

# ChemCar Safety Rules 2021

Rev. 1.0.2021



## 1. Scope

Process- and operational safety is always a core issue in chemical engineering and this is especially true if chemicals are handled in public areas. For that reason, a detailed safety analysis has to be provided for each ChemCar. All questions from “Leitfaden\_Sicherheitstechnik\_2021.pdf” or “safety\_guideline\_2021.pdf” have to be answered. Please refer to a safety officer of your institute for assistance. Safety audits will be performed by an audit team of the ChemCar organization.

## 2. Assistance

There is no restriction on requesting assistance for vehicle safety. Teams may request safety assistance from their faculty advisor, other faculty members, other universities, and professional practitioners in industry and elsewhere. All ChemCar students who handle chemicals either at their host institution or at the competition must understand the hazardous properties of these chemicals. Before using a specific chemical, safe handling methods must always be reviewed. Faculty advisers are responsible for ensuring that the equipment and instruction needed to work safely with chemicals is provided.

## 3. Audits

### 3.1. Paperwork Audit

An audit of your system design and safety compliance will be determined from the documentation your team provides. By 14.06.2021 the following items must be provided. Any delay in submission will result in exclusion from the competition. Have the completed safety analysis reviewed by your faculty advisor, to ensure that you have identified the major hazards and have controlled them properly. The following documents are part of the documentation:

- Certifications Page (template provided)
- Completed Safety analysis (according to Safety Guidelines)
- A quantitative design basis for pressure relieving load, if applicable (Chapter 6.2)
- Sizing calculations for a pressure relief device, if applicable (Chapter 6.2)
- Test procedure and results for a pressure relief, if applicable (Chapter 6.2)
- Pressure Vessel Testing Protocol (Appendix A)
- A picture of your vehicle. These pictures must be current. The entire car must be visible in the picture
- Material Safety Data Sheets and operating instructions for all chemicals used

**Note:** All documents should be combined to **one pdf-file**. Please send a scanned copy of your forms including original signatures to [chemcar@vdi.de](mailto:chemcar@vdi.de)

In order to keep the total amount of chemicals as low as possible there will be an additional deadline (16.08.2021) for the revision of the safety analysis concerning the total quantity of chemicals required for the competition.

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## 3.2. Physical Audit

During the competition, a safety officer will inspect each vehicle to insure that all of the safety requirements have been completed and that the vehicle will operate without risk to the operators, contest staff and spectators. If the audit team deems the vehicle safe to operate, then the vehicle will be given permission to compete. This permission is not automatic and must be earned using the guidelines/procedures outlined below. If a car is deemed unsafe, then it will not be given permission to compete. As the competition is virtual this year, the university's safety officer is responsible for ensuring safety on site on the day of the competition.

## 4. Disallowed Chemical Handling

### 4.1. Illegal Chemical Storage

Chemicals must not be stored in hotel rooms or other facilities not rated for chemical storage.

### 4.2. Illegal Testing of Vehicles

Testing of vehicles must only be done in a laboratory or other facility with chemical handling capability. Testing in hotel or dorm hallways, warehouses, or other facilities that are not designed for chemical handling is not allowed.

### 4.3. Illegal Disposal of Chemicals

All chemicals used at the competition site must be disposed of in a safe and environmental fashion following all regulatory measure.

## 5. Disallowed Vehicles

The following characteristics/observances will result in vehicles being disqualified:

### 5.1. Flames and/or smoke

All cars are restricted from having any open flames or emitting any smoke.

### 5.2. Liquid Discharge

Liquid may not be discharged under normal operating conditions. Liquid discharge is allowed during emergency relief situations to protect the equipment from rupture/explosion. This discharge must be collected in a containment vessel.

### 5.3. Exhaust

No harmful gas may be exhausted into the environment. Emissions of harmless material may occur, if safety analysis documents that only small<sup>1</sup> amounts are emitted without any risk being

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<sup>1</sup> Emission caps have to be agreed individual with the conference organization and depends on the conference venue

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exposed neither for persons nor for environment. Flammable or explosive gases must not leak into the atmosphere. The following material may be exhausted in small amounts:

- Nitrogen
- Carbon dioxide
- Oxygen
- Water vapor
- Hydrogen (expected quantity must be determined and evaluated. The hydrogen must be contained or diluted to an extent that the lower explosive limit is not exceeded.)

## 5.4. Open and/or Improperly Secured Containers

All containers on the vehicle containing chemicals must be securely attached to the vehicle to prevent the container from tipping over during the competition. The lid to this container must also be securely attached to the container and must be capable to preventing escape of the chemical during any phase of the competition, including an accident involving tipping over of the vehicle.

## 5.5. No Open Containers or Chemical Pouring at the Starting Line

No open containers or pouring of chemicals is permitted at the starting line. For mixing chemicals to start a reaction, it is suggested that a small holding tank with a valve or a syringe be provided on your vehicle to add the chemical at the starting line. The chemical is added either by pushing on the syringe, or flow through the valve. All containers, syringes, packets, etc. brought to the starting line must be properly labeled. All containers must have a secure lid and must be properly managed to prevent spillage.

## 5.6. No Liquid Hydrogen Peroxide Concentrations Greater than 30%

Liquid hydrogen peroxide is very unstable and difficult to handle at concentrations greater than 30%.

## 6. Pressure Related Restrictions

Pressurized vessels and vehicle components represent a significant explosion hazard due to the substantial energy contained in the pressure. Student teams must demonstrate through appropriate pressure measurements that the pressure during normal operations do not exceed equipment specifications. Teams cannot just assume that the pressures are low. Appropriate documentation must be available for the safety auditors. The student team must also demonstrate that the proper safety systems have been installed to prevent an explosion. The following restrictions apply to vehicles operating under pressure:

### 6.1. Maximum potential Energy

The product of chamber volume and pressure must never exceed 50 [bar \* L]



## 6.2. Pressure Requirements

If your vehicle has any pressures greater than 1 bar<sub>g</sub>, then the requirements listed below must be met. Further a pressure vessel test according to appendix A is mandatory for each pressurized vessel.

### 6.2.1. Pressure gauge

All vessels and equipment with pressures greater than 1 bar<sub>g</sub> must have a pressure gauge that reads from 0 bar to 2 times the maximum operating pressure.

### 6.2.2. Emergency Relief Device

If a pressure exceeding the maximum operating pressure can occur in any situation – including malfunction or maloperation - an industry standard relief valve that is appropriately sized, and is set at no more than 1.1 times the maximum operating pressure is required. The maximum operating pressure is typically defined as the pressure that would need to be generated to propel the vehicle 20 m and carry the maximum load.

The design scenario for the emergency relief device must be clearly stated. For example, state the amount of reacting material assumed, the concentration of reacting material, the initial temperature, and any consideration of operating error such as overcharge, use of wrong material, or wrong concentration, and, if so, what is the "design case" error. Also, the emergency relief system calculations must be included in the documentation.

### 6.2.3. Emergency Relief Device in Proper Location

The relief device must be properly located. For vessels, the relief valve must be located at the top of the vessel without any closeable valves between the vessel and the relief. The piping connecting the relief to the vessel must be of appropriate size. Consideration must also be provided for any entrained liquid or solids that might carry over from the vessel and prevent proper relief function or irregular emissions. Blow-off gas must meet the specifications named in chapter 5.3 and has to be treated in a nonpressurized vessel containing a proper adsorbent material for retention of any entrained substance.

### 6.2.4. Proper Management System to Prevent Over or Mis-Charging

Student teams must also be aware that the maximum operating pressure is dependent on the amount of reactant(s) charged. Students must demonstrate that proper management systems and controls are in place to insure that the proper quantity of reactant is charged to the vehicle. The following guidelines are recommended to insure proper charging of your vehicle: (1) The quantity to be charged should be agreed upon by all team members and must be supported by run data. (2) Measuring devices such as beakers and graduated cylinders should have the maximum permissible charge volume indicated. (3) At least one team member should observe both the measuring and charging operation to insure that it is done properly. (4) The car should be tagged once the charging is completed. This tag should remain until the run is finished.

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## 6.2.5. PVC rules

No PVC, cPVC or polyethylene terephthalate (PETE or PET) vessels or piping used for pressurized gases. All of these three types of plastics have microscopic defects that result in hoop stress failure.

## 7. Other potential hazards

### 7.1. Temperature Hazards

All exposed surfaces on your vehicle with temperatures greater than 60°C or under 0°C must either be insulated or covered to prevent contact with human skin.

### 7.2. Electrical Hazards

All wiring and exposed electrical components must be electrically insulated or covered to prevent the possibility of electrical shock or ignition of any component of a vehicle. Alligator clips and twisted wires represent both an electrical shock hazard and an ignition source for flammable vapors/liquids and are not allowed. Use more robust electrical connectors such as banana plugs or binding posts.

### 7.3. Mechanical Hazards

Guards must be present for any moving parts and pinch points. This includes gears, belts, linkages, actuator arms and any other part that may present a pinch point.

### 7.4. Biohazards

If any biological organisms are used during any phase of the design, development, operation, competition and preparation of your ChemCar, these biological hazards must be no more than biological hazard level 1 (also called biosafety level 1). This would include any bacterial, fungal, viral, or yeast organisms.

## 8. Competition day rules

Each team must use appropriate safety procedures and equipment in the chemical preparation area to insure against chemical exposures, spills, and mis-identification or mixing of chemicals. The following rules apply:

### 8.1. PSA

Each team must provide the appropriate personal protective equipment for use in the chemical prep area, as identified in their safety analysis, and must use them properly. This includes lab coats, safety glasses, gloves, face shields, and hearing protection. The personal protective equipment must be used appropriately by all team members depending upon the hazards encountered during the chemical preparation. Each team has to provide a sufficient amount of PSA, especially protective gloves (single use) for every team member.

### 8.2. Equipment

All containers with chemicals, including bottles, beakers, syringes and plastic bags must be properly labeled. This includes containers holding reactants, intermediates, products or mixtures.

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The label must minimally include the identity of the chemical(s), and the identity of the ChemCar team.

### **8.3. Handling**

All chemical pouring or mixing in the preparation area must be done with spill containment. A transportation tray for the ChemCar is mandatory. In order to facilitate the safe use of chemicals at the competition site, a designated area must be identified where teams can mix or prepare their chemicals. Teams that violate these safety rules jeopardize the continued operation of the ChemCar Competition and may be disqualified by the judges.

### **8.4. Documentation**

All safety documents, including safety concept, operating instructions and safety data sheets of all chemicals used have to be brought to the competition in printed version.

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## Appendix A: Pressure Vessel Test Protocol and Procedure

The test pressure is the maximum operation pressure (including all considered maloperation) multiplied with a security factor of 1.2. The manufacturer recommendations for the use of all pressurized components, especially plastic components, for a vehicle must be thoroughly researched and documented. The use of PVC, cPVC or polyethylene terephthalate (PETE or PET) for pressurized gases is prohibited in this competition. All of these three types of plastics have microscopic defects that result in hoop stress failure. If other types of plastic components are used for pressurized gases such as ABS (Acrylonitrile-Butadiene-Styrene), Nylon, or Teflon (PTFE), then the manufacturer's specifications should be consulted as well as evidence of proper/adequate hydraulic testing be conducted.

### Hydrotesting Procedure

Hydrostatic testing (using water) is the standard for pressure vessel testing. Pneumatic tests using air, nitrogen, carbon dioxide or other gases is not permitted due to the explosive nature of rapidly expanding gases.

### Pressure Gauge Requirements

The pressure gauge must have an indication range of not less than 1.5 and not more than 4 times the test pressure.

### Measurement of Vessel Deformation

During pressure testing a gauge must be configured to measure any deformation of the vessel. This gauge must be visible to the operator applying pressure. Use a dial gauge accurate to at least 0.02 mm. Ensure that the dial gauge is in good working condition and properly calibrated. To confirm that plastic yielding (expansion) has not occurred during pressurization, the vessel must be measured along its centerline in three directions (x, y, z) both before and after hydrostatic testing. Measurements shall be taken using a caliper or mechanical gauge accurate to 0.02 mm or less.

### Test Area

The test area should be restricted and barricaded. The vessel being pressure-tested should be oriented so that bolts, flanges, and other possible missiles point away from people and other equipment. All pressure tests must be conducted remotely. A barrier (sand bags, lumber) must be used to limit the potential from flying projectiles should the vessel fail the test. The barrier should be around all four sides of the vessel and should extend above the vessel.

### Test Procedure

Provide a vent to allow air to leave the vessel while filling with water. You might consider providing a bottom drain to remove water when the testing is done.

Fill the vessel with water and remove the air. Make sure the vessel is completely filled with liquid prior to the test.

First, increase the pressure to a maximum of one-half of the test pressure. Then, raise the pressure in increments of 0.1 times the test pressure until the test pressure is reached. The

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final test pressure must be held for a minimum of 30 minutes. Pressure should hold steady and not change significantly during the test. A change of 10% of the test pressure or 0.1 bar is significant. No water leaks or drips should be observed.

The pressure should then be lowered to the operating pressure of the vessel and held for a visual inspection of all joints and connections. No water leaks or drips should be observed.

Take appropriate vessel measurements, accurate to within 0.02 mm, both before and after testing to show that detectable plastic yielding has not occurred during pressurization.

## **Documentation of Test**

Provide the following documentation in support of the hydrotest.

- Identification of the vessel
- Volume of the vessel
- Planned operating condition (Pressure, Temperature)
- Planned test pressure
- Supporting calculations
- Date and time that test started
- Date and time that test was completed or failed
- Maximum pressure attained
- Chart of test-pressure sequence (optional)
- Test liquid
- External temperature of system
- Temperature of test liquid
- Measurements of Vessel Deformation
- Signature of the team advisor to certify the completion of the test.

## **Exclusion of Liability**

All information available in this document was compiled with the greatest possible care and control of its contents. However, we would ask your understanding for the fact that freedom from error cannot be guaranteed and that we take no responsibility for the current relevance, accuracy, completeness or quality of the available information.