ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

HVL High Voltage Laboratory

HVL Safety Concept

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replaces all previous versions

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1 Summary

Principle

Our common intention is to work at a safe and enjoyable workplace. We support each other not only on a technical basis but also with safety relevant issues. The safety culture should be lived in the group, and we hold regular discussions on best practice. The result is this general "*HVL Safety Concept*" and "*HVL Electric Safety*" concept, which are regularly updated.
These concepts apply to everyone who works at the facilities of the High Voltage Laboratory (HVL) of ETH Zurich (including students, interns and scientific guests). The philosophy and measures described herein shall reduce accident probability to the lowest possible level, while still enabling efficient working.
Each member of the HVL must confirm with their signature that they know and understand the contents of these instructions.

Validity

This document applies to all work in the laboratories of the HVL, the premises ETZ and ETL of the ETH Zurich. A complete list of rooms can be found in chapter 8. As far as possible, it shall also be applied to experimental activities of an HVL employee outside ETH Zurich.

Inspection Duty

After setting up **any** kind of test circuit or assembly, a check must be carried out by the responsible internal control person (e.g., laboratory manager or authorized inspector). A strict dual control principle applies (**4-eye principle**). The inspection duty applies to setups with certain associated risks, which are roughly quantified in section 2.1 ("roughly" means that this quantification does not exempt anyone from applying sanity check on their setup).

Instruction

The instruction of employees regarding application of the *"HVL Safety Concept"* is repeated and documented periodically at least annually. At the same time, general knowledge is taught on the subject of escape routes, emergency calls inside and outside the ETH, and how to behave in emergency situations (e.g., fire, accident, etc.). Briefings on operating instructions are carried out and documented individually according to the workplace and scope of work.

Responsible Behavior

The safety concept and the associated training instruction shall give maximum possible guidance for safe working in an experimental environment. However, it relies on the risk awareness and the critical mind of the users. The rules shall not relieve the users from critical thinking and regular sanity checks.

Reporting Obligation

Safety-relevant malfunctions or defects of test or measuring equipment are to be reported immediately to the laboratory manager. Ongoing tests must be interrupted and not continued until repair, control and release have been completed.

Manipulations, Modifications

By **no means** it is allowed to manipulate safety installations.

Work on house installation, such as repairs, modifications, or new installations, must not be carried out by HVL employees.
Repairs and modification of existing 400V/230V components and circuits may be carried out by HVL employees after prior consultation with the laboratory or group manager. It is to be decided on a case-by-case basis whether the works can be carried out by HVL employees or a qualified external company or authority.

Documentation

All safety relevant documents, i.e., concepts, training material, work instructions, training and maintenance evidence etc. are accessible on the HVL-NAS:
\\d.ethz.ch\groups\itet\eeh\hvl\fachgruppe-hvl\Safety_and_Work_Instructions

2 Occupational Safety

Research in the field of high voltage engineering is typically very interdisciplinary. Consequently, the regulations for occupational safety have to cover various disciplines. Furthermore, the highly flexible and non-standardized nature of the work at a research institution makes it often inconvenient to apply standard operating procedures from industry.

Therefore, experimental activities at HVL should be assessed through the generic approach for work safety:

1.) Risk Assessment	2.) Risk Mitigation	3.) Emergency Strategy

The **idea and goal** of risk assessment and risk mitigation are described in the following subsection. The **implementation** of the risk mitigation and the emergency strategy at HVL is then further described in dedicated chapters.

2.1 Risk Assessment

The basis of the risk assessment is the **awareness** that a certain activity may lead to injury or death – and therefore has a certain risk. The first and most important step of the risk assessment therefore consists of an objective description of the hazard. A list of possible hazards - without claim of completeness – can be found in Table 1 below.

Table 1: List of potential hazards in a high voltage laboratory

Type	Limit Values	Reference
Voltage	U_{AC} < 25 V - f < 500 Hz U_{DC} < 60 V f < 500 Hz	SN EN 50191 [1]
Current	Inductive Energy = 0.5×L×I² Value for energy limit below	SN EN 50191 [1]
Energy	300 mJ	SN EN 50191 [1]
Electric / Magnetic Fields	400 A/m, f = 50 Hz 10 kV/m, f = 50 Hz	SUVA [12] SUVA [6][7]
Weight/Load Handling	15 - 25 kg (without technical aid) 500 kg (incl. technical aid)	EKAS [8]
Noise	85 dB(A) continuous 120 dB(A) stochastic 1 hr sum 135 dB (C) Impulse	SUVA [9] SUVA [12]
Pressure	0.2 MPa absolute, 3000 bar × l (for usage of equipment) 0.15 MPa absolute, 50 bar × l (for construction of equipment) < 0.1 MPa absolute (if brittle materials are present, e.g., glass)	DGVV [16] DBV [17]
Light	Laser: > Class I Laser Products Ultra-Violet: Check wavelength and exposure time	SUVA [12]
Height	3 m	SUVA [11]
Mechanical Forces, Rotating Machines	Any non-enclosed rotating machine	
X-Ray	Any artificial ionizing radiation source	
Chemicals (Liquids/Gases)	Maximum allowed workplace concentration anything Labelled with Carcinogenic, Mutagenic, Toxic,	SUVA [12]

The afore mentioned hazards and combinations of these shall be as good as possible quantified with the probability of exposure and the severity of a potential accident. This leads to the risk classes as shown in Table 2 below.

Table 2: Risk Assessment matrix and corresponding classification of damage and probability. Adapted from SUVA [13] and [14]

Probability					
Frequent	4	3	2	1	1
Occasional	4	3	3	2	1
Infrequent	4	3	3	3	2
Improbable	4	3	3	3	3
Almost Impossible	4	4	4	3	3
	Minimal	Small	Medium	Severe	Very Severe

Damage

Damage	
Very Severe	Death
Severe	Serious permanent harm
Medium	Slight permanent harm
Small	Curable harm with incapacity to work
Minimal	Curable harm without incapacity to work

Probability	
Frequent	certain to occur in a short time
Occasional	certain to occur after some time
Infrequent	occurrence possible
Improbable	occurrence unlikely to occur
Almost impossible	so unlikely that the probability is almost zero

Further information about the risk assessment and detailed instructions for risk assessment can be found in SUVA [13] and [14].

2.2 Risk Mitigation

The aim of occupational safety at HVL is to perform any experimental activity in maximum a Class 3 environment, according to the risk classes in Table 2. To achieve this, the so-called STOP principle is applied:

1.) S: Substitute
2.) T: Technical Safety
3.) O: Organizational Safety
4.) P: Protective Equipment

Substitute: Before starting any kind of activity or experiment one may think if the same (or similar) knowledge can be gained by using a reduced scale setup and or any other kind of substituting a dangerous material/activity by something else.

The implementation of **technical and organizational safety** as well as **protective equipment** are in detailed explained in the following chapters.

3 Technical Safety

This section describes the technical measures undertaken to provide inherently safe experimental setups. Technical safety is always to be preferred towards organizational safety. Where applicable, the safety installations at HVL follow the SIL 3 standard (IEC 61508 [15]). The technical safety installation are based on the recommendations in SN EN 50191 [1], BGI 891 [2] and IEEE [4].

3.1 Philosophy

The technical safety installation shall make it impossible to work on or too close to energized equipment. The safety installation has to be able to interrupt all power supply lines of any kind of medium and discharge all energy storages of any kind of medium within a reasonable time[1]. It has to be able to fulfill this task also in the event of a complete energy supply loss. Further, the experiment shall be confined in order to physically separate the user from the hazard.

3.2 Implementation in the Lab

The implementation of this 'philosophy' is explained here at the example of a High Voltage Experiment. The technical elements and ideas shall be likewise applied to any other hazards mentioned in Table 1.

Depending on size, the confinement may be either a housing, a fenced area, or a Faraday cage – see example in Figure 1.

Figure 1: Example experimental setup: Complete confinement of experiment and associated dangers. Door with lock and surveillance

The integrity of the fence – i.e., its completeness and the status of the access door are supervised by a PLC-controlled safety device called "Base-Cube" or "PI-Cube" (HVL [18] and [19]). This device controls the interlock circuit, meaning it reads several input signals and only if all safety conditions are fulfilled, it releases the discharging installations and enables power flow. An example list of sensors and actors is shown below.

[1] no strict numbers are given here, and the time must be decided based on e.g. the time needed to enter the safety area after shut-down, the amount of energy stored and further relevant factors

Table 3: Sensors and actors forming the safety circuit

Sensor
Fence Integrity
Status Door
Emergency Stop
Manual Gnd Rod
Position automatic Earth Stick

Actor
Automatic Earth Stick
Door Lock
Power Supply: Frequency Converter
Power Supply 220/400V
Signal Lamps

The operating states of the experiment are listed in the table below. The safety device has to make sure that the operating states are visible.

Table 4: Operating states of safety installation

State	Lights	Meaning
Off	off	Setup Save and Shut-off Nobody working here
Green Ready	green	Setup is running Somebody working here Discharge switch closed Ground switch closed Main energy supply disabled
Red Ready	red	Setup is running Discharge switch closed Ground switch open Main energy supply disabled
Red Operate	red	Setup energized (or ready to be energized) Discharge switch open Ground switch open Main energy supply enabled
Error/Warning	Red and green Lamp blinking	Warning or Error State Accompanied by an acoustic warning sign

An example of such a signal lamp is shown in Figure 1, right hand side.

For experiments with intermittent hazards an additional acoustic signaling is recommended. Generic requirements are shown in Table 5.

Table 5: Overview of acoustic warnings

Status	
Low Tone, Intermittent	Setup energized and charging
High Tone, Continuous	Energy release immediately to happen

The type of sound may be chosen on an individual basis however, the following recommendations should be concerned:

- It should not sound like a commonly used signalisation e.g. doorbell. This will lead to confusion and a sense of amateurism.
- If the sound should act as a warning, it should not be too loud, and its power spectral density should not be distributed only in the 2kHz - 4 kHz range. Otherwise, this will lead to fatigue, and useless loss of focus of personal working in the perimeter.
- If the sound should act as an alarm, most of its power spectral density should be in the 2kHz - 4 kHz range in order to draw attention (e.g. baby cry, ambulance, alarm clock, ..)

4 Organizational Safety

Organizational safety ensures that technical safety is in place, and it further consists of a set of behavior rules in order to further mitigate the work hazards as described in Table 1. This includes but is not limited to the definition of trainings and instructions for the employees, definition of control procedures and necessary documentation for experimental devices.

4.1 Rights and Duties – Lab Hierarchy

In this section the different roles of the employees of HVL are defined and the associated rights and duties are explained. These serve as a basis for the **4-eye principle** (introduced in section 1, explained in detail in section 4.3) and the section 4.8 "**experiment design and setup**"

Group Manager

The group manager (GM) is the head of the High Voltage Laboratory (HVL) of the ETH Zurich and is responsible for the overall safety in the HVL laboratories. The GM is Prof. Christian M. Franck.

Laboratory Manager

The lab manager (LM) is appointed by the Group Manager and is responsible for the implementation and enforcement of safety in all laboratories of the HVL.

Further, the LM oversees the maintenance and safety of equipment and facilities (infrastructure) and the supply of (personal) protective equipment. He is supported by the AI, GM and the ETH departments "Operations", "Buildings" and "Safety, Security, Health, Environment (SSHE, German: SGU)". From SSHE perspective, the LM is the group safety responsible (GSR) and single point of contact for safety related topics. Further, he is the poison or laser officer of the group or delegates this task.

The LM is responsible for the training and instruction of the ER (see below) and supervises the trainings for the InP (Instructed Person, see below). The LM holds and maintains a list of all employees and workers at HVL indicating functions and responsibilities. The LM is Dr. Philipp Simka

Authorized Inspector

The authorized inspector (AI) is appointed by the GM and trained by the LM. The AI is in charge of specific trainings and maintenance tasks as defined in section 4.5 and 4.6 . The AI is Fabian Mächler.

Experiment Responsible

The experiment responsible (ER) is appointed by the GM or LM for individual test systems or types of facilities. The permitted activities are defined in the experiment specific documentation (see section 4.7).

The ER is entitled to delegate individual activities from their area of responsibility to an InP. However, the responsibility for a certain experimental setup always remains with the ER. ER are typically doctoral students or Post-Docs of the HVL group.

Instructed Person

An instructed person (InP) is working at a certain experimental setup. The InP is authorized to modify existing test systems or measuring equipment according to precise guidelines or test instructions, to perform routine tests according to specifications, or to change test objects with unchanged test circuit setup. The InP is instructed by the LM and the ER. Main responsibility for the work safety of the InP is with the ER. InP are typically further doctoral students that work on the same setup (per setup only one ER can be defined), bachelor or master students, interns or temporary lab staff.

4.2 Access Restriction

Access to all laboratories[2] of HVL is restricted to scientific/technical staff of the institute (incl. InP as defined in the previous section).

Visitors are allowed to access the laboratories of the HVL when accompanied by a member of staff (incl. InP).

Working in any of the laboratories of the HVL is only permitted after appropriate instruction by an authorized person (GM, LM) and supervisor (ER, AI).

Working at the house installations e.g., by staff of ETH building administration or external craftsmen may only be allowed after prior agreement with LM or AI. LM or AI have to verify that access is safe and that all affected lab users are informed. LM informs the building administration regularly about the access restriction rules (HVL [20]).

4.3 4-Eye Principle – Inspection Obligation

After setting up **any** kind of test circuit or assembly, a check must be carried out – before putting something into operation. A strict dual control principle applies (**4-eye principle**). The inspection can be carried out by GM, LM or AI. Preferably the inspecting person did not take part in the construction of the assembly. The inspection can be delegated by the GM or LM to further qualified persons on an individual basis.

The inspection must be documented appropriately – Concerning complete experimental setups appropriate documentation means signing a complete grey info board (see chapter 4.7).

The inspection duty applies to setups with a certain associated risk. These risks are roughly quantified in section 2.1 – in case of doubt discuss with LM, GM or AI.

4.4 Malfunctions

Malfunctions of a test facility or operating equipment, even if only temporary, must be reported immediately to LM or AI in writing

In such a case, the test facility must never be accessed alone for the purpose of troubleshooting. Another expert person is always to be consulted (GM, LM, AI, ER). This applies in particular when working outside the normal working hours.

4.5 Training / Instruction

There are general standard trainings which everyone working at HVL laboratories has to receive and special trainings for machines or hazards which are given on a need-to-know basis. Trainings should always consist of a theoretical and a practical part. The training material/concept includes rules for working with a hazard or a certain machine/experiment.

Theses Trainings are summarized in the tables below. Responsibility is with the LM, the execution of trainings may be shared between GM, LM and AI

[2] see: 'laboratories' enlisted in chapter 8

Table 6: List of HVL general safety trainings. Executed once, no refresher is planned (exceptions see corresponding footnotes)

Type	Training Material	Applies to	Trainer
Introduction to HVL premises: Labs and Storage	One Note: "Lab Plan"	Tec/Scientific Staff	GM
Introduction to HVL administration	One Note: "HVL General Information"	Tec/Scientific Staff	GM
General Safety[3]	HVL Safety Concept Corresponding PPT	Everyone	LM
Introduction to the Laboratory	Checklist on NAS	InP	ER
Introduction to the Experiment	Description in Black Folder	InP	ER
AED/BLS Course[4]		Tec/Scientific	External company

Table 7: List of HVL special safety trainings. Executed once and no refresher is planned

Type	Training Material[5]	Applies to	Trainer
Electric Safety	HVL Electric Safety Concept Corresponding PPT	Everyone	LM
Pressure Cylinders Pressurized Air Cryogenic Liquids	SSHE PPT	On demand	SSHE
Gas Handling	HVL Gas Handling Concept	On Demand	LM
Laser Safety	SUVA [21] IEF training PPT	On demand	Laser Officer
Mechanical Safety: Rotating Machines, Tabletop Drills	Internal Training for Rotating Machines	On demand	AI
Mechanical Safety: Bridge Cranes	Manual for Operating Overhead Cranes	On demand	AI
Working in Height: Haulotte, Scaffolds and Ladders	Internal training and instruction for operators of aerial work platforms	On demand	AI
Fire Extinguisher	SSHE PPT	On demand	SSHE

The execution of trainings has to be documented through a training evidence sheet. It lists the major training content and a reference to the training material. It has to be signed by the trainer and the person receiving the training.

The LM keeps track of the executed trainings and the training evidence archive.

[3] Full Training at start of employment, refresher every year
[4] Full training at start of employment, refresher every second year
[5] Training materials are stored in the Folder "Safety and Work Instructions" on the group NAS

4.6 Purchase, Maintenance and Disposal

LM and AI ensure that the machines, equipment, tools used in their labs and / or workshop facilities, correspond to the applicable safety regulations. When purchasing new equipment, they therefore demand that the declaration of conformity and operating instructions are supplied and that these documents are stored in an organized and accessible manner. Should it be necessary for research purposes to procure or to build equipment without CE declaration of conformity, then a hazard assessment must be performed. The respective documents for the individual devices are stored on the NAS under “Laboratories and Equipment”.

The LM keeps track of all necessary maintenances considering building installations and experimental hardware. All works shall be documented in an appropriate document by LM and AI.

Specific maintenance duties for LM and ER are additionally listed below. These works shall be documented in the Black Lab Folder.

Table 8: Overview of specific maintenance duties (Regular maintenance duties are enlisted on the NAS).

Type	Interval	Responsible	Executed by
Control of Personal Protective Equipment (PPE)	Halve year	ER	ER
Maintenance/Test-Run Local Emergency Stops and further safety elements	At every startup	ER	ER / InP
Laboratory Inspection	Halve Year	LM	LM
External Lab Inspection	2 – 3 Year (linked to low voltage inspection)	LM	Tophinke / Electrosuisse

‘Standard’ recyclable material such as cardboard, electronics, batteries, metals etc may be disposed on the appropriate collection stations on the hallways or in the recycling room ETZ B-Floor.

Waste gas shall be recycled according to the instructions in the HVL-Gasguideline

Further chemical waste of all kinds shall be recycled via the ETH Reclycling station at CAB. Small quantities may be carried (no car transport) to the station – for larger quantities a pick-up should be organized.

4.7 Signalization and Documentation

At every **laboratory entry door**[6]**,** a red framed laboratory information board is mounted as well as the warning signs associated to the experiments inside of this laboratory.

The warning signs and the red framed board instruct craftsmen, visitors, and employees of ETZ facility services about the access restrictions and the hazards inside the lab, consequently accompanying text shall be in German.

As the dangers indicated by the warning signs have to be handled individually by ER and InP, there are no permanent blue advice/handling instruction signs on the doors.

Special advice and/or prohibition signs maybe temporarily mounted on the laboratory information boards as well. A set of templates is available at every lab door

Figure 2: Example of Lab door signalment. Access restriction (red) and warning signs (yellow). Door Lab ETZ C79.

[6] see 'laboratories' in room listing section 8

Signalization and documentation of **experiments** at HVL consist of three different items:

Red Framed Experiment Information Board

Mounted at the entry door of a specific experiment it shall indicate the major dangers (incl. main ratings) of the experiment and the responsible person. Standard ISO 7010 warning signs shall be used. The language is German as it is addressing mainly external people. A template is provided by the LM and example shown below.

Figure 3: Examples of red-framed experiment information board

Grey Framed Circuit Information Board

Mounted at a well accessible position, preferably not next to the Red-Frame, it shall give brief but complete overview of the purpose and functionality of the setup – therefore it has to feature a circuit schematics of the test setup and a block diagram of the safety/interlock circuit. This poster is the basis and evidence for the 4-eye inspection (when signed). A template, i.e. detailed instruction is provided by the LM and an examples are shown below:

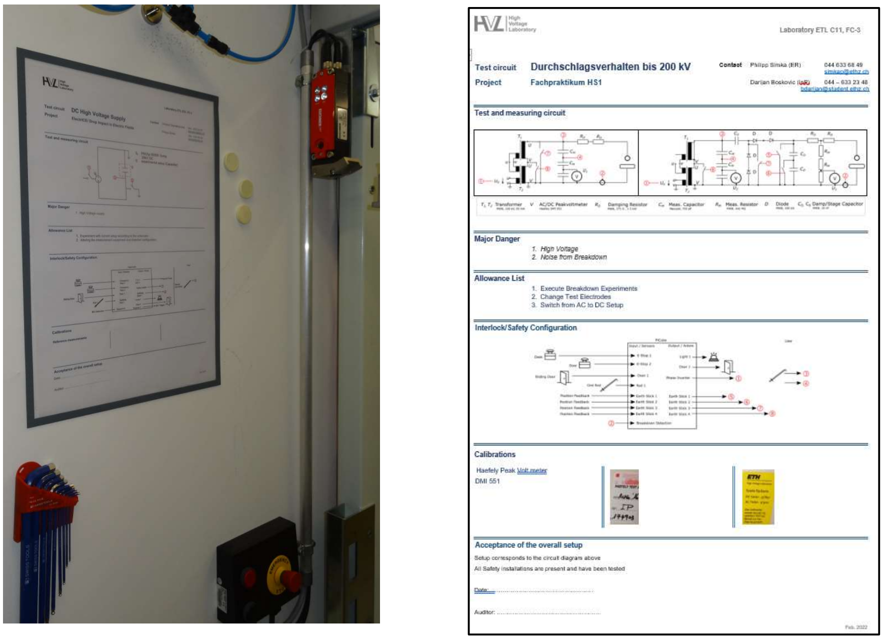

Figure 4: Examples of grey laboratory information board.

Black Facility Folder

The complete experimental setup has to be documented in a black facility folder. The content of the facility folder should at least cover the following topics:

- Detailed Setup Description
  - Complete wiring, control and safety circuit diagram (max degree of details - in contrast to the minimalistic circuit diagram on the grey board)
- Hazards of the Setup
- Procedures and PPE
  - Allowance List
  - How to Put Setup in operation
  - How to Shut-down Setup
  - Malfunction procedure
  - Emergency procedure
- Training Evidence Documents
- 4-eye Evidence
- Additional Documents

LM provides a template for the black folder.

4.8 Experiment Design and Setup

Safety and Success of experimental activities depend highly on careful planning and construction of the installation. The following chapter serves as a guidance for the design and setup of experiments at the HVL laboratories.

4.8.1 Planning and Installation of a Completely New Test Facility

Before starting to set up a test facility, it is important to be familiar with the following points:

- planned key data (e.g. test voltage amplitude/shape, pressure, radiation, dimensions of test objects, etc.)
- principle diagram of test circuit with all control and measuring equipment
- EMC concept: grounding of test and measuring equipment
- Risk assessment and risk mitigation strategy
- estimation of safety distances for all voltage parts
- indoor climate requirements
- demand for special facilities and aids (exhaust air, cooling water, etc.)
- design test circuit in a way it will inherently go to a safe state in case of power loss

The result of these preliminary works is to be discussed with **LM and GM** before starting with the setup of the test facility, placing orders or delegating major work to the electronics or mechanic’s workshop.

4.8.2 4-Eye Principle: First Commissioning of a New Test Facility/Measuring Equipment

The following points are to be presented and explained in detail to the person in charge.

- compliance with the previously established safety distances
- setup of the safety circuit, incl. arrangement of the ground rods and warning lights
- executed grounding in the test facility, and the control and measuring equipment
- protection of all signal, control and measuring lines against dangerous contact and overvoltage
- demonstration of the power-on procedure
- start-up of the test facility, performing a measurement
- shutdown of the system, disconnection and grounding of all relevant components
- thorough demonstration of all safety devices (E-Stop, Door, Gnd-Hook, etc) – demonstration of shut-down procedure at full running experiment.
- Documentation of the setup: Red Frame, Grey Frame, Black Folder. Especially allowance list. Description of procedures may be a draft, as experience has to be gained with the setup.

The inspection has to be executed by **GM, LM or AI** (or another person individually assigned by GM or LM). The Inspection has to be documented by signing the grey frame poster.

4.8.3 Conversion of Existing Test Facilities and Measuring Equipment

An Inspection has to be executed also If only individual elements are replaced in an existing test facility, e.g. only one measuring device on the low-voltage side of a high-voltage or high-current sensor. The inspection can performed by **GM, LM or AI** (or another person individually assigned by GM or LM)..

The following points are to be performed individually and explained in detail:

- type of modification, adapted test circuit diagram
- possible impact of the changes on the test or measuring circuit (safety and EMC)
- if required, updating of the associated facility file

If the test facility is accepted by the control person, this must be recorded in writing on the grey frame poster.

4.9 Unsupervised Experiments

Unsupervised tests must be planned in consultation with the LM and GM. The experimental setup has to have proven longterm reliability. “Longterm” depends on the estimated runtime and timescales to settle transients of the experiment. The actual time needs to be discussed/agreed aforehand. In any case the setup must first be run on a trial basis several weekdays during normal working hours. Only after ensuring that the operating condition fully meets the expectations, the permanent test may definitely be started.

Besides the experience the following points should be assessed and documented:

- any additional risks or failure mode arising from unattended/longterm operation of the setup (meaning additional to the standard black folder documentation)?
- If yes, proposal of mitigation strategies
- Responsibilities and description of who (ER, InP) can do what. Who has to behave how in case of failure

The switch-on authorization from **GM and LM** including a brief description of the scope of validity must be recorded in writing and stored in the black folder. Additionally, the switch-on authorization is documented by the LM in a dedicated document.

4.10 Working Hours

General

For scientific/technical staff and InP, **the presence and work** in the premises of HVL i.e. offices and laboratories is allowed 24/7. Office work is allowed 24/7. **Presence** in the laboratories after 18.00h at weekends/public holidays requires two persons or a buddy system.

The execution of experiments, any action according to hazard Table 1 or any action covered by special training (
Table 7) is only allowed in between 08.00 to 18.00h, Monday to Friday. During these times, quick help in case of accidents is ensured through the global Emergency Stop/Alarming system.

Exceptions

If execution of experiments must be performed outside of these hours and/or at weekends/public holidays special permission must be obtained from **GM and LM.**

In general, only work procedures that have already been approved and can be carried out independently and safely by the employee without any problems may be executed. In general, a second person (staff or InP) has to be present in the lab.

The permission from the LM and GM including a brief description of the scope of validity must be recorded in writing and stored in the black folder.

In case of malfunctions on the test facility or other unusual occurrences, the work must be discontinued immediately. The test facility must not be accessed alone, in particular not for the purpose of troubleshooting.

4.11 Working Alone

For the majority of setups at HVL technical and organizational safety procedures can provide a class 4 safety environment according to section 2.1. In this environment working alone is in principle possible without any supervision.

In the case of a class 3 safety environment, periodical deliberate monitoring of the ER and InP has to be established (SUVA [14]). The technical/organizational implementation hast to be discussed on case by case with GM and LM.

4.12 Good Laboratory Practice

Good laboratory practice includes two major categories: First, general behavior rules which shall not only make the workplace more safe but also comfortable and convenient for **all** staff members. Second good laboratory practice consists of a set of soft workplace design and behavior rules which enhance the experimental work in the labs.

General:

- Mutual respect and responsible everyday interaction are followed by everyone (Respect [23], Code of Conduct [22]).
- Working under the influence of alcohol or drugs is prohibited.
- Eating and drinking in the labs is generally not permitted. Exception is for plain bottled water.
- Wearing Headphones in the Laboratories is not permitted, in the offices the volume of headphones should be set such that the alarm horns are still noticed. Listening to music from speakers is allowed in agreement with all users of the lab.
- No manipulation of the house installation, i.e. the permanent piping for gas, water, pressurized air, electricity etc.
- Notify defect equipment, inappropriate behavior, and other bad states of affair to GM or LM

Laboratory:

- Keep the working environment clean and tidy. This helps to identify safety issues and threats. Make sure any material is in its dedicated area, i.e.: Experimental Area, Control Area, Assembly Area, Experiment Storage, General Storage. No Storage in the transit routes.
- When consumables run out, please refill or ensure that it is refilled.
- Equipment that is not used, should in general be switched off. This is in line with the safety signaling.
- Tools from the common workbenches/tool trolleys have to be returned immediately after the work has finished. Latest by the end of the working day.
- If tools or measurement equipment is borrowed and moved from one lab to another it has to be signposted somehow (Post-it, Note, Teams, Whiteboard, etc)
- Label everything.
- Do not use Tape for permanent installations (> two weeks)
- Do not use raw wood for installations. Remove standard euro palettes from the labs.
- Apply the HVL software, hardware and connectors standards for designing experiments. If in doubt what these standards mean for HVL, ask the colleagues or AI, LM and GM.
- Use equipment for its dedicated purpose. For example: Trolleys are no tables, kitchen gear shall not be used in chemical labs, etc.

5 Example Risk Assessment

An example of risk reduction by addressing probability and impact of injury through technical and organizational measures is shown below. The example treats the occurrence “contact with a running high voltage transformer”.

Since high voltage transformers typically run continuous and are somehow comparable in size to a human, contact with high voltage is considered *“frequent”*. This contact would be lethal; therefore, the damage is considered “very severe”. The initial assessment locates the risk in the top right corner (see Table 9 below).

Table 9: Risk assessment example for “contact with a running high voltage transformer”. Several measures reduce the risk class from 1 to 4

Probability					
Frequent	4	3	2	1	1
Occasional	4	3	3	2	1
Infrequent	4	3	3	3	2
Improbable	4	3	3	3	3
Almost Impossible	4	4	4	3	3
	Minimal	Small	Medium	Severe	Very Severe

Damage

#1 #2 #3 #4

Table 10 below lists a series of technical and organizational measures, which may reduce either the probability (P) or the damage (D) of the initial “occurrence”. Step #1 does not reduce the harm of touching the running transformer but drastically reduces its probability. Step #2 does not further reduce the probability of touching the transformer but addresses the remaining voltage and consequently the damage. Step #3 reduces the damage further by eliminating residual voltage. In case all these technical measures (and their supervision) fail, organizational measures in step #4 ensure, that damage is reduced to minimal, and the occurrence of an accident becomes “almost impossible”.

Table 10: Steps of mitigation the risk by technical and organizational measures

Step	Assessment before measure	Measure	Kind of measure	Assessment after measure
#1	P: frequent D: very severe	Confinement of the source by fences, access restriction through monitored door	Technical safety	
		Signalization of state and warning signs	Organizational safety	P: Improbable D: Very Severe
#2	P: Improbable D: Very Severe	Automatic interruption of power supply when door is opened	Technical safety	P. Improbable D: medium
#3	P. Improbable D: medium	Automatic earthing – i.e. de-energization of the system	Technical safety	P: Improbable D: small
#4	P: Improbable D: small	Instruction and training of the users – supervision of voltage measurement	Organizational safety	
		usage of manual earthing rod	Organizational safety	P: almost impossible D: very small

6 Protective Equipment

According to domestic work laws the **employer** has to provide a safe working environment which includes all necessary protective equipment (VuV [5]). The **employee** has the duty to make use of the protection equipment and to take care of the maintenance of personal protective equipment (PPE). Common protective equipment in HVL Labs are listed below.

Table 11: Overview of common protective equipment

Type	Description
Safety Shoes (Class S1 or higher).	Must be worn for any kind of laboratory work except pure data collections which is equal to office work. Safety Shoes are PPE.
Gloves	Are available in every lab for common work. Nitrile gloves for basic chemical and dirt protection, polyester gloves for basic mechanical work and thick leather gloves for heavy mechanical work or heat protection. Depending on usage intensity gloves can be PPE.
Hearing Protection	For experimental and mechanical work - are available in every lab.
Eye Protection	Are available at every machine desk
Lab Coat	For dirty mechanical or basic chemical work

Further (personal) protective equipment will be supplied on demand in-line with the specific safety instruction – see section 4.5 (e.g. special eye protection, breathing protection, cryogenic gloves, etc.)

7 Emergency Strategy

In case of accident or injury, first act according to the stop-light-scheme (Samariter [24]):

Red: Stop
- Overview of the Situation
- What happened
- Who is involved

Yellow: Think
- Dangers for helping persons?
- Dangers for other persons?
- Dangers for patients?

Green: Act
- Alarming
- Ensure self-protection
- Secure area
- Turn-off machines
- 1st -Aid

Some of the above-mentioned bullet-points are explained in more details below:

7.1 Alarming

Internal HVL:
Every laboratory of HVL is equipped with a global emergency stop system. In case of activation all electric power lines in this lab are interrupted (except of the lighting) and a visual and acoustic alarm is activated in the ETL building and the ETZ C-floor laboratory.
The location of the alarm is indicated on display panels which are distributed all over the ETL building. All employees of HVL shall be familiar with the location of the closest display panel and proceed to the indicated location whenever there is an alarm. This alarm is internal only and does not activate any external rescue brigade.

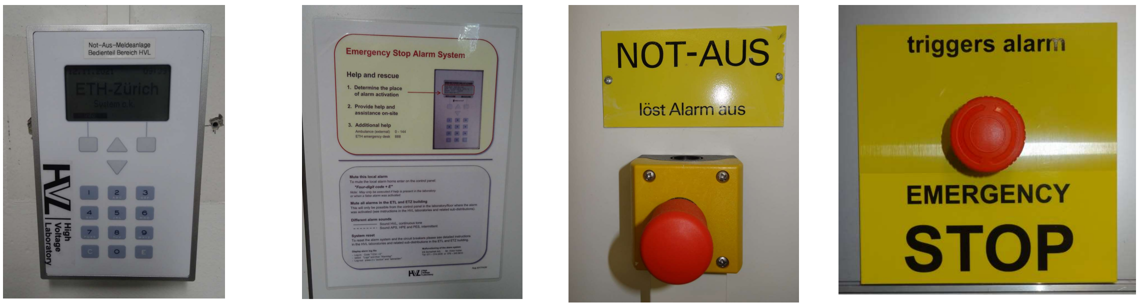

Figure 5: Alarming display panel, manual next to the panel and example of emergency stops labeled in german or englisch

Note 1:
Labs from other institutes in the ETL building are connected to the same alarming system. The alarm sound is an intermittent tone, the HVL alarm sound a continuous tone. It is expected that HVL employees proceed to locations of alarm even if they originate from a different institute.

Note 2:

The Alarming/Emergency Stop system can be deactivated to perform maintenance works on the electric sub-distribution without power interruption to the labs. This status is indicated by this sign at lab entry If it is activated NO experimental work shall be executed.

Figure 6: Illuminated warning sign "NOT-AUS Schaltung überbrückt» - indicating works on the electric sub-distribution

Internal ETH:

The ETH rescue organization is available 24/7 an can be reached by any stationary ETH phone, dialing:

888

External:

The european emergency telephone number, also valid in Switzerland is:

112

When dialed from a fixed internal ETH-phone, dial

0-112

Fire-/Smoke Alarm

Every room at ETH is equipped with a smoke detector which will automatically trigger an alarm if activated. Acoustic alarms are triggered only in the section of the smoke detection (not the whole building) and only after 17.00h and 24h at weekends. During 'regular' work hours the alarm is silent to prevent misusage from terrorists. The silent alarm is sent to the staff from facility services or the fire brigade respectively.

Manual Fire Alarm buttons can be found on every floor close to the staircases:

Figure 7: Fire-Alarm button as available close to every staircase and ceiling light indication towards the location of an activated smoke-detector

Gas-Alarm / Ventilation Alarm

In ETL C11 there is an Oxygen-Monitoring and alarm system installed. A pre-alarm is triggered when the oxygen level drops below 19%. The user shall identify the source of the problem.

- If a clear and uncritical source for the alarm trigger can be identified, the ER can reset the alarm.
- If there is no clear source for the alarm but the oxygen level rises again → Report to the LM

A full alarm is triggered when the oxygen level drops below 17%. All persons have to immediately leave the room. The alarm triggers automatically the ETH rescue organization.

Figure 8: Gas-Alarm Installation in ETL C11. Left: User Panel inside the lab, right: O2 Concentration display at Lab entry

In ETL E31, ETZ C79 and C78.2 it is indicated whether the ventilation is running or not. In case of gas-handling or other reasons which request a running ventilation, this sign has to be checked, see Figure 9 below.

Figure 9: Illuminated ventilation-error sign with associated flash light. warning

Reporting Scheme

When external help is called, refer to the following scheme (SSHE [25]):

Reporting model

Where – place where the incident occurred (building, floor, room no., lift etc.)
What – nature of incident (what kind of help is required?)
Who – name and phone no. of the caller
When – when the incident took place
How many – no. of people affected
Further information – additional information that might be important for the intervention

7.2 First Aid / Fire Fighting

Employees of HVL receive a basic BLS/AED training including refresher course every second year. The following installations help in the execution of first aid:

Basic medical supply. Available on every corridor throughout the building

Basic medical supply. Available in every lab

Automatic external defibrillator. Located at the main staircase of ETL – floor E and floor H and ETZ – floor C

Eye-Wash station

Fire-fighting equipment is present in every lab, as well as on every floor at every staircase of the building. Use it only if you feel comfortable – if not, leave the location and wait for the fire fighters. Remember to perform alarming first before fire-fighting on your own.

Fireblanket

Handheld fire-extinguisher, foam and CO_2

Water hose

Fires classes, the appropriate extinguishing agent are categorized according to the table below.

Class	A	B	C	D	F
Type of Combustion	Ordinary solid combustibles i.e. paper, wood, cloth and some plastics	Flammable liquids such as alcohol, ether, oil, gasoline and grease	Electrical equipment, appliances and wiring	Certain flammable metallic substances such as sodium and potassium.	Edible fat and grease
Water	Effective	Dangerous	Dangerous	Dangerous	Dangerous
Foam	Effective	Effective	Non-effective	Dangerous	Dangerous
BC-Powder	Non-effective	Effective	Effective	Non-Effective	Non-Effective
ABC-Powder	Effective	Effective	Effective	Non	Non-Effective
Dry Chemical	Non-effective	Non-effective	Non-effective	Effective	Non-Effective
CO2	Non-effective	Effective	None-effective	Dangerous	Non-Effective
Fat Extinguisher	Effective	Effective	Non-Effective	Dangerous	Effective

Table 12: Type of burn-classes and corresponding fire extinguishers

7.3 Reporting

Accidents and incidents have to be reported to GM and LM as well as to the authorities by using the appropriate standard form.

Accidents during work or leisure time shall be reported to SUVA via the ETH HR-Department. This is a prerequisite for covering the costs of medication or medical treatment with SUVA.

Further, all lab and workshop incidents must be reported to the LM and GM. Then they report the event to SSHE by email to sgu-schaden@ethz.ch.

An electrical accident must also be reported to the Federal Heavy Current Inspectorate.

8 Rooms of HVL / Important Rooms Non-HVL

Black: Offices/Other, Red = Storage/Workshops etc, Blue: Laboratories, Green: Non HVL-rooms, but important

****Locations ETL**

- Townsend-Lab: K15
- H30.1: Binder, F&B
- H31.2: Solder and Laser Lab
- H31.1 – H35: Offices
- H-Floor: Printer: Storage Cupboards
- H36: Library
- H27.1: Kitchen
- H24.2, H26, H28, H29: Offices / Secretary
- Terrace
- GasStorage
- Cardboard/Paper Trash (Door opening)
- Staircases and Elevators (2 + 3)
- Delivery Ramp, Crane and Pit
- G16 Student Room
- G18 – Hallway Storage and Office and Workshop
- F31: Gallery
- E25: Cables
- E30.001: High Volt Accessories
- E: D-Itet General Workshop
- E31: Main High Voltage Lab (FC- s and Xs, Workshop, Top/Down/Gallery/Bucht)
- E31.3 - SwitchYard
- D21: Tools
- D23: General Storage
  - Storage Sectors
  - (Sub-distribution, Elevator, Monkey)
- D-ITET Workshop: Material Storage
- Tunnel D-Floor
- C11: Dielectrics/Maintenance Lab
- C21.1: Storage Fluid Handling
- C21.2: Witch Kitchen
- C-Hallway Storage (Archive)
- Tunnel A-Floor

****Locations: ETZ:**

- Ramp
- Reycling B-Floor
- C77: Switchyard
- C79 : Main High Current Lab (FCs and Xs, Workplaces etc.…)
- C78.1, C78.2
- C78.3 C60.001: Lecture Storage
- C78.4 and C78.5: GIS and RLC
-
- Delivery Ramp ETZ
- Mail-Office ETZ
- Connection via Staircase ETZ (2x)
- Transport-Duct ETZ

9 Version History

?	Version 1	
?	Version 2	
Sept 2017	Version 3	Hans-Jürg Weber
Nov 2019	Version 4 Added part in documentation: red/black / grey and added maintenance list Version was never released	Hans-Jürg Weber
04.11.2021	Version 5 Merge Version 3 and Verions 4 and text from homepage Major change in table of content Added chapter occupational and technical safety. Extended chapter protective and emergency strategy	Philipp Simka
10.12.2021	Version 5.1 / 5.2 Minor changes in wording/organizational safety Added all references	Philipp Simka
21.12.2021	Version 5.3 – Release small adaptations in the working hours section	Philipp Simka
19.07.2022	Version 5.4 Integrate inputs from January feedback-session, Management Team review and SGU review	Philipp Simka

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