## Contents

## 1. Purpose of this manual

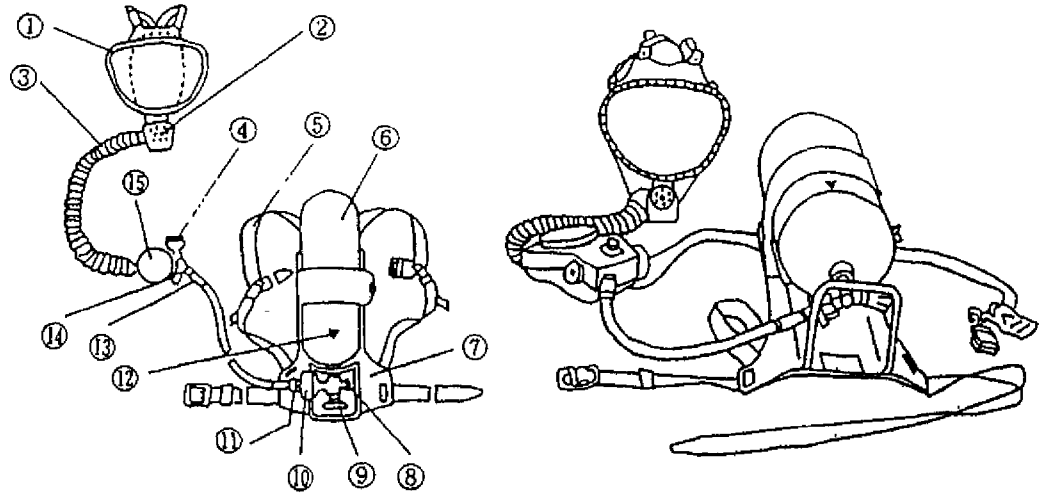
This manual provides the information critical for firefighters to acquire the proficiency and improve their skill of utilization of typical rescue equipment used either directly, indirectly or auxiliary to save life of people. Some rescue equipment with special functions are also explained in this manual.

## 2. Air breathing apparatus

Air breathing apparatus is one of the most frequently used equipment to protect a firefighter from smoke, hazardous or toxic gases and/or low oxygen air.
Air breathing apparatus are roughly classified into 2 types, a Demand-type and a Pressure-demand type. This manual contains information about conventional demand-type air breathing apparatus and automatic pressure-demand type air breathing apparatus used by the Fire Department of Osaka City.

(1) Demand-type air breathing apparatus

A. Name of each part




Type J　　Type N

| | | | | | |
|---|---|---|---|---|---|
| 1 | Mask | 6 | Oxygen container | 11 | Connection nut |
| 2 | Microphone, air valve | 7 | Hanger | 12 | Triangle mark |
| 5 | Air hose | 8 | Safety valve | 13 | High pressure hose |
| 4 | Pressure gauge | 9 | Stop valvepg | 14 | Bypass valve |
| 5 | Shoulder belt | 10 | Alarm | 15 | Regulator |

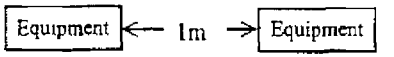
## B. Main body

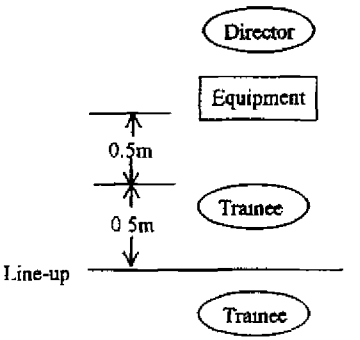
| | |
|---|---|
| Regulator | This 2-step pulmonary power reducing regulator consists of a reducer valve, medium pressure safety valve and pulmonary power valve, etc..<br><br>This regulator is capable of controlling respiration up to 180 ι per minute (equivalent to a negative pressure of about 25mmHg) by reducing the pressure down to approx. 0.5 MPa with the reducer valve and recovering the atmospheric pressure with the pulmonary power valve, thus the regulator can protect the respiration of a firefighter in any harsh conditions. |
| Bypass valve | This valve assures the safety of a firefighter even if the reducer and/or pulmonary power valve ceased functioning.<br><br>When the knob of the valve is turned, the air inside the container will bypass the reducer and pulmonary power valves and flows directly to the mask. The pressure is reduced to the atmospheric level when the air is released through the valve seat.<br><br>Necessary amount of air can be supplied within one full turn of the knob. Air amount to be supplied is controlled by changing the opening degree of the valve with the knob. |
| Alarm | This alarm system automatically outputs an alarm beep using the air pressure inside the container. When the air pressure inside the container increases to approx. 3 MPa, an alarm beeps to warn the firefighter for withdrawal.<br><br>The alarm sound does not stop until the pressure inside the container is reduced to 0.7～1.5 MPa. |

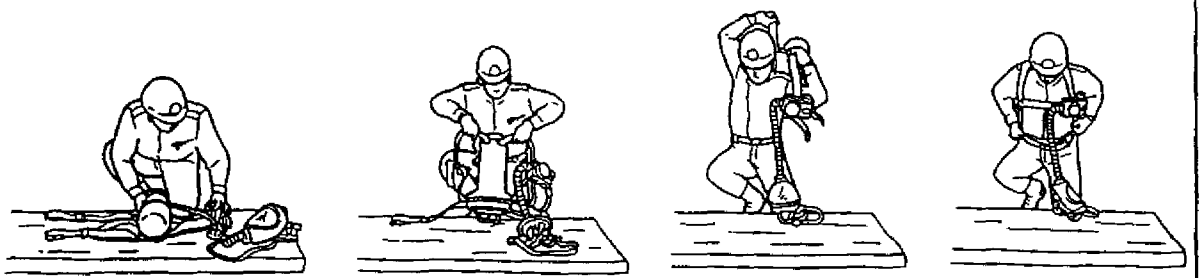
## C. Air container

| Type of container | 6 ι type | 8 ι type |
|---|---|---|
| Max. pressure (MPa) (at 35℃) | 15 | 15 |
| Internal volume ( ι ) | 6 | 8 |
| Air amount ( ι ) | 900 | 1,200 |
| Outer diameter (mm) | 164 | 176 |
| Length (mm) | 420 | 480 |
| Weight (kg) (not including air weight) | 7.4～8.1 | 9.8 |
| Pressure resistance test pressure (MPa) | 25 | 25 |
| Material | Chrome morybudemn steel | |

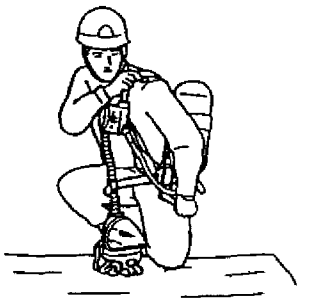
## Operational Procedure of Air Breathing Apparatus (Model 150)

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| Preparation | | 1. Position the necessary equipment at the specified locations.<br>2. If there are more than 2 operators ("sub-team"), place the equipment at an interval of 1m. *1 |  | *1: The equipment must be placed on a salvage sheet, blanket or mat. |
| 1 Line up | (1) | "Line up" *2 | **"Yes, sir"**<br>Run to the specified location, line up, and position correctly facing to the equipment.<br>* In the case of a training of a sub-team, the trainees should start running at the sign of the top trainee (positioned at the right end) to the specified position and stand in one horizontal row. *3 | *2: In the case of a sub-team, position at the center of the equipment on the right end and command. Move to the center after all the members lined up and take a roll call.<br>*3: The front member should stop in front of the equipment at the right end. |
| | (2) | "Air breathing apparatus, training start. Position." | **"Yes, sir."**<br>Move to the position before the equipment by 50cm. | |
| 2 Check | (3) | "Start checking"<br>The director should move to proper position so that he or she can check each trainee. Give instructions as necessary (the same is applied to the procedures below). | **"Yes, sir"**<br>Move the right leg forward by one step, kneel and check the equipment following the procedure below. *4<br>1. Check the connection nut and container belt for loosening. "Container connection OK."<br>2. Check the HP pipe, regulator and respiration tube. "HP pipe OK.", "Regulator OK.", "Respiration tube OK." *5<br>3. Check the respiration valve and speaking tube. "Respiration valve OK.", "Speaking tube OK."<br>4. Check the inside and outside of the mask and belt, etc. . "Mask OK."<br>5. Fully open the stop valve (turn backward by half-turn) and check the pressure. "Pressure ○○ MPa."<br>6. Open the bypass valve and check the function. "Bypass valve OK."<br>7. Close the stop valve and check the pressure reading. "No gas leak." *6<br>8. Slightly open the bypass valve and gradually lower the pressure. Make sure that the alarm beeps when the pressure is approx. 3 MPa. "Alarm OK."<br>9. Check the shoulder belt, chest belt and waist belt. "Belt OK."<br>Put the left hand on the left knee, keep the chin up and raise the right hand straight up.<br>" ** check over. No problem." *7 | *4: If any abnormality is found during inspection, it should be immediately corrected. If the abnormality cannot be corrected, the abnormality including the location and condition should be reported to the director.<br>*5: Make sure that the pressure reading is zero and the bypass valve is closed.<br>*6: There is no problem to the air tightness if the pressure reading does not change for approx. 1 minute.<br>*7: In the training of sub-team, a number can be used for **. |



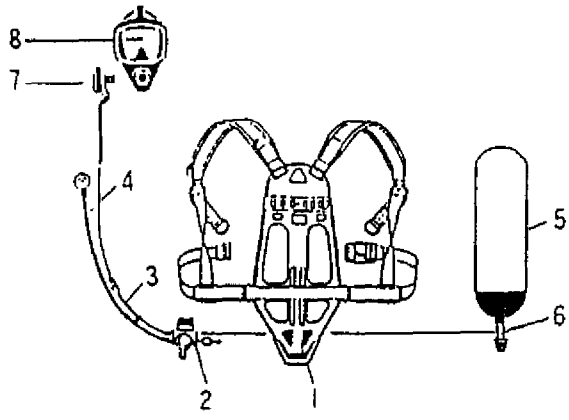
| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| 3 Wearing main unit | (4) | "Wear the apparatus." Check if each trainee is wearing the apparatus properly and give instructions as necessary. If a trainee is not wearing the apparatus correctly, the director should instruct the correct condition without helping it by directly touching his or her apparatus (the same is applied to the procedures below). | **"Yes, sir."** Wear the main unit, following the procedure below.<br>1. Hold the pressure gauge for ease of reading and fully open (turn backward by half-turn) the stop valve with the right hand." Pressure ○○ MPa."<br>2. Hold the upper portion of the right (left) shoulder belt with the right (left) hand and stand the equipment.<br>3. Carry the equipment on your back by first passing your left arm through the left shoulder belt (*8 ) and then passing through your right arm through the right shoulder belt.<br>4. Fasten the side belt. "Side belt OK." *9<br>5. Fasten the chest belt. "Chest belt OK." *10<br>6. Fasten the waist belt. "Waist belt OK" *10<br>Put the strand of the mask around your neck, stand up and keep your chin up. "Main unit OK." *11<br>Open your legs by moving the left leg by half a step, put your hands at the sides of your legs and wait for the next command.<br>  | *8: Move the main unit up so that the hand holding the belts come to your chest. Turn the main unit to the left, raise your right arm to the left back of your head and put your left arm under the belt from the elbow by twisting your left shoulder downward in diagonal direction.<br>*9: Securely fasten the belt so that you can carry as much load of the main unit as possible on your back.<br>*10: Each belt must be properly fastened so that the main unit fits your body. There should be no twisting of the belts. The end of the belts should be properly positioned on your clothes.<br>*11 Stand-up straight by drawing your right leg to the left leg. |

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| 4 Wearing mask off | (5) | "Wear Mask."<br>Check if each trainee is wearing the mask correctly.<br>In particular, a twisting of air tube and the opening degree of the valves must be carefully checked for. The director should call "Stop valve half-closed OK, Pressure ○○ MPa", etc. When the trainee is handling the apparatus correctly, tap him or her on the shoulder and call "Wearing OK." | **"Yes, sir"**<br>1. Loosen the helmet belt and move the helmet backward.<br>2. Hold the mask belts with your both hands (for the chin and temple), put your face into the mask from your chin and pull the mask backward.<br>3. Fasten the belt in order from the chin, temple and then head so that the mask securely fits your face. *12<br>4. Bent the air tube at the center and hold it with your both hands. Deeply breathe several times to confirm the air-tightness of the mask.<br>5. Wear the helmet, tighten the chin belt and raise your right hand straight up. "Mask OK." *13<br>  | *12: The mask belt should be fastened so that the center of all the belts comes to the center of your rear head.<br>*13: Do not lower your hand until the director check your wearing condition, tap on your shoulder and calls "OK.". |
| 5 Putting mask off | (6) | "Put the mask off." | **"Yes, sir"**<br>1. Loosen the chin belt and move the helmet backward.<br>2. Hold the center of all the mask belts with your left hand and remove the mask by holding the lower portion of the mask with your right hand.<br>3. Wear the helmet and wait for the next command. | |

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| 6 Putting main unit off | (7) | "Put the main unit off." | **"Yes, sir"**<br>Position in the same manner as that for wearing main unit and put the main unit off, following the procedure below:<br>1. Unfasten the waist belt, chest belt and shoulder belt.<br>2. Take the right shoulder belt off and hold the protective frame with your left hand.<br>3. Stand the main unit on your left side with the protective frame on the ground. Hold the left shoulder belt with your right hand and take the left shoulder belt off.<br>4. Hold the right and left shoulder belts with your reight and left hand, respectively, and place the main unit to the original position.<br>  | |
| 7 Store | (8) | "Store." | **"Yes, sir."**<br>1. Check the residual pressure. "Pressure ○○ MPa"<br>2. Close the stop vale, open the bypass valve to release the air trapped inside the HP pipe and then close the bypass valve.<br>3. Put the belts in order. *13<br>Go back to the line-up position, correct your clothing and wait for the next command at "At ease" position. | *13: Loosen the mask belt and waist belt to their ends. |
| 8 Break up | (9) | "Report."<br>Answer "OK" when each trainee finishes reporting. | "** and equipment., no problem" | |
| | (10) | "Break up." | **"Yes, sir"**<br>Salute and run to the stand-by position. *14 | *14: In the case of a training of a sub-team, the members should return to the stand-by position following after the member positioned at the right end of the row . The member at the right end should call command of breaking up. |

(2) Automatic pressure-demand type air breathing apparatus

A. Name of each part




1. Hanger
2. Pressure reducer (with alarm generator)
3. Medium pressure hose
4. Pressure gauge, high pressure hose
5. Container
6. Stop valve
7. Automatic pressure-demand type regulator
8. Mask (pressure-demand type)

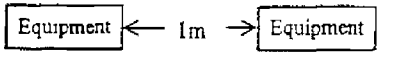
B. Main body

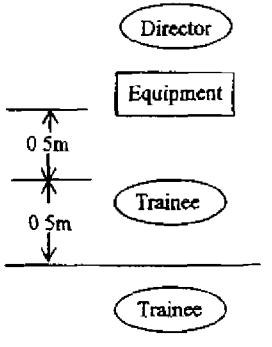
| | |
|---|---|
| Regulator | This is an automatic pressure-demand type regulator. When a firefighter wears the mask and starts breathing, the pressure inside the mask become a positive pressure, which is higher than the atmospheric pressure by 0.19 ~0.35 MPa (the positive pressure is maintained at the container pressure of 1 MPa.) |
| Reducer | This reducer is available for any container pressure up to 30 MPa.<br>Pressure drop<br>Container — 30 MPa — Reducer — Med. pressure hose 0.7 MPa — Regulator — Atmospheric pressure + 0.19 ~0.35MPa — Mask |
| Alarm | The alarm is designed for water and dust proof, and automatically beeps using the air pressure inside the container. When the pressure inside the container increases to 5 MPa, a whistle sound of over 90 phone is generated to warn the firefighter for withdrawal.<br><br>The alarm starts beeping when the container pressure increases up to 5 MPa and continues beeping at a constant level until the pressure drops to 1 MPa. |

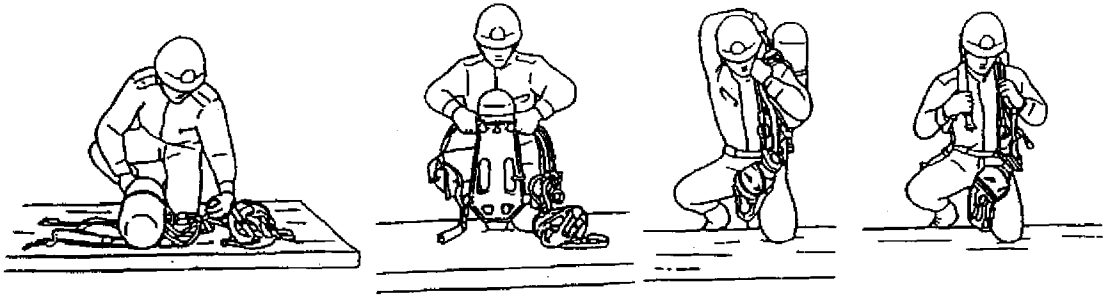
C. Air container

| Type of container | 9 ι type | 4.7 ι type |
|---|---|---|
| Max. pressure MPa (at 35℃) | 30 | 30 |
| Internal volume ( ι ) | 9 | 4.7 |
| Air amount ( ι ) | 2,700 | 1,410 |
| Outer diameter (mm) | 182 | 138 |
| Length (mm) | 610 | 565 |
| Weight (kg) (not including air weight) | Approx. 8.4 | Approx. 4.7 |
| Pressure resistance test pressure (MPa) | 50 | 50 |
| Material | Aluminum liner | Aluminum liner |

**Operational Procedure of Air Breathing Apparatus (Model 300)**

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| Preparation | | 1. Position the necessary equipment at the specified locations.<br>2. f there are more than 2 operators ("sub-team"), place the equipment at an interval of 1m. *1 |  | *1: The equipment must be placed on a salvage sheet, blanket or mat. |
| 1 Line up | (1) | "Line up" *2 | "Yes, sir"<br>Run to the specified location, line up, and position correctly facing to the equipment.<br>* In the case of a training of a sub-team, the trainees should start running at the sign of the top trainee (positioned at the right end) to the specified position and stand in one horizontal row. *3 | *2: In the case of a sub-team, position at the center of the equipment on the right end and command. Move to the center after all the members lined up and take a roll call.<br>*3: The front member should stop in front of the equipment at the right end. |
| | (2) | " Air breathing apparatus, training start. Position." | "Yes, sir"<br>Move to the position before the equipment by 50cm. | |
| 2 Check | (3) | "Start checking"<br>The director should move to proper position so that he or she can check each trainee. Give instructions as necessary (the same is applied to the procedures below). | "Yes, sir"<br>Move the right leg forward by one step, kneel and check the equipment following the procedure below. *4<br>1. Check the connection nut and container belt for loosening. "Container connection OK."<br>2. Check the high pressure and intermediate pressure hoses. "High pressure hose OK.", "Intermediate pressure hose OK."<br>3. Check the respiration valve and speaking tube. "Respiration valve OK.", "Speaking tube OK."<br>4. Check the inside and outside of the mask and belt, etc.. "Mask OK."<br>5. Connect the mask and regulator. "Mask and regulator connection OK." *5<br>6. Check the intermediate pressure hose of the less-mask and connect the hose. "Intermediate pressure hose OK.", "Less-mask connection OK."<br>7. Make sure that the stop button (red) is depressed, fully open the stop valve (turn backward by half-turn) and check the pressure. "Pressure ○○ MPa."<br>8. Put the mask over your face, breathe several times and make sure that the regulator function (positive pressure is automatically attained). "Regulator OK."<br>9. Press the stop button and remove the mask from your face. "Stop button OK." | *4: If any abnormality is found during inspection, it should be immediately corrected. If the abnormality cannot be corrected, the abnormality including the location and condition should be reported to the director.<br>*5: Make sure that the pressure reading is zero and the bypass valve is closed. |



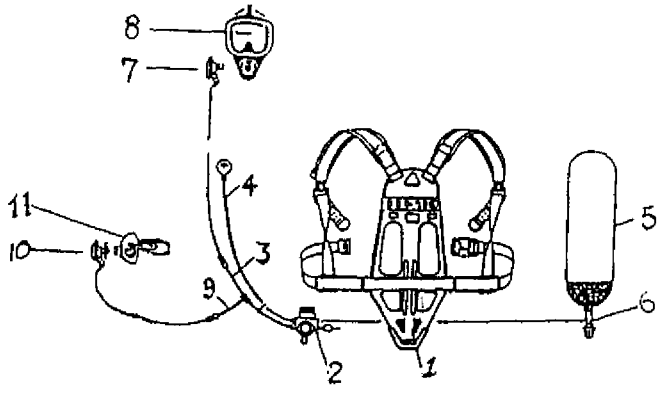
| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| | | | 10. Put the less-mask over your mouth and breathe. "Regulator function OK."<br>Push the center of the regulator and make sure that air is released. "Bypass valve OK."<br>11. Remove the mask and regulator. "Mask and regulator removal OK."<br>12. Close the stop valve and check the pressure reading. "No gas leak." *6<br>13. Disconnect the hose of the less-mask. "Less-mask disconnection OK."<br>14. Press the center of the regulator (continuous replenishing button), move your palm up gradually and make sure that air is released. "Continuous replenishing button OK."<br>15. Make sure that the alarm beeps when the pressure is approx. 50kg/cm$^2$. "Alarm OK."<br>Make sure that the pressure gauge read zero and press the stop button.<br>16. Check the shoulder belt, chest belt and waist belt. "Belt OK."<br>Put the left hand on the left knee, keep the chin up and raise the right hand straight up.<br>" ** check over. No problem." *7 | *6: There is no problem to the air tightness if the pressure reading does not change for approx. 1 minute.<br><br>*7: In the training of sub-team, a number can be used for ** |
| 3 Wearing main unit | (4) | "Wear the apparatus." Check if each trainee is wearing the apparatus properly and give instructions as necessary.<br>If a trainee is not wearing the apparatus correctly, the director should instruct the correct condition without helping it by directly touching his or her apparatus (the same is applied to the procedures below). | **"Yes, sir"**<br>Wear the main unit, following the procedure below.<br>1. Hold the pressure gauge for ease of reading and fully open (turn backward by half-turn) the stop valve with the right hand." Pressure ○○ MPa."<br>2. Hold the upper portion of the right (left) shoulder belt with the right (left) hand and stand the equipment.<br>3. Carry the equipment on your back by first passing your left arm through the left shoulder belt (*8 ) and then passing through your right arm through the right shoulder belt.<br>  | *8: Move the main unit up so that the hand holding the belts come to your chest. Turn the main unit to the left, raise your right arm to the left back of your head and put your left arm under the belt from the elbow by twisting your left shoulder downward in diagonal direction. |

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| | | | 4. Fasten the side belt. "Side belt OK." *9<br>5. Fasten the chest belt. "Chest belt OK " *10<br>6. Fasten the waist belt. "Waist belt OK" *10<br>7. Put the strand of the mask around your neck, stand up and keep your chin up. "Main unit OK." *11<br>Open your legs by moving the left leg by half a step, put your hands at the sides of your legs and wait for the next command. | *9: Securely fasten the belt so that you can carry as much load of the main unit as possible on your back.<br>*10: Each belt must be properly fastened so that the main unit fits your body. There should be no twisting of the belts. The end of the belts should be properly positioned on your clothes.<br>*11 Stand-up straight by drawing your right leg to the left leg. |
| 4 Wearing mask off | (5) | "Wear Mask."<br>Check if each trainee is wearing the mask correctly.<br>In particular, a twisting of air tube and the opening degree of the valves must be carefully checked for. The director should call "Stop valve half-closed OK, Pressure ○○ MPa", etc.,. When the trainee is handling the apparatus correctly, tap him or her on the shoulder and call "Wearing OK." | **"Yes, sir"**<br>1. Loosen the helmet belt and move the helmet backward.<br>2. Hold the mask belts with your both hands (for the chin and temple), put your face into the mask from your chin and pull the mask backward.<br>3. Fasten the belt in order from the chin, temple and then head so that the mask securely fits your face. *12<br>4. Wear the helmet, tighten the chin belt and raise your right hand straight up. "Mask OK." *13 | *12: The mask belt should be fastened so that the center of all the belts comes to the center of your rear head.<br>*13. Do not lower your hand until the director check your wearing condition, tap on your shoulder and calls "OK.". |

| Classification | Sequence | Director | Operator | Remarks |
|---|---|---|---|---|
| 5 Putting mask off | (6) | "Put the mask off." | **"Yes, sir"**<br>1. Loosen the chin belt and move the helmet backward. Press the stop button and loosen the mask belt *14<br>2. Hold the center of all the mask belts with your left hand and remove the mask by holding the lower portion of the mask with your right hand.<br>3. Wear the helmet and wait for the next command. | *14 The stop button must not be pressed until the breathing of victim is ensured. |
| 6 Putting main unit off | (7) | "Put the main unit off." | **"Yes, sir"**<br>Position in the same manner as that for wearing main unit and put the main unit off, following the procedure below:<br>1. Disconnect the mask and regulator, take the belt around your neck off, and place the mask at the original position.<br>2. Unfasten the waist belt, chest belt and shoulder belt.<br>3. Take the right shoulder belt off and hold the protective frame with your left hand.<br>4. Stand the main unit on your left side with the protective frame on the ground. Hold the left shoulder belt with your right hand and take the left shoulder belt off.<br>5. Hold the right and left shoulder belts with your right and left hand, respectively, and place the main unit to the original position | |
| 7 Store | (8) | "Store." | **"Yes, sir."**<br>1. Check the residual pressure. "Pressure ○○ MPa."<br>2. Close the stop vale, open the bypass valve to release the air trapped inside the high pressure and intermediate pressure hoses and then close the bypass valve.<br>3. Put the belts in order. *15<br>Go back to the line-up position, correct your clothing and wait for the next command at "At ease" position. | *15: Loosen the mask belt and waist belt to their ends. |
| 8 Break up | (9) | "Report."<br>Answer "OK" when each trainee finishes reporting. | "** and equipment., no problem" | |
| | (10) | "Break up." | **"Yes, sir"**<br>Salute and run to the stand-by position. *16 | *16: In the case of a training of a sub-team, the members should return to the stand-by position following after the member positioned at the right end of the row . The member at the right end should call command of breaking up. |

(3) Automatic pressure-demand type air breathing apparatus (Less-mask type)

A. Name of each part




1. Hanger
2. Pressure reducer (with alarm generator)
3. Medium pressure hose
4. Pressure gauge, high pressure hose
5. Container
6. stop valve
7. Automatic pressure-demand type regulator
8. Mask (pressure-demand type)
9. Bypass hose (for less-mask)
10. Regulator (pulmonary power type)
11. Half-mask

B. Main body

The regulator and alarm are the same as those of the standard type.

| | |
|---|---|
| Reducer | This regulator can cope with the maximum container pressure of 30MPa.<br>Pressure reduction<br>Container — 30 MPa — Reducer — Med. pressure hose 0.7 MPa — Regulator — Less-mask pulmonary power type — Half-mask<br>Regulator — Atmospheric pressure + 0.19 ~0.35 MPa — Mask |

C. Air container

The air container is the same as that of the standard type.

(4) General cautions

a. Any member who uses an air breathing apparatus must know his or her air consumption under each work load. In particular, it must be understood that the service hour of an air breathing apparatus remarkably reduces under high pressure environment due to a sharp rise of air consumption.

b. There should be no twisting of air hose and/or high pressure hose.
c. Any member who wears an air breathing apparatus must check the pressure gauge frequently to confirm the amount of remaining air.
d. The air container must not be placed under high temperature environment (including a place exposed to direct sunlight). Mixture of air and oxygen may result in an explosion. NEVER mix air and oxygen.
e. The stop valve and regulator must be free of oil.
f. The equipment must be handled carefully. Do not handle the equipment in an improper manner such as carrying it by holding the stop valve.
g. An automatic pressure-demand type air breathing apparatus is designed so that the air pressure inside the mask is higher than the pressure of external air. Therefore, it is recommended to use an automatic pressure-demand type air breathing apparatus, rather than pulmonary power type, for a rescue activity in an environment with toxic gas or shortage of oxygen.

**IMPORTANT**

Should your mask dislocate during rescue activity in an environment with toxic gas or shortage of oxygen, follow the procedure below.

* If you are wearing a pulmonary power type breathing apparatus: Stop your breath, wear the mask correctly, clean inside the mask by opening the bypass and exhaust valves, and restart breathing.
* If you are wearing automatic pressure-demand type breathing apparatus:
  There will be no problem if the automatic replenishing valve is functioning. However, if you breathe deeply with the mask slightly dislocated, the pressure inside the mask may abruptly drop. It is necessary to breathe gently.

h. Contamination of goggle glasses must be cleaned with soft cloth soaked with detergent diluted in warm water. Remove the contamination gently but carefully, and then rinse them thoroughly with water. (NEVER use organic solvents such as thinner.)
I. If your mask is contaminated with sweat, etc., disconnect the mask from the breathing apparatus main unit and clean with water. Dry well and re-connect it to the breathing apparatus main unit. (Avoid direct sunlight to dry the mask.)

**[Reference 1]**

**Standard service hour**

* Standard service hour under normal environment
  - The standard service hour can be obtained by the equation below:

$$\frac{\text{(Filling pressure - remaining pressure) x volume}}{\text{amount of respiration per minute}} = \text{standard service hour}$$

  - The pressure of remaining air necessary for a firefighter to escape is calculated using the equation below:
    (Time necessary for escape x pressure consumed per minute)
    + alarm pressure = pressure necessary for escape

* Standard service hour under high pressure atmosphere
  Since the air consumption increases in proportion to the environmental pressure, the service hour decreases in inverse proportion to the environmental pressure. The service hour under high pressure atmosphere is obtained by the equation below:

$$\frac{\text{(Filling pressure - remaining pressure) x volume}}{\text{amount of respiration per minute x (1 + environmental pressure (gauge pressure)}} = \text{standard service hour}$$

**[Reference 2]**

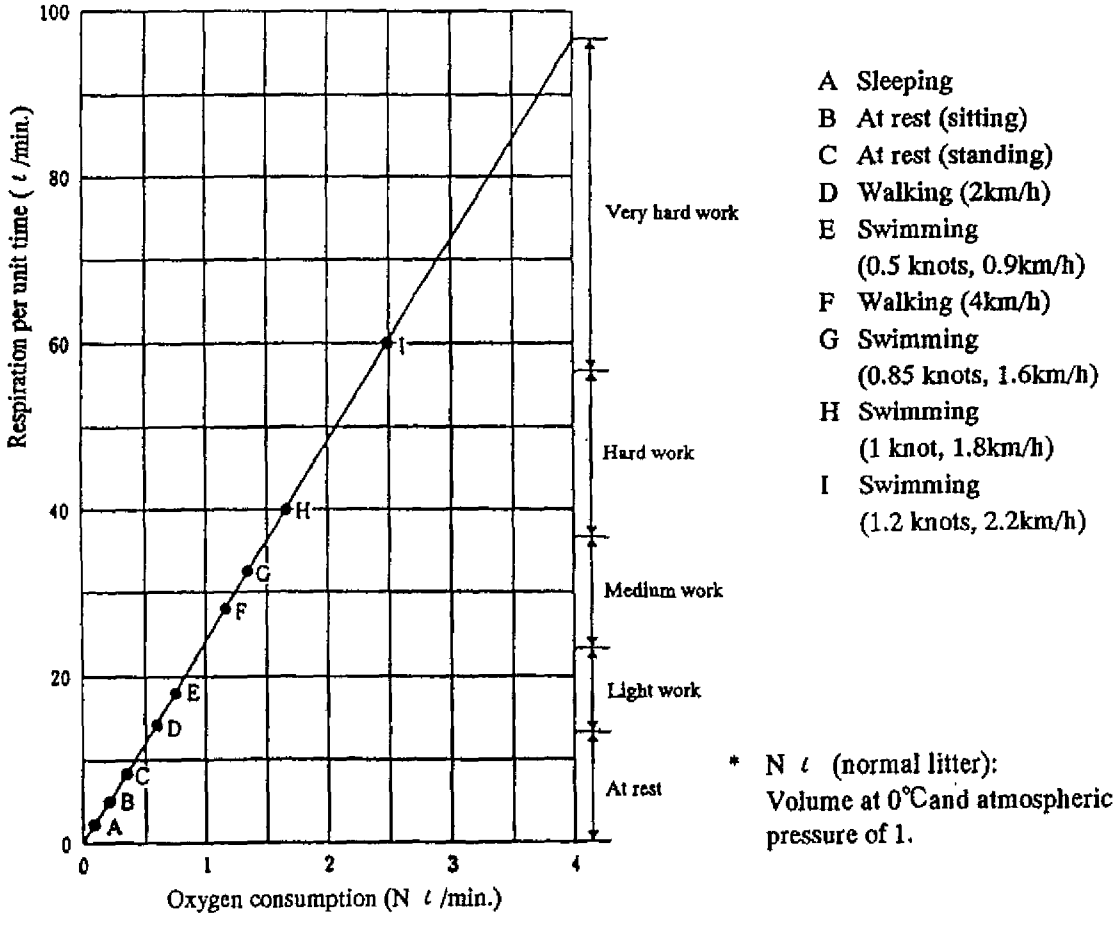
**Respiration**

* We normally breathe 4～7 ℓ of air per minute. By breathing, we take oxygen in air into our body and discharge carbon dioxide (carbon dioxide gas) produced in our body into air.
  The harder our physical labor is, the more oxygen we consume. Very hard work may require as much as 100 ℓ (air amount) per minute.
  The air taken into our body passes through trachea, bronchi and bronchiole, and then enters into small bag-like cells called pulmonary alveolus. Thus transferred oxygen is dissolved into blood flowing through the capillary vessels around the pulmonary alveolus.
  On the other hand, the carbon dioxide contained in the blood flowing through the capillary vessels goes into pulmonary alveolus.

The size of a pulmonary alveolus is 0.1～0.3 mm in diameter, and the total number of pulmonary alveolus in the left and right lungs is as many as 0.7～1.5 billion. The total surface area of these pulmonary alveolus reaches 90～140m$^2$. This means that the toxic substances in the breathed air come into contact with blood at a wide surface area in our lungs.

* Respiration amount and oxygen consumption

Fig. 1 Type and level of work load vs. respiratory amount and oxygen consumption




A Sleeping
B At rest (sitting)
C At rest (standing)
D Walking (2km/h)
E Swimming (0.5 knots, 0.9km/h)
F Walking (4km/h)
G Swimming (0.85 knots, 1.6km/h)
H Swimming (1 knot, 1.8km/h)
I Swimming (1.2 knots, 2.2km/h)

* N ℓ (normal litter): Volume at 0℃and atmospheric pressure of 1.

**[Reference 3]**

**Shortage of oxygen**

* Definition

Oxygen concentration in air is normally approx. 21%. The "shortage of oxygen" refers to a state where the oxygen concentration is below 18%.

* Anoxia

Shortage of oxygen in cells *in vivo* increases the production of lactic acid, resulting in acidification of blood. Acidic blood irritates the central respiration and cardiac systems to increase the depth and number of respiration and cardiac pulsation so that more air is inhaled to increase the oxygen intake, and a larger amount of blood, which has low oxygen content, circulates. In addition, the blood vessels in the brain expand to accept the increased amount of blood. However, all these compensation mechanisms and functions in normal person lose effects if the oxygen concentration in air drops to approx. 16% or lower.

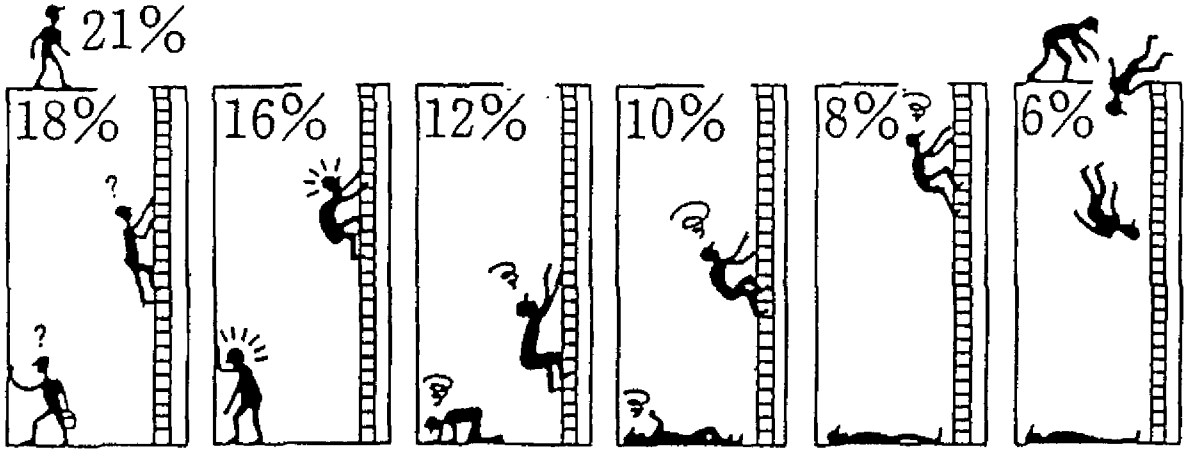



Fig. 2 Symptom developed due to oxygen shortage

**Causes of oxygen shortage**

Danger of oxygen shortage exists in areas isolated from outdoor air or with poor ventilation, such as basements, tanks, ship holds, closed conduits, and foundation portion. Oxygen shortage occurs in such areas due to the reasons below:

1. Consumption of oxygen in air
2. Air with low oxygen content jets out.
3. Replacement by gases (methane, nitrogen, carbon dioxide or freon, etc. jetting out) other than air

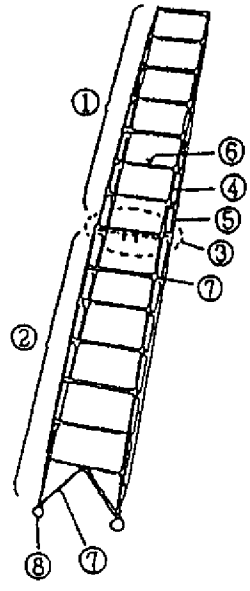
In many cases, the causative factors listed above correlate with each other, resulting in an accident. If a gas in 3 above jets out, accidents due to oxygen shortage may occur even in an outdoor area with good ventilation depending on the conditions.

## 3. Rescue ladders

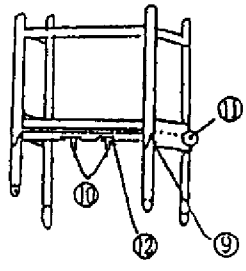
### (1) Folding ladders and ladders with hooks

#### A. Name of each part

[Folding ladder]

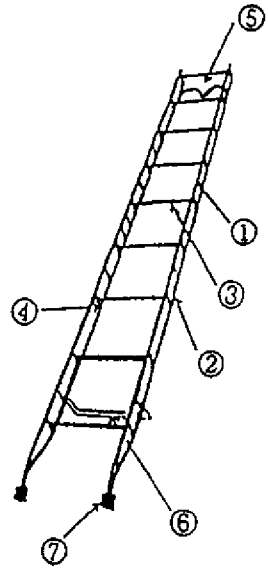



1. Upper ladder
2. Lower ladder
3. Joint
4. Main beam
5. Auxiliary beam
6. Horizontal bar
7. Strengthening beam
8. Rubber feet
9. Safety pin
10. Safety pin lever
11. Caulking pin
12. Safety pin oil hole




Magnified view of joint

[Ladder with hook]




1. Upper beam
2. Auxiliary beam
3. Horizontal bar
4. Strengthening beam
5. Large hook
6. Auxiliary leg
7. Rubber feet

#### B. Specifications

| Type | Folding ladder | Ladder with hook | |
|---|---|---|---|
| Manufacturer | | Maker A | Maker B |
| Length | 4.6m (unfolded)<br>2.36m (folded) | 3.1m | |
| Width | 450mm | 340mm | 320mm |
| Height | 268mm (storage) | 90mm | 110mm |
| Weight | Approx. 9kg | Approx. 8kg | Approx. 7kg |
| Main material | Titanium pipe for heat exchangers (TTH35W) | | Titanium pipe for piping channels (JIS H 4630) |

## C. Maximum load

| Ladder type | Maker | Load | When used by standing ladder (75 degrees) | When used in horizontal setup | When used by hanging |
|---|---|---|---|---|---|
| Folding ladder | Maker A | Dispersed load | 120kg (2 persons on ladder) | Not allowed. | Not allowed. |
| | | Load concentrated at one point | 110kg (1 person on ladder) | | |
| Ladder with hook | | Dispersed load | 180kg (2 persons on ladder) | ← | ← |
| | | Load concentrated at one point | 110kg (1 person on ladder) | ← | ← |
| | Maker B | Dispersed load | 180kg (2 persons on ladder) | ← | Not allowed. |
| | | Load concentrated at one point | 130kg (1 person on ladder) | ← | ← |

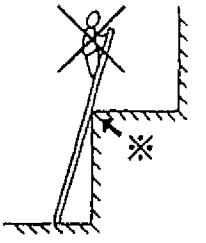
## D. Operational precautions

* Precautions common to both types of ladders
  1. When one person carries a ladder, he/she must carry it under his/her arm at the center of the ladder. (Care must be exercised not to strike against person(s) or thing(s) when making a turn.)
  2. The main beam should be used for climbing, whereas the auxiliary beam should be located on the target side.
  3. The standard angle to stand the ladder is 75 degrees. (The base of the ladder should be apart from the wall against which the ladder is leaning by 1/4 of the ladder length.

* Precautions for folding ladders
  1. When unfold the ladder, place the ladder on the ground with the upper ladder up, unfold at the joint, and make sure that the safety pin is securely inserted.
  2. When folding the ladder, place the ladder with the main beam down, pull the safety pin lever which is provided at the joint, inward, and fold.

E. Safety precautions

* Precautions common to both types of ladders
  1. A ladder must be placed at a flat, not a slanting, position.
  2. A ladder must be supported or fixed at a position close to the edge of the ladder.
  3. Climb the ladder gently to avoid excessive impact from being applied to the ladder (excessive impact will cause metallic fatigue of ladder joint).
  4. When using a ladder standing up, the standard angle should be 75 degrees, and the maximum allowed load must not be exceeded.

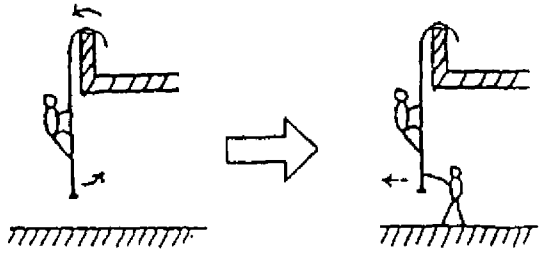



  5. The main beam should be used for climbing.
  6. A person who is going up or down a ladder must take hold of the horizontal bars for safety.
     - If you go up or down the ladder by carrying thing(s) with you, slide your empty hand along the auxiliary beam (your hand must always be in touch with the auxiliary beam).
  7. It is very dangerous to lean forward from a ladder. The ladder may slip in crosswise direction.
  8. NEVER climb on the ladder at a corner as shown in the figure on the right.
     - Since the ladder is supported at the point marked with "*" in the figure, not only the allowable load reduces but also the dangerous factors such as horizontal slipping will increase.

* Precautions for folding ladders
  1. A folding ladder must not be used in horizontal setup or being hanged.
  2. Fold the ladder gently
     - Unnecessary impact must be avoided to prevent deformation or metallic fatigue of the ladder.
  3. To move the unfolded ladder horizontally, carry the ladder with the main beam facing up.

* Precautions for ladders with hooks

1. When hanging the ladder, stand the main hook and hang it to a firmly fixed place. Make sure that the ladder is securely hooked before climbing up.
2. You must climb or do down the ladder by stepping at the centers of horizontal bars so that the equal load is applied to the entire hook as well as to prevent the ladder from swinging in crosswise direction.
3. The ladder must be secured so that the load applied to the hook is not in skew direction but in vertical direction. In particular, when the lower legs of the ladder cannot be fixed against the wall, the bottom of the ladder must be secured so that the ladder is pushed slightly away from the wall (although the ladder is pushed away from the wall, the ladder will become vertical due to the load of the person climbing up or coming down the ladder).



4. When the ladder is used in a horizontal setup, the maximum allowed load must not be exceeded.

F. Maintenance

* Precautions common to both types of ladders

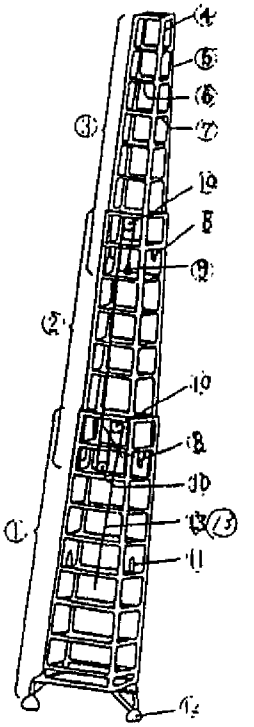
1. Confirm the items below and repair as necessary.
   (1) There should be no deformation of main or auxiliary beam, etc.
   (2) There should be no crack at welded portions
   (3) There should be no defect of anti-slip material of rubber feet and horizontal bars
   (4) There should be no abnormal abrasion
2. Lubricate the sliding portions.

(2) Triple ladder

A. Specification

| | |
|---|---|
| Length | 8.7m (unfolded)<br>3.5m (folded) |
| Width | 387mm (ladder main body, at storage) |
| Height | 200mm (not including pulley, at storage) |
| Weight | Approx. 36kg |
| Material | Pipe made of carbon steel for use for mechanical structure |

B. Name of each part



1. 1st ladder
2. 2nd ladder
3. 3rd ladder
4. Main beam
5. Auxiliary beam
6. Horizontal bar
7. Strengthening beam
8. Hook
9. Ring
10. Pulley
11. Grip
12. Rubber feet
13. Rope

C. Maximum load

| Load | When used by standing ladder | When used in horizontal setup | When used by hanging |
|---|---|---|---|
| Dispersed load | 180kg<br>(2 persons on ladder) | 180kg<br>(2 persons on ladder) | |
| Load concentrated at one point | 130kg<br>(1 person on ladder) | 130kg<br>(1 person on ladder) | Not allowed. |
| | | Can be used only when totally folded. | |

D. Operational procedure

**Unfolding ladder:**

1. This type of ladder should be carried by 2 persons; one carries the ladder at the forward end and the other at the backward end (to prevent the ladder from striking person(s) or thing(s) when a turn is made).

2. Stand the ladder vertically.
3. The person who secures the ladder should hold the grip from the rear of the ladder and press the horizontal bar at the bottom with his/her foot.
4. Pull the rope down from the front of the ladder. (Press the horizontal bar at the bottom (the same bar as that pressed by the person in 3 above) by foot.
5. The unfolding sequence of the ladder is as follows. The 3rd ladder comes out first. As soon as the 3rd ladder reaches the full length, the 2nd ladder comes out.
6. To use the ladder at its full length, hook the 2nd ladder on the 1st ladder at the position of full length, slightly loosen the rope, move the 3rd ladder down, and make sure that the 3rd ladder is hooked on the 2nd ladder.
7. Make sure that all the hooks are securely joined, gently lean the ladder against the target, pull and connect the rope to the horizontal bar.
8. The leaning angle of the ladder should be 75 degrees. (The base of the ladder should be apart from the wall by approx. 1/4 the length of the ladder.)

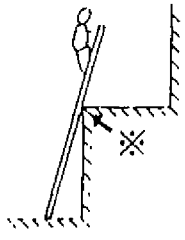
**Folding ladder:**

1. Disconnect the rope from the front of the ladder.
2. A person must support the ladder by holding the grip from the rear and press the horizontal bar at the bottom by foot.
3. Move the ladder away from the target and hold it vertically.
4. Strongly pull the rope down, and the hook of the 2nd and 3rd ladder will be disconnected. The 2nd and 3rd ladders are folded simultaneously by loosening the rope. If you pull the rope gently, not strongly, the hook of 3rd ladder will be disconnected and you can fold the 3rd ladder only.

E. Safety precautions

1. A ladder must be placed at a flat, not slanting, position.
2. A ladder must be supported or fixed properly according to the condition.
3. Climb the ladder gently to avoid excessive impact from being applied to the ladder (excessive impact will cause metallic fatigue of ladder joint).

4. When using a ladder standing up, the standard angle should be 75 degrees, and the maximum allowed load must not be exceeded.
5. When using a ladder in horizontal setup, the ladder must not be unfolded, and the maximum allowed load must not be exceeded.
6. The main beam should be used for climbing.
7. A person who is going up or down a ladder must take hold of the horizontal bars for safety.
   * If you go up or down the ladder by carrying thing(s) with you, slide your empty hand along the auxiliary beam (your hand must always be in touch with the auxiliary beam).
8 Fold the ladder gently
   * Unnecessary impact must be avoided to prevent deformation or metallic fatigue of the ladder.
9. It is very DANGEROUS to lean forward from a ladder. The ladder may slip in crosswise direction.
10. If it is necessary to use only 2 ladders depending upon the height of the target, the 1st and 3rd ladders must be used.
   * If the 1st and 2nd ladders are used, the 2nd ladder may slip down if the coupling is disconnected due to damage, etc..
   * If the 2nd and 3rd ladders are used for the upper layer, the center of gravity will become higher than the case when only the 3rd layer is unfolded, resulting in poor stability.
11. When it is necessary to adjust the height of the ladder used in full length, adjust the height with the 2nd ladder.
12. NEVER climb on the ladder at a corner as shown in the figure on the right.
   * Since the ladder is supported at the point marked with "*" in the figure, not only the allowable load reduces but also the dangerous factors such as horizontal slipping will increase.




13. NEVER move the ladder, which is unfolded to its full length, in horizontal direction by carrying the forward and backward ends.

F. Maintenance

1. Confirm the items below and repair as necessary.
   (1) There should be no deformation of main or auxiliary beam, etc.
   (2) There should be no crack at welded portions
   (3) There should be no defect of anti-slip material of rubber feet and horizontal bars
   (4) There should be neither abnormality in the function and condition of spring of hook nor deformation of or crack on arm. The nuts should not be loose.
   (5) The pulley should move smoothly.
   (6) There should be no wear or breakage of rope.
   (7) There should no defect or rust of painting.

2. Lubricate the pulley bearing, spring of hook and the sliding portions of arm.