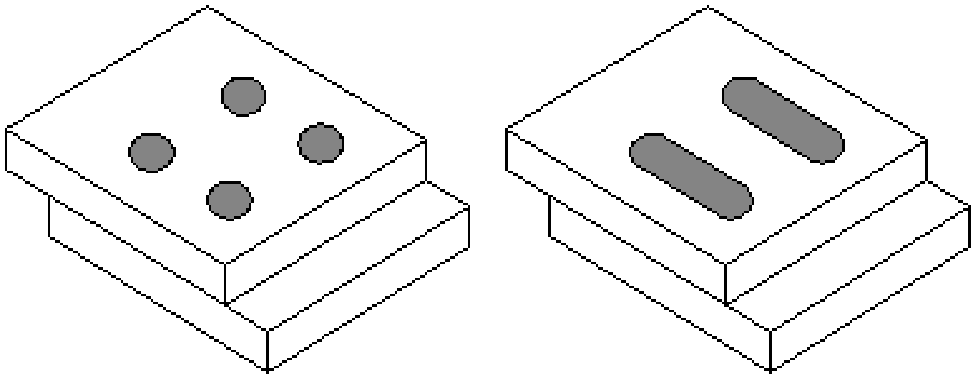


Fig. 39 Plug or slot weld

Spot or projection weld - These welds can be applied by different welding processes, which change the actual weld. Resistance welding, electron beam welding, laser welding.

Seam weld - This weld in cross section looks similar to a spot weld. The weld geometry is influenced by the welding process employed. Electron beam welding, laser welding.

Stud weld - This is a special type of a weld produced by a stud welding process, used for joining a metal stud or similar part to a workpiece.

Surfacing weld - This weld is composed of one or more stringer or weave beads deposited on base metal as an unbroken surface. It is not used to make a joint. It is used to build up surface dimensions, or provide protection of the base metal from a hostile environment.

Weld symbols – Basic weld symbols

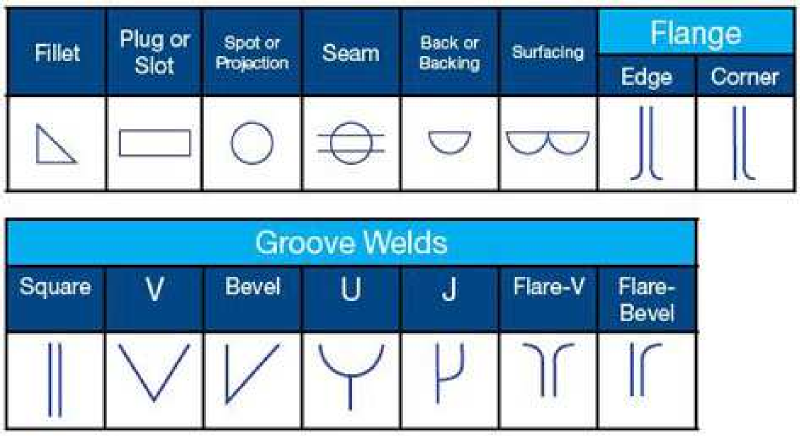


Fig. 40 Weld symbols

Weld positions – For a welder, it is important to be able to weld in different positions.

Marking according to ČSN EN ISO 6947.[1]

PA – Horizontal welding of butt welds and fillet welds in flat position

PB – Horizontal welding of fillet welds

PC – Transverse position

PD – Horizontal overhead position

PE – Overhead position

PF – Vertical up position

PG – Vertical down position

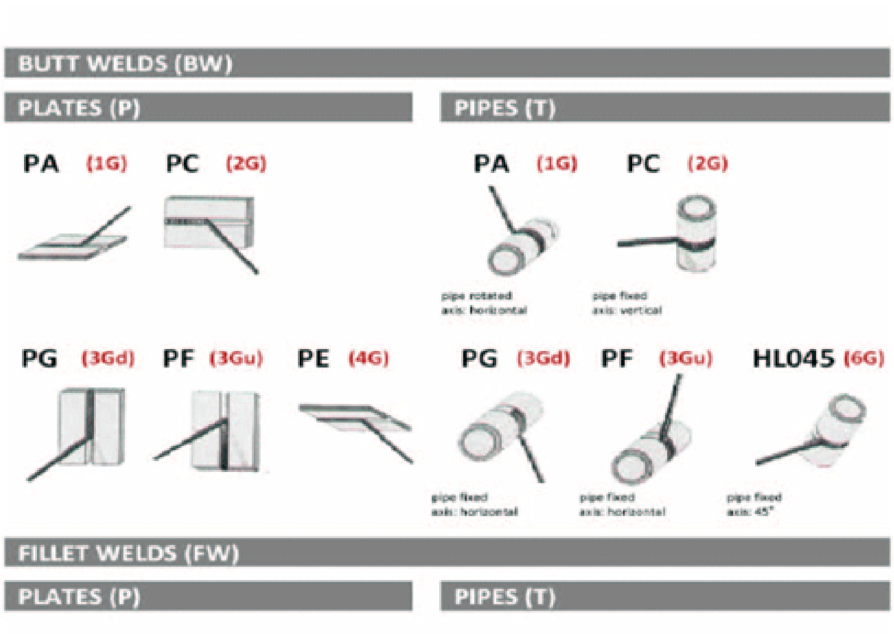


Fig. 41 Weld positions for plates and pipes

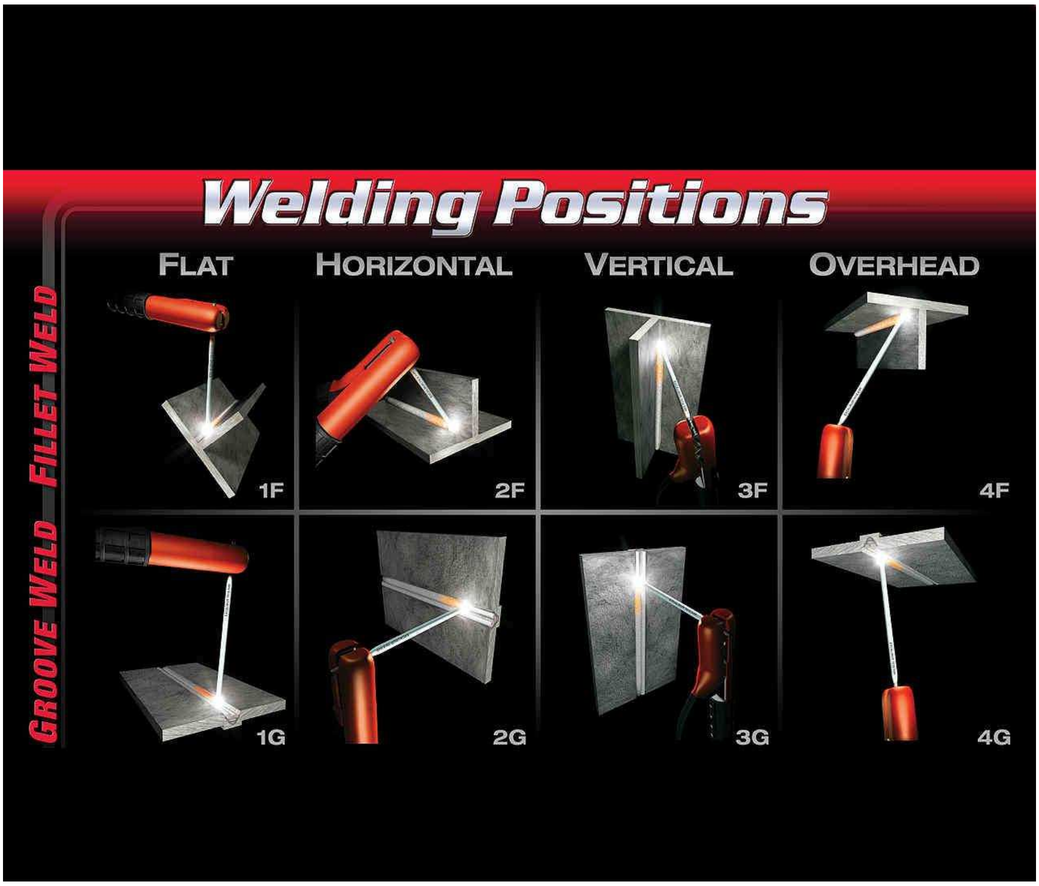


Fig. 42 Weld positions

2.3 Non destructive testing of welds

The different types of non-destructive testing used to inspect welding are shown below:

Testing methods

Ultrasonic inspection (UT)

Magnetic Particle inspection (MT)

Liquid penetrant inspection (PT)

Radiographic inspection (RT)

Visual inspection (VT)

Ultrasonic Testing - Ultrasonic methods of weld testing use beams of sound waves (vibrations) of short wavelength and high frequency, transmitted from a probe and detected by the same or other probes. This method is utilized for detection of internal flaws in welds such as slag inclusions, internal porosity, or internal cracks.[5]

Fig. 43 Ultrasonic testing of pipe

Magnetic Particle Inspection - This method involves magnetizing a specimen using a magnet or by producing a magnetic field by inducing an electric current in the specimen. This method is utilized for the detection of surface or slightly subsurface defects in ferromagnetic material.[5]

Fig. 44 Magnetic inspection of welds

Liquid Penetrant Inspection - This method employs a penetrating liquid, which is applied over the surface of the component and enters the discontinuity or crack. This method is utilized for the detection of surface flaws in welds that may or may not be visible.[5]

Fig. 45 Liquid penetrant inspection of pipe

Radiographic testing - Industrial radiography uses an X-ray device or radioactive isotope as a source of radiation. Once the radiographic film or image is processed an image of varying density is obtained. The image of imperfections is identified through density changes and analyzed by a qualified industrial radiographer. After more than a century, radiographic inspection is still the nondestructive method of choice for most projects, whether in the laboratory or in the field.Examples of application of radiographic inspection are:

Pipeline welded joint inspection

Pressure vessel fabrication quality control

Welder qualification testing

Structural steel fabrication

Detect Discontinuities in weld

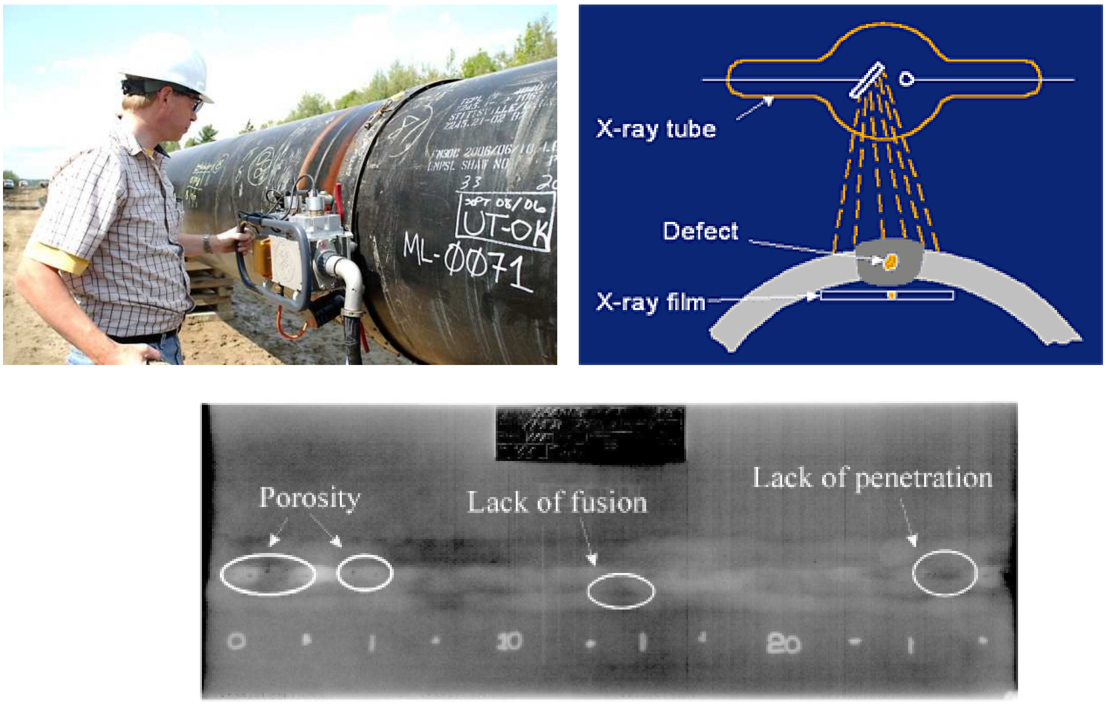
Determine the extent of corrosion (internal and external)

Locate reinforcement bar and conduit

Locate post-tension cables

Detect Discontinuities in weld

Operator is equipped with mobile equipment for on-site inspection and testing to certify to the highest testing standards on a wide variety of products.[5]



Radiography of the welded join.

Fig. 46 Radiographic testig of pipe

Visual Inspection – Visual inspection of welds is one of the most underrated ways to accomplish welding inspections, not to mention it is often the most cost-effective way. It does not require expensive equipment and can be one of the easiest forms of inspection to conduct. Having a highly trained, certified, and experienced individual perform visual inspections can dramatically increase welder performance and can be one of the most proactive methods to ensure quality.[5]

Fig. 47 Tolls for visual inspection

Tab. 10 Standards for non-destructive testing of welds [1]

Type of testing	Standard	Title
Visual testing - VT	ČSN EN ISO 17637	Visual testing of fusion - welded joints
Visual testing - VT	ČSN EN ISO 5817	Quality of levels for imperfections
Penetrant testing - PT	ČSN EN 571-1	Penetrant testing - General principles
Penetrant testing - PT	ČSN EN ISO 23277	PT of welds - Acceptance levels
Magnetic testing - MT	ČSN EN ISO 17638	Magnetic particle testing
Magnetic testing - MT	ČSN EN ISO 23278	MT of welds - Acceptance levels
Ultrasonic testing- UT	ČSN EN ISO 17640	UT- techniques, testing, assessment
Ultrasonic testing- UT	ČSN EN ISO 11666	Ultrasonic testing - Acceptance levels
Radiographic testing RT	ČSN EN ISO 17636	Radiographic testing - Part 1: X and gamma-ray techniques with film
Radiographic testing RT	ČSN EN ISO 17636	Radiographic testing - Part 2: X and gamma-ray techniques with detectors
Radiographic testing RT	ČSN EN 12517-1	NDT of welds - Evaluation of welded joints in steel - Acceptance levels
Qualification operator	ČSN EN ISO 9712	Qualification of NDT personal

2.4 Summary of theory chapter and objectives of further part of the thesis

The theoretical part describes main types of marine engines of Rolls-Royce Marine company and especially the marine Gas engine B35:40V 16AG, for which we will weld the oil sump.

Futhermore, there are metioned main welding methods in the theoretical part and the MMA a MAG welding methods are explained in detail. We will weld the oil sump using this method MAG.

- We set the targets for the practical part of this bachelor's thesis as follows:
- To define requirements for welding of lubr.oil sump
- To create a principles of quality of weld
- To make a welding plan for welding personal (to create WPS for individual types of welds, that can be found on the oil sump).
- To create a welding map for the own welding
- To issue reports for non-destructive testing in the end (Visual report, Magnetic report, Penetration report)

II. ANALYSIS

3 OBJECTIVES OF FUTHER PART OF THE THESIS

We set the targets for the practical part of this bachelor's thesis as follows:

- To define requirements for welding of lubr.oil sump (3.1)
- To create a principles of quality of weld (3.2)
- To make a welding plan for welding personal (3.3)
  (to create WPS for individual types of welds, that can be found on the oil sump).
- To create a welding map for the own welding (3.4)
- To issue reports for non-destructive testing in the end (3.5)
  (Visual report, Magnetic report, Penetration report)

3.1 Requirements for welding of lubr.oil sump

Requirement review (ISO 3834-3 section 5)

The manufacturer shall ensure that all contractual requirements, descriptions on the drawing, this document, etc., have been understood and that the requirements can be fulfilled. If in doubt the supplier shall ask for a technical review according to ISO 3834-3 section 5.3.

Requirement for welding personnel (ISO 3834-3 section 7)

Test personnel qualifications (ISO 3834-3 section 8)

Minimum level 2 according to ISO 9712.

Welding procedure (ISO 3834-3 section 10)

Welding procedure specification (WPS) to be prepared in accordance to ISO 3834-3 section 10.2.The WPS is to be qualified prior to production in according to ISO 3834-3 section 10.3.

Welding joints preparation

Welding joints to be prepared as described on the drawing. If welds are not described on the drawing, welding joints shall be prepared according to EN ISO 9692-1.

Inspection and testing (ISO 3834-3 section 14)

Inspection and testing before and during welding in accordance to 14.2.and 14.3.Inspection and testing after welding in accordance to 14.4.and 14.5.Inspection need to have special attention toward difficult areas.

Tab. 11 Inspection and testing of welds

Method	Extent of inspection	Execution
Visual testing (VT)	100% of welds	EN 970 / ISO 17637
Penetrant testing (PT) EN ISO 17638	All welded joints that may cause oil leakage	EN 571-1 / ISO3452-1
Magnetic testing (MT)	30% of all cross frames and outsider ribs.50% of welds where connected plates (flange)	EN ISO 17638

Acceptance levels

In table 12 are acceptance levels for non-destructive inspection of welds.These levels has to be writed in reports from non-destructive inspection.

Tab. 12 Acceptance levels for testing of welds

Method	Extent of inspection	Execution
Visual testing (VT)	EN ISO 5817	Level C
Penetrant testing (PT)	EN ISO 23277	Level 2
Magnetic testing (MT)	EN ISO 23278	Level 2

3.2 Principles of quality of weld for oil sump 102225

<u>Base Material</u>

Only materials S 235 JR may be used in the steel structure as indicated in the manufacturing process documentation. The base material must be ordered free of burr, annealed as per the standard; storage and handling of the material must not present any detrimental effects. The quality of the base material must be attested by a 3.1 inspection report as per ČSN EN10204/2005 by the material producer CE („Ü“). Each supply must provide the option of continuous monitoring (identification) of material. Material is to be identified legibly, with preference to stamping or laser (informatively with durable sticking labels).

<u>Supplementary Materials</u>

The supplementary material for welding are specified by the welding supervision on the grounds of the technology selected and also in respect of the chosen base material. They must be purchased bearing a 2.2 test certificate as per ČSN EN 10204 and bearing the CE (**„**Ü**“**) logo = the marking of the product must conform to applicable European standards. Storage and handling of the supplementary materials must conform to the applicable standards and/or the recommendations made by the manufacturer/supplier. Supplementary and welding electrodes must be in the original package, free of sings of corrosion, with permanent product identification by the manufacturer/supplier. Electrodes in packages and ignition powder must always be dried before use, as per the instructions provided by the manufacturer. Identification of supplementary materials is provided in the data sheets of this welding plan.

<u>Preparation of Welding Seam Edges</u>

Preparation of welding seam edges must be relevant to the welding method, thickness of the base material, and identification in the drawings (ČSN EN ISO 9692-1).Preparation of edges for those parts of the steel structure that are under dynamic load must be carried out by metal cutting, oxygen or laser cutting (in the case of the oxygen method, the seam edges must be ground to expose the metal core).Preparation of the welding seam edges must be compliant to the welding seam mark and the welding process specification (WPS).

Tack Welding

The components to be welded are to be tack-welded to provide correct position during welding. The length of individual tacks, frequency, and pitch are indicated in the drawings or they shall be performed relevant to the thickness of the base material to be welded:

Tack length – in materials up to 12mm thick must not be lower than 4x the thickness of the components to be welded, in higher thickness, the minimum tack length is 50mm.

Tack pitch - 25x the thickness of the sheet metal to be welded

Tack size 0.3–0.6x the size of the interpass seam

Welding (according to EN ISO 1011-2)

The welded components must be arranged so that the welders can access and visually inspect the welding seams (this is to be verified by the workshop inspector prior to welding). Welding is to be performed in the most suitable position – the workshop is to use positioning or turning fixtures or handling devices, the site must use a certified welder with qualifications for the required welding position. The welding sequence must allow the welds to be inspected in terms of the required parameters of quality and to rule out deformation.When using the MAG welding method, the seam area must be protected against draught or any other air flow (up to 2 m/sec.)

Welding Methods

Only the welding technologies given below may be used for the steel structure:

method 135 (MAG) Metal Active Gas Welding

Qualifications of Welding Personnel

The welders must have a valid welding certificate as per EN 287-1, EN ISO 9606, EN 1418 (welding operator) for the welding technology used; the extent of the certificate must correspond to the scope of welding works performed.

Workshop welder conducts welds as per the drawings, WPS, or instruction issued by the management of the centre or by the welding supervisor; they must know the quality requirements for the welding seam.

Welding Seam Quality Classes

Welding seam quality shall be assessed as per **EN ISO 5817**

- assessment group B – high (marked drawing, for class B)
- assessment group **C** – medium
- assessment group D **–** basic

Preheating and Interpass Temperature

The preheating temperatures given below need to be observed:

S 235 JR	t > 25 mm min. 120°C

Preheating (interpass) temperature must be checked properly; it is always necessary to achieve the required preheating of the welded components in the whole of their profile.

Temperature reading is taken on the surface of the welded component on the welder side:

from a distance A = 4 x t of the material yet not more than 50mm from the longitudinal edge of the weld area in components under 50mm thick in the weld area; in components over 50mm thick, the minimum reading distance is 75mm any direction from the weld surface. The temperature must be balanced on the heated side after the heater has been removed.

The time required to balance the temperature is 2 minutes per each 25mm of thickness of the base material (EN ISO 13916). Preheating is to be made in longitudinal, overlapping bands.

The maximum temperature of the layers (interpass) of the weld seams Ta < 250°C must never be exceeded!

3.3 WPS – Welding procedure specification

Welding procedure specification contains 11 types of welds (fillet welds and butt welds).

Fillet weld – from size 2 to size 5

Butt weld – X, K, 1/2V, V

In detailed welding procedure specifications are welding values, illustrations and welding parametrs for every type of weld.Oil sump will be welded according these welding values and paramaters.

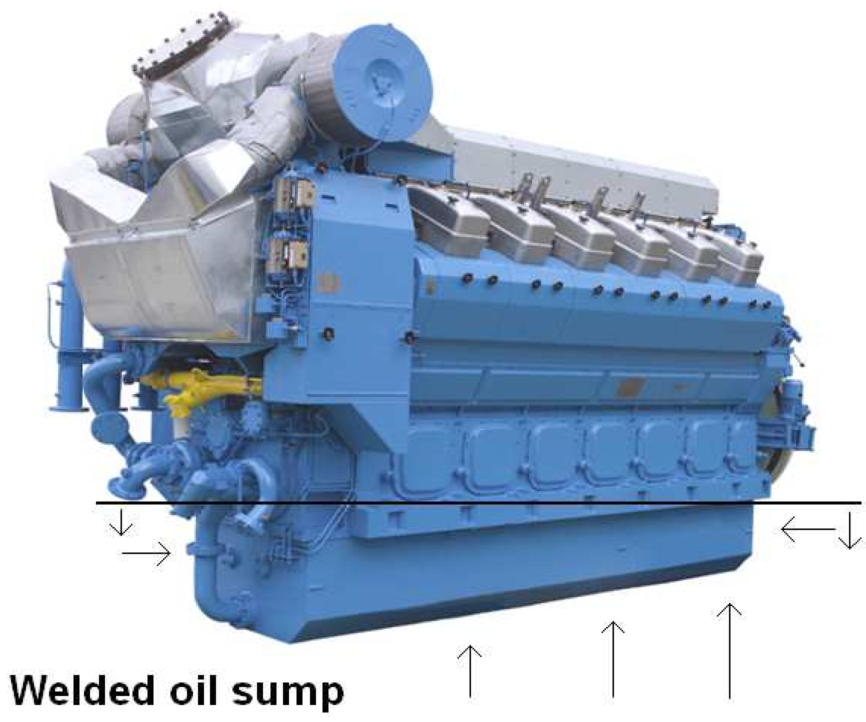


Fig. 48 Welded oil sump

Tab. 13 Welding values for all WPS

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB, PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Fig. 49 Welded oil sump 102225

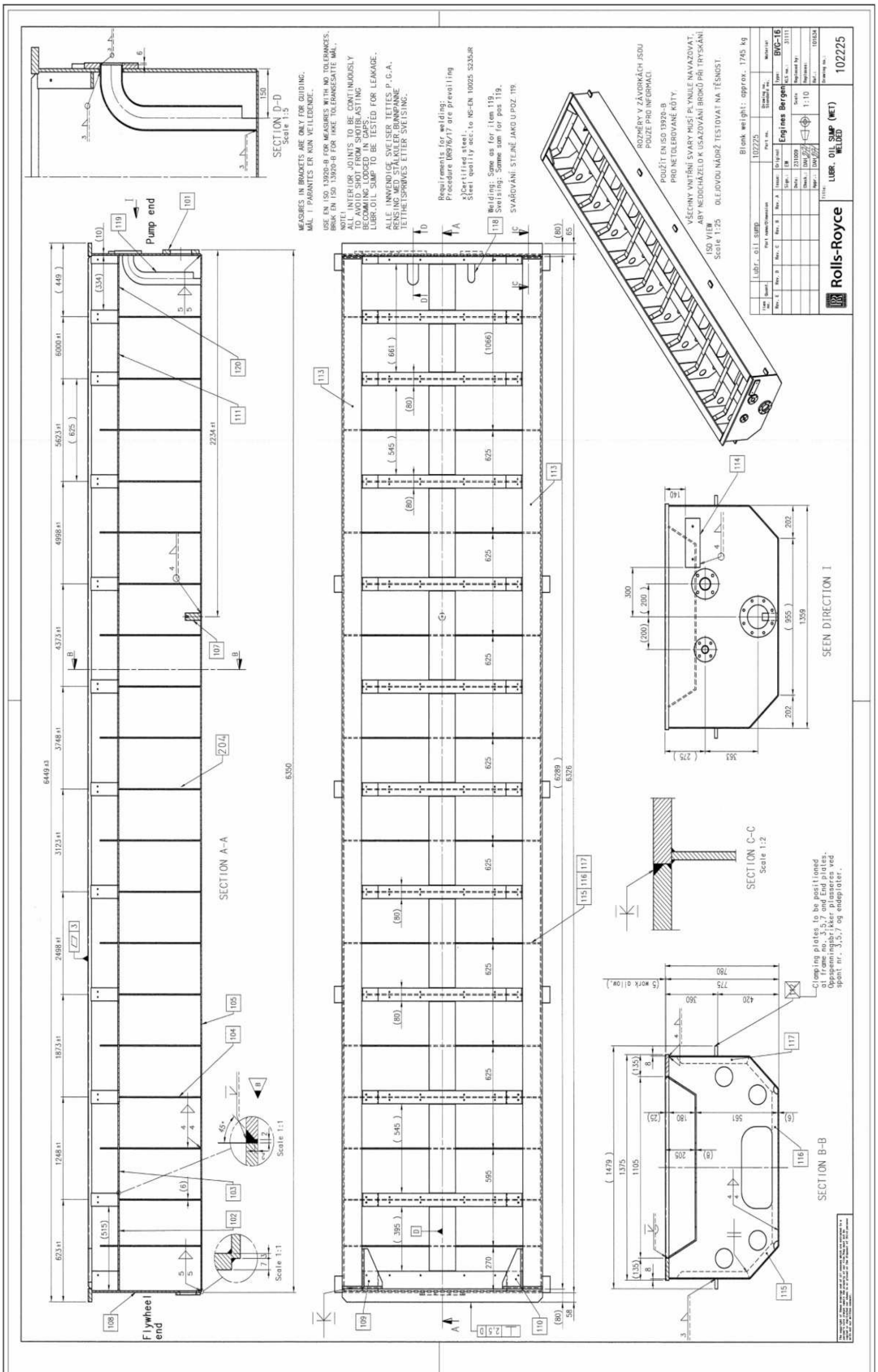


Fig. 50 Main drawing of oil sump 102225

Welding Procedure Specification
WPS

According to standard ČSN EN ISO 15614-1

Project: Welding of lubr.oil sump B:35-40V 16 AG

Product: Lubr.oil sump (wet) welded

Drawing: 102225

Welding Procedure Specification – WPS No.:1

Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

General instructions for fillet welds – Joint type: FW – all ◺

Welding values

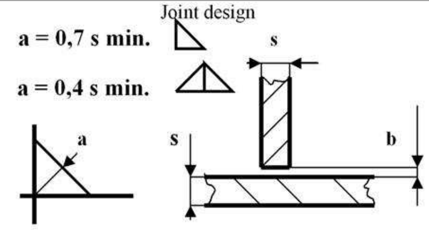
Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design

a = 0,7 s min.

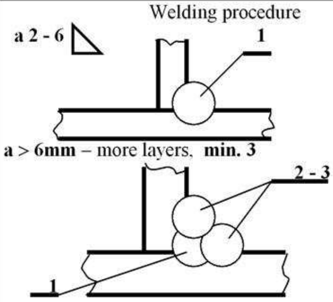
a = 0,4 s min.



Maximum permissible root gap for fillet weld :
b max. **= 0, 5 + 0,1 a**

Fillet welds :
Where not **indicated** othewise acc. drawings

Welding procedure



Oil tight weld have to be welded on 2 weld beads at lest (or double-sided) !

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Remark
1	135	PB	0,8	DC (+)	95-105	19-20	7-8	**a 2**
1			1,0	DC (+)	210-220	21-23	10-11	**a 3**
1			1,2	DC (+)	230-250	26-28	9-10	**a 4**
1			1,2	DC (+)	290-300	29-32	9-11	**a 5-6**
1		PB	1,2	DC (+)	290-310	30-33	10-12	**a > 6 mm**
2 -3			1,2	DC (+)	270-300	28-32	10-12	

Welding Procedure Specification – WPS No.:2

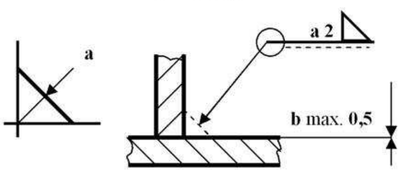
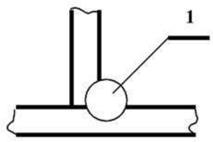
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: FW (Fillet weld) – a 2 △

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	
Weld inside – outside alternately !	**All welds has to be oiltighted !**

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PB	1,0	DC (+)	210-220	21-23	10-11	0,9-1,1

Welding Procedure Specification – WPS No.:3

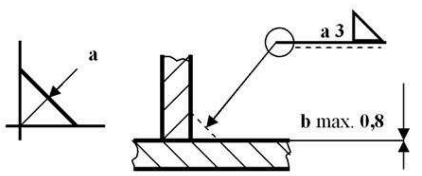
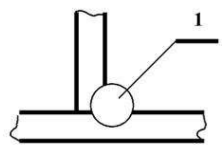
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: FW (Fillet weld)– a 3 ◺

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	
⚠ **Weld inside – outside alternately !**	**All welds has to be oiltighted !**

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PB	1,0	DC (+)	210-220	21-23	10-11	0,9-1,1

Welding Procedure Specification – WPS No.:4

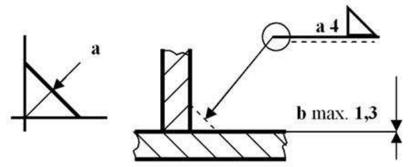
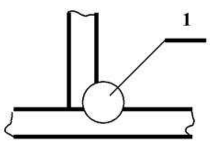
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: FW (Fillet weld) – a 4

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	
Weld inside – outside alternately !	**All welds has to be oiltighted !**

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PB	1,2	DC (+)	230-250	26-28	9-10	1,3-1,5

Welding Procedure Specification – WPS No.:5

Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

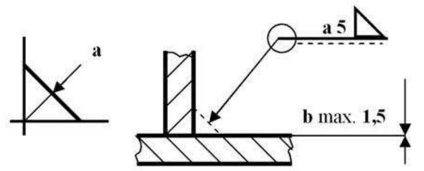
Joint type: FW (Fillet weld) – a 5

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PB
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

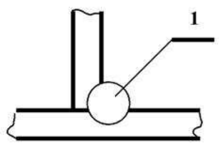
Illustration

Joint design



Weld inside – outside alternately !

Welding procedure



All welds has to be oiltighted !

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PB	1,2	DC (+)	290-300	29-32	9-11	1,8-2,0

Welding Procedure Specification – WPS No.:6

Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

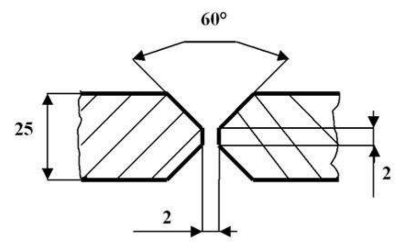
Joint type: BW (Butt weld) – X

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

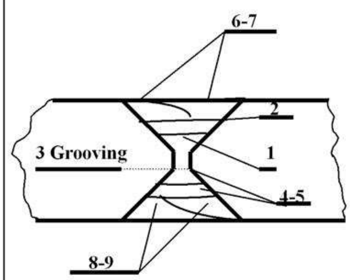
Illustration

Joint design



All welds has to be oiltighted !

Welding procedure



Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PA	1,2	DC (+)	120-140	18-20	4-5	0,43-0,56
2			1,2	DC (+)	220-240	26-28	8-10	0,92-1,01
3 Grooving								
4-5			1,2	DC (+)	240-290	25-33	7-9	0,69-1,01
6-9			1,2	DC (+)	300-320	30-34	9-11	1,44-1,54

Welding Procedure Specification – WPS No.:7

Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

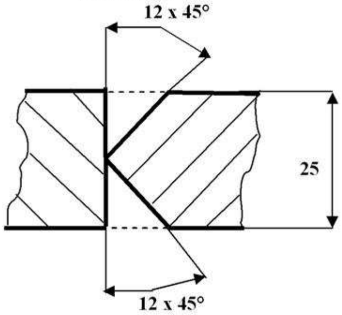
Joint type: BW (Butt weld) – K

Welding values

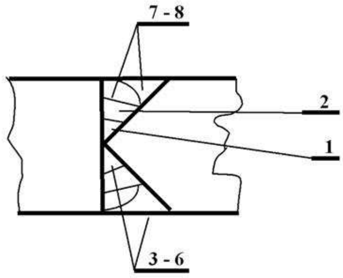
Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar+18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design



Welding procedure



A root of weld to be welded with greater current!

Welding Parameters

Weld bead	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PA	1,2	DC (+)	110-130	17-19	4-5	0,37-0,44
2			1,2	DC (+)	210-240	22-26	5-6	0,74-0,99
3-8			1,2	DC (+)	230-260	24-29	7-10	0,74-1,00

Welding Procedure Specification – WPS No.:8

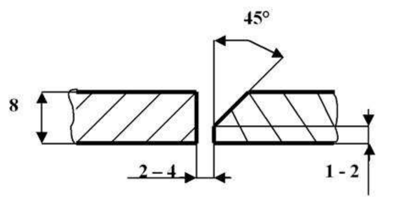
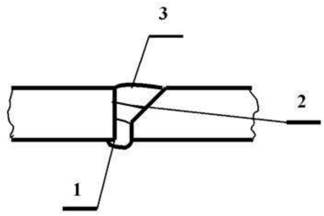
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: BW (Butt weld) – 1/2 V

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar + 18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PA	1,0	DC (+)	110-130	18-20	4-5	0,72-0,92
2			1,0	DC (+)	200-230	26-28	10-12	0,74-0,95
3			1,0	DC (+)	200-230	26-28	10-12	1,21-1,52

Welding Procedure Specification – WPS No.:9

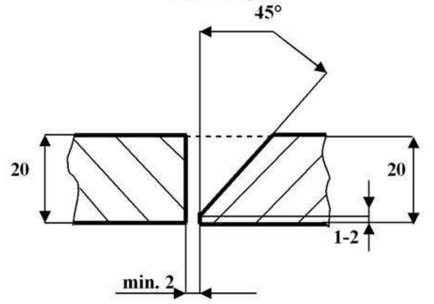
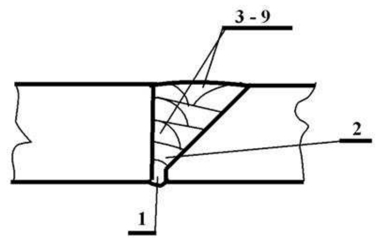
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: BW (Butt weld) – 1/2 V

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar + 18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PA	1,2	DC (+)	110-130	18-22	4-5	0,72-0,92
2			1,2	DC (+)	230-260	24-29	10-12	0,74-0,95
3-9			1,2	DC (+)	240-270	25-30	10-12	1,21-1,52

Welding Procedure Specification – WPS No.:10

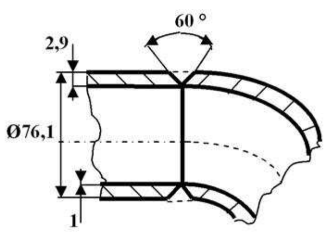
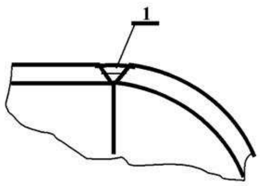
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: BW (Butt weld) – V

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar + 18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
 **All welds has to be oiltighted !**	

Welding Parameters

Weld layer No.:	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feed of welding (mm /s)	Heat input (kJ/mm)
1	135	PA	0,8	DC (+)	95-105	19-20	7-8	0,8-1,0

Welding Procedure Specification – WPS No.:11

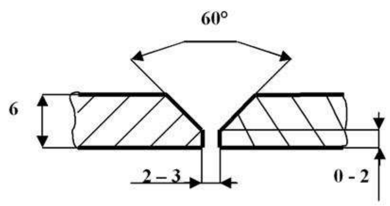
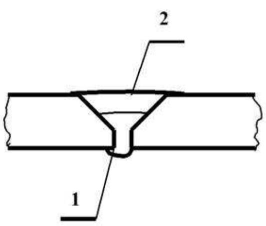
Project: Lubr.oil sump (wet) welded
Drawing No.: 102225

Joint type: BW (Butt weld) – V

Welding values

Parent metal	S 235 JR
Thickness of parent metal	According to drawings
Welding Process	135 (MAG)
Welding Position	PA
Filler metal type	EN ISO 14341-A : G3Si1
Rate of flow gas (l/min.)	12-15 (Ar + 18%CO_2)
Weld Quality	Group C (marked B) - EN ISO 5817
Preheat Temperature	S 235 JR > 25mm min. 120°C
Interpass Temperature	Maximum 250°C
Reference about weld preparation	Flame cutting or machining
Welder´s Qualification	EN 287-1

Illustration

Joint design	Welding procedure
	

Welding Parameters

Weld layer No.	Welding process	Welding position	Diam. Ø (mm)	Type of current and polarity	Welding current (A)	Welding voltage (V)	Speed feeding of wire (m /min)	Heat input (kJ/mm)
1	135	PA	1,0	DC (+)	110-130	18-20	4-5	0,70-0,92
2			1,0	DC (+)	200-230	26-28	8-10	0,75-0,95

3.4 Welding map

Welding map serves direct to welding.Welding map contains following welding parameters.

Weld number, drawing no., weld type, marking of welds, welded positions, thickness of materials, grade of materials, welding method, WPS No., quality of level, welders stamp, control % (MT, PT, VT).

Welding map has 28 welds.All welds will be welded by method 135 MAG (metal-active-gas).

In following drawings was writted weld number.These number correspond with the weld number in welding map.

List of drawings with weld numbers:

102225 – Lubr.oil sump (wet) welded

305968 – End plate pump end lubr.oil sump

304039 – Frame flywheel end wet sump

307045 – Bottom plate lubr.oil sump

436206 – Top flange

431950 – Suction pipe

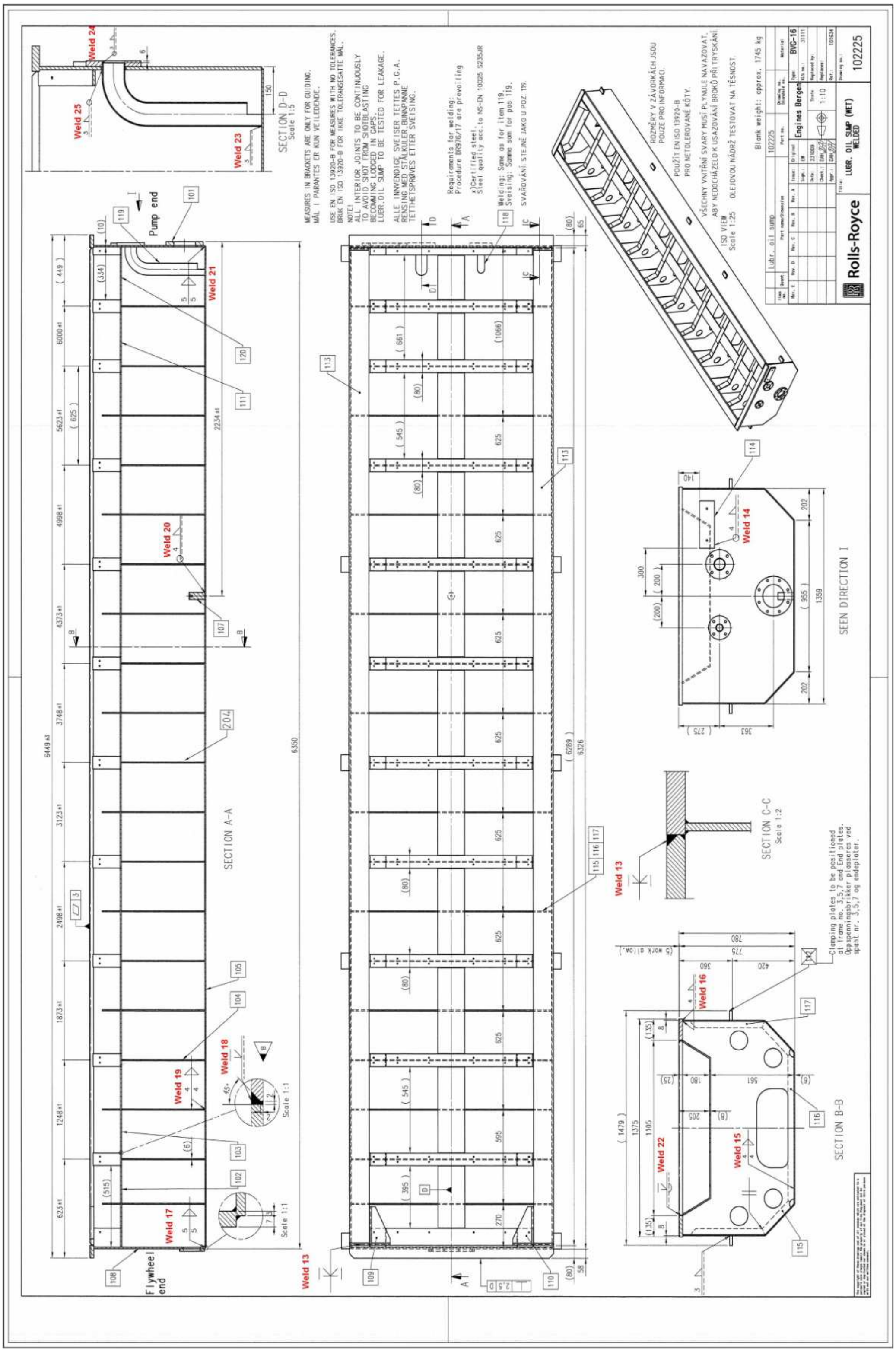


Fig. 51 Drawing 102225 with weld numbers

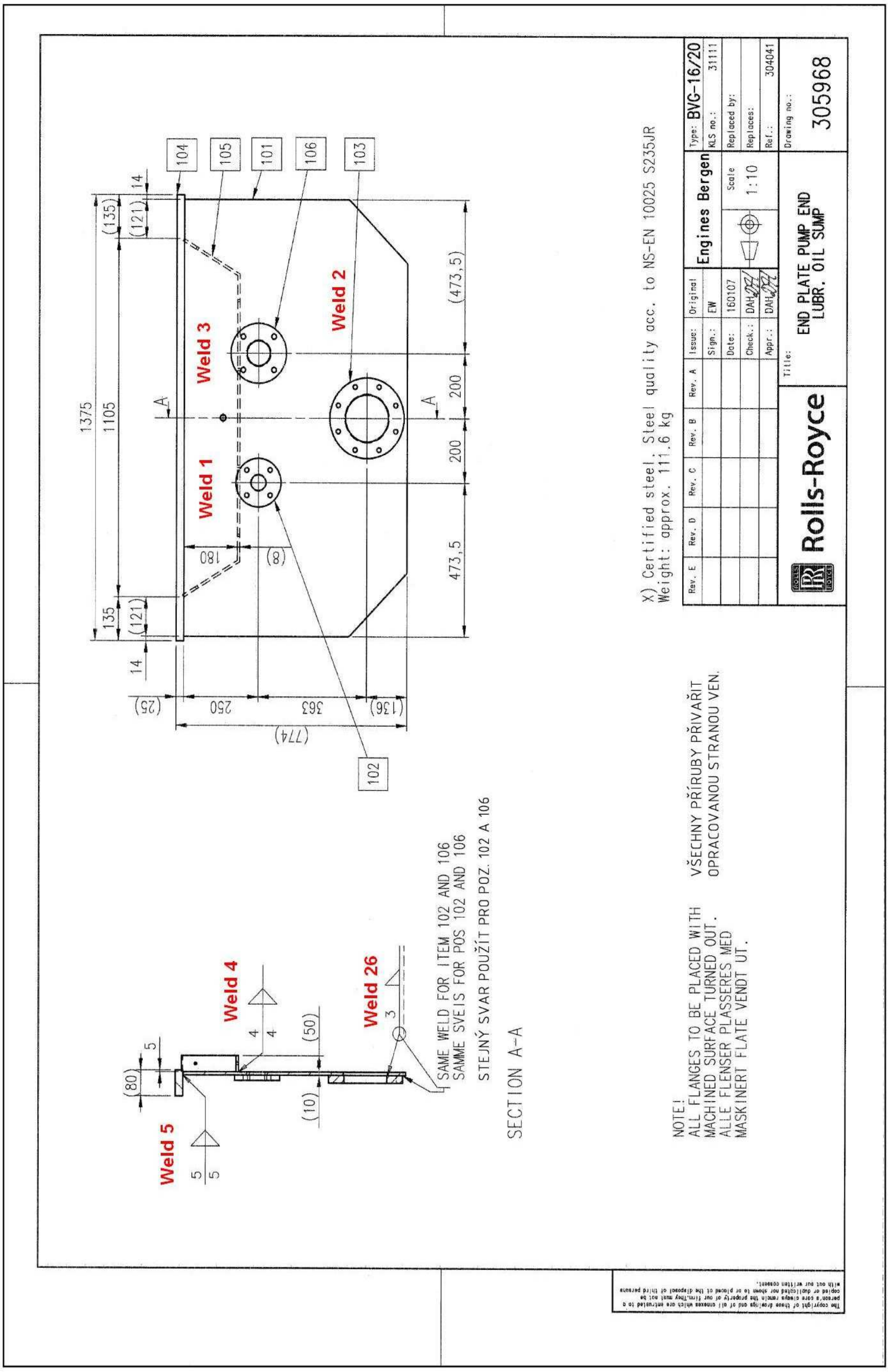


Fig. 52 Drawing 305968 with weld numebrs

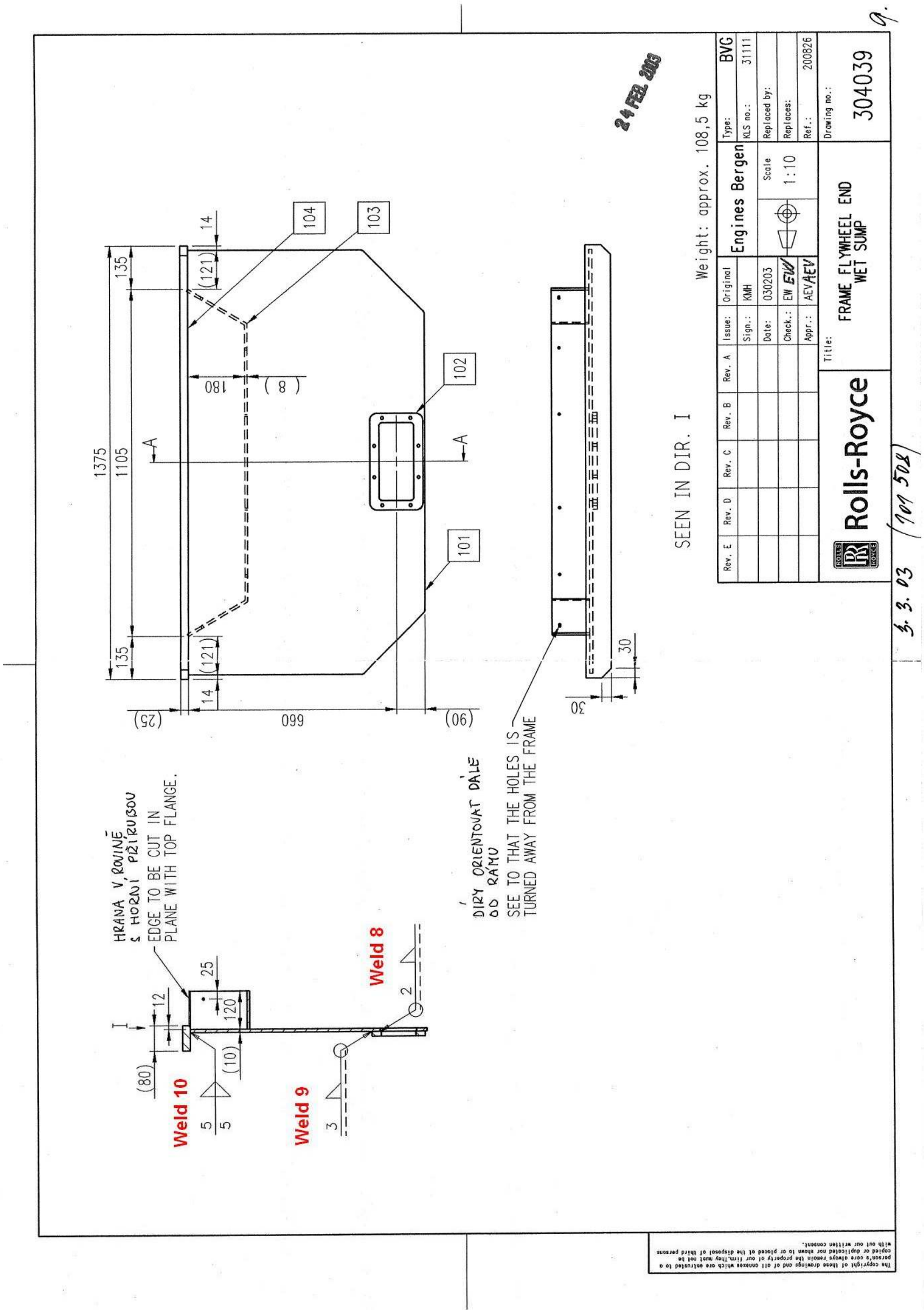


Fig. 53 Drawing 304039 with weld numbers

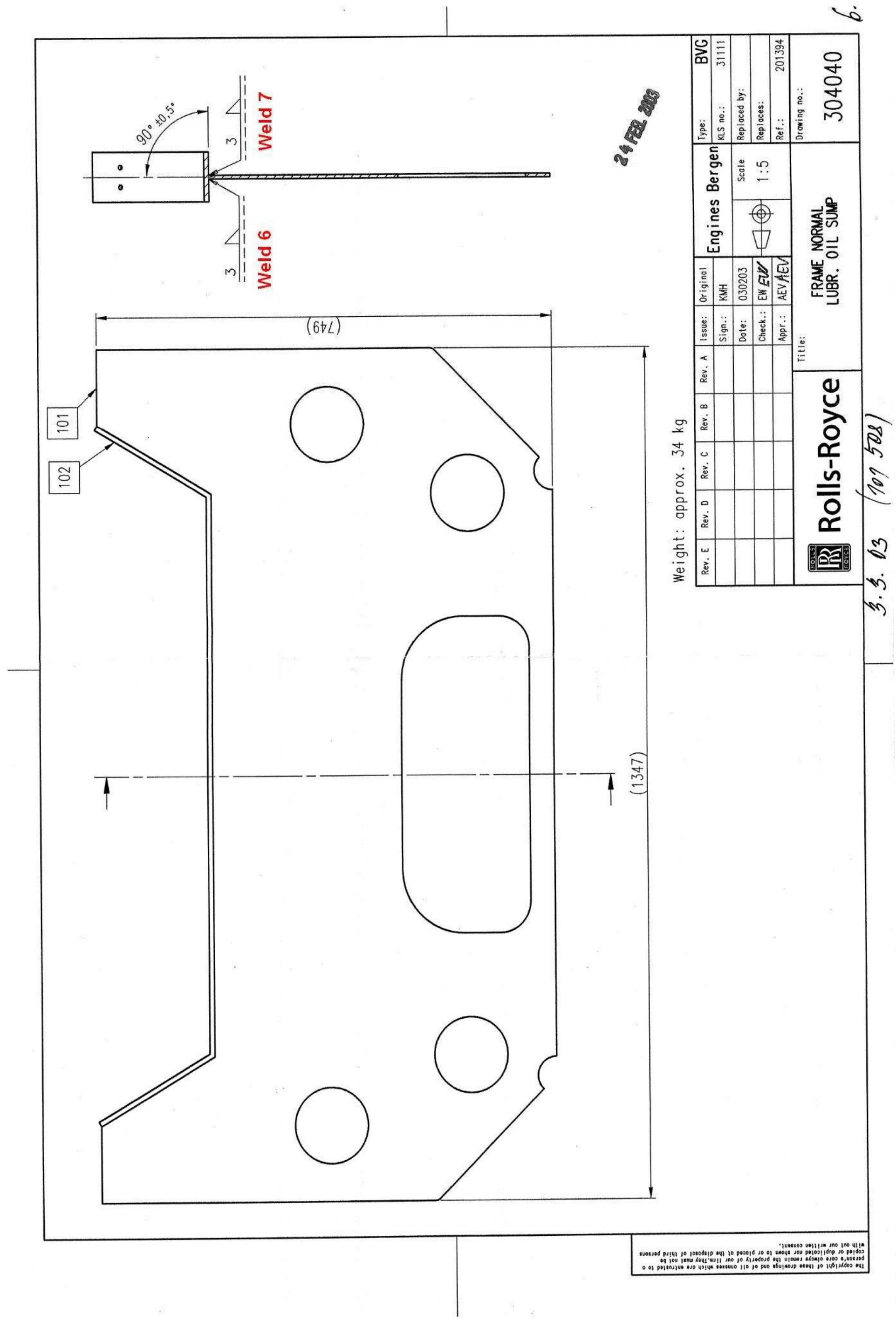


Fig. 54 Drawing 304040 with weld numbers

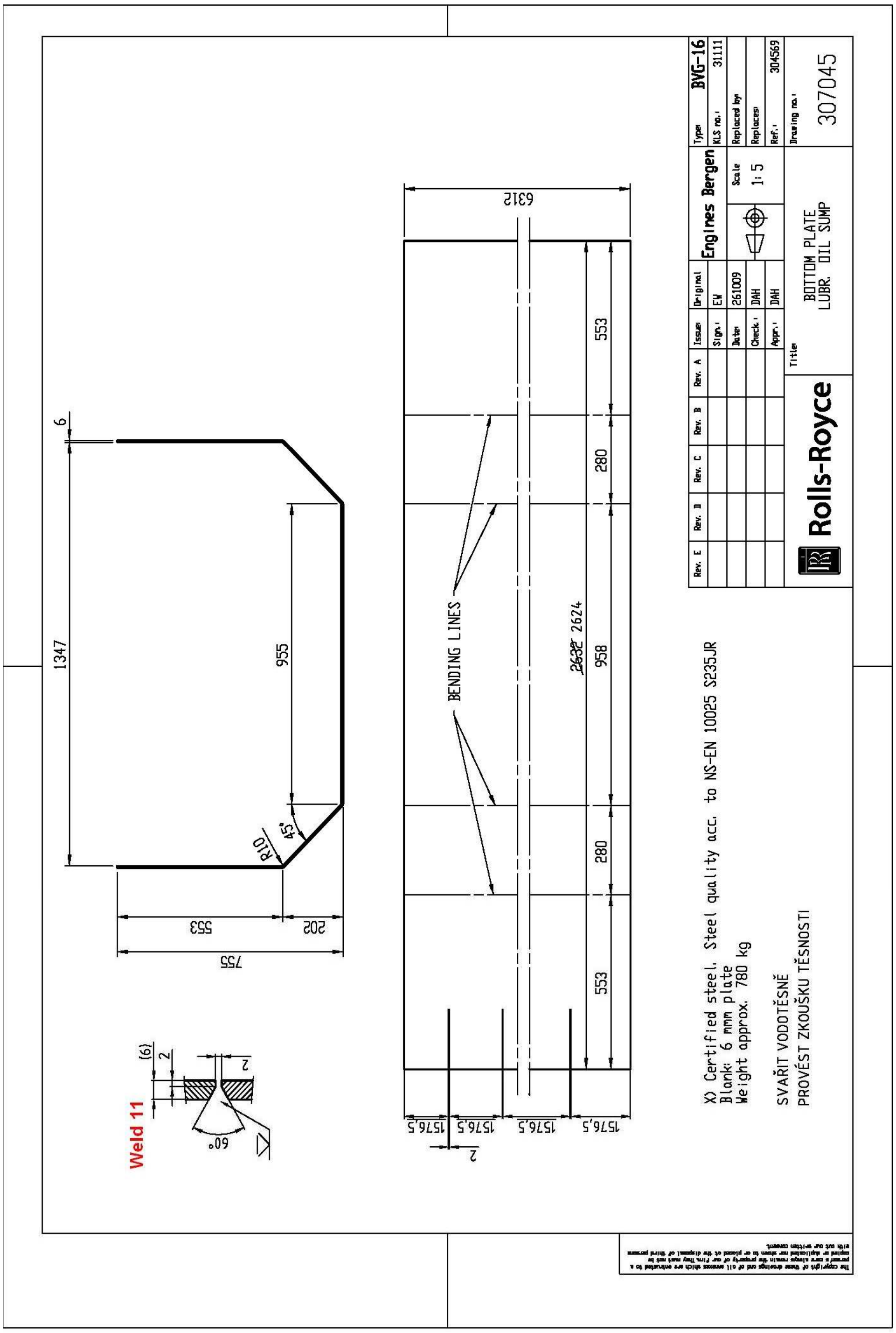


Fig. 55 Drawing 307045 with weld number

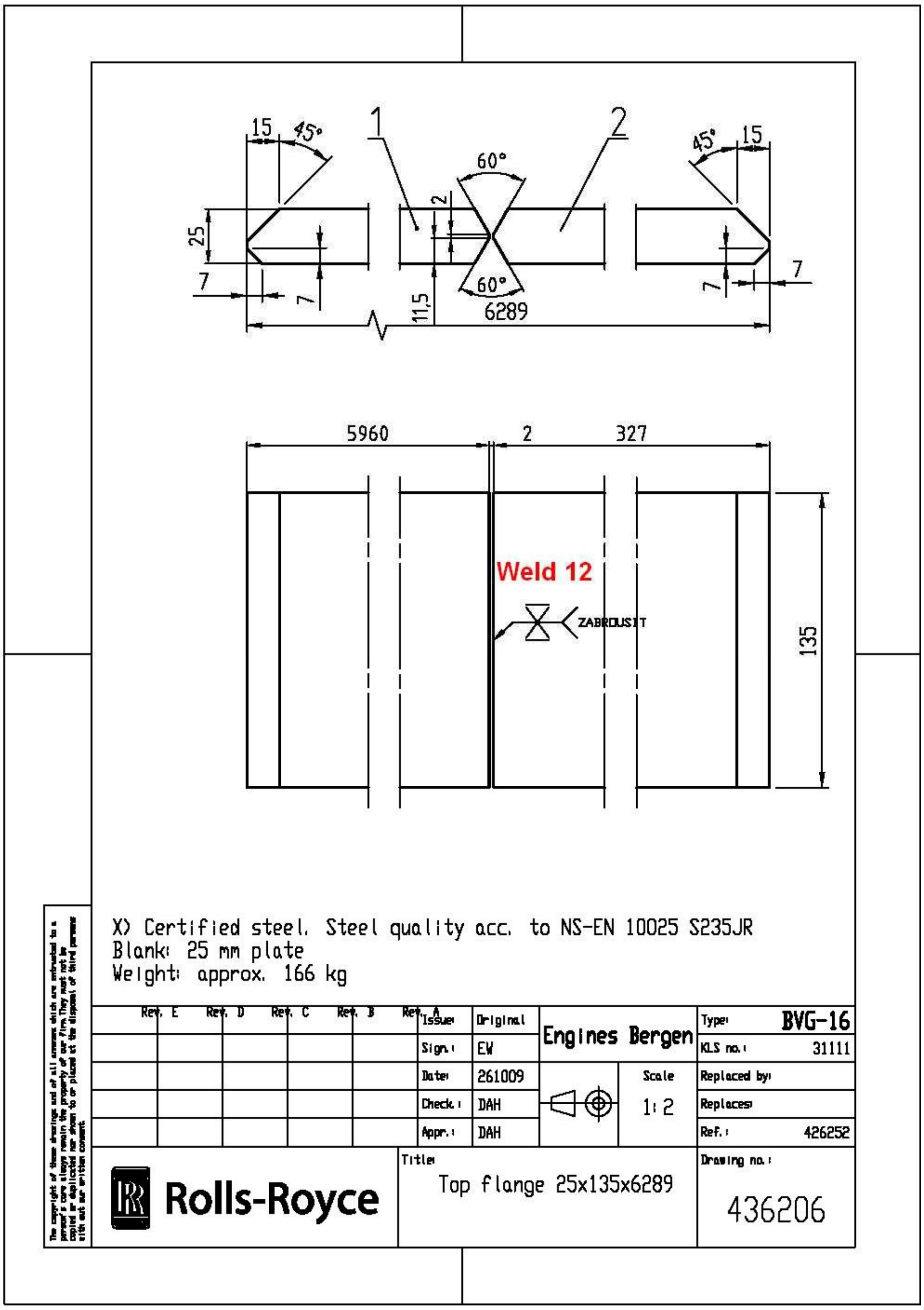


Fig. 56 Drawing 436206 with weld number

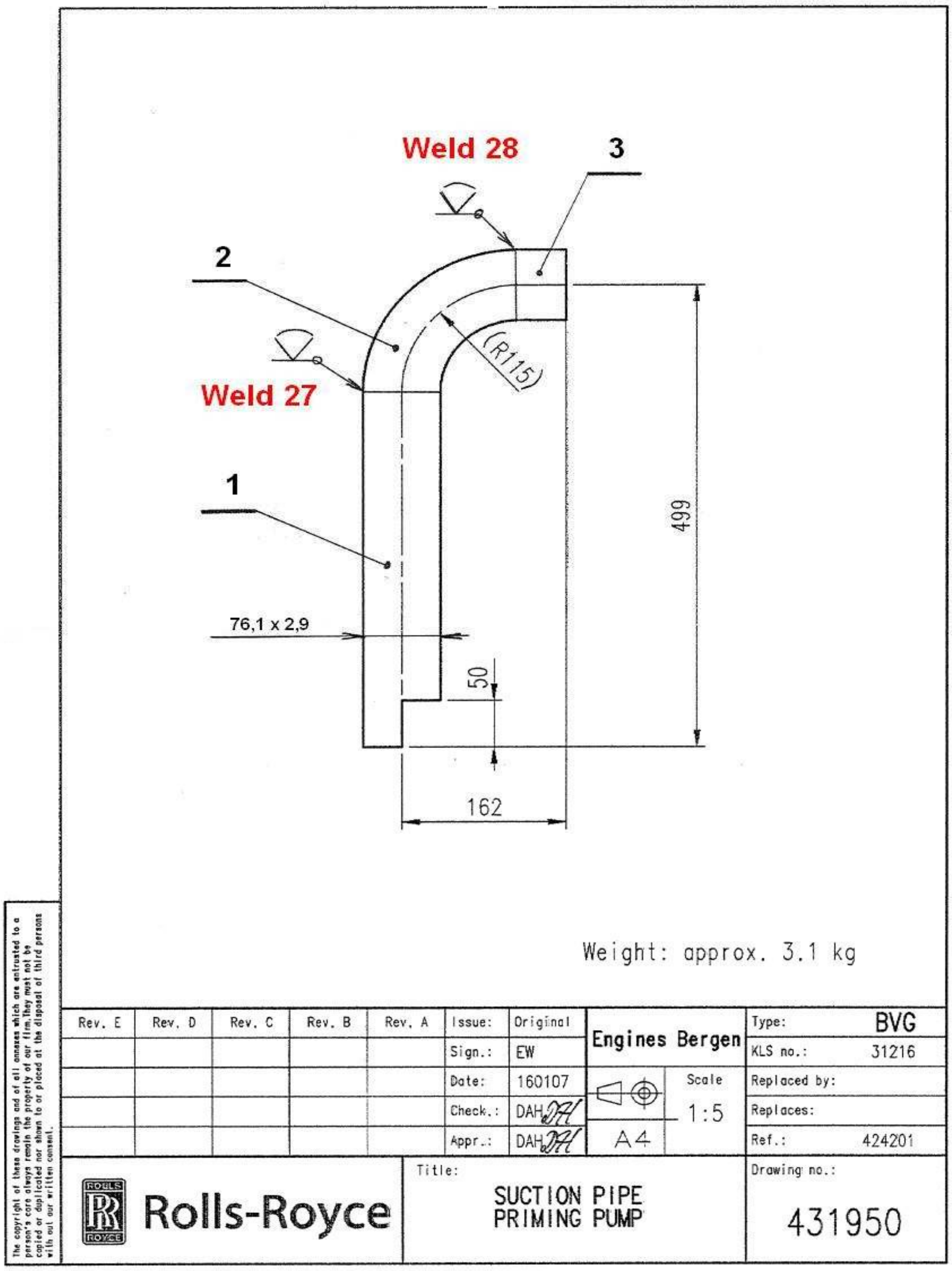


Fig. 57 Drawing 431950 with weld numbers

Rolls-Royce

Welding map

Rolls-Royce

according to specification for production DR 976/17 and rules EN 287-1, EN ISO 9692-1, EN ISO 15614-1, EN 473, EN ISO 5817

Project: Lubr.oil sump B35:40V 16AG

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Welding parametrs											Control %		
Weld No.:	Drawing No.	Weld type	Marking welds	welded positions	thickness t1/t2 (mm)	Grade of material	Welding Method	WPS No.:	Quality level	Welders stamp	MT %	PT %	VT %
1	305968	FW	a3	101 - 102	10 - 18	S235JR-S235JR	MAG	3	C			100	100
2	305598	FW	a3	101 - 103	10 - 24	S235JR-S235JR	MAG	3	C			100	100
3	305598	FW	a3	101 - 106	10 - 16	S235JR-S235JR	MAG	3	C		30	100	100
4	305598	FW	2x a4	101 - 105	10 - 8	S235JR-S235JR	MAG	4	C				100
5	305598	FW	2x a5	101 - 104	10 - 25	S235JR-S235JR	MAG	5	C			100	100
6	304040	FW	a3	101 - 102	6 - 8	S235JR-S235JR	MAG	3	C				100
7	304040	FW	a3	101 - 102	6 - 8	S235JR-S235JR	MAG	3	C				100
8	304039	FW	a2	101 - 102	10 - 15	S235JR-S235JR	MAG	2	C			100	100
9	304039	FW	a3	101 - 102	10 - 15	S235JR-S235JR	MAG	3	C			100	100
10	304039	FW	2x a5	101 - 104	10 - 25	S235JR-S235JR	MAG	5	C		30	100	100
11	307045	BW	3x - V	105 - 105	6 - 6	S235JR-S235JR	MAG	11	C		30	100	100
12	436206	BW	X	1 - 2	25 - 25	S235JR-S235JR	MAG	6	C		50		100
13	102225	BW	4x - K	113 - 109	25 - 25	S235JR-S235JR	MAG	7	C		50		100
14	102225	FW	a4	114 - 101	15 - 10	S235JR-S235JR	MAG	4	C				100
15	102225	FW	a4	116 - 105	6 - 6	S235JR-S235JR	MAG	4	C				100
16	102225	FW	a4	113 - 105	25 - 6	S235JR-S235JR	MAG	4	C			100	100
17	102225	FW	a5	108 - 105	10 - 6	S235JR-S235JR	MAG	5	C			100	100
18	102225	BW	1/2V	103 - 102	8 - 8	S235JR-S235JR	MAG	8	C				100
19	102225	FW	a4	104 - 105	6 - 6	S235JR-S235JR	MAG	4	C				100

Legend:

Weld No. - This number is marked in drawings, where are welds.

Weld Type - Types of welds - FW or BW

Marking of welds - Type of welds (a3 - fillet with size 3, 1/2V, V, X, K)

Welded positions - Positions on drawing, which we weld

Thickness t1/t2 - Thickness of materials during welding

Quality level - Quality level of welds according to rule EN ISO 5817 (B, C, D)

Control % - Weld is control % according to specification - MT (Magnetic testing), PT (penetrant testing), VT (Visual testing)

FW - Fillet weld (a2,a3, a4, a5)

BW - Butt weld (1/2V, V, X, K)

Welders stamp - Welders mark stamp near to weld.

Fig. 58 Welding map (page 1/2)

Rolls-Royce

Welding map

Rolls-Royce

according to specification for production DR 976/17 and rules EN 287-1, EN ISO 9692-1, EN ISO 15614-1, EN 473, EN ISO 5817

Project: Lubr.oil sump B35:40V 16AG

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Welding parametrs											Control %		
Weld No.:	Drawing No.	Weld type	Marking of welds	welded positions	thickness t1/t2 (mm)	Grade of material	Welding Method	WPS No.:	Quality level	Welders stamp	MT %	PT %	VT %
26	305968	FW	a3	103 - 101	18 - 10	S235JR-S235JR	MAG	3	C			100	100
27	431950	BW	V	1 - 2	Ø76,1 - 2,9	S235JR-S235JR	MAG	10	C			100	100
28	431950	BW	V	2 - 3	Ø76,1 - 2,9	S235JR-S235JR	MAG	10	C			100	100

Legend:

Weld No. - This number is marked in drawings, where are welds.
Weld Type - Types of welds - FW or BW
Marking of welds - Kind of types welds (a3 - fillet with size 3, 1/2V, V, X, K)
Welded positions - Positions on drawing, which we weld
Thickness t1/t2 - Thickness of materials during welding
Quality level - Quality level of welds according to rule EN ISO 5817 (B, C, D)
Welders stamp - Welders mark stamp near to weld.
Control % - Weld is control % according to specification - MT (Magnetic testing), PT (penetrant testing), VT (Visual testing)

FW - Fillet weld (a2,a3, a4, a5)
BW - Butt weld (1/2V, V, X, K)

Fig. 59 Welding map (page2/2)

3.5 Reports for non-destructive testing

All welds after welding has to be check by non-destructive inspections.Welds has to be controled these inspection:

Visual inspection (VT)

Magnetic inspection (MT)

Penetration inspection (PT)

Tab. 14 Inspection of welds – Control %

Method	Extent of inspection	Execution
Visual testing	100% of welds	EN 970 / ISO 17637
Penetrant testing EN ISO 17638	All welded joints that may cause oil leakage	EN 571-1 ISO3452-1
Magnetic testing	30% of all cross frames and outsider ribs.50% of welds where connected plates (flange)	EN ISO 17638

In table 15 are acceptance levels for non-destructive inspection of welds.These levels has to be writed in reports from non-destructive inspection.

Tab. 15 Acceptance levels

Method	Extent of inspection	Execution
Visual testing (VT)	EN ISO 5817	Level C
Penetrant testing (PT)	EN ISO 23277	Level 2
Magnetic testing (MT)	EN ISO 23278	Level 2

Rolls-Royce	VT	**INSPECTION VISUAL REPORT** According to ČSN EN ISO 17637	**Number:**

Customer:	ROLLS-ROYCE MARINE	**Order No.:**	
Component:	GAS Engine B35:40V 16AG	**Place of inspection:**	
Part:	Oil sump	**Drawing No.:**	102225
Name:	--	**Material:**	S235 JR
Pcs.:	1	**Drawing Position:**	AS PER DRAWING
Evaluation acc. to:	EN ISO 5817	**Level of quality:**	C

Range of examination	100%	Testing Standard	ČSN EN ISO 17637	☐	After Machining
Testing Metod	☒ Direct/ ☐ Indirect	Measuring tools:	Weld Scale	☒	After welding, sandblasting
Illuminance	500 lux	Welding technique Nº		☐	After P.W.H.T
Luminary	Daylight	Tools – equipment:		☐	No or before P.W.H.T.

FOUNDED FAULTS
Note:

☒	**No indication to record**	☐	**Indication to record**		**Enclosed No.**
☒	**Accepted**	☐	**Accepted after repair**	☐	**No accepted**

Operator: **LEVEL 2**	**NDE test room chief:**	**Inspection agency:**
Name:	....	
Certificate No .:	....	
Date/ sign.	....	

Fig. 60 Report for visual inspection (VT)

Rolls-Royce	MAGNETIC PARTICLE TEST REPORT	No.

Customer: Rolls-Royce	Order No.
Component: GAS ENGINE B35:40V 16AG	Part No. --
Part: OIL SUMP	Drawing No. 102225
Pcs. 1	Material S235JR0
Specification ČSN EN 17 638	Evaluation acc. to ČSN EN ISO 23278 2x

NDE subject	Range of Examination: To I &T plan /Dle I &T plánu		Exam. surface
☐ Base material	☒ **Outside surface**	☐ **Inside surface**	☐ Machining
☐ Welding edge	☒ No or before P.W.H.T.		☐ Sand blasting
☐ Root layer	☐ After P.W.H.T.		☒ Brushing
☒ Completed weld	☐ After P.W.H.T.		☐ Grinding
☐ Weld overlay	Temperature of the surface: 15 ° C		☐
☐ Cladding	Position – weld No.: AS PER WELDING MAP		

Technical data

Magnetization	Equipment	Examination medium: PFINDER CHEMIE 250 COLOUR FARBE 280	
☒ Yoke	Type UM8 HELLING	☐ Fluorescent	Field indicator
☐ Prod magn.	Type	☒ Colour	☒ Berthold
☐ Combined magn.	Type	☐ Dry	☐ ASME
Current	☒ ~ ☐ = ...2,4......... A	☒ Suspension	☐ ....
Note			

The requirements of the specification		No indication to record ☐	Indication to record ☐	Enclosure No.
☒ are fulfilled erfüllt. splněny	☐ fulfilled nicht erfüllt. are not nesplněny	☒ Accepted	☐ Accepted after repair	☐ No accepted

Operator LEVEL 2 ISO 9712 Name:	NDE test room chief	Inspection agency
Certificat No.:	Date/ Singnature	

Fig. 61 Report for magnetic inspection (MT)

Rolls-Royce	Surface crack examination record of welds Penetration report	Nr.: ---

Object	Order No.	Component	Drawing No.
GAS ENGINE B35:40V 16AG	---	Oil sump	102225

Part	Designation of exam.means	Material	Specification	Evaluation acc.to
---	STANDARD CHEK RED- WHITE Fa HELLING	S 235 JR	EN 571-1 II cd	ČSN EN ISO 23277-2x

Penetrant	Remover	Developer	Extent of examination
Nº 2	Nº 1	Nº 3	As per welding map

Penetration time		Time of evalution		Inspection result	
min.	hours .	After drying	After no penetration time	The requirements of the specification	
15	---	e	e	☐ are fulfilled	☐ are not fulfilled

Weld No.	Position	Note			
As per welding map	As per welding map	☐ No indication to record	☐ Indication to record	Enclosure No.	
		☐ Accepted	☐ Accepted after repair	☐ No accepted	

Operator	Date	Singnature	Certificate No.	Inspection agency
LEVEL 2 EN 473				

Fig. 62 Report for penetrant inspection (PT)

CONCLUSION

This bachelor's thesis is engaged with the welding of oil sumps for marine engines. The theoretical part is divided into two main parts. The first part of this thesis describes the marine engines and their sorting, the second part of this thesis is focused on the welding, welding methods, types of welds and non-destructive testing.

The practical part is directly aimed at the welding of oil sumps for marine engines B35:40V16AG. The welding map was created for own it's welding process and there was proposed a welding plan for the welding personal.

In the end of practical part there were suggested the protocols for non-destructive testing (visual report, magnetic report and panetration report).

All given targets of this bachelor's thesis were achieved successfully and the welding of oil tank for the ships engine block B35:40V 16AG can proceed in accordance with requested production standards and ISO standards.

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BIBLIOGRAPHY

[1]. BARTÁK, Jiří. *Učební texty pro evropské svářečské specialisty, praktiky a inspektory*. 1. vyd. Ostrava: ZEROSS, 418 s. ISBN 80-857-7197-7.

[2]. MALINA, Zdeněk. *Záklaní kurz svařování MIG/MAG*.6.vyd. Ostrava: ZEROSS, ISBN 80-85771-19-5

[3]. MINAŘÍK,Václav.*Přehled metod svařování*. Ostrava: ZEROSS, ISBN 80-85771-95-0

[4]. BARTOŠ, Jaroslav. *Základní kurz svařování metodou 111*. Ostrava: ZEROSS, ISBN 80-85771-77-2

[5]. BENATAR, Avraham. *Welding*. Munich: Hanser Publishers, c2001, 128 s. ISBN 1-56990-333-6.

[6] *Engines* [online]. [cited 19 May 2014]. Available from:

http://www.rolls-royce.com/marine/products/diesels_gas_turbines/index.jsp

[7] *Basic of the welding process* [online]. [cited 19 May 2014]. Available from:

http://www.fronius.com/cps/rde/xchg/SID-45977C55-CC097BC9/fronius_international/hs.xsl/79_811_ENG_HTML.htm#.U3nIJNJ_uHY

LIST OF ABBREVIATIONS

SCR – Selective Catalytic Reactor

rpm – Revolutions per minute

VTG – Variable Turbo Geometry

MCR – Maximum continous rating

MA – Manual welding

SA – Semiautomatic welding

ME – Mechanized welding

AU – Automatic welding

RO – Robotic welding

MMA – Manual metal arc welding

MIG – Metal inert gas welding

MAG – Metal active gas welding

TIG – Tungsten inert gas welding

MAPP – (methyl – acetylene – propane)

UT – Ultrasonic testing

MT – Magnetic particle testing

PT – Liquid Penetrant testing

RT – Radiographic testing

VT – Visual testing

LIST OF FIGURES

LIST OF TABLES