Education and Culture
Leonardo da Vinci

COURSE MANUAL: *STAINLESS STEEL TIG-WELDING*
MODULE 7

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MODULE 7

Objective.

To know and understand the dangers and the most important safety requirements when welding.
To understand the basic principals when using filler materials.
To know the background of corrosion and post weld treatment of stainless steels.

Extent.

- Electric shock
- Ultraviolet light and heat radiation
- Eye damages
- Burns and fire, prevent fire, fire extinguishing.
- Weld smoke.
- Breathing problems.
- Personal protective equipment and clothing.
- Prevent burns.
- Noise.
- Knowledge of specific laws and regulations.
- The purpose of filler materials and their function according to type (electrodes, wire, gas).
- Shield gas.
- Backside gas.
- Classifying filler materials.
- Storage, drying, and handling.
- The weld parameters' influence on the weld geometry.
- The effect of magneto blasting.
- Visual inspection.
- Anti corrosives.
- Corrosion types with stainless steels (pitting, crack corrosion, inter-granular).
- Corrosion caused by welding and environment.
- Treatment, grinding, brushing, staining.
- Heat treatment after welding: austernittic, ferritiske, martensittic, duplex (austernite-martensitte).

Expected result.

- Identify dangerous situations regarding electricity, humidity, AC, and DC.
- Identify health risks with weld smoke.
- Identify emergency exits labelling.
- Name relevant momentums for personal protective gear.
- Identify efforts to prevent burns.
- Identify efforts to prevent noise. Knowledge of laws and regulations.
- The purpose of filler materials and their function according to type (electrodes, wire, and gas).
- Shield gas.
- Backing gas.
- Classification of filler materials.
- Storage, drying, and handling.
- Perform visual control on a tig weld and consider the weld according to ISO 5817
- Describe the effect of magneto blasting.
- Describe the methods to avoid magneto blasting.
- Describe the different corrosion types.
- Describe the weldings significance to corrosion.
- Describe different methods for treatment; grinding, brushing, staining.
- Explain in short heat treatment after welding stainless steels.

Cleaning before welding.

The material to be welded must be cleaned before the welding can be completed. General instructions that may be followed are:

- The surface must be cleaned from grease moisture, scale and other pollutions in a distance of 75 mm on each side of the groove.
- During welding, each seam shall be cleaned carefully from slag.

For stainless and aluminum materials:
- For brushing and cleaning, use only tools used for stainless materials.
- By eventual grinding, the disc must not have been used for other materials than stainless.
- For removal of oxide, use staining paste.

Control during the welding.

During the welding, the welder must be in control of the work and check important parameters so the planned weld quality is achieved.

- Control of weld parameters.
  - Current.
  - Voltage.
  - Welding speed.
  - Gas flow, volume.
  - The contact nozzle's distance.
  - parameters for pulsing.

- Temperature measurements.
  - Pre-heating.
  - Temperature between the passes.

- Use and handling of filler materials.
  - Take care to follow the manufacturer's recommandations.
  - Take care to follow the company's procedures.

- Cleaning weld seams, shape and numbers.
  - Follow requirements in WPS or welding instruction.

- Weld sequence and welding position.
  - Follow requirements in WPS or welding instruction.

Control after welding.

Control after welding should include:

- Verification of control document.
  - Are all controls performed?
  - Are the data within acceptance criteria?

- Result of after-treatment.
  - grinding.
  - Other surface treatment like brushing etc.

- Non-conformances.
  - Report non-conformances.

Handling filler materials.

To give the weld the correct quality, the filler material must be handled according to the company's procedures and the supplier's directions. If not, the filler material may get a wrong characteristic and give a weld with unwanted result.

It makes sense to label the filler material regarding both to ascertain the kind of filler material, this may have its own color system, but also use a color code showing if the filler material has been re-dried or not.

For instance, the following is used:

- Filler material taken from storage with the supplier's labelling only.
- After first re-drying, the wire-end is marked green.
- After second re-drying, the wire-end is marked yellow.
- After third re-drying, the wire-end is marked blue.

Returning the filler material is done by the color code.

- The first meter of wire from spool is cut off and destroyed.

Repair of defects.

Repair of defects shall be performed by authorized personell only. Some main rules may be set up for repairs, but the company should have its own repair procedure.

- Defects are removed by carbon air gouging and grinding according to the company's procedures for this.

- The area for repair shall be cleaned and without pollutions.
- Igniting wounds outside the groove are grinned and controlled 100 % with MPI.
- Minimum repair length is 100 mm. When fractures, the repair length is the length of the fracture with 50 mm on each side in addition.

HES and welding.

When you are welding or complete a workpiece with grinding or degreasing, harmful dust and gases are created. If you breath particles and gas from weld fumes and grinding dust, it will irritate the respiratory organs.

Chronic diseases like asthma, bronchitis, and emphysema may have a connection with this. Weld smoke and grinding dust probably contributes to the development of these serious diseases. There are lots of indications that welders catch pneumonia easier than others.

When you weld, the work piece is heated. The heat releases material in the metal you are welding, the additive, paint, lacquer, etc. with which the metal is treated. You risk breathing these things in the form of weld fumes. How much weld fumes that is created and what it contains depends on the welding method, the filler material, what you are welding on, and how the metal is treated.

Take special care when you are welding on surface protected material. Paint and lacquer can contain dangerous materials like lead and isocyanate, and these are released when heated.

It is important that you are aware of what dangerous chemicals that are created when you weld, so you can protect yourself and avoid damage to your health.

At the end of Module 7 is a table showing some common substances, when they are created, and what damage they may cause over time. There you will also find an overview of several kinds of welding and their characteristics.

Three strategies for reducing the risks.

It is important to protect yourself against pollution and dangerous chemicals, but it is even better if the health risk can be avoided completely. Use of personal protective equipment is the last solution. First you should try to do some more fundamental with the problem:

1. Substitution.
   The sources of the pollutions are removed, so they are no longer a problem.
2. Ventilation.

Good ventilation and separate work operations reduces the problem.

3. Personal protective equipment.
   If substitution or ventilation can't solve the problem, it is important to use correct protective equipment.

Substitution.

Dangerous chemicals are not to be used if they can be replaced with chemicals less dangerous to the employees (substitution). You should also change the processes if possible to avoid or reduce the amount of dangerous pollutions. Plan the work so the welding can be performed in the safest possible way.

Go through the workshop and the fabrication processes step by step:

- Can the work be planned for as little welding as possible?
- Can there be used more environment friendly welding methods?
- Can the need for grinding be reduced?
- Can materials and grinding material be changed to reduce dust and give a less health risky dust?
- Can there be used methods for de-greasing giving less use of organic solvents?
- Are all chemicals and products used in the workshop really necessary?
- Can some chemicals be replaced with some less dangerous?

Check HES data sheets and information sheets for health risk and protective measures.

HES data sheet and materials file.

There shall be a materials file easily available on the work place. This shall include information about the dangerous materials you may come in contact with in your work there. All purchased chemicals shall have a health-, environment-, and safety data sheet. The data sheets are made by manufacturer or distributor, and they shall include all information necessary to consider health risks and protective measures regarding use, storage, and transport.

The data sheet shall be written in the local language, and has 16 paragraphs. These are especially important:

- 1) identifying the chemical and the responsible company.
- 2) regarding substance mixtures contents and classifying.
- 3) regarding the most important risks.
- 4) regarding first aid measures.
- 8) regarding exposure control and personal protective equipment.
- 9) regarding the chemical's physical and chemical characteristics.
- 11) regarding health risks.

There shall also be a **Data Sheet** available for wires and electrodes used for welding. The data sheet is made by employer and shall include much of the same information as the HES data sheet. Some suppliers also provide data sheets.

Ventilation.

General ventilation.

There shall be general ventilation in the work area. The necessary amount of air depends on the tasks performed, how much of the pollution can be removed by point fume extraction/process fume extraction, and how effective ventilation solutions we can achieve.

The general ventilation should be designed in a way that air is supplied into the detaining area at low speed and extracted over the ceiling.

Point fume extraction (process adjusted fume extraction).

Point fume extraction shall be used with both welding, grinding, and de-greasing/cleaning. Point fume extraction must be set in the correct position according to fume extraction method to work effectively.

By grinding, the fume extraction should as far as possible be integrated in the tool. At welding on open surfaces, there may also be fume extraction integrated in the welding gun, but this requires great accuracy so the shield gas is not disturbed. The best way to achieve a good fume extraction is to use self-bearing arms with fume extraction hood or a fume extraction nozzle with magnetic foot.

When welding, the pollutions will move upwards because of the temperature. The fume extraction must be placed so the pollutions are pulled away from the welder.

Point fume extraction from hot work can catch 50 - 90% of the pollutions when used correctly. There are three kinds of process fume extraction used: low vacuum, medium vacuum, and high vacuum. Low vacuum is the most used method.

For low vacuum, it is recommended fume extraction arms adjustable in all directions, amount of air 70 - 1200 m^3. We will then profit from the thermal effect which means a very high degree of capture while the shield gas is not touched, adjustment position 30 – 50 cm. Medium vacuum is used where there are especially large amounts of smoke and dust. The air speed is increased and adjusted to the desired amount. High vacuum is used where large flexibility is required. We can use smaller hose dimensions (38 - 50 mm) and use hoses up to 10 - 20 meters. Incorrect use will reduce efficiency drastically.

The use of fume extraction may increase the shield gas consumption some, and knowledge of correct adjustment is important. Training is necessary for correct use of all kinds of fume extraction.

Both ventilation- and fume extraction equipment need regular maintenance and cleaning. Routines for control and change of filters are necessary. The filter will gradually be filled, and the effect of fume extraction decrease.

Personal protective equipment.

In cases where it is impossible to remove health risks in other ways, it is important to use correct protection. The HES data sheet and the information sheet shall include recommendations on how to protect yourself. Remember that all personal protective equipment shall be CE-labelled.

The employer shall make sure that the equipment is properly cleaned, stored, and maintained. It shall be replaced when needed. If there is any doubt that the equipment gives sufficient protection, it shall be removed from use and be repaired or discarded.

Eye shields.

It is important to protect the eyes from sparks and metal chips from use of different tools. It can also be necessary tu use eye shields with etching fluids.

Remember to use eye shields protecting against weld flashes when welding.

Respiratory protection.

Respiratory protection is relevant in a lot of cases. It is important to use the correct kind and filter:

- With welding, it should be used respiratory protection with air supply or motor assisted respiratory protection with P2 or P3 filter combined with brown, yellow, and grey gas filter. The respiratory protection is used with weld shield.
- Dust mask must be used with all kinds of grinding. Use filter P2 or P3.
- Avoid breathing fumes from solvents. Use respiratory protection (whole or half mask) with filter against solvents.

The filter looses effect over time. Registrate the date when used the first time and change it in fixed intervals. You are then always sure that the filter protects correctly. The respiratory protection should be kept in a tight box or bag to avoid the filter catching solvents when not in use.

The employer must provide routines for regular control of the air purity.

Skin protection.

Protect your hands when working. Avoid skin contact with solvents and other chemicals, this can cause eczema and other harms to the skin.

Two types of protective gloves are relevant for welding:

- Regular working gloves.

- Heat isolating gloves.

Use working clothes or working apron without seams or pockets where weld sparks or red hot drops of metal can attach.

When purchasing gloves and clothes of flame resistant material, information must be privided in case the material is weakened by cleaning.

With de-greasing, it may be relevant to use chemistry gloves. It shall be in the HES data sheet what kind of gloves to use, meaning the material the gloves are made from.

The chemicals will penetrate the gloves over time. Therefore, it is important to change gloves in regular intervals. The same applies to work clothes: Dirty clothes should be changed right away – before the dirt penetrates the clothes to the skin. Do not wait until the end of working hours.

Precautions with welding on surface treated material.

Welding on surface treated materials can cause the surfacing chemicals to be divided and applied to the weld fumes. Welding on plumbiferous paint (lead primer) releases lead. Isocyanates og cyanides are created when welding on polyurethane covered surfaces. When welding on galvanized material, the fumes contain zinc. Welding on epoxy covered materials also emits dangerous substances.

- Remove the lacquer on the welding spot, at least 5 cm to each side. Also remove lacquer on the rear if possible.

Precautions when welding in tanks or narrow spaces.

There shall be made a safety verification (safe job analysis) before the work starts, and it shall exist a work certificate. This implies that risks are considered systematically and are followed up with necessary safety precautions.

Examples of works to be safety verified:

- Entering tanks, narrow spaces, pipelines, etc.
- Hot work on tanks, barges, etc.
- Work on systems in use (under pressure, under voltage, etc.).

Air contains 21 % oxygen. If there is more oxygen in the air, the danger of fire increases dramatically. If there is an oxygen-leak from hoses and connections, inflammable material may catch fire from the smallest spark.

To little air oxygen causes strangulation. Poisoning can also easily occur when health-risky substances from welding, solvents, etc. are concentrated in narrow spaces. With shield gas welding, (131-MIG, 135-MAG og 141-TIG) the most common protection gases are carbon dioxide (CO2) and argon (Ar), or as a mixture. The gases themselves are no health risk, but with leaks or open valves they can repress the air and cause strangulation in narrow spaces or hollows.

Poisoning from carbon monoxide may occur when welding with shielded electrodes in narrow spaces. This can happen fast!

In alle tanks or narrow spaces where there may be inflammable or dangerous fluids/gases – or too much/too little oxygen, precautions must be taken before work is started.

- Never enter contained spaces or pit holes before the room is ventilated and the oxygen level controlled.
- Never enter poorly ventilated narrow spaces or down in wells without respiration protection with fresh air supply.

Further requirements when entering tanks, pipes, and narrow spaces are:

- No one is to work in tanks/narrow spaces without supervision.
- A safety line shall be used if necessary.
- All gas hoses shall be pulled out at breaks and at end of working hours. This also applies to portable gas bottles.
- Hoses with splice(s) shall not be used.

Precautions for grinding.

Grinding dust irritates skin and mucous membranes, and it can harm the lungs. Parts of the dust is so fine it reaches all the way to the lungs and can cause life-long harm like asthma and chronic bronchitis. The risk depends on the material's chemical composition.

In addition, glowing metal particles can cause fire, and there may occur cut damages when the disc gets stuck.

Reducing the need for grinding, especially manual grinding, is the most effective effort. Much can be done to reduce the need for grinding. There is a lot of written material about this.

- Always use point fume extraction when grinding. Point fume extraction must be close to the source to be effective, and it should as far as possible be integrated into the tool. (See chapter 2 about ventilation).
- Use dust mask with all kinds of grinding. Use filter P2 or P3.

Precautions for de-greasing.

When you clean the metal, take care not to get splashes in your eyes or on your skin. Do not inhale fumes from the de-greasers, they often contain organic solvents.

By welding, remains of de-greasers containing chlorinated solvents (for instance trichlorideethane/tri) may be divided into very poisonous gases, for example fosgene.

De-greasers containing acid may develop hydrogen gas which may be explosive. It is very important with point fume extraction over the de-greasing to lead the gas away. It is also important not to weld

close by so the gas can ignite.

- Avoid inhaling solvent fumes. Use point fume extraction and breath protection.
- It is important to find alternatives that can reduce the use of solvents for de-greasing/cleaning. One possibility is to replace the solvents with de-greasers containing no or less organic solvents, for instance alkaline degreasers.

Actions against fire and explosion.

In conjunction with gas welding, there may occur fires and explosions. This especially applies to temporary work or when changing work locations.

- Check the equipment. None return valves shall be fitted.
- Oxygen couplings must not be oiled or greased. This may cause explosion.
- Remember to secure the bottles in upright position.

Danger of explosion from barrels and tanks.

Never use welding equipment to cut “empty” barrels. They may contain remains of inflammable fluids that may explode. Tanks, holds, and pipelines having contained inflammable or health risky substances must always be cleaned properly before you weld or do other hot work in or on them.

There shall be provided a work certificate before the work starts. This shall be issued by a person competent to do necessary precautionss.

For more information on fire and explosion risks, contact your local fire authoroty.

First aid.

If the accident has happened, it is important with a quick first aid response. What kind of first aid kit needed, depends on the kind of work you do.

Objects in the eye, weld blinks, and burns from sparks and hot metal is not uncommon. Equipment for eye washing is obvious, likewise equipment for treating fire damages and burns. Emergency shower and possible eye-washing shall be easy available.

Do a risk evaluation of the workshop. What can go wrong? What damage may occur? What first aid kit should be available?

HES data sheets have information on necessary first aid regarding the chemicals mentioned in the data sheet.

Consider:

- What can go wrong?
- What damage may occur?

- What first aid kit must be available?

Different kinds of welding.

Different kinds of welding have different characteristics and release harmful chemicals in different ways.

The table gives an overview over common welding methods and their characteristics.

Welding method	***Special characteristics***
Arc welding with shielded electrodes – 111-MMA (Manual metal arc welding)	When welding with shielded electrodes, it is created smoke containing metal-mixtures from base material and the electrodes, for instance iron and manganese. It is created nickel and chromium 6 when welding stainless and acid-resistant steel. The method gives a lot of weld fumes, nitrate gases, carbon monoxide, and some ozone. The type of metals there are in the fumes depend on the base material and the filler material: When welding stainless/acid-resistant steel, the smoke contains chromium 3 and nickel.
131- MIG (Metal inert gas welding) and 135-MAG (Metal active gas welding)	With CO2-welding on steel, the massive wire is copper coated, and releases copper into the fumes. Welding on iron and all kinds of steel gives manganese in the fumes. Welding on aluminum, copper, and nickel gives these materials in the fumes. There are created a lot of ozone and some nitrate gases with this kind of welding.
141-TIG - GTAW (Gas tungsten arc welding)	Welding stainless/acid-resistant steel may give chromium 3 and nickel. If the tungsten-electrode is alloyed with thorium, grinding the electrode may cause emission of radioactive dust.
3-Gas welding	Gas welding creates nitrate gases and CO2.

Laser welding	With laser welding, light in the ultra violet, visible, and infra red spectre is created. The method is known by high energy density with little heat spreading in the base material. There may be created harmful fumes depending on the base material's composition.
15- PW (Plasma Welding)	With plasma welding, ozon and nitrate gases are created. In addition, chromium 6 and nickel are created when welding stainless/acid resistant steel.
12-Powder arc welding	Flux core wire filled with alloy elements like chromium or manganese creates little fumes, but it may still be harmful. This also applies to massive wire where the alloy elements are in the wire metal. Fumes created from alloyed electrodes with a coating will also contain elements from the core's alloy material. The method is environment friendly because it creates little harmful pollutions, but refilling the powder container may give dust problems.

Overview over harmful chemicals.

This table gives an overview over some common substances, when they are created and what damage they can give over time.

Substance	***Created by***	***Health risk***
Aluminum dust	Grinding different alloys where aluminum is one component.	Irritation of the respiratory organs, asthma.
Lead	Welding and grinding material treated with certain kinds of paint. Mostly with older iron constructions coated with lead primer.	Harmful effect on blood and nervous system. With pregnancy: Embryo damage and abortion.
Cyanides	Welding and grinding on lacquer coating containing polyurethane.	Cyanides are extremely poisonous.
Epoxy	Welding and grinding on surface.	It may be created destructive products harmful to breath.

Fosgene	Welding on materials de-greased with for instance trichlorethane (tri).	Fosgene is very poisonous and etching. Low concentrations (ca. 5 - 10 ppm) are slightly irritating. High concentrations are etching the lung tissue and give fast death by strangulation.
Isocyanathes	Welding and grinding on or by polyurethane foam.	Irritates the eyes, airways, and skin. Asthma and bronchitis. Eczema.
Iron – iron oxide	Welding or grinding iron and steel.	Increased production of hard tissue in the lungs, sideroses (iron lung). Sideroses can give a light cough, but is not believed to give serious damage.
Carbon monoxide (CO)	May occur where carbon dioxide (CO_2) is used as shielding gas for the welding. Welding in narrow spaces with coated electrodes.	CO ties easier to the blood cells than oxygen, causing a lack of oxygen to the cells. The symptoms vary with concentration and duration, from tiredness and reduced concentration, to headaches, dizziness, disturbed heartbeat, loss of consciousness, and death.
Chromium	Welding and grinding stainless steel.	Irritated respiratory organs, allergic eczema, bronchitis, “dust lung”, lung cancer, mucous membrane in the nose.
Manganese	Welding and grinding most kinds of steel.	Damage to nervous system, especially trembling.
Nickel	Welding and grinding stainless steel.	Irritation in respiration, mucous membrane in nose, allergic eczema, chronic infections in airways, cancer in lungs, nose, and throat.
Nitrate gases – nitrogen oxide (NO) og nitrogen dioxide (NO_2)	Created at high temperatures – especially by welding with gas protection (MIG, MAG), plasma welding and gas welding. NO is often transformed to NO_2	Is etching on mucous membranes. Irritating airways, reduced lung function. NO2 can cause lung oedema at short, but higs exposure.
Organic solvents	Fumes from cleaning work pieces.	Eczema, headaches, loss of memory, concentration problems, indolence, depressions, change of personality, increased aggression.
Ozone	Especially created by TIG-	Low concentrations: A stitching/burning feel

	welding, but also some with MIG- and MAG-welding.	in the throat, chest pains, breathing problems. High concentrations: lung oedema.
Zinc – zinc oxide	Welding and grinding galvanized material.	Irritation in nose and throat. Zinc fever or metal fever. The symptoms look like influenza, but they only last 24 hours.