ABSTRACT of
GUIDELINE FOR DIRECT MARKING

DRAFT

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Direct Marking Working Group

1. WHAT IS DIRECT MARKING?

(1) Definition of Direct Marking

In this report, “direct marking” is defined as a generic term referring to the techniques and measures to mark a symbol directly on a product (items, parts, and their packages) instead of affixing a label or sticker to the product and to automatically identify the marked symbols.

(2) Marking Technology

Although various direct marking techniques, such as laser marking, dot peen marking, ink jet marking, sandblast marking, and thermal marking, have been developed, we will take up practically used laser marking and dot peen marking in this report.

(3) Marked Symbol

For the purpose of automatic identification, we can mark OCR (Optical Character Recognition), linear, and two-dimensional (2D) symbols on a product. Among these symbols, 2D symbol is more suitable for direct marking, so this report employs 2D symbol as a marked symbol.

(4) Needs

The advancement of information technology has brought dramatic improvements in the information system world. In the logistics industry requiring process/plant/transportation control, information system has been introduced to manage all information on manufacturing to sales consistently. This system is very helpful for manufacturers to carry out their mission to provide better and affordable products to consumers.

Additionally, considering the current situation that environmental problem and effective utilization of resources have been a focus of attention, we should establish lifecycle management system covering reuse/recycling of products as soon as possible. In order to achieve this goal, we have to develop the techniques to attach information to all products in an almost indelible manner and identify such information automatically and then construct information system to give working instructions.

(5) Technological Challenge

Since various products and materials require direct marking (See Table 1 to 4) and we have to choose a marking method from various options, such as laser, dot peen, or inkjet marking, according to the target materials, standardization of marking quality is not an easy task compared to paper labels. However, if there are many direct marking methods exclusively developed by each company, not only multi-sectional and cross-industry use but also shared use will be hampered. Therefore, we must promote standardization of direct marking.

(6) Applications

a) Production control

You can store the information on the product-related process in database under a paperless environment. In this application, the product-related data, such as line name and test data, is automatically recorded and managed as manufacturing history. Generally, the data required for production control is relatively large but marking space is small. When the marking space is small like PCB, two-dimensional symbol, which can encode large amount of data in a small space, is most suitable. As a conventional method, we have marked a symbol on a label affixed to the product. However, this method has been being replaced by direct marking, such as laser marking and silk screening, to eliminate a peeling problem and reduce manpower required to issue and affix symbol labels.

b) Ordering

Direct marking enables construction of a consistent system, where material order, receiving inspection, and inventory control (complete first-in first-out) can be efficiently managed.

c) Product improvement

Since you can track the part structure of a product individually, you can easily improve product performance pursuing correlation between characteristic of each part and total performance.

d) Service

Aircrafts, railcars, and automobiles require regular maintenance for safety. In this case, part level information is required. For example, if ten parts need maintenance and each part requires 50 or more digits data, you will have to enter more than 500 digits. The problem is how to improve efficiency of data input. If part data (manufacturer name, part name, part number, lot number, manufacturing date, etc.) is directly marked on the part, you can make a database efficiently and accurately only by inputting maintenance information. This database facilitates the planning process for future maintenance, and accelerates the investigation process to prove the cause of a field problem (accident).

e) Quality assurance

According to ISO 9000, cause investigation, corrective action, and feedback to the design section are mandatory when some part failure is found in the field. Since these actions are conducted based on the issued slip, it is difficult to get the details of failure immediately after the field failure occurs. Therefore, even though a serious failure leading to recall occurs, countermeasures tend to be passive and late. Ideally speaking, all actual defectives should be collected to investigate the cause of failure, but this is impossible. So we have to collect defectives selectively. Although the information indicated in the currently used nameplate is not sufficient (not covering lot failure), if detailed information is directly marked on the part, rapid selective collection can be achieved.

f) Reuse and recycling

Recycling has been a worldwide issue these days. To achieve recycling in the true sense, you should follow the spirit that reusable parts should be reused as much as possible before they are collected and crashed to recover usable materials. However, the currently used part data is not sufficient for reuse, and on-site automatic data input technique is also required. In the manufacturing industry, 8-year maintenance period for the discontinued model is financial burden for manufacturers because they must maintain and keep drawings, dies, and jigs. If reuse is promoted, this period can be shortened. We believe that direct marking is one solution to open and foster the reuse market, since this technique could attach all data required for reuse to the parts.

g) Environmental conservation

In the case of past environmental issues like CFC, heavy metal, and endocrine disrupter, these environmental contaminants cannot be easily collected because their environmental impacts were recognized after they had been mass-marketed. If the parts (plastic parts and assemblies) including environmental contaminants carried sufficient data, we would not find such difficulty in collection process. In the future, the detailed information attached to the parts (chemical parts) by direct marking will help obligatory and speedy collection.

Table 1-1: Steel

Steel	Rolled steel for general structure	
	Cold drawn steel (cold finished steel bar)	SS440D
	Carbon steel for machine structural use	S45C
Steel plate	SPCC	
Special steel	Alloy tool steel	SKS3
	Chrome molybdenum steel	SCM435
	High tension steel	SNCxxx
	High carbon chrome bearing steel	SUJ2
Forging/casting	Gray cast iron type 4	FC250
Stainless	SUS304 (Austenite)	
	SUS316 (Austenite)	
	SUS430 (Ferrite)	
	SUS440C (Martensite)	
Chemical processed	Chromate	
Fluororesin coating		
Metal plating (Used metal: Iron, steel, aluminum, tin etc.)	Ni plating	
	Galvanization	
	Chrome plating	
	Gilding	

Table 1-2: Nonferrous metal

Aluminum alloy	AlCu	2017
	Al-Mg	5052
	Al-Mg	5056
	Al-Mg-Si	6061
	Al-Mg-Si	6063
	Al-Zn-Mg	7075
Aluminum alloy casting	Casting type 2A	AC2A
	Casting type 4A	AC4A
	Casting type 4D	AC4D
	Casting type 5A	AC5A
	Casting type 8A	AC8A
	Casting type 8C	AC8C
Chemical processed	White alumite	
	Black alumite	
Copper alloy	Brass type 3	C2801
	Phosphor bronze for spring	C5210
	Aluminum bronze type 1	C6161
	Nickel silver type 2	C7521
	Free-cutting nickel silver	C7941
Copper alloy casting	Bronze casting type 6	

Table 1-3: Nonmetal

Paper	
Wood	
Corrugated carton (surface)	
Carton (cardboard)	
Rubber	Silicon gum
	NBR (black)
Glass (tempered, laminated)	

Table 1-4: Polymer

ABS (Acrylonitrile-Butadiene-Styrene resin)	
PA (nylon)	66 nylon
EP (epoxy resin)	Cresol novolac
	Dicyclo
	Biphenyl
PC (polycarbonate)	
PET (polyethylene terephthalate)	
Thermosetting resin	MF (melamine)
LCP (liquid crystal polymer)	
PI (polyimide) coated surface	
PP (polypropylene)	
PPS (polyphenylene sulfide)	
PS (polystyrene)	
Acrylic	
UF (urea resin)	
Glass fiber reinforced resin	66 nylon (GF30%)
	PBT (GF30%)
	EP (epoxy resin) Jim-crow (GFxx%)
	POM (GF20%)
	Epoxy (GFxx%) resist color
Polymer film	PE film
	PP film
	PVC film
	NY film
	PET film
Coated surface	Cation surface
Styrofoam	

2. SCANNING TYPE LASER MARKING EQUIPMENT

(1) Features of Scanning Type Laser Marker

Two types of laser markers, scanning type and mask type, are available. If you use the mask type, a large amount of money might be required to prepare as many masks as marked patterns and you will have to change the mask every time a marked pattern is changed. On the other hand, if you choose the scanning type, only changing data can change marked pattern and additional cost is not needed.

The scanning type laser marker has the marking mechanism that laser beam radiated from a laser resonator is flexibly deflected by two mirrors attached to the galvanometers (X/Y-axis drivers) and focused via a condensing lens onto the target part as shown in Figure 2-1. This type scanner can achieve high-speed marking (500 characters per second). Additionally, since very small beam spot is available due to laser's high focusing ability and power density, fine marking also becomes possible.

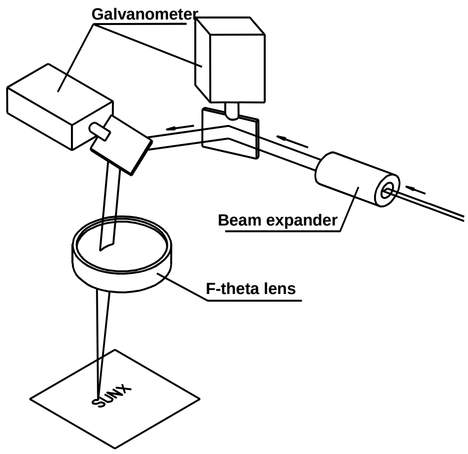


Figure 2-1: Scanning type laser marker

(2) Difference Between CO2 Laser and YAG Laser

Laser markers can be classified into the two, CO2 and YAG laser markers depending on the type of laser oscillator. They have different wavelength, and this wavelength defines application areas suitable for each marker. Table 2-1 shows difference between CO2 and YAG laser markers and their applications. There are a wide variety of processing methods for laser marking. “Surface deformation” is applied to resin materials, such as plastic cases and IC packages, to bring contrast on their surfaces by means of foaming or chemical reaction. “Engraving (surface ablation/deep engraving)” is applied to metallic materials, such as automotive parts and quartz oscillator. The coated plastic molding like buttons/key tops of cellular phones is marked by “coating ablation”. When “surface fusing” is applied, the surface of resin materials like plastic molding is melted by heat. Although the YAG laser marker is much more expensive than the CO2 laser marker, it can engrave deeply metallic materials and change the color of the resin surface. On the other hand, the CO2 laser marker, which does not have such deep engraving and color change capabilities, must fuse the resin surface to make the mark visible. (The color of some resin materials like chloroethene and melamine can be changed by wavelength of the CO2 laser marker, though.) When selecting laser markers, you should consider which processing method is best suited for the user application.

Table 2-1: Difference between CO2 and YAG

	CO2 laser marker	YAG laser marker
Wavelength	10.6 [µm]	1.06 [µm]
Engraving for metal	Not applicable	Suitable
Marking by changing color for resin	Applicable	Suitable
Marking on transparent material	Suitable	Not applicable
Paper/wood	Suitable	Applicable
Glass epoxy PCB	Suitable	Applicable

(3) CO2 Laser Marker

Photo 2-1 and 2-2 show CO2 laser markers.

Photo 2-1: Vertical type CO2 laser marker

Photo 2-2: Horizontal type CO2 laser marker

(4) Examples of CO2 Laser Marking

CO2 laser marking is applied to glass epoxy PCB, paper, and alumite (coating ablation)(See Photo 2-3). CO2 laser is not suitable for general resin materials used for resin parts and metallic material used for metallic parts because contrast required for secure reading is not provided by the wavelength of CO2 laser. In this case, the YAG laser marker is mostly used.

Glass epoxy PCB   Paper   Alumite plate

Photo 2-3: Example of CO2 laser marking

(5) YAG Laser Marker

Photo 2-4: YAG laser marker

(6) Examples of YAG Laser Marking

YAG laser marking is mainly applied to general resin and metallic parts (See Photo 2-5). Since the wavelength of YAG laser can provide sufficient contrast on these materials, the marked 2D symbol can be securely read.

Metallic part

Lead frame

ABS resin

Photo 2-5: Examples of YAG laser marking

(7) Symbol Marking by Laser

In the factory automation (FA) field, 2D symbol marking is mostly applied to provide traceability. The marked 2D symbols encode a lot of information, such as line name, test/measuring data, manufacturing date, and serial No., as manufacturing records, and they are read by the reader to check test results and automate history control.
If the label is affixed to the target object as a conventional way of marking, high running cost (including label cost) is required and peeling becomes a problem. From the viewpoint of recycling, the products with the labels are hard to be recycled. Based on these backgrounds, 2D symbol laser marking applications have been developed and become popular. Increase in the volume of information and miniaturization of parts/devices also contribute to the promotion of 2D symbol marking, because 2D symbol can store large amount of data in a small space.
2D symbol is marked on various materials, such as paper, resin, and metal, and the marker and reader determine reading performance. The marker-side factors affecting reading performance are “high contrast” and “accurate cell marking”. In order to improve reading performance, cell-marking method, laser power, and scanning speed must be properly adjusted according to the target object.
Contrast and line width of the 2D symbol marked by the laser marker vary depending on the wavelength of laser, spot diameter, laser power, scanning speed, and material to be marked. The smaller the marked symbol becomes, the more prominent this

dependency becomes. Therefore, the capability to set and adjust the marking pattern according to the part material to be marked, wavelength of laser and spot diameter are required. (See Photo 2-6.)
As one of characteristics of a laser marker, we can see more heat is conducted when cell pitch is small. In other words, if density of the cell is low, the amount of conducted heat becomes smaller. This characteristic also varies according to the target object to be marked. If a whole 2D symbol is marked with constant power, burnt marks or accumulated soot might appear because the part where cell pitch is small is thickly marked. This quality unevenness of cells and finder patterns is more likely to cause unstable reading.

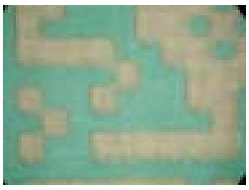
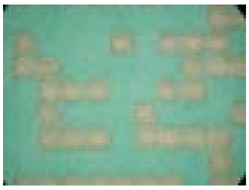
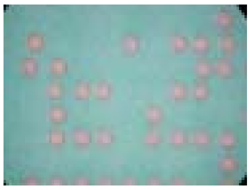




Photo 2-6: Example of cell marking pattern (glass epoxy PCB)

3. DOT PEEN MARKING EQUIPMENT

(1) What is Dot Peen Marking?

Dot peening is the method to make physical hollow on the target object by pranging a stylus pen to it. Unlike laser marking and ink jet marking, dot peen marking equipment touches the object directly. This is the most distinguishing characteristic of dot peen marking.

The stylus is moved with the compressed air controlled by the solenoid valve. The depth of hollow varies depending on the pressure of compressed air, stylus head form, and materials of the object. The depth ranges from 40 µm to 80 µm in general. The shape of the hollow at cross section depends on the form of the stylus head.

Dotting impact strength is 20 to 30 N (2 to 3 kg-weight), and load to the target object is not so heavy compared to stamping and pressing processes.

That is why this method is adopted in part marking for the aluminum engine part that is strict about deformation. Characters or 2D symbols can be represented by moving the air pen comprising stylus and stylus supports under the control of numerical control system for X-Y axis. (See figure 3-2)

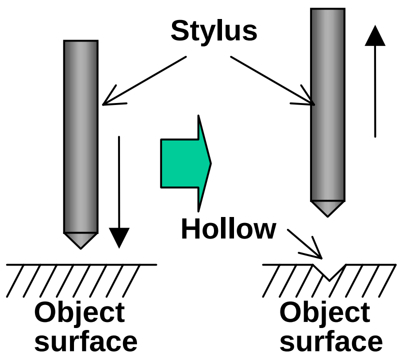


Figure 3-1: Concept of dot peen method

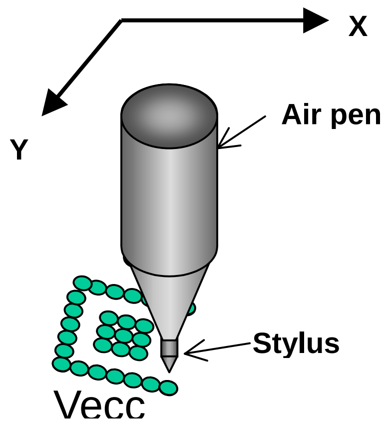


Figure 3-2: Concept of making mechanism

Since the dot peen method is repeating process of dotting and moving, its marking speed is inferior to that of laser marking or ink jet marking. Fundamentally the marked characters or 2D symbols are the group of dots, so the appearance is also inferior to laser marking or ink jet marking.

The depth of the marking of dot peen method, however, gains a great advantage. In addition, while laser method requires adjustment of wavelength and power according to the material, dot peen method only requires a certain degree of material hardness. It is not affected by material of target object nor oil spot. Further, low cost and safe marking is the obvious benefit of dot peen method. When establishing a marking system, virtues of each method should be fully considered. For instance, in case of electronic parts, which take short tact time and are unsuitable for dotting itself, laser method or ink jet method is suitable. On the other hand, in case of machine parts and auto parts, dot peen method is suitable because long life and robust marking is required and the tact time is relatively long.

(2) Examples of Dot Peen Marking Equipment

Photo 3-1: Dot peen marking equipment

(3) Examples of Dot-Peened Mark

Photo 3-2 is the example of QR Code marked with dot peen marking equipment. Photo 3-3 is the image of the symbol obtained by scanner.
In this case, the target object has smooth cut surface and the 2D symbol extracted from the scanned image is clear, but such case is rare. From a practical standpoint, working surfaces tend to be rougher as described later.

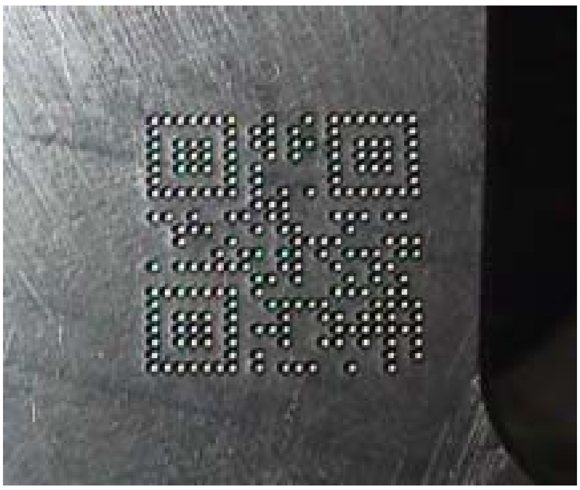


Photo 3-2: Marked symbol

Photo 3-3: Scanned image

(4) Symbol Marking by Dot Peening

Marking test helps you picture actual marking, and also provides the opportunity for reading test. (See photo 3-4)

The important thing in marking test is making a wide variety of test conditions possible at work site in order to clarify which condition can bring about secure reading by scanner. The test condition includes marking location, propriety of marking surface, and judgment of surface preparation need.

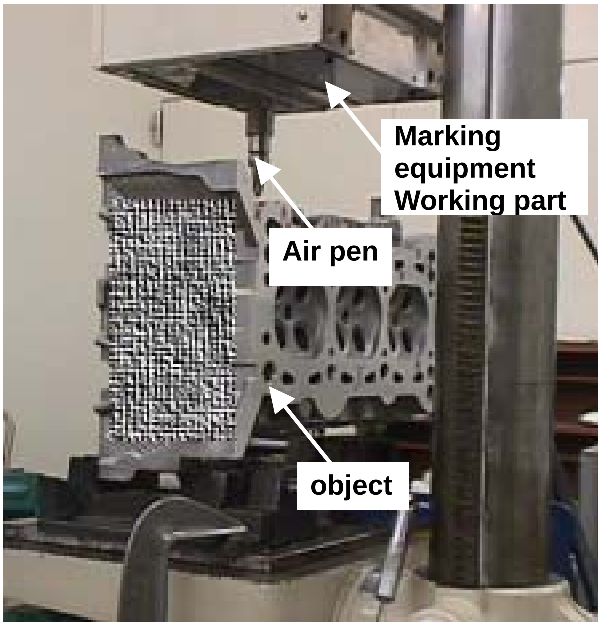


Photo 3-4: Marking test equipment

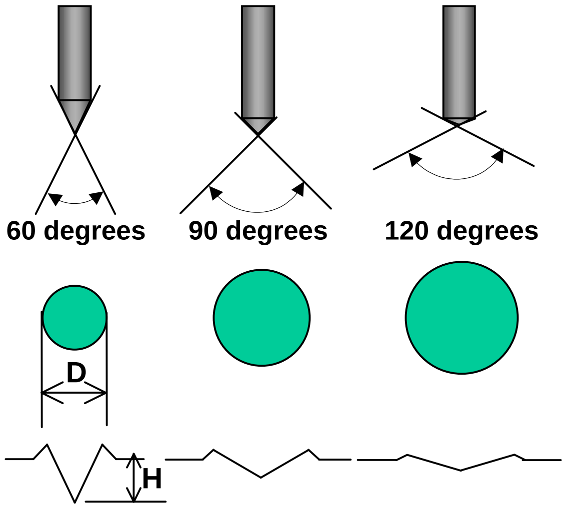


Figure 3-3: Stylus head form and dot appearance

Regarding the reading condition like light source and illumination, cooperation of reading equipment manufacturers will be needed. Anyway, we are concerned here with marking-related items only. These items include stylus head form, best suited dot pitch, necessary time for marking, etc.

Stylus head is conically-shape, and its point angle determines dot size and depth. Figure 3-3 shows the relationship between stylus head form and shape of the hollow at cross section and dot diameter. You can find that the sharper point angle makes diameter D shorter and depth H deeper. The distance between dots can be changed by changing dot pitch. Some reading devices are bad at reading overlapped dots, but others need overlapping of dots according to their algorithm. Therefore you will have to adjust dot pitch in response to the reading equipment. Photo 3-5 and Photo 3-6 are scanned images showing a difference caused by dot pitch difference. The other marking conditions are identical; material of object is aluminum and stylus point angle is 60 degrees. In general pitch shown in Photo 3-6 is favorable.

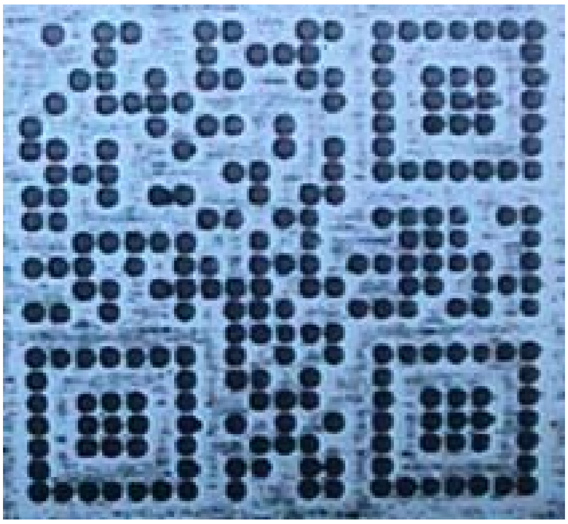


Photo 3-5: High dot pitch

Photo 3-6: Low dot pitch

Stylus point angle greatly affects the contrast of a scanned image. Photo 3-7 and Photo 3-8 provide the images of two different symbols marked by different styluses and scanned under the same light source of the same height. Photo 3-7 is marked by 60-degree headed stylus, Photo 3-8 by 120-degree headed one. Light source is ring-shaped LED set at 150 mm high from working surface. 120-degree headed stylus brings about better contrast in this case. However, this is a result obtained under the equal conditions. If the height of light source is properly adjusted, poor contrast in Photo 3-7 can be improved. The reading equipment in actual operation environment like production line tends to be subject to restrictions on light source type or location in order to avoid interference of parts and transfer mechanisms. In such cases, it is effective to take the measure of selecting different angled stylus to improve the contrast.

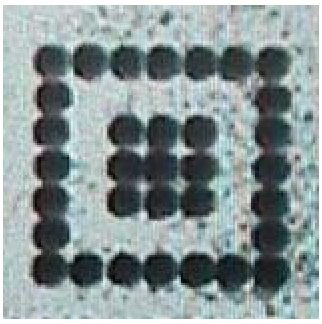


Photo 3-7: 60-degree headed stylus

Photo 3-8: 120-degree headed stylus

The above is based on the premise that marking surface condition is fixed, but in actual environments, there are many factors to cause variations in marking surfaces. For example, die wearing and miss run at die casting might cause surface roughness, and cutting process might leave various tool marks. Especially cylinder block and crankshaft often need marking on casting surface, but the surface roughness varies so widely that stable reading is difficult. 2D symbol marking makes no sense when the symbols cannot be read automatically, since 2D symbol is not human readable. In such case, you might have to smooth the surface before marking. It will be the shortcut to stable reading after all, then to deriving the maximum benefit from 2D

symbol solution.
Stylus head will wear little by little as it is used. The degree and speed of wear vary by stylus point angle. After the head wore to a certain extent, the wearing pace drops but does not stop. So, you have to change stylus on some regular basis. If you leave stylus wearing, dot shape may change in so much that automatic reading is unavailable. Some marking systems are equipped with a dotting counter and alert users when the count exceeds a pre-set limit. This capability will be useful for users to decide timing of stylus replacement. On the other hand, as for reading equipment, some can output the grade of the scanned 2D symbol appearance and quality, and others can provide graphical representation of grade transition and put out a signal when the grade is below pre-set threshold. Therefore users also can decide the timing of stylus replacement based on the reading results obtained by these functions. In any case, users should consider how to maintain the whole system easily, what kind of functions the marking and reading equipment have, and how to maximize the effectiveness of them, at the marking test stage.

4. READING EQUIPMENT

(1) Basic Setup of 2D Symbol Reading System

Figure 4-1 shows the basic setup of the 2D symbol reading system.

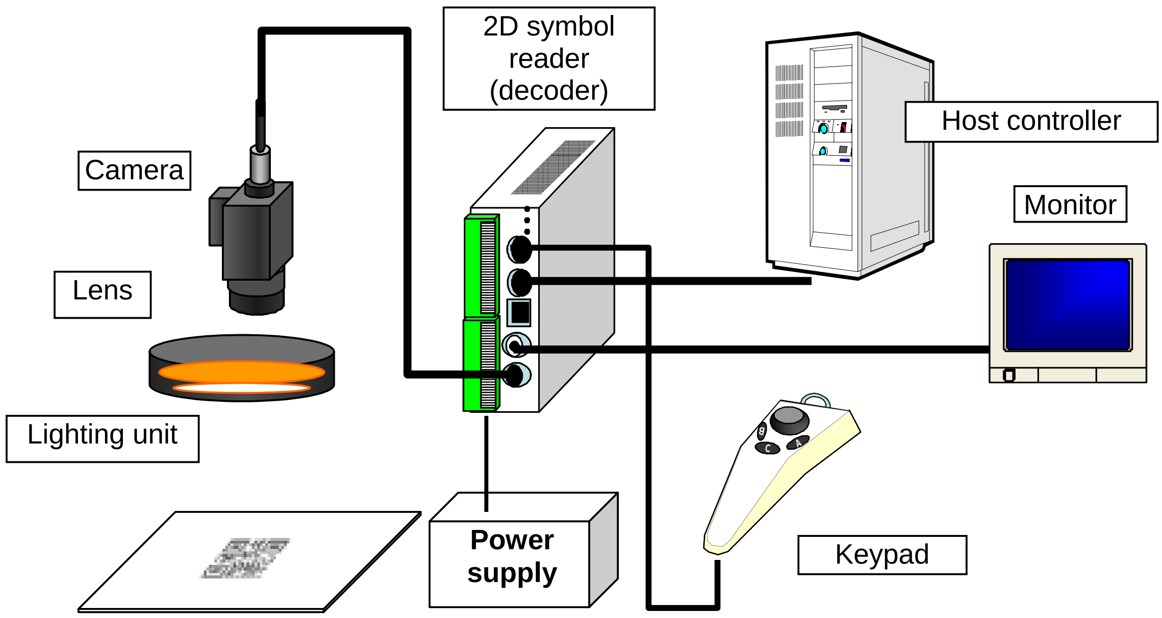


Figure 4-1: Basic setup of 2D symbol reading system

When the lighting unit directs a beam at a 2D symbol marked on the part, the beam is reflected from the 2D symbol and captured by the CCD of the camera through the lens. The image captured by the CCD is converted into image signals and outputted from the camera, and then inputted to the 2D symbol reader (decoder). This 2D symbol reader (decoder) outputs the read data to the host unit after decoding the received image signals. To improve reading performance, proper selection of lens and lighting unit is critical.

The monitor is used to confirm the reading results and captured 2D symbol image and to fine-tune the lens and lighting unit during the installation of the 2D symbol reader.

The host controller (PC, sequencer, etc.) receives the data read by the 2D symbol reader via serial communication.

The 2D symbol reader shown in Figure 4-1 is a separated type, in which the camera and decoder are set separately, but a camera-integrated decoder is also available. Users can choose a suitable one for their applications.

To read 2D symbol successfully, the operation parameters of the 2D symbol reader (symbol type, communication conditions, etc.) must be properly set. Some users can set parameters by means of control commands transmitted between the host controller and the reader, and others can use utility program, which allows them to set the parameters on the monitor with the keypad (or mouse) connected to the reader unit.

(2) Directly Marked Symbol Reading

Figure 4-2 shows the outline of installation procedures of the 2D symbol reader. The details are described in the sections that follow.

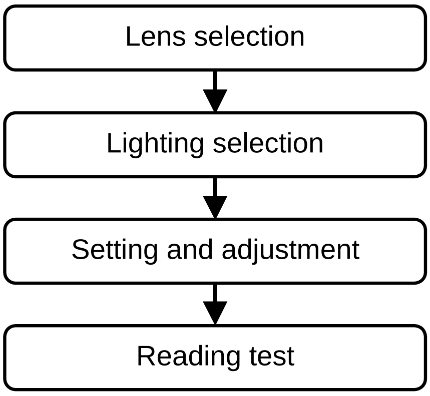


Figure 4-2: Installation procedures

a) Lens selection

Lens is selected based on the size of field of view and working distance. (See Figure 4-3.)

Maximum field of view is determined by the resolution, or cell size of the readable 2D symbol.

For the 2D symbol reader equipped with a changeable lens, normally, the minimum readable cell size is expressed in pixels (on CCD) per cell. Maximum field of view can be obtained based on this value.

For example, if the minimum readable cell size of the 2D symbol reader is 5 pixels per cell, and this reader reads a 2D symbol comprised of 0.25mm cells using a CCD camera with 512x512 effective square pixels, the side length of the maximum field of view can be calculated as follows:

Maximum side length of field of view = 0.25 (mm/cell) x 512 (pixels) ÷ 5 (pixels/cell)
= 25.6mm

Therefore, the side length of field of view exceeding 25.6mm is not allowable.

Minimum field of view is determined by 2D symbol size and its positioning accuracy.

For example, if the cell size of a QR Code is 0.25mm/cell and the cell count per side is 21, the side length of the QR Code becomes 5.3mm (= 0.25 (mm/cell) x 21 cells) and the minimum field of view must be larger than this value. Generally, in addition to the side length of a symbol, quiet zone, positioning, and symbol orientation are also considered to determine minimum field of view.

These are the procedures to determine the maximum and minimum field of view.

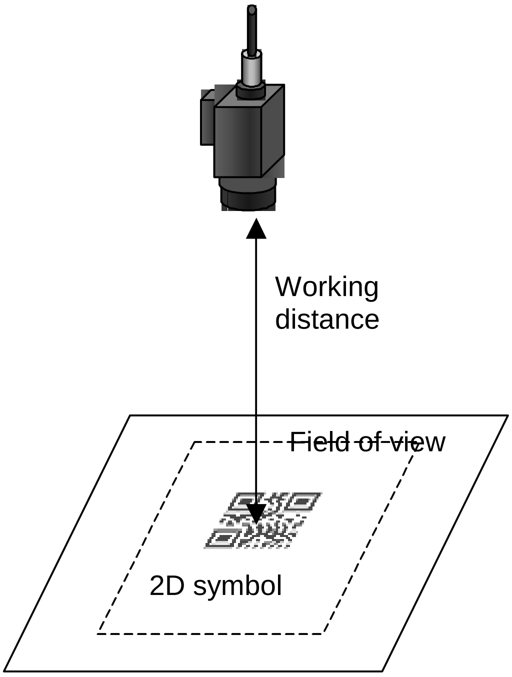


Figure 4-3: Working distance and field of view

In the next step, lens is selected considering the working distance and field of view. The typical 2D symbol reader adopts the CCTV lens and this lens is selected based on the focal length f. The focal length f ranges from 7.5mm to 100mm and focal point (focus) of the lens can be adjusted by inserting an extension tube between the camera and lens. You can find the relationship of extension tube length, field of view, and working distance by referring to the lens specifications provided by lens or reader manufacturers.
The relationship of focal length f, extension tube length, field of view, and working distance can be summarized as follows:

i) The working distance is approximately proportional to the field of view under the condition that the same camera and lens are used. (This relationship becomes clear especially when the working distance is long.)

ii) If a long extension tube is employed under the condition that the same camera and lens are used, the working distance is reduced and the field of view is also narrowed.

iii) If you want to reduce the working distance with the field of view fixed for a given camera, employ the lens with a small focal length f and the short extension tube. If you want to increase the working distance, employ the lens with a long focal length f and the long extension tube. (See Figure 4-4.)

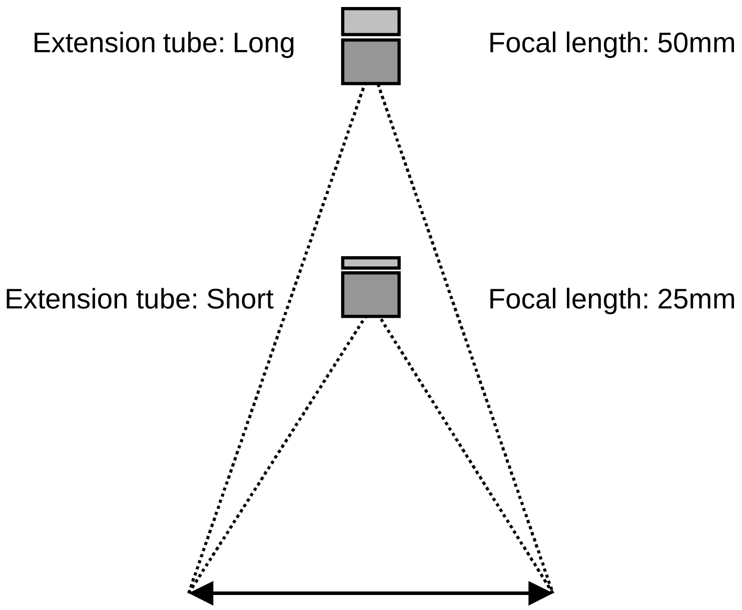
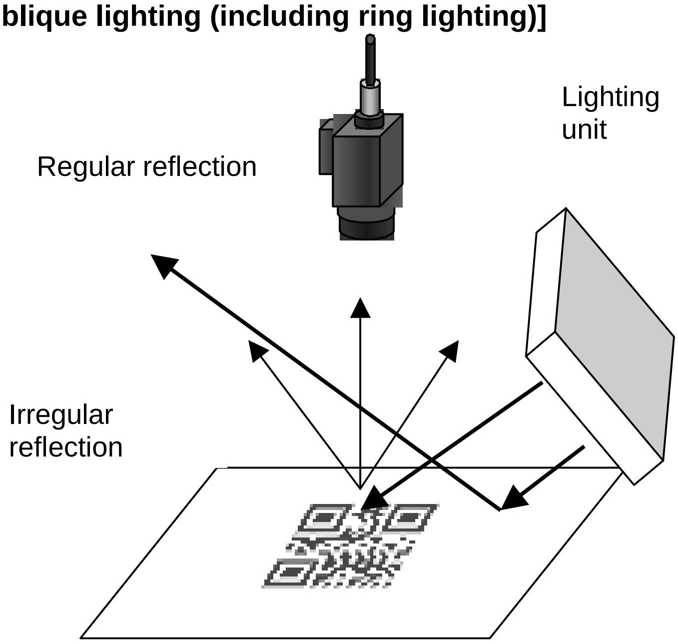


Figure 4-4:　Relationship between focal length of lens and extension tube length
(Field of view is fixed)

b) Selection of lighting method

When reading the conventional 2D symbol black ink printed on paper, the installation of the lighting unit is not so critical since sufficient contrast required for reading can be obtained by properly adjusting the focal point of the lens.
In the case of the 2D symbol directly marked on a part, however, the lighting method must be carefully selected considering part material, part shape, and marking method in order to obtain sufficient contrast.
This section describes lighting methods commonly used when reading a directly marked symbol.

[Oblique lighting (including ring lighting)]



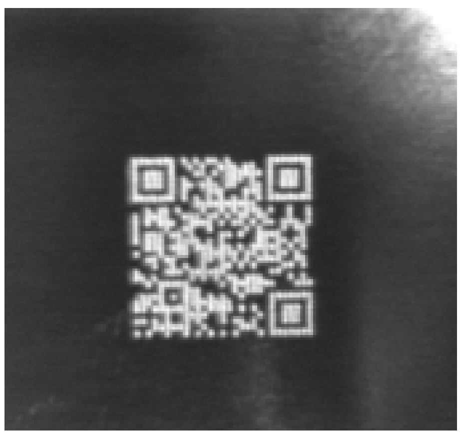


Figure 4-5:　Oblique lighting　　　　Figure 4-6: Image captured with oblique lighting

Oblique lighting is the method, which applies oblique light to the part surface.　(See

Figure 4-5.) This method is particularly effective in reading 2D symbol marked on the PCB or electronic parts. Among various oblique lighting, ring lighting is commonly used, because this method can emit larger amount of uniform light and compact installation can be achieved by attaching the ring light to a camera lens.
When the 2D symbol is laser-marked on the PCB, cells of the 2D symbol look white in the captured image since the laser-marked area reflects larger amount of light irregularly and becomes brighter than the background area. (See Figure 4-6.)
Oblique lighting can be classified into direct lighting and indirect lighting. While direct lighting applies LED light directly to a target part, indirect lighting applies LED light to a diffusion plate so that diffused light can be applied to the target part. In the case of direct lighting, strong light can be applied but unnecessary image may be reflected on the surface if it is glossy. If indirect lighting is employed, such unnecessary image does not appear even though the part surface is glossy, and you can get uniform brightness easily.

[Coaxial (incident) lighting]

When coaxial lighting is employed, the axis of incident light to the part surface and the axis of reflected light to the camera are perpendicular to the part surface. (See Figure 4-7.) This method uses a half mirror to change the direction of the optical axis of the light source so that the incident light is applied from the same axis of the camera lens. Since the light applied to the background area is reflected totally and the light applied to the marked area is reflected diffusely, the cells of the 2D symbol look darker (black) in the captured image. (See Figure 4-8.)
This method is particularly effective when reading the 2D symbol marked on the specular surface, such as glass and metal, but the reading performance is greatly affected by the inclination and surface bending of the target part.

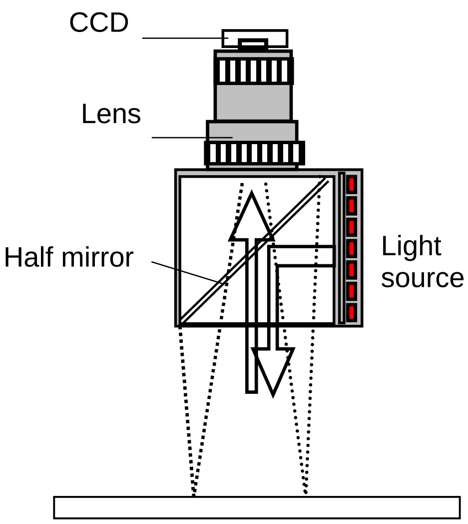


Figure 4-7: Coaxial lighting

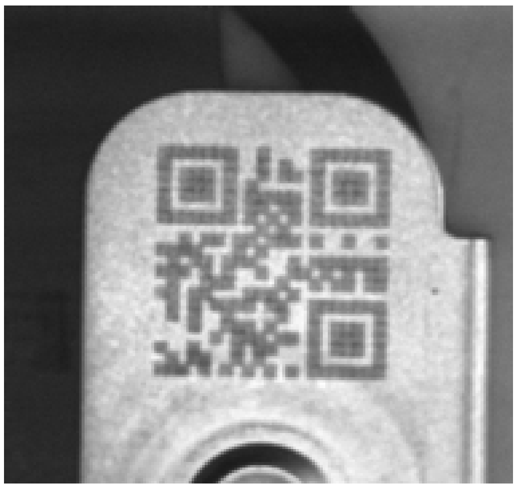
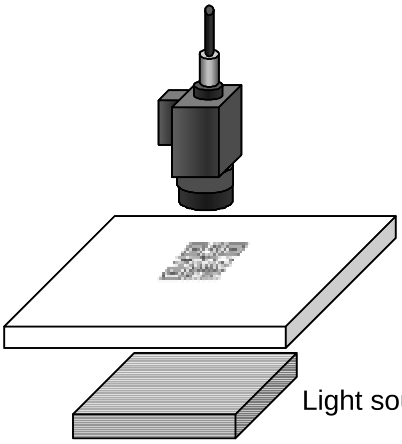


Figure 4-8: Image captured with coaxial lighting

[Transmitted lighting]

Transmitted lighting is the method to apply the light from the backside of the part to obtain a silhouette of the part. (See Figure 4-9 and 4-10.) This method is also known as backlight lighting.
The contrast of the 2D symbol results from the difference of the light transmittance of the target part.



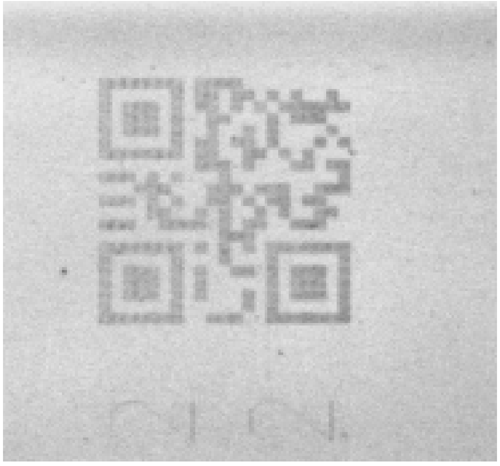


Figure 4-9: Transmitted lighting   Figure 4-10: Image captured with transmitted lighting

c) Setting of lens aperture and electronic shutter

When the lens and lighting method are properly selected, field adjustment of the actually installed reading device is required. This section focuses on the lens aperture and electronic shutter speed.

Adjusting lens aperture can change depth of field, or the range of the distance from the lens in which the target object is in focus.

The smaller the lens aperture is, the larger the depth of field becomes, and vice versa. When the working distance varies for every reading, you must narrow the lens aperture to get large depth of field. However, you should note here that if you set the lens aperture small in order to get large depth of field, the amount of the light allowed through the lens is limited and sufficient contrast required for reading might not be obtained. In such case, you must increase light intensity to get sufficient light.

Some 2D symbol readers and cameras are equipped with the electronic shutter which can change the shutter speed (exposure time).

When the target object is moving or vibrating, high shutter speed is required to improve reading performance. The shutter speed can be changed within the range from 1/60s to 1/10000s and higher shutter speed enables moving object reading. Like lens aperture, the shutter speed also affects the amount of the light allowed through the lens. Therefore, in order to obtain sufficient contrast, you must increase light intensity or make the lens aperture larger.

For the stable reading of 2D symbols, light intensity, lens aperture, and shutter speed must be considered together.

d) Parameter setting for 2D symbol reader

This section explains parameter setting for the 2D symbol reader. Although various parameters are defined by each manufacturer, the following parameters seem to be commonly used.

[Code type]

2D symbol type, such as QR Code and Data Matrix, is selected. If the 2D symbol reader has multi-code reading capability, reading time may be shortened by reducing the number of selected 2D symbol types.

[White/black reversal]

Normal mode (2D symbol with black cells on a white background) or white/black reversal mode (2D symbol with white cells on a black background) is selected. You must consider lighting conditions to decide which mode is suitable. For example, when the 2D symbol laser-marked on the PCB is read with oblique lighting, the white cells appear on the black background, so you have to select white/black reversal mode.

[Left/right reversal]
Normal mode or left-right reversal mode is selected. When reading the 2D symbol marked on clear material, such as glass, from the backside, you must select the left-right reversal mode.

[Marked pattern (normal/dot pattern)]
The cell shape of the 2D symbol is selected. Normal pattern is the conventional pattern as marked on paper media. Dot pattern (dot-marked pattern) is comprised of circle-shaped cells and there might appear gaps between cells as shown in Figure 4-11. You can find the dot size and cell pitch in Figure 4-11.

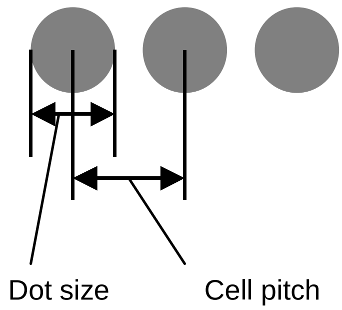


Figure 4-11: Dot pattern

(3) Reading Adjustment and Verification
How to perform reading test is described in this section. Figure 4-12 shows the flow of typical adjustment and test procedures.

Install 2D symbol reading system and power it on.

↓

Set parameters for 2D symbol reader.

↓

Place the 2D symbol in the field of view of the camera
and adjust the focus watching the monitor.

↓

Set lighting, lens aperture
and electronic shutter speed of camera.

↓

Perform reading test.
(Verify decode rate, contrast, error correction rate, etc.)

Figure 4-12: Reading test procedures

For the details of Figure 4-12, refer to the above sections.
The reading test confirms that the lens and lighting were properly set in the procedures

shown in Figure 4-12 and 2D symbol is successfully marked.
In this test, reading performance and likelihood of the 2D symbol reading system for a given marked sample must be examined. The reading performance can be evaluated based on decode rate, error correction rate, contrast, etc.
The decode rate is obtained by dividing the number of successfully decoded symbols by the number of reading attempts. 100% is ideal for this value.
The error correction rate indicates how often the error correction function of the 2D symbol is used. When this value is large, error correction is frequently used and reading likelihood comes low. The error correction function of 2D symbol is essential to withstand damage. The directly marked 2D symbol has lower quality than the conventional 2D symbol printed on paper, and requires error correction more frequently. If the error correction rate is too high, even though the decode rate is 100%, you must review the installation of the lens and light, and marking conditions.
2D symbol contrast indicates the difference of brightness between white and black cells on the captured image (See Figure 4-13). Generally, reading performance of the 2D symbol is improved when the symbol contrast is high. So proper adjustment to make the symbol contrast high can raise reading likelihood.
When you perform the reading test, you should follow the above guideline. If you perform the reading test repeatedly and get optimal marking conditions, decode rate, and highest leading likelihood, you can finally construct a stable system.

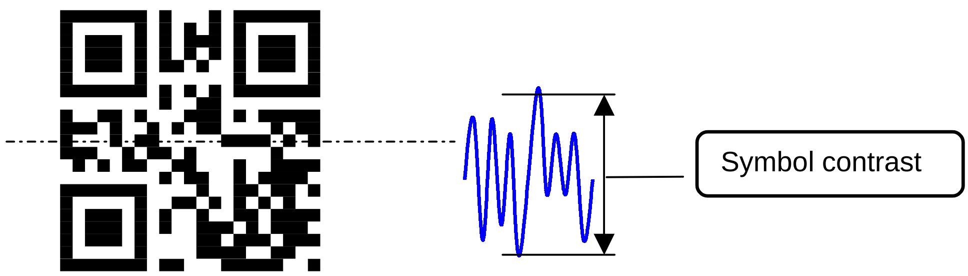


Figure 4-13: Symbol contrast