Resistance Projection Welding
Design, Calculation, Process Assurance

Descriptors: projection welding, resistance projection welding, welding, weld projection, round projection, ring projection, long projection

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Changes
The following changes have been made as compared to VW 01103: 2003-10:
- Section 3.1.1: Notes expanded
- Section 3.3.2: Notes under Table 3 added
- Section 4, 5, 5.2 and 6 expanded, Section 5.1 added
- Referenced standards updated
1 Scope
This standard is used for the design, calculation and workmanship of statically and dynamically stressed projection welded sheet steel structures and structures with auxiliary parts.

The method is referred to as "projection welding" below.

The scope of this standard includes (resistance) projection welding (code number 23 according to DIN EN ISO 4063) on single-shear projection welded joints and quality characteristics for process assurance of single-projection and multiple-projection welded joints.

The following basic regulations are based on experience with low to high degrees of mechanization and on test results, as well as on industrial standards and technical regulations, e.g. DVS 2905.

2 Procedure

2.1 Basic principles of projection welding
Projection welding is a resistance pressure welding method where large electrodes are used to join two components through the application of electrical current and force. One of the two parts generally includes a projection. This projection results in the current being concentrated at the joint. The projections are partially reshaped during welding as a result of the force exerted by the electrodes and the heat generated by the electrical current, producing non-removable connections at the points of contact in the form of a melted area in the joining plane, the so-called weld nugget. Around the weld nugget is a heat-affected zone. This connection is referred to as a projection welded joint.

One or more projections can be welded at the same time in a single processing step if the design and performance of the welding equipment allow this.

2.2 Definitions

2.2.1 Heat-affected zone (HAZ)
Base material in direct proximity to the joint that undergoes a microstructural change as a result of the thermal energy applied during projection welding.

2.2.2 Unaffected base material
Area of the base material that experienced no evident microstructural changes as a result of the energy applied during projection welding.
3 Requirements

To achieve the greatest possible design strength in accordance with the design goal while ensuring sufficient reliability and a favorable cost/quality ratio, every projection welding design must be appropriate for welding. The dimensions in the projection welding equipment and the electrode space requirement, as well as accessibility to the workpiece must already be taken into consideration during advance engineering.

The weldability depends on three influence variables

- Welding suitability (material)
- Weldability for service (design)
- Welding capability (manufacturing)

All three criteria are of equal priority for weldability, see Figure 1.

![Figure 1 – Schematic representation of the weldability of spot weld joints based on DIN 8528-1](image-url)
3.1 Materials (welding suitability)

Welding suitability is a material property. It is present if a projection welded joint that meets the requirements set according to the standards can be produced because of the chemical composition.

3.1.1 Estimation of the welding parameters

For a first estimation of the welding parameters of a joining task, it is recommended that a welding range diagram (time/current diagram) be prepared, in which the limit line for the minimum fused joint or nugget (spot) diameter is determined for a constant electrode force, Figure 2.

![Figure 2 - Basic course of a welding range for projection welding](image)

Explanation for the course in the welding range diagram:

During resistance spot welding of two or more sheets, the faying surface in the respective joining plane remains almost constant throughout the entire welding process.

When preparing a welding range diagram (time/current diagram), the welding current therefore must be slightly reduced if the welding times are increased when determining the 3.5 \sqrt{t} limit line so as to satisfy the minimum requirement for the nugget diameter (3.5 \sqrt{t} limit).

The course of the 3.5 \sqrt{t} limit line is negative in this case (course: from bottom right to top left); see also DIN EN ISO 14327.

The situation is different with resistance projection welding.

When a part (e.g. sheet) with a projection and a counter sheet are resistance projection welded, the faying surface increases by a multiple during the welding process.

The faying area between the projection and the counter sheet is small at the start of the welding process. If the welding time is extended, the projection sinks deeper into the counter sheet and the faying surface between the projection and the counter sheet increases in size many times over. If the welding time is extended, the welding current must also be increased in order to satisfy the minimum requirement for the fused joint or the 3.5 \sqrt{t} limit line for the nugget diameter. The course of the limit line is positive in this case (possible course: from bottom left to top right).
When welding only one projection, the welding current must be optimized in combination with the welding force and welding current time so that the required nugget diameter can be achieved, for example.

When welding multiple projections, the electrode force and welding current must be increased in accordance with the number of projections to be welded.

NOTE: In practice it is obvious that partial currents of different intensities may be generated, which lead to weld spatters, due to design- and system-specific conditions (tolerance of projection heights and electrodes, type of welding system, etc.). To avoid this, it is recommended to reduce the welding current by 30 – 40% and to weld with a current increase (2 periods) and a follow-up device. The appropriate parameters shall be determined in trials.

### 3.1.2 Microstructure/hardness

The chemical composition basically influences the microstructure, hardening, nugget formation and strength of the projection welded joint.

The less the material-related factors have to be considered in manufacturing and in design, the greater the welding suitability of a material within a material group.

All steels with a C content up to 0.25% (max. 0.3 %) are suitable for welding. In many cases, the carbon equivalent value (CEV) is used for determining the welding suitability (hardening) of unalloyed and low-alloyed steels.

According to DVS 2905, the following equation is valid for a first estimate of the hardening of the weld metal:

\[
CEV = C + \frac{Mn}{6} + \frac{(Cr+Mo+V)}{5} + \frac{(Cu+Ni)}{15}\ in\ \%  
\]

The hardness values in the nugget area increase in tandem with the carbon equivalent value.

The hardening tendency is mainly influenced by the following factors:

- the chemical composition of the steel
- the welding conditions selected on the basis of the sheet combinations and the related cooling times
- the design situation such as the mass of the components and heat conduction

However, high hardness values alone are not an indication that the load-bearing performance of a joint will be impaired. Table 1 provides information on hardening (hardness values of the base material in comparison with the hardness values of the weld nugget).

<table>
<thead>
<tr>
<th>Base material</th>
<th>Weld nugget</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV 1</td>
<td>HV 1</td>
</tr>
<tr>
<td>&lt; 120</td>
<td>&lt; 350</td>
</tr>
<tr>
<td>&gt; 120 ≤ 200</td>
<td>&lt; 450</td>
</tr>
<tr>
<td>&gt; 200 ≤ 300</td>
<td>&lt; 550</td>
</tr>
<tr>
<td>&gt; 300</td>
<td>&lt; 600</td>
</tr>
</tbody>
</table>

The values contained in this table apply exclusively to unalloyed and low-alloy steels in original (unshaped) state. The hardness values can be reduced through the use of suitable heat control when welding, for example a current program for reheating.
3.2 Weldability for service (design notes)

The projection welded joint is a connection of two parts directly at the weld joint by one or more weld projections. The parts involved are designated on drawings as an ASSY (welded assembly) or WGR (welding group).

Figure 3 to Figure 9 show examples of different projection shapes (not yet welded on):

Figure 3 – Circular projections formed by a non-machining operation

Figure 4 – Long projections formed by a non-machining operation

Figure 5 – Round projections formed by a non-machining operation

Figure 6 – Round projections formed by a machining operation

Figure 7 – Ring projections formed by a machining operation

Figure 8 – Cut projections

Figure 9 – Natural projections
3.3 Welding capability (manufacturing)

3.3.1 Dimensions of embossed projections

Table 2, Figure 10 and Figure 11 show dimensions for embossed projections according to DIN EN 28167.

<table>
<thead>
<tr>
<th>d₁</th>
<th>a</th>
<th>d₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>2.0</td>
<td>0.5</td>
<td>0.63</td>
</tr>
<tr>
<td>2.5</td>
<td>0.63</td>
<td>0.8</td>
</tr>
<tr>
<td>3.2</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>4.0</td>
<td>1.0</td>
<td>1.25</td>
</tr>
<tr>
<td>5.0</td>
<td>1.25</td>
<td>1.6</td>
</tr>
<tr>
<td>6.3</td>
<td>1.6</td>
<td>2.0</td>
</tr>
<tr>
<td>8.0</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>10.0</td>
<td>2.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Figure 10 – Projection for resistance welding

Figure 11 – Transverse microsection through an embossed projection

See Appendix A for information on projections used at Volkswagen.
3.3.2 Relationship between sheet thickness and projection diameter

It is recommended that the following three groups of projection diameters (see Table 3) be accepted according to the sheet thicknesses for the different applications and the required strength (which is determined by the seam strength and the material properties):

- **Group A:** Contains projections with small dimensions for tight spaces or minor embossing.
- **Group B:** Projections for standard applications, which normally require more space and greater embossing than those of group A.
- **Group C:** Projections with large dimensions for increased strength requirements where the space requirement or shape restrict the application or the use of multiple spots; normally used with high-strength steels.

### Table 3 – Projection diameter groups (according to DIN EN 28167)

<table>
<thead>
<tr>
<th>Sheet thickness $t$</th>
<th>Projection diameter $d_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
</tr>
<tr>
<td>$t \leq 0.5$</td>
<td>1.6</td>
</tr>
<tr>
<td>$0.5 &lt; t \leq 0.63$</td>
<td>2</td>
</tr>
<tr>
<td>$0.63 &lt; t \leq 1$</td>
<td>2.5</td>
</tr>
<tr>
<td>$1 &lt; t \leq 1.6$</td>
<td>3.2</td>
</tr>
<tr>
<td>$1.6 &lt; t \leq 2.5$</td>
<td>4</td>
</tr>
<tr>
<td>$2.5 &lt; t \leq 3$</td>
<td>5</td>
</tr>
</tbody>
</table>

**NOTE:** The thickness of the counter sheet must also be considered when selecting the group. Group A shall be selected for thin counter sheets, Group C for thick counter sheets.

3.3.3 Location of projection designations

The following definitions apply to the correct arrangement of the projections on the workpiece from a design and manufacturing point of view, Figure 12:

- Sheet thickness $t$
- Overlap $b$
- Edge distance $a$
- Edge distance $v$
- Projection distance $e_1$
- Row distance $e_2$
- Offset $X$

![Figure 12 – Designations for projection arrangement](image)

3.3.3.1 Sheet thickness $t$

When specifying the thickness of the parts to be joined, a distinction must be made between the sheet thickness $t$ (DIN EN 22553 "workpiece thickness") and the overall sheet thickness (specified as the sum of the individual sheet thicknesses).

Specifications in work instructions are generally assumed to be the individual sheet thickness; in the case of different sheet thicknesses, the specification is assumed to be for the thinner sheet. The projection is generally embossed into the thicker sheet.
3.3.3.2 Overlap b
The overlap b is measured as the width of the contact area normal to one edge of the overlapping sections.

3.3.3.3 Edge distance a
The edge distance a is the distance between the center of the projection and the nearest edge of the sheet without projections.

3.3.3.4 Edge distance v
The edge distance v is the distance between the center of the projection and the nearest edge of the sheet with projections.

3.3.3.5 Projection distance \( e_1 \)
The projection distance \( e_1 \) is the centre distance between two adjacent weld projections.

3.3.3.6 Row distance \( e_2 \)
With several rows of projections, the row distance \( e_2 \) is the distance between adjacent rows, referred to the centres of the projections.

3.3.3.7 Offset x
The offset x is the lateral shift in projection rows with the same projection distance and row distance.

3.3.4 Welding equipment
Information on welding equipment can be found in specification DVS 2907.
If the mains loads are going to be high, it is recommended that machines be prepared for a three-phase connection (direct current, rectifier, inverter).
Special attention must also be paid to the follow-up behavior of the electrode head since the head must follow the weld projection and continue to maintain the force as the weld projection undergoes a rapid collapse.
Heavy spattering can occur in systems that are too sluggish, for example because of excessive weight and/or friction.

Machines based on a C-frame design
Machines with a C-frame design are widely used because of the easy accessibility of the welding tool. It must however be noted that this design has a strong tendency to "bend upward", which means that the force and current distribution when welding multiple projections will be uneven. It may need optimization through the use of a suitable tool circuit and current control system.

Machines based on a portal design
Machines with a portal design have the advantage with regard to rigidity and hence offer even force distribution, which has a positive effect on the quality of the joint.
4 Calculation of the number of projections

See VW 011 05-1.

For the calculation of adequate strength, it must be considered that the specifications for the nugget diameter differ in resistance spot welding and resistance projection welding.

In projection welding, the nugget diameter depends on the selected projection diameter (see Section 3.3.2): 

\[ d_{\text{nugget}} = d_1 \]

In spot welding, the nugget diameter predominantly depends on the sheet thickness: 

\[ d_c = 3.5 \times \sqrt{t} \]

5 Process reliability/quality assurance

Each projection welded joint is characterized by the sum of its characteristic values and their manufacturing influences, which are evaluated according to the quality requirement using measurable and/or countable values as test characteristics.

The measurable values according to which the quality of an individual projection welded joint is evaluated are the tolerance values of the individual test characteristics of the spot weld geometry in relation to evaluation group B analogous to DIN EN ISO 5817.

The countable value according to which the quality of a multiple projection welded joint is evaluated is the test characteristic "number of weld projections" in the case of round projections.

The test sequence for standard production monitoring and the test methods (e.g. chisel test, microsection) shall be carried out based on Test Specifications PV 6702 and PV 6717, taking into account the specifications for resistance projection welding.

The quality of the joint is verified by checking the nugget and spot diameters and determining the shear tension force or the torque or cross tension forces.

The nugget and spot diameters and the weld zone area are determined in a destructive test. The nugget diameter is measured using a transverse microsection and the spot or slug diameter is determined by means of chisel testing, for example.

The forces are determined according to the information in Test Specifications.

A quality evaluation of the projection welding process requires an overall evaluation to be performed when first defining the welding parameters. This involves evaluating the nugget and slug diameters in a destructive test and, if applicable, checking further specifications (e.g. shearing forces, cross tension forces or torques).

5.1 Nugget penetration depth f

The weld nuggets are normally symmetrical. If there are any asymmetrical weld nuggets (sheet thickness / material influence, etc.), the welded joint is sufficient once a continuous fused-closed joint with a measurable penetration depth of \( f = 0.2 \) mm is created between the sheets involved.

Permissible penetration depths \( f = 0.2 \) mm shall be indicated in the drawing or specified in a component-specific test specification.

The weld quality and/or strength must be verified by means of a dynamic strength test and a microscopic examination.
5.2 Nugget diameter \( d_L \)

The nugget diameter \( d_L \) is the diameter of the area in the joining plane (vertical to the joint plane) of the workpiece parts that was molten during the welding process and is distinguished from the two base materials by its different (own) microstructure, Figure 13 and Figure 14.

![Figure 13 – Projection weld with the beginnings of a weld nugget](image1)

![Figure 14 – Projection weld with distinct weld nugget](image2)

If there is no weld nugget discernible in the transverse microsection, then the diameter of the continuous fused joint through the entire projection can instead be used as the minimum requirement for an acceptable weld, Figure 15. No separating line shall be visible. If the nugget diameter is smaller than the specification, this shall be agreed with the Design department and the value shall be entered in the drawing.

![Figure 15 – Projection weld with the beginnings of a continuous fused joint in the joining plane](image3)

The continuous fused joint shall be detected using microsections enlarged to \( > 100 : 1 \).

If the transverse microsection shows signs of ring welding (no fusion in the core), the projection weld in question shall be considered unacceptable.
Figure 16 shows a joint without continuous fused joint.

![Figure 16 – Projection weld with areas without bond (in the core)](image)

Measurement of the nugget diameter \(d_L\) and evaluation of the weld nugget for weld defects are carried out using metallographic testing (macrosection).

The nugget diameter \(d_L\) or the diameter of the continuous fused joint shall reach at least the size of the unwelded projection diameter \(d_1\), unless otherwise specified.

The nugget diameter required for the necessary strength or the diameter of the continuous fused joint shall be specified in drawings.

5.3 Weld point diameter \(d_P\)

The weld point diameter \(d_P\) is determined in a destructive test (usually a chisel test).

The fracture will be one of three types, depending on the quality of the joint:

- Shear fracture at the transition to the sheet with \(d_{PA}\) (symmetrical or asymmetrical), so-called “slug”
- Forced fracture with \(d_G\) (fracture in the entire joining plane)
- Mixed fracture (fracture in the joining plane with one area without fusion in the core)

The fracture type is dependent on the welding parameters and the thickness of the sheets to be joined.
5.3.1 Shear fracture at the transition to the sheet

With a shear fracture at the transition to the sheet, the average diameter $d_{PA}$ of the slug is determined, Figure 17, Figure 18.

![Diagram of projection weld with shear fracture at transition to the sheet]

Legend:
- $d = d_{PA}$ Spot diameter
- $d_1, d_2$ measuring points for $d_p$
- $d_3$ not measured

**Figure 17 – Projection weld with shear fracture at transition to the sheet**

The slug diameter (average diameter) should be at least the same as the projection diameter.

![Image of shear fracture with measurement points]

**Figure 18 – Shear fracture at the transition to the sheet as the result of a destructive chisel test with $d_{PA} = 5.1$ mm**

5.3.2 Forced fracture

With a forced fracture, the fracture area/diameter $d_A$ in the joining plane is determined, see Figure 19.

The fracture area/diameter must be at least the same as the area/diameter of the projection.
5.3.3 Mixed fracture

With a mixed fracture, in addition to the forced fracture portion (outer area) there will also be areas without bond, Figure 20, Figure 21. In the example, there is no fused joint in the core. This fracture type is classed as unsatisfactory (not OK) from a welding quality point of view.

The figure below schematically illustrates the shear diameters and the fracture in the joining plane.

Legend:
- \( d_H \) = Diameter of the adhesion zone
- \( d_K \) = Diameter of the core (unwelded area)

---

**Figure 19** – Weld with fracture in the joining plane (forced fracture)

**Figure 20** – Weld with fracture in the joining plane (mixed fracture)

**Figure 21** – Fracture profile of a joint with areas without fusion (in the core)
5.3.4 Gap size

There will generally always be a gap between the sheets (joining plane) because of the geometric conditions of the joining partners. The permissible gap size shall be determined by means of process testing.

5.3.5 Markings on the counter sheet

Due to the thermal load of the electrodes and the joining partners, craters appear on the contact surface of the counter electrode after a distinct number of welds. These craters lead to markings or in certain boundaries to raised areas on the counter sheet.

The Design Engineering departments shall determine or limit the requirements on the counter surface (contact surface, screw-mounting surface) with respect to raised areas due to projection collapses / craters.

NOTE: To avoid this disturbance, the tool life of the counter electrode shall be limited.

6 Overall evaluation

An overall evaluation shall be used to ensure that the quality of a projection welded joint is maintained across the entire manufacturing period.

An overall evaluation of a projection weld shall take place when:

– preparing a machine for delivery,
– performing first sampling and

when implementing parameter changes that are expected to result in a considerable change in the overall evaluation.

The overall evaluation shall include:

– nugget diameter \(d_L\) or diameter of the continuous fused joint (no "ring nugget") and
– spot or slug diameter (e.g. by means of chisel test)

The following are standard values for comparing nugget and shear diameters.

For round projections:

\[d_L \geq d_1\]
\[d_{PA} \geq d_1\]

\(d_1 = \) diameter of the unwelded projection
\(d_L = \) nugget diameter
\(d_{PA} = \) spot weld shear diameter

For ring or long projections:

\[F_L \geq F_B\]
\[F_{PA} \geq F_B\]

\(F = \) projected area of the projection (length x width)
Evaluation of a projection weld:

<table>
<thead>
<tr>
<th>Welding OK:</th>
<th>$d_L$</th>
<th>OK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_P$</td>
<td>OK</td>
</tr>
<tr>
<td>Torque/cross tension force</td>
<td>OK</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welding conditionally OK:</th>
<th>$d_L$</th>
<th>Not OK</th>
<th>Not OK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_P$</td>
<td>Not OK</td>
<td>OK</td>
</tr>
<tr>
<td>Torque/cross tension force</td>
<td>OK</td>
<td>OK</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Welding not OK:</th>
<th>$d_L$</th>
<th>Not OK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_P$</td>
<td>Not OK</td>
</tr>
<tr>
<td></td>
<td>$d_R$ (ring nugget)</td>
<td>Not OK</td>
</tr>
<tr>
<td>Torque/cross tension force</td>
<td>Not OK</td>
<td></td>
</tr>
</tbody>
</table>

The evaluation of pores in the weld nugget is carried out acc. to PV 6702.
The welding parameters shall be reviewed in the event of "conditionally OK" or "Not OK" result.
The torque or the cross tension force must also be determined according to VW 605 60 when evaluating projection welding of functional components (e.g. nuts or screws).
7 Drawing entries

For the dimensions b, e, v and a (see also Figure 12) the general tolerances according to DIN ISO 2768-medium apply.

Figure 22 shows the dimensioning and symbolic representation of round projections in assembly drawings and PDM drawings.

DIN EN 12345 contains further data and general principles for the definition of projection welded seams.

![Diagram of a projection weld](image)

**Figure 31 – Symbolic representation of a projection weld (example)**

NOTE 1: Symbol meaning according to DIN EN 22553:
The weld nugget diameter \( d_{L_{\text{min}}} \) must lie between sheets \( t_1 \) and \( t_2 \) in the joining plane.

NOTE 2: For the exact definition and transfer of position of the weld spots within the „Body“ process chain, the applicable requirements of CAD/CAM data in VW 010 59-1 are to be complied with.

NOTE 3: For technical reasons, the specification of the minimum nugget diameter \( d_{L_{\text{min}}} \) is necessary.
8 Referenced standards

VW 011 05-1 Resistance Spot Welding; Design, Calculation, Process Assurance; Uncoated and Coated Sheet Steels
VW 010 59-1 Requirements for CAD/CAM Data; Representation of Technical Characteristics
VW 605 60 Strength Test for Welded Joints of Weld Nuts/Welded Bolts; Projection Welds
PV 6702 Spot Weld Joints; Strength Testing of Steel Materials
DVS 2905 Projection Welding of Steels
DIN EN 12345 Welding - Multilingual Terms for Welded Joints with Illustrations
DIN EN 22553 Welded, Brazed and Soldered Joints – Symbolic Representation on Drawings
DIN EN ISO 4063 Welding and Allied Processes – Nomenclature of Processes and Reference Numbers
DIN EN ISO 5817 Welding – Fusion-Welded Joints in Steel, Nickel, Titanium and Their Alloys (Beam Welding Excluded) – Quality Levels for Imperfections
DIN EN ISO 6520-2 Welding and Allied Processes – Classification of Geometric Imperfections in Metallic Materials – Part 2: Welding with Pressure
DIN EN ISO 14327 Resistance Welding - Procedures for Determining the Weldability Lobe for Resistance Spot, Projection and Seam Welding
DIN EN ISO 14329 Resistance Welding - Destructive Tests of Welds - Failure Types and Geometric Measurements for Resistance Spot, Seam and Projection Welds

Other standards

DIN EN ISO 14554-1 Quality Requirements for Welding - Resistance Welding of Metallic Materials – Part 1: Comprehensive Quality Requirements
DIN EN ISO 14554-2 Quality Requirements for Welding - Resistance Welding of Metallic Materials – Part 2: Elementary Quality Requirements
DIN EN ISO 14270 Specimen Dimensions and Procedure for Mechanized Peel Testing Resistance Spot, Seam and Embossed Projection Welds
DIN EN ISO 14271 Vickers Hardness Testing of Resistance Spot, Projection and Seam Welds (Low Load and Microhardness)
DIN EN ISO 14272 Specimen Dimensions and Procedure for Cross Tension Testing Resistance Spot and Embossed Projection Welds
DIN EN ISO 14273 Specimen Dimensions and Procedure for Shear Testing Resistance Spot, Seam and Embossed Projection Welds

1 In this section terminological inconsistencies may occur as the original titles are used.
Deviating from DIN EN 28167 and DIN 8519, the following projection dimensions are defined (Figure A.1 and Table A.1). They are matched with the associated tools (stamps and dies) according to operating equipment standard 39 V 1252.

<table>
<thead>
<tr>
<th>Round projection</th>
<th>Parallel sheets$^{1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Long projection</th>
<th>Sheets normal to one another$^{1)}$</th>
</tr>
</thead>
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<td></td>
<td><img src="image2" alt="Diagram" /></td>
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<table>
<thead>
<tr>
<th></th>
<th>Parallel sheets without edge distance$^{1)}$</th>
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<tbody>
<tr>
<td></td>
<td><img src="image3" alt="Diagram" /></td>
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1) Sheets with different projection shapes cannot be welded in the same processing step. The radius $r$ refers to the rounding on the tool (see 39-V-1252).

**Figure A.1 – Round and long projection dimensions**

The values contained in Table A.1 are valid for projections in sheets of equal or greater thickness with a carbon content $\leq 0.22\%$ and for even contact surfaces only. Exceptions, for example projections in the thinner sheet or on curved surfaces, smaller edge distances $e$ or smaller distances between the weld projections, as well as projections in alloyed sheets or sheets with a higher carbon content shall be agreed with the Body Planning department (welding technology) and if applicable determined by means of welding tests.

A tolerance of $\pm 1$ mm applies to the position of the projections. With formed parts, the dimensions shall be measured from a center line, hole or bent edge if possible.
Table A.1 – Dimensions in mm for different sheet thickness combinations

<table>
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<tr>
<th>Sheet thickness</th>
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<th>Projection Ø d₁ ± 0.2</th>
<th>Projection height ¹</th>
<th>Edge distance</th>
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<td>t₂</td>
<td>a</td>
<td>Tol.</td>
<td>v ≥</td>
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</tr>
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<td></td>
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<tr>
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¹ The difference in height between multiple projections in a single weld surface must not exceed 0.1 mm.