Chapter 4 Handling of Electricity, Gas, Lasers, Machine Tools, etc.

Section 1 Electrical Safety Tips

1 What are the types of electrical accidents?

(1) Fire accidents

This is caused by leakage or poor contact due to faulty electrical work, short circuits due to aging of unmaintained equipment, improper use of equipment, overloaded operation, and tracking due to dust in electrical outlets.

(2) Electric shock accidents

This can be caused by inadequate electrical work or grounding, use of inappropriate equipment, careless operation with wet hands, etc., and can result in loss of life in an instant.

(3) Explosion accidents

Capacitors can explode if operated over capacity or a reverse voltage is applied to deteriorated capacitors or electrolytic capacitors. Moreover, when an oil-filled transformer is short-circuited, an explosion may also occur, requiring caution.

From the perspective of safety and management, various regulations have been established for various electrical facilities in terms of construction, management, and operation.

2 Fires caused by electricity

If the thickness of a copper wire (cable) is small, fire may occur due to overheating. Table 4-1 shows the allowable current values for insulated wires. Table 4-2 shows specific examples of causes of fire accidents and preventive measures.

Particular attention should be given to the following.

(1) Iron or copper wire should never be used as a substitute for fuses, nor should large-capacity fuses that exceed the capacity of the circuit be installed. Even if you want to use the equipment immediately, such as in the middle of an experiment, always prepare and use a spare fuse to avoid using a substitute or wire for convenience after removing the cause of the blown fuse. In addition, the use of circuit breakers eliminates the need for fuse maintenance.

(2) When using "octopus wiring," as it is commonly referred to (using several fixtures with branch sockets), carefully consider the electrical capacity used.

Since the danger of "octopus wiring" largely depends on the electrical capacity used, the number of plugs plugged into a table tap should, in principle, be less than or equal to the number of plugs, and the number of plugs should not be increased by connecting another table tap (the total capacity should

be less than or equal to the capacity of the table tap to be used.)

Large capacity appliances (such as electric heaters) should be connected directly to wall or floor outlets. Daily inspections are also necessary, such as taking care to avoid dusty outlets.

(3) Do not use wiring or equipment that violates the law. Do not perform so-called amateur work.

(4) Failure countermeasures and repairs of electrical machinery and equipment must be performed by engineers with expertise or in specialized factories, and must not be used as temporary first aid measures.

(5) Do not neglect the care of electrical equipment. Always maintain them and keep them clean.

(6) When wiring, etc., the experimental panel, or the breaker is turned off, clearly indicate this to prevent electric shock and lock the door to prevent others from accidentally energizing the equipment.

(7) When using a drum cord, observe the allowable current for the drum cord and avoid using the cord while it is wound around the drum. There have been cases of cords not dissipating heat properly, resulting in fires even at our university. (Even a drum cord with a rated current of 15 A has an allowable current of approximately 5 A when left wound.)

(8) The outlet is designed to clamp the plug terminal by the force of the metal spring, but if force is applied while the plug is plugged in, or if the plug is repeatedly and roughly plugged in or unplugged, or if it is bent in an inappropriate manner, there is a possibility that the contact will fail. When an arc occurs, the metal melts, and the area around the outlet becomes blackened and carbonized, making it more and more susceptible to arcing and leakage of electricity, with a very large possibility of fire as a result. When using large currents (15 A or more) in particular, wiring should be performed from the test board as much as possible. If power supply from an outlet is unavoidable, it is necessary to pay attention to the deterioration of the outlet, poor contact, and surrounding conditions, and replace it with a new one as soon as possible to prevent fire. In addition, when obtaining power from a test panel, use a breaker and wiring appropriate for the load capacity; otherwise, a fire may result.

(9) In the event of a fire, immediately shut off the power supply and extinguish the fire using a fire extinguisher (powder fire extinguisher, etc.) suitable for electrical fires.

Table 4-1 Allowable current of insulated wires

Condition Conductor: Copper

Insulator: Vinyl or natural rubber with an allowable temperature of 60 °C

Ambient temperature: 30 °C

Wiring method: Overshot wiring and wiring with wires enclosed in the following

Metal pipes, metal wire spines, flexible conduit pipes, synthetic resin pipes, synthetic resin wire spines

Conductor		Insulator distribution line	VV cable (F cable) 3 leads or less	Wiring to pipe or wire pins			
				Number of wires in the same pipe or wire [wires]			
				>3	4	5-6	7-15
Type	Thickness*	Allowable current ratio					
		1.00	0.70	0.70	0.63	0.56	0.49
		Allowable current [A]					
Single wire	1 mm	(16)	—	(11)	(10)	(9)	(8)
	1.2	(19)	(13)	(13)	(12)	(10)	(9)
	1.6	27	19	19	17	15	13
	2	35	24	24	22	19	17
	2.6	48	33	33	30	27	23
	3.2	62	43	43	39	34	30
	4	81	—	56	51	45	39
	5	107	—	75	67	60	52
Formed single and stranded wires	0.9 mm^2	(17)	—	(12)	(10)	(9)	(8)
	1.25	(19)	—	(13)	(12)	(10)	(9)
	2	27	19	19	17	15	13
	3.5	37	24	26	23	20	18
	5.5	49	34	34	31	27	24
	8	61	42	42	38	34	30
	14	88	61	61	55	49	43
	22	115	80	80	72	64	56
	38	162	113	113	102	90	79
	60	217	150	152	137	121	106
	100	298	202	208	187	167	146
	150	395	269	276	248	221	193
	200	469	318	328	295	263	230
	250	556	367	389	350	310	272
	325	650	435	455	410	363	318
	400	745	—	521	470	417	365
	500	842	—	590	530	471	413

*For intermediate thicknesses, use the allowable current of the smaller size.

*Wires with a diameter of 1.2 mm or less and a cross-sectional area of 1.25 mm^2 or less are not generally recognized as wires for wiring; thus, the allowable current is shown in parentheses for reference.

(Reference) Allowable current in cord

Thin vinyl cords (cross-sectional area 0.75 mm^2) 7 A

Thick vinyl cords (cross-sectional area 1.25 mm^2) 12 A

Extra-thick vinyl cord (cross-sectional area 2.00 mm^2) 17 A (e.g., OA tap rated 15 A)

Table 4-2 Causes of electrical fires and preventive measures

Cause		Preventative measures
Category	Specific examples	
Poor insulation of wiring	Carelessness when embedding or stippling cables into molding material	Periodically measure insulation resistance between wires and between wires and earth.
Incomplete connections	Poorly tightened wire connections or terminals on switches and fixtures	Inspect frequently and maintain in perfect condition.
Defective equipment	Poor insulation, short circuits, and leakage	Insulation resistance measurements and circuit tests should be performed, and defective parts should be completely repaired.
	Use of inferior electrical goods without type approval	Replace with suitable quality.
	Wear and tear	Renew at the end of its service life.
	Poorly cared for (dust and debris can interfere with heat dissipation and dust can burn). Dust accumulated between the electrodes of a plug that has been plugged into a wall outlet for a long period can become conductive owing to moisture in the air, resulting in a short circuit (tracking phenomenon).	Maintain in a state of complete maintenance by constant inspection and care.
	Faulty protective device (thermostat failure, no thermal fuse)	Repair protective devices.
Misuse of equipment	Overload during operation	Use within the rated load.
	Current over the allowable current is applied.	Use within the allowable current.
	Use other than the intended purpose (use a light bulb or a stove for a floor hearth.)	Use correctly.
Unsuitable for use	Short circuit	Check the circuit before connecting the power supply.
	Unsuitable operating environment (e.g., proximity to combustible materials)	Use according to the environment.
	Leaving the power on	Precautions during and after use
	Careless tipping over	Precautions during use

3 Electric shock accidents

The effect on the body is related to the magnitude and duration of the current passing through the heart, and even a considerably large current between the fingers will not cause death. The effects of electric shocks on the body are not generally clear-cut because of individual differences and differences in the parts of the body that are electrocuted, but are approximately as shown in Table 4-3.

However, even low voltages are dangerous when (1) sweating, (2) bare feet on concrete or on the ground,

(3) hands and feet are wet, or (4) while bathing. In addition, accidents can be further aggravated by electric shock causing falls and crashes, etc. Therefore, protective equipment such as helmets and safety belts should always be used when handling electrical equipment at high places.

Table 4-3 Effects on the body depending on the current value

Current value (mA)	Impact
1 (or less)	Feeling of electric shock and numbness.
5 or more	Feeling of pain and lingering sluggishness.
10	Feeling unbearable pain and trauma at the point of inflow of electric current.
20	Muscle contraction and spasms occur, and the body loses its freedom, and the electrocuted person himself cannot escape from the charging object.
30	Burn-like symptoms may occur, and the person may lose consciousness.
50	Breathing may cease, and in some cases, cardiac function may stop.
100	Fatal consequences and death in most cases.

4 How to prevent electric shock

(1) Be careful not to touch the part directly connected to electricity (charging section). To check whether the power is being supplied, use an electric detector (do not use one built into the handle of a screwdriver) or a tester.

Figure 4-1 Detector

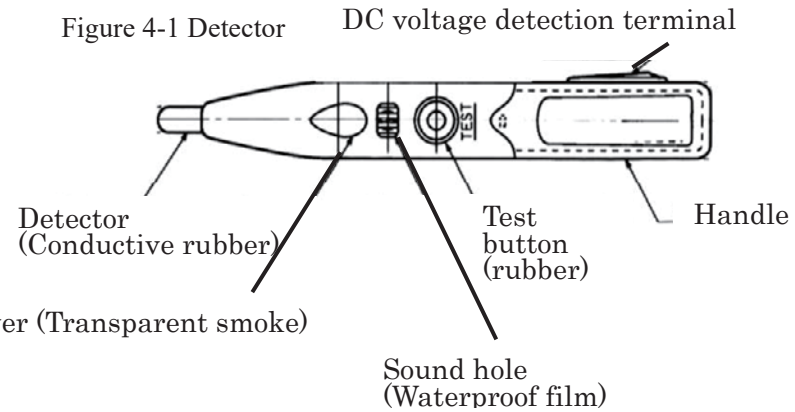


Figure 4-1 shows an electric detector. However, note that it is dangerous to use such a device to check equipment with a voltage exceeding 400 V.

(2) Electrical equipment that requires the connection of a grounding (earth) wire should be grounded (earthed), and a 30 mA or less earth leakage circuit breaker should be used for power supplies that may cause electric shock.

(3) High voltage is dangerous even if it is not touched; for 2,500 V or more, the distance must be 30 cm or more, and for 50,000 V or more, the distance must be 1 m or more.

(4) Electrical equipment should not be wetted by water, particularly salt water. If it is wet, dry it and measure its insulation resistance with an insulation resistance tester (mega tester) before use.

(5) Always short-circuit (discharge) both terminals before handling capacitors. When short-circuiting, do not short-circuit directly, but use a resistor or similar device. Capacitors may recover their voltage after a short circuit for a long time, which may cause electric shock. Special care should be taken with

electrolytic capacitors and high-voltage capacitors.

(6) When measuring power supply voltages with an oscilloscope, wear protective equipment such as electric shock protective gear because the case may be electrically charged and direct touching of the case may cause electric shock.

(7) When opening and closing a switch, the hand that does not grip the handle should not touch other objects, particularly metal. Operate the switch with the right hand. If you operate the switch with your left hand, you will suffer an electric shock affecting your heart.

(8) When switching off a circuit with large inductance, such as an electromagnet, sparks may fly and cause burns or electric shock, so wear electric shock protective equipment and protective gear. When turning off the field current of a DC motor, quickly turn off the switch as well.

5 Grounding work

Various types of electrical equipment must be grounded to ensure safety. There are four types of grounding operations: Class A, B, C, and D. The types, resistance values, and grounding locations are listed in Tables 4-4 and 4-5. However, if there are specifications or instruction manuals for the equipment, the instructions should be followed.

Most of the grounding terminals of the experimental panel are class D grounding. Gas pipes, water pipes, etc. should never be used in place of the grounding terminal. Additionally, do not connect a grounding (earth) wire to the N-pole (grounding side).

Table 4-4 Types of Grounding tasks, grounding resistance, and thickness of grounding wire

Type of grounding work	Grounding resistance value	Grounding wire thickness
Type A	<10 Ω	diameter >2.6 mm or >5.5 mm^2
Type B	Ohms equal to the amperage of one line earth fault current on the high voltage side or special high voltage side of the transformer divided by 150	Diameter 4 mm or 14 mm^2 (2.6 mm or 5.5 mm^2 when coupling a transformer to a high voltage current or special high voltage overhead power line) or more
Type C	100 Ω or less (500 Ω or less when a device that automatically shuts down the power line within 0.5 seconds when a ground fault occurs on a low voltage power line is installed)	diameter >1.6 mm
Type D	<10 Ω (same as above)	(same as above)

Table 4-5 Grounding points and types of grounding for various types of equipment

Equipment	Grounding point	Type of grounding work
Instrument transformers for low or high voltage exceeding 300 V	Secondary side	Type D
Equipment for low-voltage use below 300 V	Outer box, iron core for those without outer box	Type D
Low-voltage equipment exceeding 300 V	Iron core for those without an outer box or outer casing	Type C
Equipment for high voltage or special high voltage	Outer box, iron core for those without outer box	Type A
Indoor metallic wiring ducts of 300 V or less	Pipes	Type D
Indoor metal wiring ducts exceeding 300 V	Pipes	Type C
Metal wires for indoor wiring	Wires	Type D
Indoor wiring flexible pipe of 300 V or less	Flexible pipes	Type D
Indoor metal wiring duct flexible pipe exceeding 300 V	Flexible pipes	Type C
Metal duct for indoor wiring under 300 V	Ducts	Type D
Metal ducts for indoor wiring exceeding 300 V	Ducts	Type C
Indoor wiring bus ducts of 300 V or less	Ducts	Type D
Indoor wiring bus ducts exceeding 300 V	Ducts	Type C
Floor ducts	Ducts	Type D
Metal device to house captive tire cable	Metal protective equipment	Type D
Metal junction box or metal sheathing for indoor cable wiring of 300 V or less	Junction box, metal clad	Type D
When exceeding 300 V in the preceding paragraph	Junction box, metal clad	Type C
Contact wires for indoor use (e.g., traveling cranes)	Contact wire	Type A
Discharge lamp fixtures of 300 V or less and 1 A or less	Outer box, metal components	Type D
If the value exceeds 1 A in the preceding paragraph	Outer box, metal components	Type C
Electrical machinery and appliances housing incandescent lamps	Metal components	Type D

6 Other hazards caused by electricity

(1) Use extreme caution when using electric heaters. In addition to scorching the surrounding area at the heater, there is a risk of fire if there are combustibles nearby or through the wire sheath of the main unit. In addition, there is also the risk of electric shock; therefore, be very careful when using this product.

(2) Do not place flammable or explosive materials near switches, electric motors, distribution boards, or experimental panels. Sparks from blown fuses or interrupted switchgear can cause fires or burns.

(3) Refrigerators are equipped with an automatic temperature control switch. If the room is filled with explosive gas, sparks from opening and closing the switch may become an ignition source and cause

an explosion; thus, explosion-proof refrigerated storage should be used for refrigerated storage of chemicals.

(4) In locations where flammable or tributary gases (city gas, hydrogen, acetylene, ammonia, carbon monoxide, oxygen gas, etc.), hazardous materials (alcohol, ether, gasoline, thinners, benzene, etc.), dust (flour, starch, cocoa, milk powder, sulfur), etc. are present, it is recommended that explosion protection measures be taken because overheated equipment, sparks, or arcs when opening and closing switches may become ignition sources and cause explosion accidents.

(5) In locations where corrosive gases (acids, alkalis, potassium chlorate, bleaching powder, dyes, or places where electrolysis or electroplating is performed, storage battery rooms, etc.) are present, insulation failures and other disorders due to corrosion may occur. Special measures should be taken to prevent easy corrosion and deterioration by using corrosion-resistant materials and equipment or applying anti-corrosion paint, and periodic (yearly) inspections should be conducted to ensure that no corrosion has occurred.

(6) Whenever a circuit breaker shuts down or a fuse blows, the cause should be investigated, and the circuit should be restored after taking countermeasures. Failure to do so may result in electric shock or fire.

7 Tips related to power failures

Electrical equipment should generally be maintained in anticipation of the inevitability of several power outages per year. Measures to address such situations are described as follows.

(1) Special consideration should be given to power supplies for electrical equipment and systems that may cause major disasters or disrupt education and research owing to unexpected power outages, such as continuous laboratory equipment, server systems, and cooling systems that are explosion-proof. Specifically, all possible measures should be taken to improve the stability of the power supply, and to set up backup power sources and quickly switch between them.

(2) In certain types of equipment containing rotating machines, such as old exhaust systems, the load is very excessive when the power is switched back on after a power failure that the rotating machine may be unable to start rotating on its own. In such cases, care should be taken because a fire may occur from the heat generated. In general, equipment (electric furnaces, exhaust pumps, etc.) that must be operated all night in an unoccupied room at night should be equipped with a safety circuit such as a protective relay for each of these devices.

(3) A flashlight should be stored in an easily accessible place in case of sudden power failure at night, causing darkness.

(4) In the event of a power failure, switch off the electric motors. DC machines, induction machines, synchronous machines, etc. may burn out when power is restored. In addition, the electric charge of capacitors, etc. should be checked before each use.

8 Special training for handling low-voltage electricity

Only persons who have completed special training for handling low-voltage electricity may perform work such as laying or repairing low-voltage charging lines. (Article 59 of the Industrial Safety and Health Act, Article 36 of the Industrial Safety and Health Regulations)

In addition, even if a person has obtained a second-class electrician's license from the Ministry of Economy, Trade and Industry, he/she must complete the Ministry of Health, Labour and Welfare's special training for electric handling (low voltage) work if he/she is to handle low voltage electrical systems.

Table 4-6 shows the work that can only be performed by those who have been issued a Type 2 Electrician License under the Electrician Act and have completed the Special Training for Handling Low-Voltage Electricity.

Table 4-6 Tasks that cannot be performed without an electrician license

1 Connecting wires
2 Attaching electrical wires to insulators
3 Attaching electric wires to building materials or other objects
4 Fitting electric wires into conduit pipes, wire spines, ducts, and other similar objects
5 Fixing wiring apparatuses to building materials or other objects or connecting wires to them. However, work to replace exposed flashers or exposed outlets is excluded.
6 Bending or threading conduit pipes, or connecting conduit pipes to each other or to boxes and other fittings
7 Attaching boxes to building materials or other objects
8 Installation of protective devices where wires, conduits, spines, ducts, or other similar objects penetrate the construction material
9 Attaching metal conduits, wires, ducts, or similar items, or their accessories to metal laths, wire laths, or metal plate clad parts of buildings.
10 Attaching a distributer board to the building materials
11 Attaching grounding wires to electrical facilities for general or private use, connecting grounding wires to each other or to grounding wires, or burying grounding poles in the ground.

Table 4-7 shows minor tasks that can be performed without a qualified electrician. However, even in this case, the work can only be performed by those who have completed the special training for handling low-voltage electricity mentioned above.

Even in the above work, it is permissible for a non-electrician to assist the electrician when the electrician is working. In addition, a non-electrician may be considered be able to perform any task, including those listed in Table 4-7, except for those listed in 1 through 11 above.

Table 4-7 Minor tasks that can be performed by non-electricians

1 Construction work to connect cords and captive tire cables to a junction or switch used at a voltage of 600 V or less.
2 Screwing electric wires (including cords and cables) to the terminals of electrical machinery and appliances (excluding wiring apparatus) used at voltages of 600 V or less
3 Installation and removal of watt-hour meters, current limiters, and fuses for use at voltages of 600 V or less
4 Wiring work on the secondary side of small transformers with a secondary voltage of 36 V or less (intercom, electric bell, etc.)
5 Installation or modification of poles, braces, etc. to support electric lines
6 Installation or modification of underground cables or pipes

9 Others

(1) Electrical wires should not be stepped on, pinched, or used as a substitute for ropes, etc. If there is a risk of such a situation, be sure to attach the prescribed cover. However, it is prohibited to use cords secured with staples or contained in cords, etc.

(2) When working at heights, use a lifeline or similar device to prevent a fall.

(3) Avoid working alone with electricity. Work in unoccupied places or at night is strictly prohibited.

(4) It is dangerous to walk near electrical equipment with long metal rods.

(5) Refer to Chapter 2 "First Aid" (page 9) for information on how to administer artificial respiration in the event of an electrical accident.

Section 2 Handling of laser equipment

1 Precautions for eyes against light and microwaves

(1) Do not look directly at laser beam, even if it is weak. Even when not looking directly at it, laser beam may be reflected from window glass, etc., therefore be mindful of reflected light also (Refer to the following “Measures to prevent damage by lasers”).

(2) Mercury lamps, arcs, etc., contain a large amount of ultraviolet rays, therefore do not look directly at them. In such cases, use safety glasses.

(3) Microwaves such as from microwave ovens even with a small output are harmful to the eyes, therefore keep eyes away from them.

2 Measures, etc. to prevent injury by lasers

(1) Laser beam features

Laser beam propagates with high energy density because it has a coherent wavefront and excellent directivity, and the spread of the beam is small. Even locations that are sufficiently far from the laser device and thought to be safe may still be dangerous owing to direct strong light or secondary light due to scattering. The wavelength region extends to vacuum ultraviolet, visible, infrared, and millimeter waves. Generally, laser beam is easily absorbed by a living body, and absorption of excessive light energy causes destruction of living tissue, mainly of the eyes and skin, by its heat, photochemical reaction, ionization, etc. There is also a risk of fire if the laser hits a combustible material, therefore use non-combustible curtains in the laser laboratory to prevent fire. Dealing with unwanted light is also important. It should be noted that laser beam neither gets transmitted through a living body like radiation (e.g., X-rays, gamma rays), nor has the accumulation effect proportional to the integrated light irradiation time.

(2) Laser hazards

1) The danger to the eyes depends on the laser output and wavelength.

① Laser beam in the far infrared region, such as a carbon dioxide laser (10.6 μm), is well absorbed by water, thereby causing burns on the corneal surface of the eye. Receiving high-power light directly on the skin results in a burn.

② Laser beam in the mid-infrared region with a wavelength of 1.4–3 μm reaches inside the eye and causes cataracts.

③ Near-infrared and visible lasers (e.g., YAG, semiconductor, titanium sapphire, second harmonic of YAG, and argon ion lasers) have the highest risk of blindness because their beam reaches the retina.

④ Ultraviolet lasers (e.g., excimer lasers) light absorbed by the corneal surface causes burns. Skin

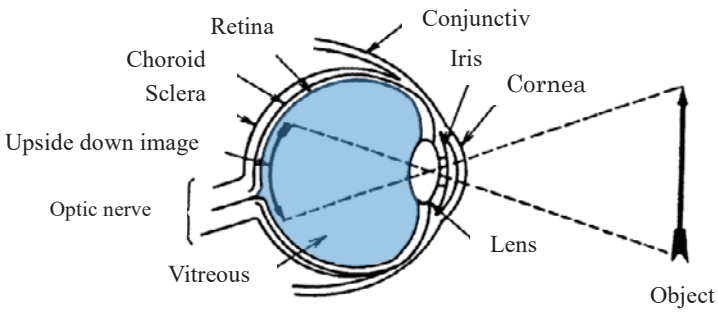
cancer and burns can be caused by the direct contact of laser beam with the skin.

2) High-voltage circuits and capacitors are used in the laser body and power supply section, therefore be mindful of electric shocks. Note that the capacitor may not be discharged even when the switch is turned off. Also, be careful of lasers such as excimer lasers that use poisonous gas in their ventilation and exhaust. Ozone and other chemicals are generated in the air by ultraviolet lasers, therefore measures for exhaust gas may need to be taken in the laboratory.

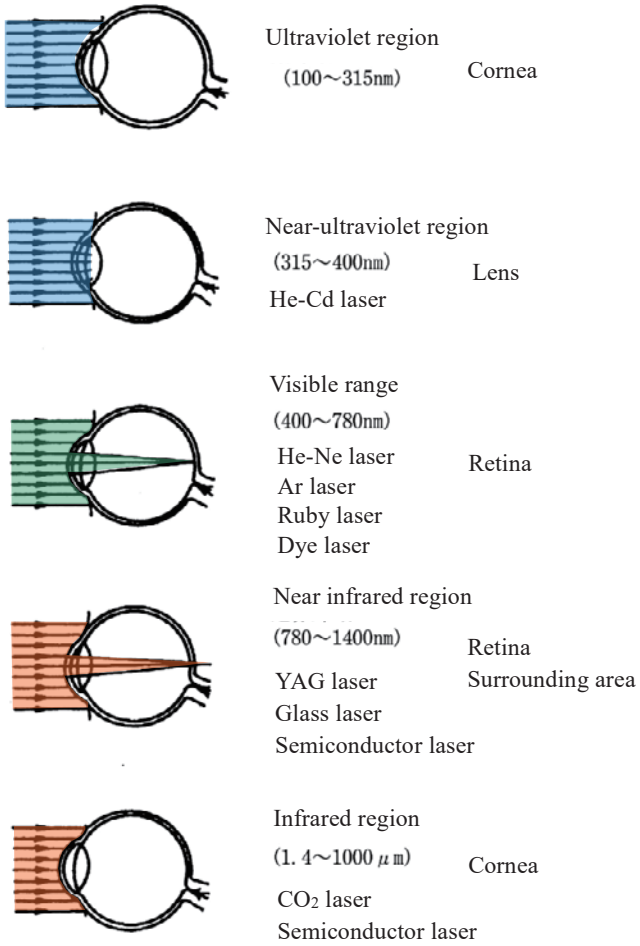
(3) Eye injuries

Lasers have extremely high energy densities and can cause major damage to the human body. The most dangerous case is eye injury. Maximum precautions should be followed to protect the eyes when conducting experiments. The figure below shows various effects of laser beam on the eye.

Schematic of the human eye[1)]



Laser beam wavelength range and eye absorption site [1)]



In the case of visible and near-infrared light, the laser beam that passes through the cornea gets focused on a spot on the retina because of the crystalline lens. This spot is as small as beam's wavelength, therefore the energy density becomes significantly high, and the retina gets destroyed causing visual

impairment. The Q-switched pulsed laser can damage the retina even with energies of a few mJ/pulse. In the case of a near-infrared laser such as a YAG laser, the scattered light of the laser beam cannot be seen, therefore precaution must be taken when adjusting laser's optical path, as described later. According to a report that investigated 50 eyes in 43 cases of laser eye injury in Japan[2], most of the accidents occurred during experiments in the laboratory, and the university affiliates (staff, graduate students, and undergraduate students) and researchers were responsible for the accidents. The accidents more likely occurred when adjusting the optical axis. In many cases, the misalignment of the laser beam owing to a delicate operation resulted in the reflection of the beam on a side wall, etc., further causing redirection of its path to an unexpected direction, and its subsequent projection on an unintended object. The YAG, titanium sapphire and argon lasers caused accidents.

(4) Laser classification (classification by danger of laser)

A standard value called the accessible emission limit (AEL) is set as a safety measure for laser equipment according to the danger of the laser beam (JIS Standard C6802 "Safety of Laser Products"). This JIS standard was revised on January 20, 2005 (JIS C 6802:2005). Previously, a five-stage laser classification of class 1, 2, 3A, 3B, and 4, in order from the safest to least safe, was adopted. In the revision, a low-class classification was added for laser beams with a large beam spread angle (light output from a semiconductor laser or optical fiber) or for laser beams with a large beam diameter such that the power (energy) density was less than or equal to the maximum permissible exposure (MPE); and the seven stages of class 1, 1M, 2, 2M, 3R, 3B, and 4 were adopted. The contents are summarized below in a comprehensible format. Users should know the class of the laser device to be used.

Class 1 : Either inherently safe or technically designed to be safe. Output is approximately 0.39 μW or less (in the case of continuous light with wavelength of 400–550 nm), and there is no danger under normal operating conditions. The AEL value is displayed as the power obtained by multiplying the MPE value by limit aperture area. Therefore, even if a laser beam of class 1 or lower is focused by a lens, the power density averaged by the limit aperture area does not exceed the MPE. As a result, the class 1 power limit value is essentially at a safe level, when considering the use of loupes and binoculars. If the amount of exposure to the human body can be limited to the AEL or lower by using enclosures, etc., then the laser will be classified as a Class 1 product, regardless of the output of the laser alone.

Class 1M : This class is newly established as "safe to the naked eye". The exposure condition is defined as observing the laser beam with the naked eye at a distance of 100 nm from the light source. Therefore, in this class, observation through a lens system may cause damage.

Class 2 : Low output with visible light (400–700 nm). With a continuous wave (CW) laser, the output is 1 mW or less. It is not inherently safe, but in the case of this class of laser beam,

even accidental eye entry is usually protected by aversive reactions of the eye (i.e., blinking). However, long-term eye irradiation will cause damage. Therefore, do not look directly into the laser beam.

Class 2M : Similar to Class 1M, this is a newly established class where the laser beam is “safe to the naked eye”. It is a Class 2 with limited conditions, where observing the laser with the naked eye (distance of 100 mm) is still safe due to aversive reactions. Therefore, observation through a lens system can result in damage as well.

Class 3R : Using optical means for in-beam observations is dangerous. The beam to the eyes through binoculars can cause damage. The lasers of this class have radiation power of 5 mW or less with CW visible light. The wavelength of visible light is five times the Class 2 AEL or less; the wavelength of non-visible light is five times the Class 1 AEL or less.

Class 3B : Direct or mirror-reflected light is always dangerous and can cause unexpected damage. Never make direct in-beam observations. This class corresponds to visible and invisible lasers with 0.5 W or less for CW lasers, and 10^5 J/cm^2 or less for pulsed lasers.

Class 4 : High-output lasers that exceed Class 3B, where not only direct and mirror-reflected light but also diffuse reflections are dangerous. The laser beam of this class causes eye and skin damage. There is also risk of fire.

Note: JIS C 6802:2005 was amended in 2011 to the latest version as JIS C 6802:2011.

(5) Safety management of facility equipment

・A warning label must be placed on the room where a laser device of Class 2 or higher is used.

・If there is a laser device in the research/laboratory, display the label on entry/exit door on the hallway side.

・For laser equipment of Class 3B or higher, install a warning indicator (laser in use) that can be identified from the outside during use.

(6) Principles for safe use of lasers

Considering the abovementioned concepts, it is thought that the precautions for using the laser safely are clear, but general precautions are listed below for high-output lasers of Class 3B or higher.

1) Wear protective glasses according to the wavelength of the laser used.

Protective glasses have no effect unless they correspond to the wavelength of the laser being used. Protective glass types include the fully absorbent and partially transmissive types; in the case of a high-power invisible laser, the fully absorbent type should be used.

2) It is strictly forbidden to look directly at the laser beam.

Do not look directly at the laser beam even when wearing protective glasses.

3) The direct and diffused beams are dangerous but the reflected and diffused beam also are dangerous, and ensure that they do not enter the eyes.

・Remove watches, rings, and other items that may reflect light when working.

・Turn on the lights as much as possible and work in a bright environment (the pupils widen in dark, therefore the amount of light entering the eyes increases).

・Do not bring your eyes to the height of the beam. Conversely, install the laser optical path such that the beam does not travel at the height of the eyes.

4) Do not stand in the laser optical path and its extension.

There is a possibility that a mirror, etc., might shift or fall into the optical path extension at some instance and result in the laser beam hitting it. Such potential hazards also need to be avoided.

When possible, it is advisable to cover the optical path of the laser with a non-transmissive flame-retardant pipe.

5) Place an absorbent and non-flammable shield at the end of the laser beam.

Even in cases where there is no risk of fire, such as with a single shot laser or operation for short periods of time, a fire can still break out due to repeated operation or long-term laser irradiation.

6) When adjusting the laser or its optical path, reduce the laser output and repetitions as much as possible.

7) Avoid exposing the skin directly to the laser beam. Clothes should be made of non-combustible material to reduce the exposure of the skin (chemical fiber garments that melt into beads are not preferred).

Furthermore, ultraviolet laser beams (e.g., KrF excimer lasers) are highly absorbed by the skin, and even diffused reflected and scattered light cause “sunburns”, therefore use face mask-type protective equipment, and avoid exposure of the eyes and skin, such as the face.

8) The laser body and power supply unit have high-voltage terminals and capacitors, and there is a high risk of electric shock. Open the main body and power supply unit only in the presence of an instructor or manager.

9) When using the laser, carefully read the manual and ensure correct operation.

10) Pay attention to harmful substances that may be generated by laser irradiation, and take appropriate preventive measures. Especially with ultraviolet lasers, pay attention to the generation of ozone in the air.

Some lasers use harmful and hazardous substances (excimer lasers use halogen gas, dye lasers dyes and solvents, etc.), therefore take care when handling these lasers.

11) The Industrial Safety and Health Act describes the specific contents of safety and preventive measures for labor using lasers of Classes 1M, 2M, 3R, 3B, and 4 under “Measures to prevent obstacles caused by laser beams”. These criteria are listed below for reference.

Measure (item only)			Measure	Laser device class			
				4	3B	3R	2M 1M
Appointment of Laser Equipment Manager				○	○	○※1	
Controlled area (no-entry signs, etc.)			Separated from other areas and clearly indicated by signs, etc., no entry except for those involved	○	○		
Laser device	Laser optical path	Optical path position	Avoid the eye level of the worker	○	○	○	○
		Optical path shielding	Shield with opaque, non-flammable material	○	○	○※1	
		End with fireproof material	Fireproof structure at the end of laser. Anti-reflection / scattering in enclosure	○	○	○※1	○※2
Laser device	Key control		Structure operated by key	○	○		
	Emergency stop switch	Emergency stop switch	Emergency stop switch that can stop the laser beam emission immediately	○	○		
		Alarm equipment	Alarm equipment such as automatic indicator lights that can be easily confirmed	○	○	○※1	
		Shutter	Shutter to avoid unexpected discharge from outlet	○	○		
	Interlock system		Laser beam emission is automatically stopped when the controlled area is opened or the optical path is shielding is released	○	○		
	Outlet display		Display on laser beam outlet	○	○	○	
Work management, etc.	Operating position		Control the laser equipment as far away from the laser optical path as possible	○			
	Optical system adjustment		Use the minimum required power when adjusting the optical system	○	○	○	○
	Protective equipment	Protective glasses	Wear appropriate laser protective glasses for each type of laser	○	○	○※1	
		Protective clothing	Wear clothes with less exposed skin	○	○		
		Use of flame-retardant material	Wear clothes made of flame-retardant material; chemical fibers that melt into beads is not suitable	○			
	Inspection / maintenance		Start-up inspection, regular inspections, adjustments	○	○	○	○
	Safety and health education		Education when hiring workers, changing work content, changing lasers	○	○	○	○

	Health management	Anterior eye examination	Cornea and lens examinations in conjunction with visual acuity examinations when hiring or relocating	○	○	○※1	
		Fundus examination	In conjunction with visual acuity examination when hiring or relocating	○			
Other	Post		Laser equipment manager name	○	○	○※1	
			Dangers, precautions	○	○	○	○
			Laser installation sign	○	○		
	Display of high-voltage parts of laser equipment		Display of high voltage parts, measures to prevent electric shock	○	○	○	○
	Prohibit carry-in of hazardous materials		Explosives, inflammable substances	○	○		
	Harmful gas dust		Measures prescribed by the Industrial Safety and Health Act	○	○		
	Physician's consultation and treatment for suspected laser beam injuries		Immediate medical examination when laser beam damage is suspected	○	○	○	○

*1 Measures are required for laser equipment that emits laser beams outside the 400nm~700nm.

*2 For Class 1M and Class 2M products that output a laser as a parallel beam, measures need to be taken at the end of the laser optical path.

References

1) Applied Laser Technology Handbook (Asakura Publishing Co., Ltd., 1991).

2) Kamijo Y., Ozawa T., “Laser eye injury in Japan”, Japanese Review of Clinical Ophthalmology, 97(2), 95-100, 2003.

Section 3 City gas, tap water

1 City gas

When using city gas in each room, please be mindful of the following points.

(1) Confirmation of ignition and fire extinguishing

A When igniting, ensure that the burner is completely lit.

B Ensure complete combustion by the color or smell of the flame.

C When the gas is ignited, do not leave the site. Also, ensure to extinguish the flame when leaving the site.

D When extinguishing the flame, ensure that the equipment and gas plugs are closed.

(2) Precautions during use

A During use, be mindful of ventilation, by checking whether the ventilation fan is always in operation and the air supply and exhaust ports are not blocked.

B Open the windows at regular intervals for ventilation if there is no ventilation equipment.

(3) Regarding rubber pipes (reinforced gas hoses)

A Cracked or hardened old rubber tubing should be replaced immediately with a new one, such as a reinforced gas hose.

B Do not connect a short gas hose with a joint.

C Insert reinforced gas hose firmly up to the red line of the gas and equipment plugs.

D Secure the reinforced gas hose with a safety band.

E When using a one touch-type plug, use an appropriate joint.

(4) Other

A Keep area around gas equipment tidy, and do not place inflammable materials nearby.

B If a foul odor or physical discomfort is noticed while using the gas, immediately stop using the gas and open the windows and doors for ventilation.

C Take diligent care of gas equipment.

D In the event of an earthquake, immediately close the equipment and gas plugs.

2 Tap water

Tap water is used as various purposes for experimental not only as domestic water. Especially when used for cooling equipment, the correct operation method of the equipment must be followed. The important points for safety are mentioned below.

(1) The water supply pipe and port of the device are connected by a pipe. If it must be connected with a hose, etc., use a hose that can withstand the water pressure, and firmly fix the connection part between the water supply pipe and port of the device with a safety band so that the pipe does not come off owing to fluctuations in water pressure.

(2) Electrical equipment and other items that pose a danger owing to water leakage in the laboratory should be placed in advance to avoid the effects of water leakage due to damage or disconnection of hoses and pipes.

(3) In cases where water leakage to the floor is expected to last a for long period due to an accident, etc., there is a risk of water leakage to the lower floors. Therefore, consider counter measures in advance, such as installing a waterproof pan or a floor drain, and install experimental equipment and piping.

(4) Tap water should be used while the experimenter is in the room to the extent possible. However, when there is a need for continuous or late-night operation of a device, a display should be placed at the entrance of the room or elsewhere notifying others of this.

Section 4 High-pressure gas, liquefied gas

In general, gas containers, arrangements, valves, etc., are dangerous when destroyed by internal pressure, regardless of the type of gas, therefore their design method is stipulated by law according to the working pressure and size of the container (refer to pressurized container structure standards). Therefore, when using them, the name plate or engraving etc. should be checked so that the specifications and performance of the containers used are suitable for the maximum possible pressure.

1 High-pressure gas container (cylinder)

(1) A cylinder is manufactured with high-quality steel based on guidelines mentioned in JISB8241. These cylinders are all subjected to pressure resistance tests, airtightness tests, etc., by the High-Pressure Gas Safety Act, and only those passing these tests are used.

(2) The cylinder has a stamp on the shoulder as shown in Fig. 4-2.

(3) Outside of the cylinder is painted with a specified color (Table 4-8) indicating the type of filled gas.

(4) The structure of the valve is shown in Fig. 4-3. The combustible and other gas outlets use the left-hand and right-hand screw are set to the left- and right-hand sides, respectively. Exceptions are helium on the left, and methyl bromide and ammonia on the right.

(5) The High-Pressure Gas Safety Act does not allow the university to fill cylinders with gas.

(6) Cylinders should be re-inspected (e.g., pressure resistance, weight) every five years (three years prior to 1989), and the grades should be written on the stamp and container certificate. There are some exceptions for re-inspection such as with small containers of propane (every six years), and if the gas is still in use after five years, the cylinder will be re-inspected during re-filling.

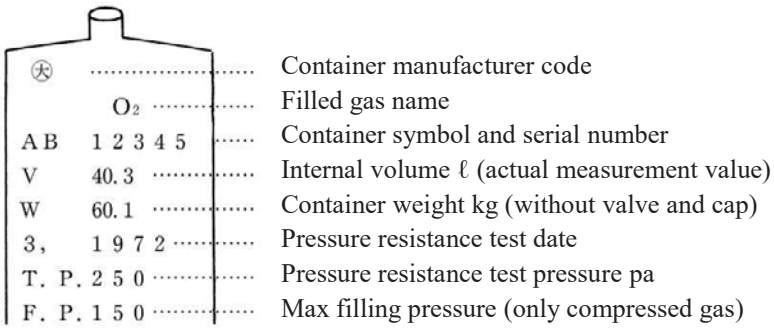


Fig. 4-2 Cylinder engravings

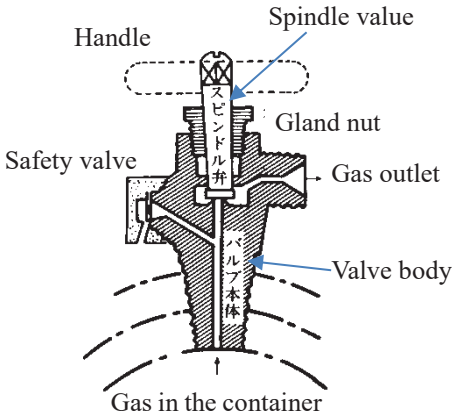


Fig. 4-3 Schematic of a valve

Table 4-8 Cylinder color and gas properties

Gas name	Color	Poisonous	Combustible	State inside
Oxygen	Black	N	—	Gas body
Hydrogen	Red	〃	Y	〃
Carbon dioxide	Green	〃	N	Liquid and gas body
Ammonia	White	Y	Y	〃
Chlorine	Yellow	〃	—	〃
Acetylene	Brown	N	Y	Dissolved gas
Argon	Gray	〃	N	Gas body
Nitrogen	〃 "	〃	〃	〃
Methane	〃	〃	Y	〃
LP gas	〃	〃	〃	Liquid and gas body
Carbon monoxide	〃	Y	〃	Gas body
Phosgene	〃	〃	N	Liquid and gas body
Ethylene	〃	N	Y	〃

2 Precautions for handling high-pressure gas cylinder

(1) General precautions

1. Information

A The cylinder should be handled by a person with sufficient knowledge or under the guidance of such a person.

B Various types of gases should be handled after becoming familiar with their properties and methods to handle them.

2. Storage

C Fix the cylinder at two points on a strong support to prevent it from falling.

D Combustible gas, poisonous gas, and oxygen should be stored separately, and filled cylinders should be separated from empty cylinders.

E Always close the valve, and cover the unused cylinders with a cap.

F Place the cylinder in a well-ventilated area so that the temperature does not exceed 40 °C.

G When storing cylinders, do not place anything other than the necessary items around them. Also, do not place flames or flammable/ignitable materials within a radius of 2 m from the cylinders.

H Do not expose the cylinder to wind and rain or place it in a humid place, and take measures to prevent it from rotting. Take measures to avoid exposing it to direct sunlight.

I Avoid storing the cylinders near electric and ground wires.

3. Movement

J When moving the cylinder, inspect the value and be sure to attach the cap.

K Use a hand cart to move the cylinder, and do not drag or slide the it.

4. Other

L It is desirable to maintain a residual pressure of approximately 1 MPa inside the empty cylinder when handing it to the trader. Never decompress the cylinder. Additionally, transferring gas from cylinder to cylinder is prohibited.

M When disposing of a cylinder that does not pass container inspection, do not abandon it without permission, and always ask a high-pressure gas handling company to dispose of it.

(2) Precautions for combustible gas, oxygen, poisonous gas, and suffocating gas

A Do not use a fire within 5 m from equipment that uses combustible gas (hydrogen, hydrocarbons, etc.) or oxygen, and do not place inflammable or ignitable materials nearby. However, this excludes equipment in the facility.

B Use oxygen after removing combustible substances, such as petroleum and oils, from the equipment. Use a pressure regulator for oxygen only. Do not use inflammable packing material for the connection.

C Ethylene oxide should be consumed after replacing the inside of the equipment with N_2, CO_2, etc. Also, install a backflow prevention device between the cylinder and equipment.

D Conduct activities with sufficient knowledge of poisonous gases. Employ preventive measures in a local exhaust ventilation such as a draft chamber to prevent inhaling of a toxic gas (H_2S, CO, Cl_2, etc.).

E Direct the gas exhaust outside, and make poisonous exhausted gas harmless by passing it through alkali absorbers, etc.

F When using combustible or poisonous gases, installing a gas leak alarm sensor or an oxygen monitor is desirable.

(3) Precautions for silane gas, etc. (silane, disilane, diborane, etc.)

Semiconductor manufacturing involves the use of various chemical substances in the process of CVD, etching, and cleaning; among these, 37 types of gases listed in Table 4-9 in particular are called “special material gases” that exhibit wide explosive range with spontaneous combustibility or decomposing explosiveness; some are also poisonous and extremely hazardous, and these gases should be handled with caution. Of these, the seven types of combustible gases consumed in large quantities (see Table 4-9) require a notification to the prefectural governor prior to their use. Accidents leading to death or serious injury even in university laboratories have been reported, therefore all possible preparation and precautions need to be followed when using these gases, with considering following points:

A House the gas cylinder in a cylinder cabinet, and equip the cabinet with a gas alarm sensor, watering nozzle, and forced exhaust duct.

B Install a compressed air-operated pneumatic valve on the cylinder main plug so that it automatically closes in an event of a power outage or gas leak.

C Use SUS316 for the piping between the cylinder and reaction device (experimental device), and prepare a check valve and nitrogen gas supply system for purging.

D Install experimental and gas supply equipment in a sufficiently safe manner. Install a gas alarm sensor in the upper part of the room and an exhaust duct in the ceiling.

E If possible, install a security power supply in the laboratory.

F Connect the exhaust side of the experimental equipment to the removal equipment, and do not release harmful substances to the outside air. Absorb the reaction and poisonous gases by the adsorption cylinder, but carry out sufficient maintenance and inspection of this removal equipment.

G Install a fire extinguisher next to or near the laboratory, and ensure that the user is aware of its position.

H Silane-based gas reacts explosively with an oxidizing gas, therefore the purging gas should not be shared with other gases, and an independent system containing no oxidizing gas should be prepared.

Table 4-9 Special material gases (37 types) and special high-pressure gases (seven types, marked with *) and their properties

Gas name	Chemical	Properties	Gas name	Chemical	Properties
Silanes			Boron trifluoride	BF_3	
Silane*	SiH_4	SC	Boron trichloride	BCl_3	
Disilane*	Si_2H_6	SC	Boron tribromide	BBr_3	
Dichlorosilane	SiH_2Cl_2	C	Metal hydride		
Trichlorosilane	$SiHCl_3$	C	Hydrogen selenide*	H_2Se	C
Silicon tetrachloride	$SiCl_4$		Germane*	GeH_4	D
Silicon tetrafluoride	SiF_4		Hydrogen telluride	H_2Te	D
Arsenic			Stibine	SbH_3	D
Arsine*	AsH_3	C	Tin hydride	SnH_4	D
Arsenic trifluoride	AsF_3		Halides		
Arsenic pentafluoride	AsF_5		Nitrogen trifluoride	NF_3	S
Arsenic trichloride	$AsCl_3$		Sulfur tetrafluoride	SF_4	S
Arsenic pentachloride	$AsCl_5$		Tungsten hexafluoride	WF_6	
Phosphorus			Molybdenum	MoF_6	
Phosphine*	PH_3	SC	Germanium tetrachloride	$GeCl_4$	
Phosphorus trifluoride	PF_3		Tin tetrachloride	$SnCl_4$	
Phosphorus pentafluoride	PF_5		Antimony trichloride	$SbCl_5$	
Phosphorus trichloride	PCl_3		Molybdenum pentoxide	$MoCl_5$	
Phosphorus pentachloride	PCl_5		Tungsten hexachloride	WCl_6	
Phosphorus oxychloride	$POCl_3$		Metal alkyl compounds		
Boron			Trialkyl gallium	GaR_3	D
Diborane*	B_2H_6	C	Trialkyl indium	InR_3	D

Note) C = Combustible in air, SC = spontaneously combustible at room temperature in air, S = combustion-supporting, D = decomposition explosive

3 Precautions for operation using high-pressure gas

(1) Equipment assembly

A Even for short-term experiments, build a solid stand or frame for the device, and conduct an experiment after the device is safely fixed.

B Use pressure regulators, pipes, hoses, etc., exclusively for gas, and never divert them. Especially for oxygen cylinders, use a dedicated pressure regulator with the indication of "Oil prohibited".

C Use a pressure gauge that can handle 1.5 to 3.0 times the normal pressure.

(2) Electrical wiring

Be careful when wiring to avoid explosions and sparks.

(3) Gas leak prevention

Ensure that the equipment is properly connected to prevent gas leakage. For example, in a normal pressure reactor, complete the pipe-to-pipe and device-to-pipe connections. In the pressurized reactor, pay attention to the flange connection, welded part, etc., and in either case, perform a gas leak test using an inert gas such as N_2 before starting the reaction.

(4) Explosion prevention

In a gas reactor, though combustion may occur while pressure is applied and gas is blowing out, there is a risk of drawing in air and causing an explosion inside a device during decompression. Therefore, it is preferable to pipe inert gas such as N_2 to purge the gas inside the reactor with the inert gas. The explosion limits are shown in Table 4-10. When conducting a gas phase oxidation reaction with air (or oxygen) such as hydrocarbons, the explosion limit must be carefully considered. In particular, even if the explosion limit is considered during reactions, the gas concentration may change at the start or end of the reaction and reach the explosion limit. Therefore, please be mindful of the explosion limit concentration and ensure that explosions are prevented.

(5) Gas supply

Install a pressure regulator on the cylinder after confirming that there is no malfunction. Keep in mind that oils on valves and pressure regulators can easily cause a fire. Do not unnecessarily lubricate the pressure regulator.

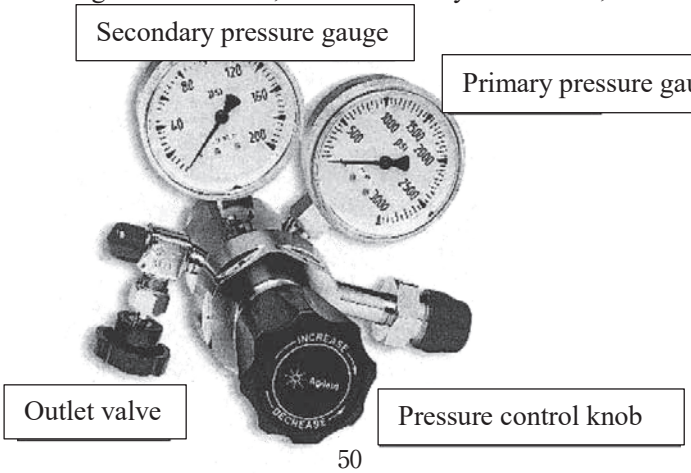
A Attach the pressure regulator to the cylinder and firmly tighten its inlet nut. Then, connect the pipe to the outlet of the pressure regulator.

B If the pressure regulator has an outlet valve, close it. Then, fully turn the control knob of the pressure regulator counterclockwise to close the pressure regulator.

C Slowly open the valve of the cylinder, and gradually increase the pressure. When the high-pressure gauge indicates full pressure, fully open the cylinder valve.

D Turn the control knob clockwise and adjust until the outlet pressure gauge reaches the desired pressure. If the regulator has an outlet valve, open it and readjust the outlet pressure if needed.

E De-gas the pressure regulator after use, and close the cylinder valve, control knob, and outlet valve.



(6) Gas leak confirmation

Check for gas leaks from the connections between the cylinder and pressure regulator, connections between the pressure regulator and device, and the pressure regulator itself. Leaked parts can be easily found by applying a gas leak detection liquid and examining it. Check for leaks by measuring changes in pressure gauge readings.

(7) Equipment material

Select the material according to the type of gas used for the experiment. For example, ammonia corrodes copper, therefore use stainless steel as piping materials.

(8) Exhaust gas treatment

Exhaust gas after the reaction is discharged to the outside. To avoid the risk of gas poisoning, fire, explosion, etc., use methods such as absorption into gas absorbers to prevent other effects.

(9) Deterioration of piping material

If the piping material is used for a long period, it may be deteriorated or damaged by chemicals, light, oxygen, humidity, etc. There is a need for frequent checks and prompt replacements. Replace the gasket used in the pressure regulator as soon as possible.

(10) The mounting position of the pressure gauge should be higher than eye level.

(11) Response in the event of an accident

A Notify nearby people of the accident and immediately contact the energy center (ext. 2233 or 9290).

B If poisonous gas is used, wear protective equipment to prevent the occurrence of secondary disasters, and then immediately move the victim to fresh air.

C Let the victim rest, loosen their clothes, and keep them warm.

D Give artificial respiration depending on the situation of the victim.

E Seek help from a physician.

Table 4-10 Explosion limit in air of major gases

(1 atm, normal temperature, upward transmission of flame)

Gas	Lower limit	Upper limit
Hydrogen	4.0	75.0
Methane	5.0	15.0
Propane	2.1	9.5
Butane	1.8	8.4
Ethylene	2.7	36.0
Acetylene	2.5	81.0 *
Ethylene oxide	3.0	80.0 *
Ammonia	15.0	28.0

Note 1) Numbers are volume percentages of combustible gas.
2) *Acetylene, ethylene oxide, hydrazine, etc., may explode even at 100% depending on the conditions.

4 High-pressure devices

When a high-pressure device bursts, debris scattered at high speed and shock waves of rapidly released gas cause major damage to people, equipment, and facilities; additionally, it is often accompanied by major secondary disasters, such as explosions and fires, caused by the gas used and chemicals existing nearby. Therefore, many high-pressure devices are subjected to the High-Pressure Gas Safety Act, and punishments are involved if they are handled without permission.

(1) General precautions

A Ensure the installation of safety devices and their regular inspections.

B Perform a pressure resistance test at a pressure 1.5 times or more than normal pressure. The absence of gas leakage beyond the normal pressure must be confirmed, but attention should also be paid to indoor ventilation so that any leakages do not dwell inside the room.

C Care should be taken to arrange the equipment in the laboratory to minimize the damage to the equipment in case of an accident.

D Place signs outside and around the laboratory for the outsiders to clearly understand the contents of the experiment and gas used.

E High-pressure experiments are highly dangerous; user should be familiar with the structure and handling of various devices and equipment before carefully conducting experiments. If there are any suspicious points, refer to specialized books or receive expert guidance.

(2) High-pressure reactor (autoclave)

Carrying out the desired reaction under pressure requires a high-pressure device suitable for it. Reactors, pipes, valves, and instrumentation play their respective roles in the equipment, and their safety factor is considered so that they can withstand corrosion and runaway caused by reactants. Also, choose a place with good ventilation against gas leaks, and use a protective device with good explosion resistance.

When operating the autoclave, perform it at the designated place according to the specified handling method.

(3) Reactor

A The withstand voltage of the reactor should be designed as approximately twice the normal pressure.

B Always keep the tightened part of the main body and lid clean regardless of the presence or absence of the gasket. It should be tightened by gradually increasing the force and following the order shown in Fig. 4-4. Do not tighten one side.

C Replace the air inside the vessel with sufficient amount of nitrogen or the target gas.

D Depending on the stirring method, be mindful of gas leakage

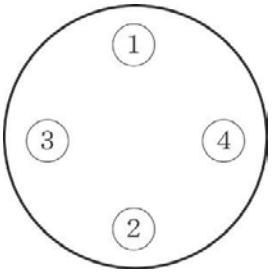


Fig. 4-4 Tightening

from rotating parts and blockage of piping due to catalysts.

E Raw materials must not be charged in more than 1/3rd of the internal volume of the container.

(4) Piping and valves

A Tighten the piping joint by pressing force to prevent the piping from twisting.

B High-pressure valves makes it easy for gas leak from the moving parts (valve spindles).

C Safety valves are of thin plate and spring types etc., and they are used together when it is dangerous.

(5) Pressure gauge

A Always inspect and use accurate instructions.

B Bourdon tube type pressure gauges are often used, but its material should be selected according to the gas used. In addition, oxygen can only be used if it is clearly stated as "Oil for oxygen prohibited".

C A pressure scale that is about twice the normal pressure is easy and safe to use.

D Use a gauge with a safety device. If the gauge has a glass lid, cover it with a wire mesh before using.

5 Liquefied gas

(1) Freezers

A Large refrigerators are subjected to the "High-Pressure Gas Safety Act" and can be operated and maintained only by a "freezer work supervisor". Small freezers are not regulated by law, but should be handled in accordance with the Act.

B The freezers operate at fairly high-pressure, therefore they need to be carefully handled in the same way as high-pressure devices. In addition, correct handling must be ensured based on the type of coolant used.

(2) Cryogenic liquefied gas

A Extremely low temperature causes frostbites. Use leather gloves and wear protective goggles, protective surfaces, etc. If liquefied gas adheres to cloth gloves, it will penetrate into the interior and is rather dangerous.

B Materials become prone to failure due to low temperature brittleness causing a secondary disaster.

C Liquid hydrogen-liquid oxygen, liquid oxygen-fat or hydrocarbon fuel etc. may cause a condensed phase explosion.

D When the liquefied gas vaporizes, its volume expands 800 to 900 times, and it replaces the air at the place of use. There is a risk of suffocation depending on the gas.

E Excessive heat vaporizes the liquefied gas explosively.

F Do not put liquefied gas in a closed container. Ensure that an escape port is available for vaporized gas. Further, even when a safety valve or an exhaust gas vent is provided, moisture or carbon dioxide

gas in the air may be frozen, solidified, and clogged at the ends thereof.

G Handle the liquefied gas container carefully, and place it in a well-ventilated place away from direct sunlight.

6 Precautions for handling liquid nitrogen

(1) Handling precautions

A When using liquid nitrogen as cryogen in a closed place such as a clean room, sufficiently ventilate the room to prevent oxygen scarcity. Make sure that the closed area can be seen from the outside, and be sure to conduct experiments with two or more people.

B Oxygen in air liquefies when liquid nitrogen is used as a freezing bath. Since liquid oxygen is extremely dangerous, traps and like should not be left in liquid nitrogen for a long time in an open system.

C Always cover open containers. In closed containers, close the booster and liquid take-out valves, and open the gas release valve.

D Liquid nitrogen that has been used for a long time and evaporated and decreased should not be used for cooling organic matter because oxygen is concentrated. As the oxygen content increases, it becomes bluish liquid.

E The liquid nitrogen storage container has a weak neck, therefore do not lay it on its side. It is also vulnerable to shocks, therefore handle it carefully.

F Use a metal container exclusively for liquid nitrogen. Wrap tape around the outer circumference of a bare glass dewar bottle.

G When taking out liquid nitrogen from the storage tank, first slightly open the take-out valve, sufficiently cool the inside of the container with the low-temperature gas that comes out, and then gradually open the valve to take out an appropriate amount of liquid nitrogen.

H Do not sprinkle liquid nitrogen on the edge of the dewar bottle.

I Consider the degree of shrinkage of equipment and piping due to cooling.

J Do not touch liquid nitrogen or low-temperature metal parts directly with bare hands.

K Storing liquid nitrogen (boiling point 77K) for a long time in a wide-mouthed container can result in the mixing of oxygen (boiling point 90K) from the atmosphere and accumulation of liquid oxygen. Oxygen ignites violently when it comes in contact with organic matter, therefore take care when handling fire even around liquid nitrogen.

(2) Guidelines for transporting low-temperature liquefied gases such as liquid nitrogen by elevator.

A When transporting low-temperature liquefied gases such as liquid nitrogen by elevator, avoid riding with ordinary people as much as possible.

B Do not transport low-temperature liquefied gas such as liquid nitrogen in a state where it can easily scatter in the elevator or when the container is open.

C Take measures to prevent the container from tipping over in the elevator, and handle it gently.

7 Precautions for handling liquid helium

A Liquid helium, which is normally used as a freezing bath, has a mass number of 4 and chemical formula of ^4He. The boiling point of liquid helium is 4.2K, and the heat of vaporization [J/cm^3] is extremely small, approximately 1/60th of that of liquid nitrogen, and it should be noted that even if there is a slight inflow of heat from the outside, it will evaporate rapidly and expand in volume.

B Liquid helium is contained in a vacuum-insulated metal container. Since its center of gravity is high, there is a risk of falling. When moving, hold the handle in the center near the center of gravity, not the top of the container, and take care not to tip the container over. Furthermore, the inner container is an extremely thin special metal container (expensive) to minimize the heat inflow from the outside. The cylinder is also almost suspended in the neck, therefore prone to breakage, and this should be handled carefully to avoid impacts.

C At the time of the experiment, it is advisable to attach a rubber balloon to the evaporation gas discharge port for evaporation monitoring. However, if air flows back from the discharge port, it solidifies inside the container (neck part of the container) and the container gets blocked, therefore care must be taken.

D A dedicated transfer tube is used to transfer liquid helium, and the transfer should be conducted while carefully following the precautions or instructions of those who are accustomed to its transfer. Also, when storing liquid in a liquid helium container, pay sufficient attention towards confirming the opening and closing of the safety valve installed at the top of the container, securing the lid of the liquid helium supply port and gas discharge port (micropores).

Section 5 Electric Furnaces

1 Precautions when using electric furnaces

The safety precautions when using an electric furnace are as follows.

(1) Confirm that there are no flammable substances, combustible gases, etc. around the furnace.

(2) Confirm that the thermocouple for temperature measurement is installed in the specified position.

(3) Read the manual carefully, and check the operation and procedure. If unavailable, receive guidance from an administrator.

(4) Do not insert the sample more than the capacity of the furnace or damage the furnace body, core tube, etc.

(5) Keep an eye on the electric furnace while in use.

(6) Do not apply overvoltage during heating. Do not raise the temperature above the capacity of the furnace.

(7) Wear gloves when handling high temperature objects.

(8) Wear safety clothing, safety shoes, and protective glasses for dangerous work such as heat treatment.

(9) When operating a device unmanned, set up a display with the user details, work details, and contact information.

(10) At the end of the work, make sure that the furnace temperature is at a sufficiently safe low temperature.

Section 6 Safety precautions of machine tools

1 General safety precautions of machine tools (*Must be read carefully before work as a precautionary measure!!)

(1) Regarding clothing

A Work in clothes that will not get caught in the machine. Loose shirts, hanging towels around the neck and hips, exposed ties and towels around the neck are extremely dangerous.

B Wear safety shoes (conforming to JSAA A type or JIS S type) when using the work center. Safety shoes are protective equipment in the event of accidental dropping of heavy objects or stepping on tools or chips.

C Wear a cap and protective glasses when using Center for machining technology development. Depending on the work content, a mask may be used. If in doubt, follow the instructions of instructors and managers.

D Do not use gloves in machine tool work as they are easily caught in the machines.

(2) Installation/removal of workpieces

A Be mindful during attachment/detachment to and from the machine, as it is easy to pinch fingers or cause contact injury due to blades.

B Do not forcibly install and remove heavy items alone; instead, do so with multiple people or with a lifting device.

C When processing articles with complicated or unstable shapes, use jigs and appropriate fasteners to securely attach them.

(3) Machine operation

Strictly observe the safety precautions for each machine

A When the installation of an item is completed and when operating the machine, clear the surrounding area of unnecessary tools and make it safe before starting the work.

B At the start of work, idle the machine to determine the quality of the attachment of the workpiece and tools and the condition of the machine. When operating, do not enter the direction of movement of the machine, rotating plane, or within the dangerous area of the machine.

C While operating the machine, concentrate on the work and stay near the machine.

D Be sure to turn off the main switch when leaving the machine.

E Do not stop the machine with the automatic feed set, or stop the machine while the tool and the workpiece are in contact with each other.

F Always pay attention to the sound, vibration, and heat of the machine; if there are any abnormalities, immediately stop the operation and notify the staff of Center for machining technology development.

G Do not stop the inertial movement of the machine with hands, feet, tools, etc.

H Collaborative work should involve ensuring the safety of oneself and proceeding with the work while paying attention to the surroundings, such as preventing injuries to others by calling out to them when needed.

I If the machine breaks down or an abnormality is found, immediately contact the staff of Center for machining technology development and receive the necessary instructions.

J Avoid mechanical work during overwork as much as possible.

K When operating the machine, it is advisable to utilize the Internet etc. to study the necessary background before starting the work (the machining center is equipped with teaching materials for machining, which should be effectively used).

L If there is a sudden power outage during processing, turn off the main power of the machine you are using, and then follow the instructions of staff of Center for machining technology development.

M Ensure sufficient safety when recording measurements using a machine.

(4) Regarding chips

A Chips are as sharp as a blade. Do not dispose of with bare hands, instead use appropriate tools such as brushes and pliers.

B Longer chips are more likely to be wrapped around the workpiece, which may damage the work or prove dangerous to the human body. Dispose of the chips in a short period of time.

C Chips that are scattered on the floor may stick to the soles of the feet or cause tripping or slipping. Clean up during every work break.

D or work where chips are scattered and easily get into the eyes (such as grindstone work), use an appropriate cover or wear protective glasses.

2 Precautions regarding the handling of various machine tools (read the relevant parts carefully before starting work!!)

(1) Lathe work

A Wear work clothes with tight sleeves and hem to prevent them from getting caught in the machine.

B Assume a work posture where the chips do not enter the eyes. Wear protective glasses when processing materials that scatter chips.

C When installing/removing chuck and flats, lay a board on the bed in advance to prevent injuries or mechanical damage even if they are dropped.

D If the chuck claws must be stuck out while working, then manually turn the spindle before starting the operation to prevent the claws from touching the bed or tool post.

E Do not leave the handle or fastener attached to the chuck or flat. Remove it immediately after use.

F Installation/removal of tools/workpieces and measurement of geographic features should be performed by stopping the machine and put the gear in neutral or turning off the power supply.

G Do not touch or wipe the rotating machine or workpiece with hands or cloth. Especially on rough processed surfaces, there is a danger of the cloth being caught or the fingertips getting cut.

H Stop the machine and dispose of chips wrapped around blades and workpieces using appropriate tools.

I Do not place unnecessary tools or materials on the bed.

J Install the bite as short as possible. Long protrusions cause the tool to bite excessively on the workpiece.

K Do not install work that deteriorates the accuracy of the chuck or chuck claws.

L For thin and long workpieces, mounting and cutting conditions should be considered sufficiently.

(2) Milling machine work

A Install/remove the workpiece and measure the machined part when the machine is stopped.

B Do not wipe the surface of the work piece with a waste cloth or hand, or remove chips while the blade is rotating.

C Consider the direction of rotation of the blade and acquire a position with no danger.

D Consider the characteristics of the blade and try to process materials reasonably.

E Safely change the spindle and feed by stopping the rotation.

F Rapid feed should be performed after checking the position of the blade and the condition of the workpiece.

G Try to use the central part of the base when sandwiching the workpiece between the vise.

(3) Drilling machine work

A Make sure to attach the workpiece to the fixed table to prevent it from swinging around.

B Take special care to avoid swinging when drilling small workpieces, thin plates, or soft materials.

C There is a high risk of swinging when the hole is drilled in the material and the drill reverses. Clogged chips from deep holes and the use of drills that are struggling to cut the material can also cause swinging.

D Do not forcibly hold down the swinging workpiece. Immediately stop the machine before taking action.

E Do not touch the rotating drill or wrapping chips with hands.

F Do not wear gloves as they may get entangled. Be careful of frayed cuffs.

G Use a tapered drill or sleeve after wiping it with a clean cloth.

H When drilling a large hole, lay a plate underneath and securely attach the workpiece to the vise or table.

I Select a drill shape and drilling tool that matches the material of the workpiece and the size of the hole, and machine under appropriate machining conditions.

J Ensure to remove the tightening tool from the chuck.

(4) Work using an electric hand drill

A Drilling with an electric hand drill is dangerous because it uses the force of the arm and the weight of the body, therefore when the hole is drilled, the large torque shakes the body, and the user may lose balance causing a hazard. The work piece may also rotate. Consider the distribution of power.

B If a bending moment acts on the rotating drill, the drill becomes more prone to failure and becomes dangerous. Ensure that the drill is perpendicular to the machined surface.

(5) Grinding machine work

The replacement of the grinding wheel or implementation of a trial run at the time of replacement can only be performed by a person who has completed the special education stipulated in the Industrial Safety and Health Act.

A When turning on the grindstone rotation switch, do not stand in direction of its rotation.

B Let the device idle for 1 to 2 minutes after turning on the grindstone rotation switch. Incidents where the grindstone breaks and flies often occur during this time.

C Roughness, clogging, and imbalance on the surface of the grindstone are extremely dangerous, therefore if noticed, immediately contact the staff of Center for machining technology development.

D When attaching unstable workpieces such as those with small contact surfaces or tall ones to the magnetic chuck, use blocks, vices, angle plates, etc. to securely attach them.

E Carefully check the positional relationship between the grindstone and work piece when using rapid feed.

F Process with an appropriate cutting depth, and do not forcefully grind the workpiece.

G Workpiece installation/removal and measurement work should be done in a safe place by stopping the rotation and separating it from the grindstone.

H Always wear protective glasses.

I After use, be sure to idle the grinding stone for approximately 5 minutes to prevent any grinding fluid absorbed by the grindstone from being left.

(6) Die-sinking and wire electrical discharge machines

Consult with the staff of the work center before using the machine.

A Chips entering the electrical discharge machine may cause unstable processing; therefore to thoroughly remove the chips, blow air with a machine that is installed in the worksite.

B Stable electrical discharge machining cannot be sustained if there is an insulating material such as black-dyed leather, therefore remove this in advance.

C Workpieces cannot be positioned and stable electric discharge machining, so remove with a file or a grindstone.

D Severe oil stains are also unfavorable for electrical discharge machining, therefore wipe them off with a waste cloth.

E To prevent electric shock, do not touch the electrodes during processing.

F To prevent fire, set the liquid level 50 mm or more above the top of the workpiece.

G When a problem occurs, press the emergency stop button and promptly report to the staff of Center for machining technology development.

(7) CNC machine tools such as machining centers

Before using the machine, consult with the staff of the work center.

A Check the NC program thoroughly. If necessary, perform computer simulation to confirm NC operation.

B Make sure that there is no tool interfering the NC program path.

C Do not touch the machine operating range during operation.

D Select a tool that matches the material of the workpiece, and machine under appropriate machining conditions.

E When a problem occurs, press the emergency stop button and promptly report to the staff of Center for machining technology development.

(8) Grinder

The replacement of the grinding wheel or implementation of a trial run at the time of replacement can only be performed by a person who has completed the special education stipulated in the Industrial Safety and Health Act.

A Grindstones rotating at high speed are dangerous when unbalanced or have deformed surfaces. If

such abnormalities are noticed, immediately contact the staff of Center for machining technology development.

B Do not stand in front of the grindstone for about 1 to 2 minutes when it starts.

C Use only the work surface of the grindstone, and do not work on other surfaces.

D Use the device with a space of 1–2 mm or less between the grindstone and cutting table.

E Forcibly pressing the workpiece is incorrect and dangerous.

F Take care not to let small workpieces scatter over the workspace.

G Do not work while wearing gloves or wrap the workpiece with a cloth. Gloves and cloth can become entangled.

H Use protective glasses to protect eyes from flying abrasive grains and chips.

(9) Sample cutting machine

The replacement of the grinding wheel or implementation of a trial run at the time of replacement can only be performed by a person who has completed the special education stipulated in the Industrial Safety and Health Act.

A Make sure that the amount of cutting fluid is appropriate.

B The selection of the grindstone is important for the wear and cutting accuracy of the grindstone. Please be sure to check this. If the grindstone needs to be replaced, please contact the staff of Center for machining technology development.

C Do not process small or thin objects that may enter the cutting escape groove. This may damage the grindstone.

D If the grindstone is damaged, stop the machine and promptly notify the staff of the work center.

E Do not stand in front of the grindstone for 1 minute when it starts.

F When performing automatic operation, carefully check the rapid feed and cutting positions.

G Use protective glasses to protect the eyes from flying abrasive grains and chips.

H To cut, rotate the grindstone, check the discharge of cooling water, and then gently move the cutting lever. Adjust the cutting speed while referring to the cut meter pointer.

(10) Saw work

A Securely attach the workpiece when sandwiching it between a vise. Pay particular attention while installing unstable materials.

B Select the blade and processing conditions suitable for the shape and material of the workpiece and work. When having difficulty making a choice, ask the staff of Center for machining technology development.

C Pour an appropriate amount of cutting oil to prevent the surroundings from becoming dirty.

D If you need to replace the blade, contact the staff of Center for machining technology development.

(11) Band saw work

A Periodically inspect the welded part of the blade to make sure that it is safe.

B If the blade needs to be replaced, contact the staff of Center for machining technology development.

C When any abnormalities such as an unstable cut surface are found, notify the staff of Center for machining technology development.

D Use the provided presser to cut small workpieces.

E Process at an appropriate cutting speed without forcibly pressing the workpiece against the blade.

(12) Pressing and shearing work

A Pressing and shearing work is injury-prone, which can cause amputation of fingertips. Please conduct these tasks carefully.

B When cutting the sheet metal with a shearer, attach it securely using an appropriate tool such as a presser foot. Do not touch the area near the blade or presser.

C Materials that exceed the cutting capacity of the machine are not to be handled.

(13) Gas welding and fusing work

Welding, fusing, and heating of metals using combustible gas and oxygen can only be done by those who have completed the gas welding skill training stipulated in the Industrial Safety and Health Act.

A Do not operate the oxygen container, regulator, torch, etc., with oil or grease on your hands or gloves.

B Make sure to connect the adjuster, torch, conduit, etc. using a fastener. Inspect each joint for leaks using soapy water.

C In a case of backfire during work, immediately close the oxygen valve of the torch and then close the acetylene valve.

D Check the nozzle that caused the backfire and ignite again if there are no abnormalities. If a backfiring repeats, replace the nozzle.

E Use the built-in cleaning stick to clean the nozzle. Large deformed holes can cause backfire.

F Gas welding and fusing may cause burns due to the scattering of high-temperature molten metal. Wear protective glasses, gloves, hats, apron, etc.

G Do not work near inflammable objects.

(14) Shielded metal arc welding work

Arc welding can only be done by those who have completed the special education stipulated in the Industrial Safety and Health Act.

A Prevention of injuries caused by electric shock

◇ Use insulating gloves and footwear.

◇ Do not work while wearing wet work clothes (due to sweat or water).

◇ Use completely insulated holders.

◇ Ensure that the power supply of the welding machine is turned off when stopping work.

B Prevention of injuries caused by harmful rays

◇ Use a light-shielding surface when looking at intense rays of the arc. Viewing the arc with the naked eye can result in electricity-induced eye inflammation.

◇ Use hand shields and protective glasses for work, and if necessary, use helmets, leather aprons, arm pads, and foot covers.

◇ Do not roll up the sleeves of work clothes or work with open-chested clothes.

◇ Use a screen to prevent the scattering of arc light to prevent harm to other workers.

C Prevention of injuries due to welding smoke

◇ Sufficiently ventilate the work room.

◇ Use dry welding rods.

D Prevention of other disasters

◇ When touching the welded part directly with hands, be sure to touch it after checking the temperature to avoid burns.

◇ After finishing using welding rods, confirm that their temperature has dropped, after which discard them in a designated location.

◇ Do not work with combustible gas or highly inflammable materials nearby.

3 Precautions when malfunctions or injuries occur in various machine tools and work equipment (important as a follow-up measure!!)

(1) Malfunctions of machine tools and work equipment

A In case of even a slight unusual discomfort from information obtained from eyesight, hearing, or smell during work, contact the staff of Center for machining technology development and receive instructions.

B If the machine breaks down or an abnormality is found, promptly contact the staff of the work center and receive the necessary instructions.

C If there is a sudden power failure during processing, turn off the main power supply of the machine that is in use, and then follow the instructions of the staff of Center for machining technology development.

D For any malfunctions due to inattentiveness rather than the machine life or sudden accident, inform the staff of Center for machining technology development in detail about the reason for the malfunction, the process, etc., to avoid recurrence.

(2) Injuries, etc.

A In a case of sustaining an injury during work, contact the staff of the work center and receive necessary first aid, appropriate treatment, and other instructions from the appropriate individual (i.e., person instructed by staff of Center for machining technology development).

B To avoid recurrence of similar accidents, report the reason, process, and situation of the injury to the staff of the work center as soon as possible after the completion of treatment.

* Attention!

The most frequent accident at the center for Machining Technology Development in the university is a “fingertip” injury.

The injuries in machining work using lathes, milling machines, grinding machines, drilling machines, saws, etc., occur due to:

◇Inadvertent contact with sharp blades

◇Processing chips with bare hands

◇Workpieces swinging or flying off due to board being set in an unstable manner.

Most of the injuries were mild, such as those requiring emergency bandages, but some of them were serious, that needed a month for complete recovery. Many of these were just one step away from finger amputation. To enjoy the satisfaction of completing a product, please ensure to carefully read the “Safety precautions of machine tools” and work very carefully to avoid injuries.

Section 7 Transportation and work at heights

Transportation work includes work using cranes, derricks, chain blocks, and other lifting devices and transport vehicles. Additionally, when working at heights, stepladders and ladders may be used to climb roofs etc.

Devices such as cranes can only be operated by those who have a license or qualification, and those without them are not to conduct this kind of work.

High-elevation work refers to work done at a height of 2 m or more from the ground or floor, and work must be done with multiple people wearing safety belts and hard hats.

This type of work often involves multiple workers and has high risk of accident-based injuries. Therefore, instructions and instruction system during work need to be clarified. Work involving the transportation of heavy objects should be done under a single instructor.

1 Work that requires specified licenses, qualifications, etc.

The following types of work, which have a high risk of harm, must not be conducted by an individual unless they have a specified license or qualification stipulated for that work.

(1) Work involving the operating or slinging of cranes with a lifting load of 5 t or more, mobile cranes, or other lifting equipment, and derricks with a load limit of 5 t or more.

(2) Work involving lifting with lifting equipment with a limit load of 1 t or more, cranes with a lifting load of 1 t or more, or mobile cranes and derricks.

(3) Work involving the operation of vehicle-based construction machinery (e.g., for leveling, transportation, loading) with a body weight of 3 t or more.

2 Work other than the above

Work involving operations that do not require a specified license or qualification cannot be conducted by instructors or students unless they have undergone special training of risk prevention regarding the structure, function, work method, handling of equipment, and risk prevention provisions.

3 Work with cranes, derricks, and chain blocks etc.

(1) These are used for lifting or moving heavy objects and are operated electrically or manually. However, only authorized individuals are to be engaged in the operation or other work, and the following precautions should be sufficiently followed:

A Do not touch the power supply equipment.

B Be sufficiently far from under or near heavy objects during lifting/lowering and moving work.

C Operate according to the worker's instructions and observe the hazardous work until an unqualified

person is allowed to assist.

D Individuals should seriously take the utmost care towards their physical safety.

(2) Individuals other than the driver should avoid chattering or fooling around and pay close attention to prevent accidental personal injury due to inattentiveness. Do not let the person ignoring this warning engage in related work or experiments.

(3) People engaged in this work should wear safety caps (helmets), safety shoes, and clothing that is suitable for work.

4 Work with transport vehicle

Private car should not be used for research, education, etc., but if it must be used, then please observe the following precautions:

(1) To avoid accidents due to fatigue and busyness, give sufficient consideration especially when transporting to a distant location, and follow the instructions of an instructor such as riding or driving with two or more people.

(2) Load the cargo as low as possible and properly fasten the same. Do not overload the vehicle.

(3) Do not stack material on one side, and ensure that the items do not stick out of the vehicle body.

(4) Load heavy items first and light items later.

(5) Use a danger sign when transporting hazardous materials and large items.

(6) Have a lookout or signaler in a particular need.

5 Work at heights

(1) Be well-prepared and well-positioned, and never conduct unreasonable or hazardous work. Always have an observer.

(2) Pay attention to scaffolding; always use a lifeline such as a safety belt, and confirm the safety of the support part of the lifeline.

(3) When working on the roof, pay particular attention to feet placement. Prepare tread especially in the case of a slate. Also, be especially careful when passing over beams.

(4) Never use slippery footwear when conducting high-elevation work.

(5) Do not underestimate situations when working at elevations. Even slightly elevated areas can cause death if an individual falls.

(6) When using scaffolding, roofs, lifelines, ladders, etc., make sure that they are sufficiently safe before starting work.

(7) When using force for work at high elevations, avoid using more than half the force that would be used on the ground.

(8) Do not lift or carry heavy objects on scaffolding or roofs.

(9) Precautions regarding ladders

A Use ladders that are durable, not too long, and well-suited for the task. When hanging a ladder, choose a location where the scaffolding is solid, avoid places in front of hinged doors and places where people may pass along corridors, and have an observer at the base. An angle of around 15° with respect to the wall is appropriate.

B Do not use ladders when they are wet or oily and in a slippery state. Additionally, do not use items that may break the crossbar.

C Going up and down a ladder should be done alone. Do not hold any items while doing so.