1.

Gas Welding
Although the oxy-acetylene process has been introduced long time ago it is still applied for its flexibility and mobility. **Equipment for oxyacetylene welding** consists of just a few elements, the energy necessary for welding can be transported in cylinders, Figure 1.1.

**Figure 1.1**

1. oxygen cylinder with pressure reducer
2. acetylene cylinder with pressure reducer
3. oxygen hose
4. acetylene hose
5. welding torch
6. welding rod
7. workpiece
8. welding nozzle
9. welding flame

**Figure 1.2**

Process energy is obtained from the exothermal chemical reaction between oxygen and a combustible gas, Figure 1.2. Suitable combustible gases are \( \text{C}_2\text{H}_2 \), lighting gas, \( \text{H}_2 \), \( \text{C}_3\text{H}_8 \) and natural gas; here \( \text{C}_3\text{H}_8 \) has the highest calorific value. The highest flame intensity from point of view of calorific value and flame propagation speed is, however, obtained with \( \text{C}_2\text{H}_2 \).
C$_2$H$_2$ is produced in **acetylene gas generators** by the exothermal transformation of calcium carbide with water, Figure 1.3. Carbide is obtained from the reaction of lime and carbon in the arc furnace.

C$_2$H$_2$ tends to decompose already at a pressure of 0.2 MPa. Nonetheless, commercial quantities can be stored when **C$_2$H$_2$ is dissolved in acetone** (1 l of acetone dissolves approx. 24 l of C$_2$H$_2$ at 0.1 MPa), Figure 1.4.

Acetone disintegrates at a pressure of more than 1.8 MPa, i.e., with a filling pressure of 1.5 MPa the storage of 6m$^3$ of C$_2$H$_2$ is possible in a standard cylinder (40 l). For gas exchange (storage and drawing of quantities up to 700 l/h) a larger surface is necessary, therefore the gas cylinders are filled with a porous mass (diatomite). Gas consumption during welding can be observed from the weight reduction of the gas cylinder.
Oxygen is produced by **fractional distillation** of liquid air and stored in cylinders with a filling pressure of up to 20 MPa, Figure 1.5. For higher oxygen consumption, storage in a liquid state and cold gasification is more profitable.

The **standard cylinder** (40 l) contains, at a filling pressure of 15 MPa, 6 m³ of O₂ (pressureless state), Figure 1.6. Moreover, cylinders with contents of 10 or 20 l (15 MPa) as well as 50 l at 20 MPa are common. Gas consumption can be calculated from the pressure difference by means of the general gas equation.
In order to prevent mistakes, the gas cylinders are colour-coded. Figure 1.7 shows a survey of the present colour code and the future colour code which is in accordance with DIN EN 1089.

<table>
<thead>
<tr>
<th>Old condition</th>
<th>DIN EN 1089</th>
<th>Old condition</th>
<th>DIN EN 1089</th>
</tr>
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<tbody>
<tr>
<td>blue</td>
<td>white</td>
<td>grey</td>
<td>brown</td>
</tr>
<tr>
<td>oxygen techn.</td>
<td>blue (grey)</td>
<td>grey</td>
<td>grey</td>
</tr>
<tr>
<td>yellow</td>
<td>brown</td>
<td>red</td>
<td>red</td>
</tr>
<tr>
<td>acetylene</td>
<td>grey</td>
<td>grey</td>
<td>vivid green</td>
</tr>
<tr>
<td>grey</td>
<td>grey</td>
<td>grey</td>
<td>grey</td>
</tr>
<tr>
<td>argon</td>
<td>dark green</td>
<td>grey</td>
<td>grey</td>
</tr>
<tr>
<td>dark green</td>
<td>black</td>
<td>grey</td>
<td>grey</td>
</tr>
<tr>
<td>nitrogen</td>
<td>dark green</td>
<td>carbon-dioxide</td>
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</tr>
<tr>
<td></td>
<td>grey</td>
<td>grey</td>
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</tr>
</tbody>
</table>

Figure 1.7

The cylinder valves are also of different designs. Oxygen cylinder connections show a right-hand thread union nut. Acetylene cylinder valves are equipped with screw clamp retentions. Cylinder valves for other combustible gases have a left-hand thread-connection with a circumferential groove.

**Pressure regulators** reduce the cylinder pressure to the requested working pressure, Figures 1.8 and 1.9.

Figure 1.8
At a low cylinder pressure (e.g. acetylene cylinder) and low pressure fluctuations, single-stage regulators are applied; at higher cylinder pressures normally two-stage pressure regulators are used. The requested pressure is set by the adjusting screw. If the pressure increases on the low pressure side, the throttle valve closes the increased pressure onto the membrane.

The **injector-type torch** consists of a body with valves and welding chamber with welding nozzle, Figure 1.10. By the selection of suitable welding chambers, the flame intensity can be adjusted for welding different plate thicknesses.

The special form of the mixing chamber guarantees highest possible **safety against flashback**, Figure 1.11. The high outlet speed of the escaping $O_2$ generates a negative pressure in the acetylene gas line, in consequence $C_2H_2$ is sucked and drawn-in. $C_2H_2$ is therefore available with a very low pressure of 0.02 up to 0.05 MPa - compared with $O_2$ (0.2 up to 0.3 MPa).
A neutral flame adjustment allows the differentiation of three zones of a chemical reaction, Figure 1.12:

0. dark core:       escaping gas mixture

1. brightly shining centre cone:   acetylene decomposition
   \( C_2H_2 \to 2C + H_2 \)

2. welding zone:        1\textsuperscript{st} stage of combustion
   \( 2C + H_2 + O_2 \) (cylinder) \( \to 2CO + H_2 \)

3. outer flame:   2\textsuperscript{nd} stage of combustion
   \( 4CO + 2H_2 + 3O_2 \) (air) \( \to 4CO_2 + 2H_2O \)

complete reaction: \( 2C_2H_2 + 5O_2 \to 4CO_2 + 2H_2O \)

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Figure 1.11
By changing the mixture ratio of the volumes $O_2:C_2H_2$ the weld pool can greatly be influenced, Figure 1.13. At a neutral flame adjustment the mixture ratio is $O_2:C_2H_2 = 1:1$. By reason of the higher flame temperature, an excess oxygen flame might allow faster welding of steel, however, there is the risk of oxidizing (flame cutting).

Area of application: brass

The excess acetylene causes the carburising of steel materials.

Area of application: cast iron
By changing the gas mixture outlet speed the flame can be adjusted to the heat requirements of the welding job, for example when welding plates (thickness: 2 to 4 mm) with the welding chamber size 3: “2 to 4 mm”, Figure 1.14. The gas mixture outlet speed is 100 to 130 m/s when using a medium or normal flame, applied to, for example, a 3 mm plate. Using a soft flame, the gas outlet speed is lower (80 to 100 m/s) for the 2 mm plate, with a hard flame it is higher (130 to 160 m/s) for the 4 mm plate.

Depending on the plate thickness are the working methods “leftward welding” and “rightward welding” applied, Figure 1.15. A decisive factor for the designation of the working method is the sequence of flame and welding rod as well as the manipulation of flame and welding rod. The welding direction itself is of no importance. In leftward welding the flame is pointed at the open gap and “wets” the molten pool; the heat input to the molten pool can be well controlled by a slight movement of the torch (s ≤ 3 mm).

### Gap Shapes for Gas Welding

<table>
<thead>
<tr>
<th>plate thickness range s [mm]</th>
<th>gap preparations</th>
<th>denotation</th>
<th>symbol</th>
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<tbody>
<tr>
<td>from</td>
<td>to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,5</td>
<td></td>
<td>flange weld</td>
<td>~ ~</td>
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<tr>
<td>1,0</td>
<td></td>
<td>plain butt weld</td>
<td>™ ™</td>
</tr>
<tr>
<td>1,0</td>
<td>4,0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,0</td>
<td>12,0</td>
<td>V-weld</td>
<td>v v</td>
</tr>
<tr>
<td>1,0</td>
<td>8,0</td>
<td>corner weld</td>
<td>o o</td>
</tr>
<tr>
<td>1,0</td>
<td>8,0</td>
<td>lap seam</td>
<td>_ _</td>
</tr>
<tr>
<td>1,0</td>
<td>8,0</td>
<td>fillet weld</td>
<td>_ _</td>
</tr>
</tbody>
</table>

Figure 1.15

Figure 1.16
In **rightward welding** the flame is directed onto the molten pool; a weld keyhole is formed \((s \geq 3 \text{ mm})\).

Flanged welds and plain butt welds can be applied to a plate thickness of approx. 1.5 mm without filler material, but this does not apply to any other plate thickness and weld shape, Figure 1.16.

By the specific heat input of the different welding methods all welding positions can be carried out using the oxyacetylene welding method, Figures 1.17 and 1.18.

When working in **tanks and confined spaces**, the welder (and all other persons present!) have to be protected against the welding heat, the gases produced during welding and lack of oxygen \((1.5 \% \text{ (vol.) } \text{O}_2 \text{ per } 2 \% \text{ (vol.) } \text{C}_2\text{H}_2 \text{ are taken out from the ambient atmosphere})\), Figure 1.19. The addition of pure oxygen is unsuitable (explosion hazard!).

A special type of autogene method is **flame-straightening**, where specific locally applied flame heating allows for shape correction of workpieces, Figure 1.20. Much experience is needed to carry out flame straightening processes.

The basic principle of flame straightening depends on locally applied heating in connection with prevention of expansion. This proc-
ess causes the appearance of a heated zone. During cooling, shrinking forces are generated in the heated zone and lead to the desired shape correction.

**Figure 1.19**

Safety in welding and cutting inside of tanks and narrow rooms

Hazards through gas, fumes, explosive mixtures, electric current

**protective measures / safety precautions**

1. requirement for a permission to enter
2. extraction unit, ventilation
3. second person for safety reasons
4. illumination and electric machines: max 42volt
5. after welding: Removing the equipment from the tank

**Gas Welding in Tanks and Narrow Rooms**

**Figure 1.20**

Flame straightening

first warm up both lateral plates, then belt

butt weld 3 to 5 heat sources close to the weld-seam

double fillet weld 1,3 or 5 heat sources