



Technical Specification

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Guidelines for UHV-Components at DESY

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1 General Information

1.1 Introduction

The effective and reliable operation of the vacuum systems of particle accelerators and their connected experiments is strongly related to obtaining and keeping ultrahigh vacuum (UHV) conditions. These guidelines for UHV-components at DESY contains rules and important information for the design, manufacturing, cleaning, handling and acceptance tests for UHV components to be installed in the DESY vacuum systems.

Deviations from these guidelines need to be clarified and accepted in advance by the DESY vacuum groups MVS respectively FS-BT.

1.2 Materials

Only UHV-compatible materials may be used for the manufacturing of vacuum components. Table 1 shows a list of UHV-compatible and incompatible materials. For components made out of austenitic steel, in the followings called stainless steel, for particle beam lines the content of nickel and the permeability of the material have to be considered. A different choice of material is only permitted after acceptance by the DESY vacuum groups before beginning the production.

	UHV-compatible materials	UHV-incompatible materials
Pure Materials	aluminum indium copper molybdenum silicon tantalum titanium tungsten	zinc cadmium lead
Stainless Steel	preferred types: 1.4429 1.4435 1.4404 (see also DESY material specifications Vacuum/002/2008, Vacuum/003/2008 and Vacuum 006/2009))	
Alloys	appropriate aluminum alloys AMPCO® 18 copper-beryllium DENSIMET® INCONEL® 600 or 718 Mu-Metal tin-bronze (e.g. CuSn 8) GLIDCOP®	alloys containing: zinc (e.g. brass) lead
Insulators	preferred types: aluminum ceramics macor* sapphire	organic materials (with a few exceptions)

Table 1: Selection of UHV-compatible and incompatible materials

* for applications in accelerators only after consultation with the DESY vacuum group MVS

1.3 UHV-compatible Design

- Choose designs which:
 - avoid virtual leaks (see also Annex A),
 - allow easy cleaning (e.g. avoid inaccessible volumes). This is of particular importance if a component has to be particle-free (see paragraph 3).
- It is not allowed to use brazed or welded joints to separate UHV from water.

2 Guidelines for UHV-Components

2.1 Manufacturing and Assembly

- Clean and degrease all machined parts before welding, e.g. by:
 - Prewashing, using a high-pressure cleaner to remove coarse contaminations, followed by washing with a suitable detergent.
 - Pickling - the pickling bath must be suited for the material and the pickling of UHV-components. The following rinsing with deionized water must be done after the pickling immediately. Do not pickle flanges. Possible etching methods:
 - Aluminum: Diluted NaOH, water rinse, neutralization ('Dekapierung')¹ with diluted nitric acid, water rinse, drying
 - Stainless steel: Water based mixtures of HF + HNO₃ or HF + H₂SO₄, water rinse, drying
- Welds must be completed on the vacuum side of the vessel only. In cases the welds have to be done from outside, the interior of the vessel must be formed with inert gas. Spillings inside the vacuum vessel and sink holes in the welding seam as well as sagging must be avoided. If necessary the welds have to be covered from inside and flushed with shielding gas. The welds have to be performed with full penetration.
- Tolerable welding procedures are: inert-gas tungsten-arc welding (TIG), inert-gas metal-arc welding (MIG), plasma, electron beam, and laser welding.
- Welds have to be brushed only with suited brushes, which are not contaminated by other materials.
- Brazed joints must be carried out under vacuum or shielding gas atmosphere without fluxing agent. The brazing solders used needs an approval by the DESY vacuum groups MVS respectively FS-BT in advance.
- Vacuum parts which will be assembled to larger units must be cleaned in advance. This has to be performed after mechanical manufacturing taking into account the UHV-cleaning requirements (see paragraph 2.2).
- Smaller units and welds, which are not accessible separately after mounting, need to be leak tested before final assembly.
- Contamination of the components must be avoided during the assembling or welding processes. Therefore:
 - Mounting and welding in a clean room separated from the mechanical manufacturing.
 - Wear clean lint-free gloves during assembly.
- Surface treatments such as glass-bead blasting or electro polishing must be approved by the DESY vacuum groups in advance.
- Necessary subsequent machining must be approved in advance by the DESY vacuum groups MVS respectively FS-BT. Only isopropanol might be used as cooling fluid. New cutting tools must be used. Standard cooling lubricants and cutting oils are not allowed.

¹ Neutralisation: After a surface treatment with alkaline solutions an additional treatment step needs to be done to avoid contaminations to subsequent processes. As an alkaline solutions are more difficult to remove than acids, a rinse or dipping in diluted acids (5–10% HCl or H₂SO₄) is necessary. With this a neutralisation of the surface can be achieved. The diluted acid can easily be removed with a water rinse.

2.2 UHV-compatible Cleaning

- Initial cleaning with e.g. high-pressure cleaner to remove coarse contaminations.
- Final cleaning in an ultrasonic bath: This means a bath with circulating hot deionized water containing a detergent to degrease the parts residue-free. The detergent must be matched to the material to be cleaned.
- Ultrasound operation e.g. 3 to 6 times for 5 min. interrupted by short rinsing periods (at least 1 min.)
- Examples for detergents are:
 - Stainless steel / copper: 1% Tickopur R33 at 50°C and 1.5% Elma Clean 115c at 65°C;
 - Aluminum: 2-5% P3 Almeco 18 at 65°C (removal of oxide).
- Thorough rinsing in hot (50°C) deionized water.
- Continuously dry in low-dust and hydrocarbon free atmosphere (e.g. dry nitrogen or air flow).
- Smaller parts can be cleaned alternatively in a laboratory washing machine.
- After cleaning:
 - Any contamination by e.g. lubricants, oils and / or grease is prohibited, even for leak tests.
 - For wiping of e.g. flanges use Isopropanol only.
- Handle clean parts on all vacuum surfaces with clean lint-free gloves only.

2.3 Vacuum Tests

All vacuum tests have to be performed using hydrocarbonfree pumping systems.

2.3.1 Leak Test

- The integral leak rate (sum of all leaks) has to be $\leq 1 \cdot 10^{-10}$ mbar·l·sec⁻¹.
- Units and welds which are no longer accessible after assembly need to be leak tested before assembling.
- The leak test can be performed using a standard leak detector or a residual gas analyzer. The required sensitivity and the correct function of the leak detector need to be verified in advance with a test leak.
- Components which are vacuum fired (see paragraph 4) and / or baked under vacuum need to be leak tested before and after the thermal treatment at room temperature.
- For the final leak test of vessels metal gaskets have to be used.

2.3.2 Content of Hydrocarbons and Desorption Rates

The outgassing of all UHV-components has to be free of hydrocarbons. Appropriate proofs have to be performed using a sufficiently sensitive residual gas analyzer, usually equipped with a secondary electron multiplier (SEM). Components are considered as hydrocarbon free when the two conditions are fulfilled:

the leak-free system reaches a total pressure below 10^{-7} mbar

the sum of the partial pressures of masses from mass 45 on to at least mass 100 is less than 10^{-3} of the total pressure.

For clarification examples of typical mass spectra up to mass 100 are shown in Figures 1 and 2. For documentation a mass spectrum (at least masses 0-100 amu) of each component is needed as well as a reference spectrum of the applied pumping system itself.

The integral specific desorption rate for baked components should be equal to or less than $5 \cdot 10^{-12}$ mbar·l·sec⁻¹·cm⁻². The method of verification has to be approved by the DESY vacuum groups.

2.4 Packing

- Fill vacuum vessels with dry nitrogen and seal off with blank flanges or seal flanges of the vessel with polyethylene plastic foil. Protect knife edges and sealing surfaces with covering caps.
- Alternatively, wrap the evacuated vacuum vessel in polyethylene plastic foil.
- Wrap and seal other components in polyethylene plastic foil.
- For transport movable components like bellows, rotating flanges, etc. need to be fixed.

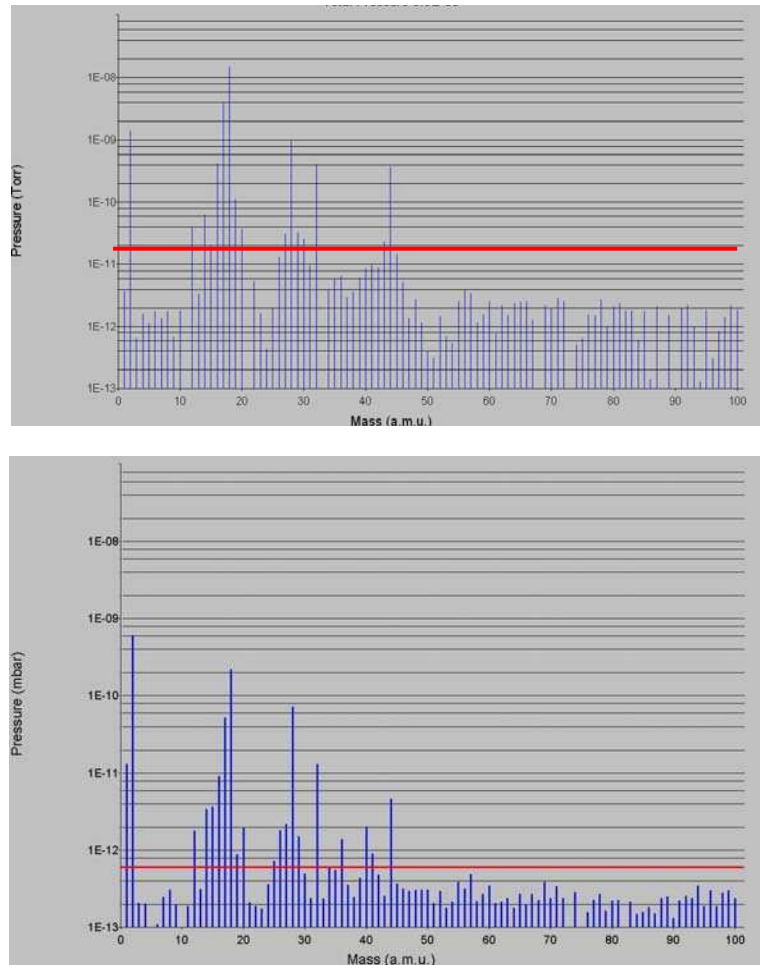


Figure 1: Examples of residual gas spectra that prove the absence of hydrocarbons. The red line marks 10^{-3} of the total pressure. In the lower example this value is already close to the noise level of the residual gas analyzer.

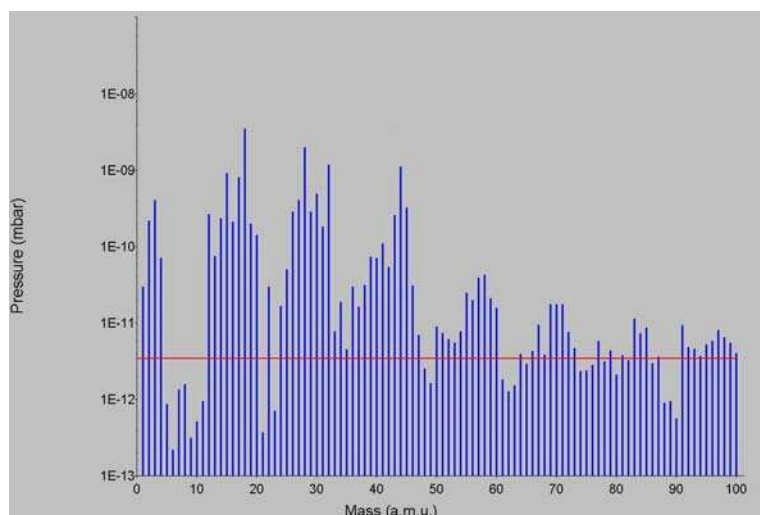


Figure 2: Example of a residual gas spectrum where hydrocarbons can easily be identified. The red line marks 10^{-3} of the total pressure. Many masses ≥ 45 are above the red line.

3 Particle-free UHV-Components

To obtain particle-free UHV-components the following guidelines must be followed:

3.1 Design

Designs have to be chosen that allow cleaning procedures in baths described in paragraph 3.2. It is essential e.g. to avoid inaccessible corners that makes it impossible to completely remove residues of cleaning liquids.

3.2 Cleaning and Assembly

- After a UHV-compatible cleaning (see paragraph 2.2) the following **additional** steps must be performed:
 - Ultrasonic bath in ultra-pure water and suitable detergent (e.g. Tickopur, see paragraph 2.2.) in a clean room class ISO 6 or better.
 - Ultrasound e.g. 3 to 6 times for 5 min. by short rinsing (at least 1 min.)
 - Examples for detergents are:
 - Stainless steel / copper: 1% Tickopur R33 at 50°C and 1.5% Elma Clean 115c at 65°C;
 - Aluminum: 2-5% P3 Almeco 18 at 65°C (removal of oxide).
 - Rinsing with ultra-pure water until a residual bath resistance of $> 12 \text{ M}\Omega/\text{m}$ is reached.
 - Drying in particle-free (better than class ISO 5) air.
 - Alternatively to these three steps: laboratory washing machine with ultra-pure water and suitable detergents; unloading in a room with class ISO 5 or better.
- Components that cannot be cleaned using ultrasonic and rinsing bath (e.g. mirrors, detectors etc.) have to be placed in a clean room in particle-free air flow (better than class ISO 5) for several hours before assembly.
- The absence of particles has to be controlled in a clean room class ISO 5 or better. Therefore the components will be cleaned with particle free ionized nitrogen. After 5 minutes using a gas throughput of 28 l/min there should be at maximum 10 particles/minute $\geq 0.3 \mu\text{m}$ be detected. Due to the multitude of components to be analyzed and their different geometries there is no standardized test set-up or specification of the procedure. Thus a suitable positioning of the particle counter and the chosen blow process for the components needs to be approved by the DESY vacuum groups.
- The assembly of components and the joining of vacuum parts has to be performed in a environment according to the specified clean room class.
- For the assembly in clean rooms only unlubricated and uncoated screws which do not cold weld must be used (e.g. titanium screws in components made of stainless steel).
- After the leak test vacuum components have to be vented with particle-free gas (nitrogen) and packed dust-tight for storage (see paragraph 3.3.).
- Gaps in flange connections need to be masked on the outside with clean room compatible adhesive tape.
- Loose parts such as bellows and rotatable flanges need to be fixed for transport.

3.3 Packing

- Fill vacuum vessels with particle-free nitrogen and fit with blank flanges, or seal vessel flanges with antistatic polyethylene plastic film and protect knife edges and sealing surfaces with particle-free covering caps. Wrap (see 2.4) flooded vacuum vessels in two layers of antistatic polyethylene plastic foil.
- The use of aluminum foil is not permitted.
- Flexible parts as bellows and rotatable flanges need to be fixed for transport.

4 Special Treatment of UHV-Components

4.1 Vacuum Firing

To reduce the hydrogen outgassing of UHV-components made out of stainless steel, vacuum firing at 950°C is required. In this case the vacuum flanges have to be made out of stainless steel 1.4429 ESR according to DESY specification Vacuum/002/2008. In this context the following needs to be taken care of:

- Put properly cleaned vacuum components (outer and inner surfaces, see paragraph 2.2.) into the vacuum furnace using appropriate gloves and support them if necessary.
- Firing of components according to vacuum firing cycle in Fig. 3.
- For vacuum chambers that do not fit into the furnace as a whole: produce adequately short pieces to be welded after the vacuum firing.
- Seal vacuum fired components with cleaned covers and pack in polyethylene plastic film if necessary.
- Perform final leak tests of vacuum fired UHV-components with metal gaskets only (see paragraph 2.3.1).

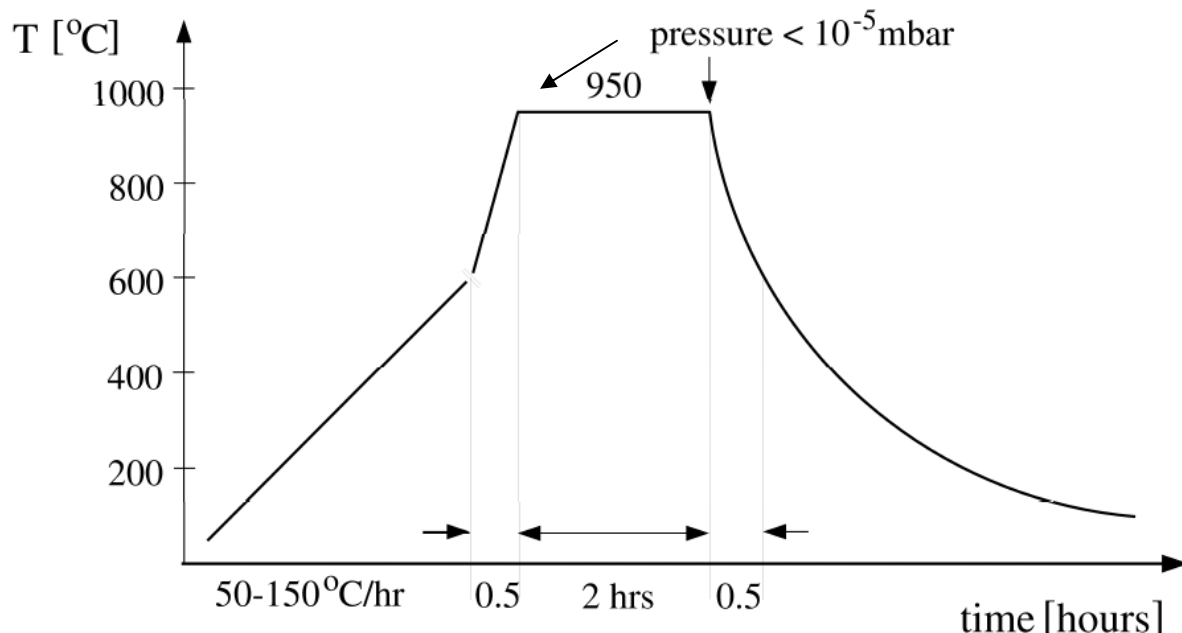


Figure 3: Standard heating cycle for vacuum firing of stainless-steel components according to CERN procedure. The pressure p must be $< 10^{-5}$ mbar during the whole heating process.

At DESY there is a vacuum furnace with the following dimensions:

- diameter x length = 750 mm x 2000 mm

At CERN there are vacuum furnaces with the following dimensions:

- diameter x length = 550 mm x 1500 mm
- 1000 mm x 5500 mm

4.2 Copper Plating / Plating of UHV-Components

All types of plating of UHV-components inside the vacuum have to be performed blister-free and need to conform to the requirements for cleanliness described in this guidelines.

For the copper plating of stainless-steel components applies in particular:

- The plating must endure further cleaning methods such as ultrasonic treatment and high-pressure rinsing if necessary, without blistering or debonding peel off.
- The plating must endure a heat treatment in a vacuum furnace for 1 hour at 300°C to control the quality of the copper plating without blistering or peel off.

5 Annex A

The design of screws and pins shall preferably include venting holes. If this is not possible, the following designs shown in Fig. 4 should be used.

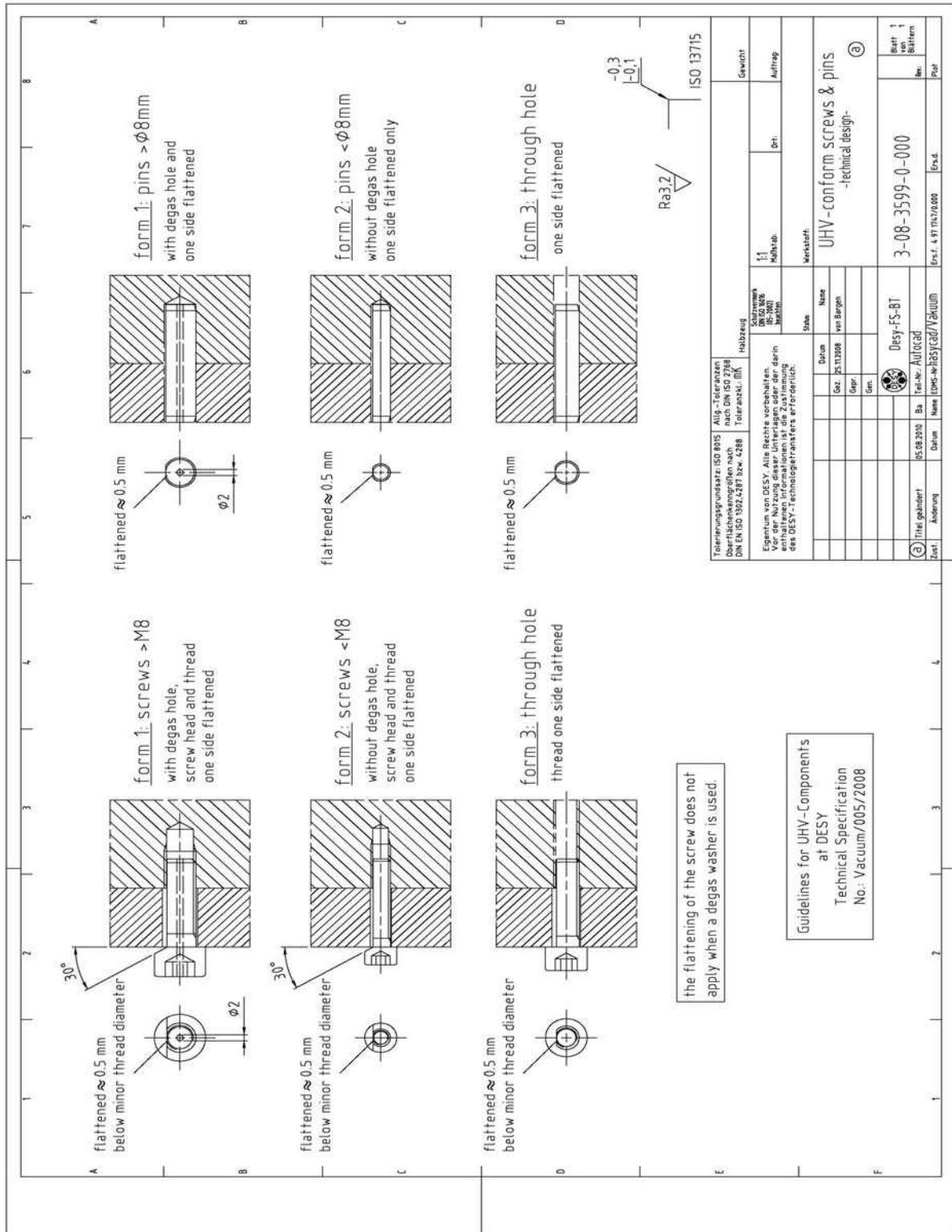


Figure 4: UHV-compatible designs of screws and pins.