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**Standard practice for thermal
insulation works**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Thermal Insulation Association (JTIA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS A 9501**:2014 is replaced with this Standard.

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Standard practice for thermal insulation works

Introduction

This Japanese Industrial Standard was established in 1952, and has gone through 16 revisions including this one. The last revision was made in 2014, and the revision at this time is to respond to changes in social needs and in execution technology of thermal insulation works. The comparison table between previous and current editions of this Standard on technically significant revisions is given in Annex I.

No corresponding International Standard has been established at this point.

1 Scope

This Standard specifies the types, usage methods, design methods and execution guidelines of thermal insulation materials and subsidiary materials used in the thermal insulation works on apparatuses relevant to chemical industry, fuel industry and heat utilizing power, and facilities of air conditioning, water supply/drainage for sanitation, etc. The thermal insulation works on refrigerators/ships/railway rolling stocks are excluded. The temperatures intended for the thermal insulation works applicable in this Standard shall be -180°C to $1\,000^{\circ}\text{C}$.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS A 0202 *Thermal insulation—Vocabulary*

JIS A 1322 *Testing method for incombustibility of thin materials for buildings*

JIS A 1412-2 *Test method for thermal resistance and related properties of thermal insulations—Part 2: Heat flow meter apparatus*

JIS A 5538 *Adhesives for wall and ceiling boards*

JIS A 5547 *Adhesives for preformed cellular plastics thermal insulation board*

JIS A 5549 *Adhesives for fixture*

JIS A 5556 *Staples*

JIS A 5758 *Sealants for sealing and glazing in buildings*

JIS A 9504 *Man made mineral fibre thermal insulation materials*

JIS A 9510 *Inorganic porous thermal insulation materials*

JIS A 9511 *Preformed cellular plastics thermal insulation materials*

JIS B 0147 *Blind rivets—Terminology and definitions*

JIS B 1122 *Cross recessed head tapping screws*

JIS B 1123 *Hexagon head tapping screws*

- JIS B 1126 *Hexagon washer head tapping screws*
- JIS B 1181 *Hexagon nuts and hexagon thin nuts*
- JIS B 7414 *Glass thermometers*
- JIS C 1602 *Thermocouples*
- JIS C 2336 *Pressure-sensitive polyvinyl chloride tapes for electrical purposes*
- JIS G 3302 *Hot-dip zinc-coated steel sheet and strip*
- JIS G 3312 *Prepainted hot-dip zinc-coated steel sheet and strip*
- JIS G 3313 *Electrolytic zinc-coated steel sheet and strip*
- JIS G 3314 *Hot-dip aluminium-coated steel sheet and strip*
- JIS G 3316 *Shapes and dimensions of corrugated steel sheets*
- JIS G 3317 *Hot-dip zinc-5 % aluminium alloy-coated steel sheet and strip*
- JIS G 3318 *Prepainted hot-dip zinc-5 % aluminium alloy-coated steel sheet and strip*
- JIS G 3321 *Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip*
- JIS G 3322 *Prepainted hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip*
- JIS G 3350 *Light gauge steel sections for general structure*
- JIS G 3352 *Steel Decks*
- JIS G 3547 *Zinc-coated low carbon steel wires*
- JIS G 3551 *Welded steel wire and bar fabrics*
- JIS G 3553 *Crimped wire cloth*
- JIS G 3554 *Hexagonal wire netting*
- JIS G 4305 *Cold-rolled stainless steel plate, sheet and strip*
- JIS G 4309 *Stainless steel wires*
- JIS H 4000 *Aluminium and aluminium alloy sheets, strips and plates*
- JIS H 4001 *Painted and baked aluminium and aluminium alloy sheets and strips*
- JIS H 4160 *Aluminium and aluminium alloy foils*
- JIS K 6804 *Poly(vinylacetate) emulsion adhesives for woods*
- JIS Z 1524 *Pressure sensitive adhesive cloth tapes for packaging*
- JIS Z 1528 *Pressure sensitive adhesive double coated tapes*
- JIS Z 1702 *Polyethylene films for packaging*
- JIS Z 8806 *Humidity—Measurement methods*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS A 0202**, and the following apply.

3.1

hot insulation

measure to reduce the thermal radiation of an object at an ordinary temperature or over up to and including approximately 1 000 °C by putting a cover, or to lower the surface temperature thereof after covering

NOTE The definition in **JIS A 0202** is altered.

3.2

hot insulation material

material used for the purpose of hot insulation, the thermal conductivity of which is generally 0.065 W/(m·K) or under at ordinary temperature

NOTE The definition in **JIS A 0202** is altered.

3.3

cold insulation

measure to reduce the intruding quantity of heat into an object at ordinary temperature or under by putting a cover, or to prevent the dew condensation on the surface after covering by keeping the surface temperature at the dew-point temperature or higher

3.4

cold insulation material

material used for the purpose of cold insulation

Generally, its thermal conductivity and the moisture permeability are low.

NOTE The definition in **JIS A 0202** is altered.

3.5

dew proofing

one of the cold insulation measures to prevent the dew condensation on the surface of object mainly at 0 °C or higher up to and including an ordinary temperature

NOTE The definition in **JIS A 0202** is altered.

3.6

dew proofing material

material used for the purpose of dew proofing

3.7

prevention of freezing of water in pipe

one of the hot insulation measures to prevent the internal fluid in a static state (generally water) from freezing for a definite time

3.8

hot insulation cover

integrated cover in which a hot insulation material is attached on the inner surface of covering material such as textile and thin metal plate

3.9

thermal insulation mattress

mattress-like hot insulation material, in which a core material made of man made mineral fibre thermal insulation material specified in **JIS A 9504** is covered with various textiles such as glass fibre cloth

3.10

ambient temperature

temperature of the position not affected by other heat sources such as direct sunlight in the environment where the object to be thermally insulated is placed

3.11

joint

material used for the connection, etc. of piping

A generic term of elbow, tee, reducer, etc.

3.12

elbow joint

execution method that the hot insulation materials and the covering materials are respectively mated at right angles at the curving part of smaller diameter piping

3.13

seam-joint

generic term of the seamed portion in which the ends of two metal plates are folded and interlocked together, or the execution method itself

3.14

button punch seaming

generic term of the seamed portion in which the end of one metal plate is doubly folded, the end of the other metal plate having a stopper is inserted into the gap between the doubly folded parts, and the two metal plates are interlocked together, or the execution method itself

3.15

rivet

nail having the length according to the thickness of hot insulation material to support it, which is planted in a steel-plate washer and attached to the equipment or the duct surface by spot welding or adhesives

NOTE A rivet is also called a fixing pin of hot insulation material.

3.16

mitre joint

execution method in which the hot insulation materials and the covering materials are cut into the sections, and attached and finished along the curving part of piping

3.17

prefabricated elbow

hot insulation material preliminary processed or fabricated to the shape of a curving part of piping

3.18

thermal insulating economical thickness

hot insulation thickness when the sum of the price of execution in one year and the price of quantity of heat equivalent to the radiating quantity of heat becomes minimum

3.19

price of quantity of heat

value obtained by dividing the one-year total cost including the fuel cost, facility depreciation cost and operating cost necessary for the quantity of heat by the total quantity of heat generation in one year

3.20

price of execution

one-year cost to depreciate the construction work cost per unit quantity

3.21

aluminium foil paper

aluminium foil specified in **JIS H 4160** having the thickness of 0.007 mm or over, to which craft paper is adhered

3.22

formed resin elbow

material used when a fibrous hot insulation material is attached to the elbow part of piping to trace the elbow shape

In some cases, the elbow part is finished as above; or in other cases, a covering material is further wrapped on it.

3.23

decorative resin cover

exterior cover made of synthetic resin conforming to the anti-flaming Grade 2 specified in **JIS A 1322**

3.24

rubber-based covering material

covering material processed into a sheet of chlorosulfonated polyethylene (CSM) rubber, etc.

3.25

metal and resin laminated covering material

covering material in which a metal foil such as aluminium foil having the mechanical strength and a resin film are laminated

3.26

aluminium laminated glass cloth

aluminium foil specified in **JIS H 4160** having the thickness of 0.02 mm or over, to which glass cloth is adhered

3.27

base paper

cardboard mainly made of recycled paper, having a basis weight of 370 g/m² or over, used for forming

NOTE The definition in **JIS P 0001** is altered.

3.28

aluminium laminated glass cloth base paper

base paper, to which aluminium laminated glass cloth is adhered

3.29

steel frame

galvanized steel base sheet (the standard thickness is 0.4 mm or over) processed into a frame of various shapes, used for the slip-prevention of hot insulation material

3.30

decorative pin

retaining pin for the overlapped part of a decorative resin cover and an aluminium laminated glass cloth base paper

3.31

sealing material

material mainly called and used in the hot insulation execution on facilities, which exerts its function such as waterproof and airtightness by filling it into grouts and clearances of a structure

NOTE The definition in **JIS K 6800** is altered.

3.32

caulking material

material mainly called and used in the hot insulation execution on plants, which exerts its function such as waterproof and airtightness by filling it into grouts and clearances

This is a synonym of sealing material.

3.33

fibre-reinforced tape

pressure sensitive adhesive tape reinforced with glass fibres or polyester fibres

4 Materials used in thermal insulation works

4.1 Selection of types of materials

The materials shall be determined considering the following conditions, as required.

- a) Service temperature range
- b) Thermal insulation performance
- c) Mechanical performance and chemical stability
- d) Grading by emission of formaldehyde in indoor service
- e) Moisture permeability
- f) Flammability
- g) Number of service years
- h) Cost per unit volume
- i) Adaptability to work site situations
- j) Consideration on corrosion of piping/equipment (see Annex G)

4.2 Main thermal insulation materials used in thermal insulation works

The thermal insulation materials mainly used in thermal insulation works shall generally be those conforming to the following standards or having the quality equal or superior thereto.

JIS A 9504 *Man made mineral fibre thermal insulation materials*

JIS A 9510 *Inorganic porous thermal insulation materials*

JIS A 9511 *Preformed cellular plastics thermal insulation materials*

4.3 Main subsidiary materials

The optimal subsidiary materials mainly used in thermal insulation works shall be selected from those given in Table 1 or having the quality equal or superior thereto.

Table 1 List of subsidiary materials

	Hot insulation work (Clause 6)	Cold insulation work (Clause 7)	Building utility (Clause 8)	Title of standard or others
Metal covering materials	JIS G 3302			Hot-dip zinc-coated steel sheet and strip
	JIS G 3312			Prepainted hot-dip zinc-coated steel sheet and strip
	JIS G 3314			Hot-dip aluminium-coated steel sheet and strip
	JIS G 3316			Shapes and dimensions of corrugated steel sheets
	JIS G 3317			Hot-dip zinc-5 % aluminium alloy-coated steel sheet and strip
	JIS G 3318			Prepainted hot-dip zinc-5 % aluminium alloy-coated steel sheet and strip
	JIS G 3321			Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip
	JIS G 3322			Prepainted hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip
	JIS G 3352			Steel Decks
	JIS G 4305			Cold-rolled stainless steel plate, sheet and strip
	JIS H 4000			Aluminium and aluminium alloy sheets, strips and plates
	JIS H 4001			Painted and baked aluminium and aluminium alloy sheets and strips
Other covering materials	Textile such as glass cloth	—		—
	Various textiles			Including those with metal foil
	Mastic	—		—
	Decorative resin cover			
	Formed resin elbow			
	Aluminium laminated glass cloth			Including products with adhesive and those of tape-shape
	Aluminium foil paper			
	Coloured aluminium laminated glass cloth			
	Aluminium laminated glass cloth base paper			—
	Rubber-based covering material			CSM, etc.
	Metal and resin laminated covering material			—
Binding materials	—	—	JIS C 2336	Pressure-sensitive polyvinyl chloride tapes for electrical purposes
	JIS G 3313			Electrolytic zinc-coated steel sheet and strip
	JIS G 3547			Zinc-coated low carbon steel wires
	JIS G 3554			Hexagonal wire netting
	JIS G 4305			Cold-rolled stainless steel plate, sheet and strip
	JIS G 4309			Stainless steel wires

Table 1 (continued)

	Hot insulation work (Clause 6)	Cold insulation work (Clause 7)	Building utility (Clause 8)	Title of standard or others
Binding materials	JIS H 4000	—	—	Aluminium and aluminium alloy sheets, strips and plates
	—	JIS Z 1524		Pressure sensitive adhesive cloth tapes for packaging
	—	Fibre-reinforced tape	—	—
Water vapour retarders	—	—	JIS Z 1702	Polyethylene films for packaging
		Asphaltic oily mastic	—	—
		Resin or rubber based mastic	—	—
		Resin or rubber-based film or sheet (including metal foil composite sheet)		
Adhesive-ness	—	JIS A 5538		Adhesives for wall and ceiling boards
		JIS A 5547		Adhesives for preformed cellular plastics thermal insulation board
		JIS A 5549		Adhesives for fixture
		—	JIS K 6804	Poly (vinylacetate) emulsion adhesives for woods
		JIS Z 1528		Pressure sensitive adhesive double coated tapes
		—	Synthetic rubber system	Selected from those not affecting hot insulation materials. Confirmation by batch test, etc. is required.
		Rubber system	—	
		Reclaimed rubber		
		Epoxy resin system adhesives		
		Urethane system adhesives	—	
		—	Vinylacetate resign system	
		—	Modified silicon resign system	
		—	Modified acrylic resign system	
Joint sealer	—	Sealing material made of oils or rubbers as base	—	—

Table 1 (concluded)

	Hot insulation work (Clause 6)	Cold insulation work (Clause 7)	Building utility (Clause 8)	Title of standard or others
Other materials	—	—	JIS A 5556	Staples
	—	—	JIS A 5758	Sealants for sealing and glazing in buildings
	JIS B 0147			Blind rivets—Terminology and definitions
	JIS B 1122			Cross recessed head tapping screws
	JIS B 1123			Hexagon head tapping screws
	JIS B 1126			Hexagon washer head tapping screws
	JIS B 1181			Hexagon nuts and hexagon thin nuts
	JIS G 3350		—	Light gauge steel sections for general structure
	JIS G 3551	—	—	Welded steel wire and bar fabrics
	JIS G 3553	—	—	Crimped wire cloth
	—	—	Steel frame	—
	Rivet	—	Rivet	Including weld type.
	—	—	Decorative pin	—
	Various textiles		—	Victoria lawn, cloth for finish coating, etc.
	Insulating cement	—	—	—
	Mastic	—	—	—
	Caulking material		—	—
	—	—	Base paper	—
	—	—	Rubber-based sealing material	—

5 Thickness calculation of hot insulation material or cold insulation material

5.1 Basic formulae for heat transfer calculation

5.1.1 In the case of plane

5.1.1.1 General

The temperature of internal fluid (θ_i), ambient temperature (θ_a), coefficient of surface heat transfer (h_{sc}) and type of hot insulation material are deemed to be known. The relation between the radiating quantity of heat (q) and the thermal transmittance (U) is expressed as follows.

$$q = U \times (\theta_i - \theta_a)$$

Also, the thermal transmittance in a state where a hot insulation material or a cold insulation material is attached is obtained according to the following formula.

$$\frac{1}{U} = R_T$$

$$= R_{si} + R + R_{se}$$

If the surface thermal resistance (R_{si}) of internal fluid is very small and negligible, the radiating quantity of heat and the total thermal resistance are obtained according to Formula (1) and Formula (2). In this case, the calculation should be carried out regarding the temperature of internal fluid (θ_i) as being equivalent to the inner surface temperature (θ_{si}) of the hot insulation material or the cold insulation material.

$$q = \frac{1}{R_T} \times (\theta_{si} - \theta_a) \dots\dots\dots (1)$$

$$R_T = R + R_{se} = \frac{d}{\lambda} + \frac{1}{h_{se}} \dots\dots\dots (2)$$

5.1.1.2 Heat transfer calculation in the case of single layer

From Fourier's law and Newton's law of cooling, the hot insulation thickness or the cold insulation thickness (d) is obtained according to Formula (3).

$$d = \frac{\lambda \times (\theta_{si} - \theta_{se})}{h_{se} \times (\theta_{se} - \theta_a)} \dots\dots\dots (3)$$

Also, from Newton's law of cooling, the surface temperature (θ_{se}) of the hot insulation material or the cold insulation material is obtained according to Formula (4).

$$\theta_{se} = \frac{q}{h_{se}} + \theta_a \dots\dots\dots (4)$$

- where,
- q : radiating quantity of heat in the case of plane (W/m²)
 - U : thermal transmittance in the case of plane [W/(m²·K)]
 - R_T : total thermal resistance in the case of plane (m²·K/W)
 - R_{si} : surface thermal resistance of internal fluid in the case of plane (m²·K/W)
 - R : thermal resistance of hot insulation material or cold insulation material in the case of plane (m²·K/W)
 - R_{se} : surface thermal resistance in the case of plane (m²·K/W)
 - d : hot insulation thickness or cold insulation thickness (m)
 - λ : thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
 - h_{se} : coefficient of surface heat transfer [W/(m²·K)]
 - θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)

θ_{se} : surface temperature of hot insulation material or cold insulation material (°C)

θ_a : ambient temperature (°C)

5.1.1.3 Heat transfer calculation in the case of multi layers

The heat transfer calculation for the execution using multi-layered (two or more types) hot insulation materials or cold insulation materials is in accordance with the following formulae.

The total thermal resistance in the case of a plane (R_T) is obtained according to Formula (5) from the sum of the thermal resistances of respective layers and the surface thermal resistance (R_{se}).

$$R_T = R' + R_{se}$$

$$= \sum_{j=1}^n \frac{d_j}{\lambda_j} + \frac{1}{h_{se}} \dots\dots\dots (5)$$

The boundary temperature between respective layers and the surface temperature (θ_{se}) of hot insulation material or cold insulation material are obtained according to Formula (1) and Formula (6).

$$\left. \begin{aligned} \theta_{si} - \theta_1 &= \frac{R_1}{R_T} \times (\theta_{si} - \theta_a) \\ \theta_1 - \theta_2 &= \frac{R_2}{R_T} \times (\theta_{si} - \theta_a) \\ &\vdots \\ \theta_{se} - \theta_a &= \frac{R_{se}}{R_T} \times (\theta_{si} - \theta_a) \end{aligned} \right\} \dots\dots\dots (6)$$

where, R' : thermal resistance of multi-layered hot insulation materials or cold insulation materials in the case of plane ($m^2 \cdot K/W$)

5.1.2 In the case of pipe

5.1.2.1 General

The relation between the radiating quantity of heat (q_i) and the thermal transmittance (U_i) is expressed as follows.

$$q_i = U_i \times (\theta_i - \theta_a)$$

Also, the thermal transmittance in a state where a hot insulation material or a cold insulation material is attached is obtained according to the following formula.

$$\frac{1}{U_i} = R_{Ti} = R_{ii} + R_i + R_{ie}$$

If the surface thermal resistance (R_{ii}) of internal fluid is very small and negligible, the radiating quantity of heat and the total thermal resistance are obtained according to Formula (7) and Formula (8). In this case, the calculation should be carried out regarding the temperature of internal fluid (θ_i) as being equivalent to the inner surface temperature (θ_{si}) of the hot insulation material or the cold insulation material.

$$q_l = \frac{1}{R_{Tl}} \times (\theta_{si} - \theta_a) \dots\dots\dots (7)$$

$$R_{Tl} = R_l + R_{le} = \frac{\ln\left(\frac{D_e}{D_i}\right)}{2 \times \pi \times \lambda} + \frac{1}{h_{se} \times \pi \times D_e} \dots\dots\dots (8)$$

5.1.2.2 Heat transfer calculation in the case of single layer

From Fourier's law and Newton's law of cooling, the hot insulation thickness or the cold insulation thickness (d) is obtained according to Formula (9).

$$D_e \times \ln\left(\frac{D_e}{D_i}\right) = \frac{2 \times \lambda \times (\theta_{si} - \theta_{se})}{h_{se} \times (\theta_{se} - \theta_a)} \dots\dots\dots (9)$$

$$d = \frac{D_e - D_i}{2}$$

Also, from Newton's law of cooling, the surface temperature (θ_{se}) of the hot insulation material or the cold insulation material is obtained according to Formula (10).

$$\theta_{se} = \frac{q_l}{h_{se} \times \pi \times D_e} + \theta_a \dots\dots\dots (10)$$

where, q_l : radiating quantity of heat in the case of pipe (W/m)

U_l : thermal transmittance in the case of pipe
[W/(m · K)]

R_{Tl} : total thermal resistance in the case of pipe (m · K/W)

R_{li} : surface thermal resistance of internal fluid in the
case of pipe (m · K/W)

R_l : thermal resistance of hot insulation material or cold
insulation material in the case of pipe (m · K/W)

R_{le} : surface thermal resistance in the case of pipe
(m · K/W)

d : hot insulation thickness or cold insulation thickness
(m)

λ : thermal conductivity of hot insulation material or
cold insulation material [W/(m · K)]

h_{se} : coefficient of surface heat transfer [W/(m² · K)]

θ_i : temperature of internal fluid (°C)

θ_{si} : inner surface temperature of hot insulation mate-
rial or cold insulation material (°C)

θ_{se} : surface temperature of hot insulation material or
cold insulation material (°C)

θ_a : ambient temperature (°C)

D_i : inside diameter of hot insulation material or cold
insulation material (m)

D_e : outside diameter of hot insulation material or cold
insulation material (m)

5.1.2.3 Heat transfer calculation in the case of multi layers

The heat transfer calculation for the execution using multi-layered (two or more types) hot insulation materials or cold insulation materials is in accordance with the following formulae.

In the case of a pipe, the heat transfer calculation is in accordance with Formula (11) in the same way as 5.1.1.3.

$$R_{\pi} = R_1' + R_{le}$$

$$= \frac{1}{2 \times \pi} \times \sum_{j=1}^n \left(\frac{1}{\lambda_j} \times \ln \frac{D_{ej}}{D_{ij}} \right) + \frac{1}{h_{se} \times \pi \times D_e} \dots\dots\dots (11)$$

The boundary temperature between respective layers and the surface temperature (θ_{se}) of hot insulation material or cold insulation material are obtained according to Formula (7) and Formula (12).

$$\left. \begin{aligned} \theta_{si} - \theta_1 &= \frac{R_{11}}{R_{\pi}} \times (\theta_{si} - \theta_a) \\ \theta_1 - \theta_2 &= \frac{R_{12}}{R_{\pi}} \times (\theta_{si} - \theta_a) \\ &\vdots \\ \theta_{se} - \theta_a &= \frac{R_{le}}{R_{\pi}} \times (\theta_{si} - \theta_a) \end{aligned} \right\} \dots\dots\dots (12)$$

where, R_1' : thermal resistance of multi-layered hot insulation materials or cold insulation materials in the case of pipe (m • K/W)

When the coefficient of surface heat transfer is obtained by calculation, Annex D should be referred to.

5.2 Basic formulae of mean thermal conductivity

5.2.1 General

If the temperature of internal fluid and the inflow/outflow of heat to/from the surface of hot insulation material or cold insulation material are constant, the temperature difference between the inner surface temperature and the surface temperature of a hot insulation material will occur; however, eventually, a steady state will be reached. In this case, when the thermal conductivity (λ) of hot insulation material or cold insulation material is expressed by $\lambda=f(\theta)$ as the function of temperature (θ), the mean thermal conductivity (λ_m) is obtained by integral-averaging of $\lambda=f(\theta)$. In order to calculate the hot insulation thickness or cold insulation thickness, this mean thermal conductivity (λ_m) should be used.

If the thermal conductivity (λ) is expressed by $\lambda=f(\theta)$ as the function of temperature (θ), the mean thermal conductivity (λ_m) is obtained according to Formula (13) as an integral average.

In the case of the cold insulation, the calculation is carried out by taking the value of θ_{se} as θ_{si} and the value of θ_{si} as θ_{se} .

$$\lambda_m = \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \dots\dots\dots (13)$$

where, θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)

θ_{se} : surface temperature of hot insulation material or cold insulation material (°C)

5.2.2 Primary expression only

The mean thermal conductivity (λ_m) is obtained according to Formula (14) in the case where the approximate expression of thermal conductivity (λ) is expressed as a primary expression.

$$\lambda = a_0 + a_1 \times \theta$$

$$\begin{aligned} \lambda_m &= \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \dots\dots\dots (14) \\ &= a_0 + \frac{a_1 \times (\theta_{si} + \theta_{se})}{2} \end{aligned}$$

5.2.3 Secondary expression only

The mean thermal conductivity (λ_m) is obtained according to Formula (15) in the case where the approximate expression of thermal conductivity (λ) is expressed as a secondary expression.

$$\lambda = a_0 + a_1 \times \theta + a_2 \times \theta^2$$

$$\begin{aligned} \lambda_m &= \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \dots\dots\dots (15) \\ &= a_0 + \frac{a_1 \times (\theta_{si} + \theta_{se})}{2} + \frac{a_2 \times (\theta_{si}^2 + \theta_{si} \times \theta_{se} + \theta_{se}^2)}{3} \end{aligned}$$

5.2.4 Combination of primary expression and secondary expression

The mean thermal conductivity (λ_m) is obtained according to Formula (16) and Formula (17) in the case where the approximate expression of thermal conductivity (λ) is expressed as the combination of primary expression and secondary expression at a temperature (θ_y).

$$\text{When } \theta \leq \theta_y, \quad \lambda = a_0 + a_1 \times \theta$$

$$\text{When } \theta > \theta_y, \quad \lambda = b_0 + b_1 \times \theta + b_2 \times \theta^2$$

• When $\theta_{se} < \theta_{si} \leq \theta_y$,

$$\begin{aligned} \lambda_m &= \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \\ &= a_0 + \frac{a_1 \times (\theta_{si} + \theta_{se})}{2} \dots\dots\dots (16) \end{aligned}$$

- When $\theta_{se} < \theta_y \leq \theta_{si}$,

$$\begin{aligned}\lambda_m &= \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \\ &= \frac{1}{(\theta_{si} - \theta_{se})} \times \left\{ (\theta_y - \theta_{se}) \times \left[a_0 + \frac{a_1 \times (\theta_y + \theta_{se})}{2} \right] \right. \\ &\quad \left. + (\theta_{si} - \theta_y) \times \left[b_0 + \frac{b_1 \times (\theta_{si} + \theta_y)}{2} + \frac{b_2 \times (\theta_{si}^2 + \theta_{si} \times \theta_y + \theta_y^2)}{3} \right] \right\} \dots\dots\dots (17)\end{aligned}$$

5.3 Design condition of thickness of hot insulation material or cold insulation material

In general, the thickness of hot insulation material or cold insulation material used in the thermal insulation execution shall be calculated according to the design conditions shown below.

On the setting of the design conditions, energy saving [such as global warming prevention and reduction of carbon dioxide (CO₂)] should be taken into consideration.

- Hot insulation in which radiating quantity of heat is set as design condition** The thickness of hot insulation material is obtained according to 5.4, when the radiating quantity of heat is used as the design condition and set to not more than the predetermined design value.
- Hot insulation in which surface temperature is set as design condition** The thickness of hot insulation material is obtained in accordance with 5.5, when the surface temperature of the hot insulation material is used as the design condition and set to not more than the predetermined design value.
- Thickness of cold insulation material used in cold insulation execution** When the design condition is set to be no dew condensation after the cold insulation execution, the thickness of cold insulation material is obtained in accordance with 5.6 a) from the dew-point temperature (surface temperature) on the surface of cold insulation material. If the intruding quantity of heat is set as the design condition, either the thickness that the intruding quantity of heat is not more than the designated design value or the cold insulation thickness obtained in accordance with 5.6 a), whichever is larger shall be used. When only the intruding quantity of heat is set as the design basis, the thickness of cold insulation material is obtained in accordance with 5.6 b).
- Thickness of dew proofing material used in dew proofing work** The thickness of dew proofing material used in the dew proofing work is obtained in accordance with 5.7 under the condition to be no dew condensation on the surface after the dew proofing work.
- Thermal insulating economical thickness is set as design condition** The hot insulation economical thickness means the hot insulation thickness when the sum of the price of execution in one year and the price of quantity of heat equivalent to the radiating quantity of heat becomes minimum; and this is the hot insulation thickness of minimum cost in terms of the balance between the cost required

for hot insulation execution and the price of quantity of heat caused by the heat loss. The thermal insulating economical thickness is obtained according to 5.8.

The concept of calculation method is given in Annex E.

- f) **Temperature change of fluid in piping during transportation is set as design condition** When the hot insulation of piping is executed to suppress the temperature change of fluid in piping during transportation, the thickness of hot insulation material is obtained in accordance with Annex A from the predetermined design value of temperature change.
- g) **Temperature change of static fluid in piping/equipment/container with time is set as design condition** When the hot insulation is executed on inside of piping/equipment/container to make the temperature change of static fluid within the designed value for the specified period, the thickness of hot insulation material is obtained in accordance with Annex B from the predetermined design value of temperature change.
- h) **Prevention of freezing of water in pipe is set as design condition** When the freezing of water for a definite time in pipe is prevented by the hot insulation execution, the thickness of hot insulation material is obtained from the predetermined design time for prevention in accordance with Annex C.
- i) **Execution thickness of hot insulation/cold insulation/dew proofing material used for building utility** The execution thickness of hot insulation/cold insulation/dew proofing material used in building utility (except detached houses) for facilities of air conditioning and of water supply/drainage for sanitation is obtained according to the formulae given in 5.4 to 5.7. For the object such as a cold/hot water pipe utilizing both the hot insulation and the cold insulation, the larger thickness of the material shall be used. The economical thickness and the radiating quantity of heat are obtained in accordance with 5.8 for the hot insulation material used in the hot insulation work.

5.4 In the case where radiating quantity of heat is set as design condition

5.4.1 General

The common formula shall be as follows, when the calculations specified in 5.4.2 and 5.4.3 are carried out by setting the design value of radiating quantity of heat as (q).

- a) When the thickness of hot insulation material or cold insulation material is determined, the virtual surface temperature (θ_{se}) of hot insulation material or cold insulation material shall be set according to Formula (4).

$$\theta_{se} = \frac{q}{h_{se}} + \theta_a \dots\dots\dots (4)$$

- b) The thermal conductivity of hot insulation material or cold insulation material is expressed as a function of temperature, and the function suitable for the hot insulation material or cold insulation material to be used shall apply.

As an example of the function, the reference formulae for thermal conductivity calculation of main thermal insulation materials are given in Table 2 to Table 4.

$$\lambda = f(\theta) \dots\dots\dots (18)$$

- c) The mean thermal conductivity (λ_m) of hot insulation material or cold insulation material is obtained according to Formula (13) derived from Formula (18), using the virtual surface temperature (θ_{sc}) of hot insulation material or cold insulation material obtained according to Formula (4).

$$\lambda_m = \frac{1}{(\theta_{si} - \theta_{sc})} \times \int_{\theta_{sc}}^{\theta_{si}} f(\theta) d\theta \dots\dots\dots (13)$$

5.4.2 In the case of plane

In the case of a plane, the thickness of hot insulation material or cold insulation material is obtained as follows.

- a) The hot insulation thickness or cold insulation thickness (d) is obtained according to Formula (19), by substituting the mean thermal conductivity (λ_m) into Formula (3).

$$d = \frac{\lambda_m \times (\theta_{si} - \theta_{sc})}{h_{se} \times (\theta_{sc} - \theta_a)} \dots\dots\dots (19)$$

The product thickness (d') of hot insulation material or cold insulation material to be used shall be the thickness of not less than d but close to d obtained by Formula (19).

- b) Based on d' determined in **a**), the radiating quantity of heat (q') is obtained according to Formula (20), and it shall be confirmed not to be more than the design value of radiating quantity of heat (q).

$$q' = \frac{(\theta_{si} - \theta_a)}{\frac{d'}{\lambda_m} + \frac{1}{h_{se}}} \dots\dots\dots (20)$$

- where, q' : radiating quantity of heat in product thickness in the case of plane (W/m²)
- d : hot insulation thickness or cold insulation thickness (m)
- d' : product thickness of hot insulation material or cold insulation material (m)
- λ : thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
- λ_m : mean thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
- h_{se} : coefficient of surface heat transfer [W/(m²·K)]
- θ_i : temperature of internal fluid (°C)
- θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)
- θ_{sc} : surface temperature of hot insulation material or cold insulation material (°C)
- θ_a : ambient temperature (°C)

5.4.3 In the case of pipe

In the case of a pipe, the thickness of hot insulation material or cold insulation material is obtained as follows.

- a) The hot insulation thickness or cold insulation thickness (d) is obtained according to Formula (21), by substituting the mean thermal conductivity (λ_m) into Formula (9).

$$D_e \times \ln \left(\frac{D_e}{D_i} \right) = \frac{2 \times \lambda_m \times (\theta_{si} - \theta_{se})}{h_{se} \times (\theta_{se} - \theta_a)} \dots\dots\dots (21)$$

$$d = \frac{D_e - D_i}{2}$$

The value of the calculation result in the right-hand side of Formula (21) shall be checked against the values in Table 5¹⁾, and the hot insulation thickness or cold insulation thickness (d) shall be determined.

The hot insulation thickness or cold insulation thickness shall be determined in such a way that the solution of the right-hand side of Formula (21) is taken as x , and the hot insulation thickness or cold insulation thickness is selected from the row of thermal insulation thickness in Table 5 relevant to the numerical value of not less than x in the row of the piping size. The hot insulation thickness or cold insulation thickness corresponding to the value of $D_e \times \ln(D_e/D_i)$ of not less than x but close to x becomes the minimum thickness conforming to the condition of virtual surface temperature, and the product thickness (d') of hot insulation material or cold insulation material to be used shall be the product standard thickness of hot insulation material or cold insulation material of not less than d but close to d .

Note ¹⁾ Table 5 is the table prepared by substituting the various pipe diameters and the hot insulation thicknesses or cold insulation thicknesses into the left-hand side [$D_e \times \ln(D_e/D_i)$] of Formula (21).

- b) Based on the product thickness (d') of hot insulation material or cold insulation material, the product outside diameter of hot insulation material or cold insulation material to be used is taken as (D_e'), and the radiating quantity of heat (q_1') is obtained according to Formula (22).

$$q_1' = \frac{(\theta_{si} - \theta_a)}{\left(\frac{\ln \left(\frac{D_e'}{D_i} \right)}{2 \times \pi \times \lambda_m} + \frac{1}{h_{se} \times \pi \times D_e'} \right)} \dots\dots\dots (22)$$

$$d' = \frac{D_e' - D_i}{2}$$

- c) When the design value of radiating quantity of heat (q) is given by the radiating quantity of heat per unit area, the radiating quantity of heat (q_1') obtained according to Formula (22) is converted to the radiating quantity of heat per unit area (q_a'), and it shall be confirmed whether or not the design value of radiating quantity of heat (q) is satisfied.

$$q_a' = \frac{q_i'}{(D_i + 2d') \times \pi} \dots\dots\dots (23)$$

When the radiating quantity of heat per unit area (q_a') is not more than the design value of radiating quantity of heat (q), the product thickness (d') of hot insulation material or cold insulation material shall be used.

- d) In Formula (23), when the radiating quantity of heat per unit area (q_a') is larger than the design value of radiating quantity of heat (q), the product thickness of hot insulation material or cold insulation material shall be increased and the calculation shall be carried out by repeating Formula (21), Formula (22) and Formula (23).

where, q_i' : radiating quantity of heat in product thickness in the case of pipe (W/m)
 q_a' : radiating quantity of heat per unit area in the case of pipe (W/m²)
 d : hot insulation thickness or cold insulation thickness (m)
 d' : product thickness of hot insulation material or cold insulation material (m)
 λ : thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
 λ_m : mean thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
 h_{sc} : coefficient of surface heat transfer [W/(m²·K)]
 θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)
 θ_{se} : surface temperature of hot insulation material or cold insulation material (°C)
 θ_a : ambient temperature (°C)
 D_i : inside diameter of hot insulation material or cold insulation material (m)
 D_e : outside diameter of hot insulation material or cold insulation material (m)
 D_e' : product outside diameter of hot insulation material or cold insulation material (m)

5.5 In the case where surface temperature is set as design condition

5.5.1 General

The common formula for the calculations specified in 5.5.2 and 5.5.3 shall be as follows, by setting the design value of surface temperature as (θ_{sc}).

- a) The thermal conductivity of hot insulation material or cold insulation material is expressed as a function of temperature, and the function suitable for the hot insulation material or the cold insulation material to be used shall apply.

As an example of the function, the reference formulae for thermal conductivity calculation of main thermal insulation materials are given in Table 2 to Table 4.

$$\lambda = f(\theta) \dots\dots\dots (18)$$

- b) The mean thermal conductivity (λ_m) of hot insulation material or cold insulation material is obtained according to Formula (13) derived from Formula (18), using the design value of surface temperature (θ_{se}) of hot insulation material or cold insulation material.

$$\lambda_m = \frac{1}{(\theta_{si} - \theta_{se})} \times \int_{\theta_{se}}^{\theta_{si}} f(\theta) d\theta \dots\dots\dots (13)$$

5.5.2 In the case of plane

In the case of a plane, the thickness of hot insulation material or cold insulation material is obtained as follows.

- a) The hot insulation thickness or cold insulation thickness (d) is obtained according to Formula (19).

$$d = \frac{\lambda_m \times (\theta_{si} - \theta_{se})}{h_{se} \times (\theta_{se} - \theta_a)} \dots\dots\dots (19)$$

The product thickness (d') of hot insulation material or cold insulation material to be used shall be the thickness of not less than d but close to d obtained by Formula (19).

- b) Based on d' determined in **a**), the radiating quantity of heat (q') is obtained according to Formula (20).

$$q' = \frac{(\theta_{si} - \theta_a)}{\frac{d'}{\lambda_m} + \frac{1}{h_{se}}} \dots\dots\dots (20)$$

- c) The surface temperature (θ_{se}') of hot insulation material or cold insulation material is obtained according to Formula (24) by substituting the radiating quantity of heat (q') obtained according to Formula (20) to Formula (4).

$$\theta_{se}' = \frac{q'}{h_{se}} + \theta_a \dots\dots\dots (24)$$

It shall be confirmed that the surface temperature (θ_{se}') of hot insulation material or cold insulation material having the product thickness (d'), and the design value of surface temperature (θ_{se}) have the following relation.

In the case of hot insulation $\theta_{se}' < \theta_{se}$

In the case of cold insulation $\theta_{se}' > \theta_{se}$

where, q' : radiating quantity of heat in product thickness in the case of plane (W/m²)

d : hot insulation thickness or cold insulation thickness (m)

d' : product thickness of hot insulation material or cold insulation material (m)

- λ : thermal conductivity of hot insulation material or cold insulation material [W/(m · K)]
- λ_m : mean thermal conductivity of hot insulation material or cold insulation material [W/(m · K)]
- h_{se} : coefficient of surface heat transfer [W/(m² · K)]
- θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)
- θ_{se} : surface temperature of hot insulation material or cold insulation material (°C)
- θ_{se}' : surface temperature of hot insulation material or cold insulation material in product thickness (°C)
- θ_a : ambient temperature (°C)

5.5.3 In the case of pipe

In the case of a pipe, the thickness of hot insulation material or cold insulation material is obtained as follows.

- a) The hot insulation thickness or cold insulation thickness (d) is obtained according to Formula (21).

$$D_e \times \ln \left(\frac{D_e}{D_i} \right) = \frac{2 \times \lambda_m \times (\theta_{si} - \theta_{se})}{h_{se} \times (\theta_{se} - \theta_a)} \dots\dots\dots (21)$$

$$d = \frac{D_e - D_i}{2}$$

In the same way as **5.4.3 a)**, the value of the calculation result in the right-hand side of Formula (21) shall be checked against the values in Table 5, and the hot insulation thickness or cold insulation thickness (d) shall be determined. The product thickness (d') of hot insulation material or cold insulation material to be used shall be the thickness of not less than d but close to d .

- b) Based on d' determined in **a)**, the product outside diameter of hot insulation material or cold insulation material shall be taken as (D_e'), and the radiating quantity of heat (q_1') is obtained according to Formula (25).

$$q_1' = \frac{(\theta_{si} - \theta_a)}{\left(\frac{\ln \left(\frac{D_e'}{D_i} \right)}{2 \times \pi \times \lambda_m} + \frac{1}{h_{se} \times \pi \times D_e'} \right)} \dots\dots\dots (25)$$

$$d' = \frac{D_e' - D_i}{2}$$

- c) The surface temperature (θ_{se}') of hot insulation material or cold insulation material is obtained according to Formula (26) by substituting the radiating quantity of heat (q_1') obtained according to Formula (25) and the product outside diameter (D_e') of hot insulation material or cold insulation material to Formula (10).

$$\theta_{se}' = \frac{q_1'}{h_{se} \times \pi \times D_e'} + \theta_a \dots\dots\dots (26)$$

It shall be confirmed that the surface temperature (θ_{se}') of hot insulation material or cold insulation material having the product thickness (d'), and the design value of surface temperature (θ_{se}) of hot insulation material or cold insulation material have the following relation.

In the case of hot insulation $\theta_{se}' < \theta_{se}$

In the case of cold insulation $\theta_{se}' > \theta_{se}$

- where,
- q_1' : radiating quantity of heat in product thickness in the case of pipe (W/m)
 - d : hot insulation thickness or cold insulation thickness (m)
 - d' : product thickness of hot insulation material or cold insulation material (m)
 - λ : thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
 - λ_m : mean thermal conductivity of hot insulation material or cold insulation material [W/(m·K)]
 - h_{se} : coefficient of surface heat transfer [W/(m²·K)]
 - θ_{si} : inner surface temperature of hot insulation material or cold insulation material (°C)
 - θ_{se} : surface temperature of hot insulation material or cold insulation material (°C)
 - θ_{se}' : surface temperature of hot insulation material or cold insulation material in product thickness (°C)
 - θ_a : ambient temperature (°C)
 - D_i : inside diameter of hot insulation material or cold insulation material (m)
 - D_e : outside diameter of hot insulation material or cold insulation material (m)
 - D_e' : product outside diameter of hot insulation material or cold insulation material (m)

5.6 In the case of cold insulation

The cold insulation thickness in the cold insulation execution is obtained taking the dew proofing based on the surface temperature or the intruding quantity of heat based on the radiating quantity of heat as the design condition.

- a) When the dew proofing is taken as a design condition, the partial pressure (p) of water vapour is obtained from the ambient temperature (θ_a) and relative humidity (ϕ) according to Formula (27), taking the saturated water vapour pressure at ambient temperature (θ_a) as (p^*) based on the saturated water vapour pressure table of Table 6.

$$p = p^* \times \frac{\phi}{100} \dots\dots\dots (27)$$

The partial pressure (p) of water vapour in Formula (27) shall be checked against the values in Table 6, and the dew-point temperature (θ_d) at which p becomes saturated water vapour pressure and dew condensation occurs shall be determined. According to Formula (28), the thickness of cold insulation material is obtained according to 5.5 taking the temperature obtained by adding x °C to the dew-point temperature (θ_d) as a surface temperature (θ_{sc}) in consideration of a safety factor. The safety factor shall be determined upon the agreement between the parties concerned with delivery.

$$\theta_{sc} = \theta_d + x^{2)} \dots\dots\dots (28)$$

The radiating quantity of heat (q_{sc}) at this time is obtained according to Formula (29).

$$q_{sc} = h_{se} \times (\theta_{sc} - \theta_a) \dots\dots\dots (29)$$

Note ²⁾ The temperature of x °C added as a safety factor should be 0.3 °C at an ambient temperature 30 °C and at a relative humidity 85 %. The conditions in which the relative humidity is over 85 %, the addition of 0.3 °C is sometimes not enough.

- b) When the intruding quantity of heat is taken as a design condition, the relation between the design value (Q) of intruding quantity of heat and the radiating quantity of heat (q) shall be as follows.

$$Q = -q$$

Also when the intruding quantity of heat is set as a design criterion, based on the basic requirement that no dew condensation is recognized on the surface of cold insulation material, the thickness of cold insulation material shall be calculated in accordance with 5.4, if the intruding quantity of heat obtained from the radiating quantity of heat calculated according to Formula (29) does not satisfy the design value of intruding quantity of heat.

- where, Q : intruding quantity of heat in the case of plane (W/m²)
 q : radiating quantity of heat in the case of plane (W/m²)
 q_{sc} : radiating quantity of heat at dew-point temperature + x °C in the case of plane (W/m²)
 p^* : saturated water vapour pressure (kPa)
 p : partial pressure of water vapour (kPa)
 ϕ : relative humidity (%)
 h_{se} : coefficient of surface heat transfer [W/(m² · K)]
 θ_{sc} : surface temperature of hot insulation material or cold insulation material (°C)
 θ_d : dew-point temperature (°C)
 θ_a : ambient temperature (°C)

5.7 In the case of dew proofing

The dew proofing thickness of dew proof material is obtained in the same way as 5.6 a).

5.8 Calculation of thermal insulating economical thickness**5.8.1 General**

The calculation method of thermal insulating economical thickness shall be in accordance with 5.8.2 or 5.8.3.

The execution cost, price of quantity of heat, annual service hours, annual interest rate, number of service years, etc. shall be determined by the user, in principle.

The view of price of execution and price of quantity of heat are given in Annex E.

5.8.2 In the case of plane

In the case of a plane, the annual total cost (F_f) which is the sum of the price of execution and the price of quantity of heat equivalent to the radiating quantity of heat in one year is obtained according to Formula (30).

$$F_f = a \times d \times N + b \times t \times q \dots\dots\dots (30)$$

The thermal insulating economical thickness (de) shall be the hot insulation thickness when Formula (30) becomes the minimum value. The radiating quantity of heat (q) at that time is obtained according to Formula (31) and Formula (32). The reference formulae for thermal conductivity calculation of the main hot insulation materials or cold insulation materials are given in Table 2 to Table 4 to obtain the mean thermal conductivity (λ_m).

$$q = \frac{1}{R_T} \times (\theta_{si} - \theta_a) \dots\dots\dots (31)$$

$$R_T = R + R_{se} = \frac{d}{\lambda_m} + \frac{1}{h_{se}} \dots\dots\dots (32)$$

5.8.3 In the case of pipe

In the case of a pipe, the annual total cost (F_i), which is the sum of the price of execution and the price of quantity of heat equivalent to radiating quantity of heat in one year, is obtained according to Formula (33).

$$F_i = \frac{\pi \times (D_e^2 - D_i^2)}{4} \times a \times N + b \times t \times q_i \dots\dots\dots (33)$$

$$d = \frac{D_e - D_i}{2}$$

The thermal insulating economical thickness (de) shall be the hot insulation thickness when Formula (33) becomes the minimum value. The radiating quantity of heat (q_i) at that time is obtained according to Formula (7) and Formula (34).

The reference formulae for thermal conductivity calculation of the main thermal insulation materials are given in Table 2 to Table 4 to obtain the mean thermal conductivity (λ_m).

$$q_l = \frac{1}{R_{Tl}} \times (\theta_{si} - \theta_a) \dots\dots\dots (7)$$

$$R_{Tl} = R_l + R_{le} = \frac{\ln\left(\frac{D_e}{D_i}\right)}{2 \times \pi \times \lambda_m} + \frac{1}{h_{se} \times \pi \times D_e} \dots\dots\dots (34)$$

where, F_f : annual total cost of hot insulation in the case of plane (yen/m²)

F_l : annual total cost of hot insulation in the case of pipe (yen/m)

a : construction work cost per unit volume (yen/m³)

b : price of quantity of heat [yen/(kW·h)]

t : annual service hours (h)

n : annual interest rate

y : number of service years (year)

N : depreciation ratio $N = \frac{n \times (1+n)^y}{(1+n)^y - 1}$

q : radiating quantity of heat in the case of plane (W/m²)

q_l : radiating quantity of heat in the case of pipe (W/m)

R_T : total thermal resistance in the case of plane (m²·K/W)

R : thermal resistance of hot insulation material in the case of plane (m²·K/W)

R_{se} : surface thermal resistance in the case of plane (m²·K/W)

R_{Tl} : total thermal resistance in the case of pipe (m·K/W)

R_l : thermal resistance of hot insulation material in the case of pipe (m·K/W)

R_{le} : surface thermal resistance in the case of pipe (m·K/W)

de : thermal insulating economical thickness (m)

λ_m : mean thermal conductivity of hot insulation material [W/(m·K)]

h_{se} : coefficient of surface heat transfer [W/(m²·K)]

θ_{si} : inner surface temperature of hot insulation material (°C)

θ_a : ambient temperature (°C)

D_i : inside diameter of hot insulation material (m)

D_e : outside diameter of hot insulation material (m)

6 Execution methods for hot insulation works

6.1 Hot insulation materials

6.1.1 General matters

General matters shall be as follows.

- a) An appropriate hot insulation material to be used shall be determined by referring to Clause 4 and considering the safety and workability.
- b) Even though the respective service temperature is indicated on each hot insulation material, it is the value simply certificated under a certain condition. Attention should be paid to the determination of the service temperature range, because the long-term stability differs depending on the hot insulation materials.

6.1.2 Selection of material

The selection of material shall be as follows.

- a) An appropriate material and type of the hot insulation material shall be selected in accordance with Clause 4.
- b) Annex F should be referred to for the applicable maximum temperature of hot insulation material.
- c) When using an aluminium sheet, any measures should be taken to prevent alkali corrosion.
- d) If the temperature of surface to be worked is under 150 °C, the environment beneath the hot insulation material easily forms corrosion; therefore, attention should be paid to the selection of material.

6.1.3 Execution thickness

The execution thickness of hot insulation material shall be in accordance with **a), b), e), f), g) and h)** of 5.3.

6.2 Main subsidiary materials

6.2.1 Covering materials

The covering materials to be used in the works shall be selected, considering the following matters.

- a) Weatherability/durability/heat resistance/corrosion resistance/abrasion resistance
- b) Acid resistance/alkali resistance/solvent resistance
- c) Shape of hot insulation material and adaptability to the execution site
- d) Safety (no peculiar odour and dust, and the like)
- e) Workability

6.2.1.1 Metal covering materials

The metal covering materials³⁾ shall be those given in Table 1 or those having the weather resistance⁴⁾ equal or superior thereto.

- Notes ³⁾ Flat sheets, round corrugated sheets and square corrugated sheets are usually used for metal plates having the weatherability.
- ⁴⁾ As the materials having the weatherability equal or superior thereto, coated stainless steel sheets, vinyl chloride steel sheets, fluoro-resin steel sheets, silicon-polyester steel sheets and the like are available.

6.2.1.2 Other covering materials

Other covering materials given in Table 1, in addition to those in **6.2.1.1**, may be used as the covering material for inside/outside of room, etc.

6.2.2 Other materials

6.2.2.1 Binding materials

The binding materials shall be a wire rod in the case for piping of smaller diameter, and a steel strip in the case for piping of larger diameter, vessels, and the like. The material quality thereof shall be as given in Table 1 or that equal or superior thereto, considering the temperature/corrosion resistance/strength, etc.

6.2.2.2 Other materials

Other materials used for hot insulation works such as slip-prevention material/grout material/filler material/waterproof material shall be as specified in “Other materials” of Table 1, or as follows.

- a) As the material to fill up grout parts and gaps, the hot insulation material such as the man made mineral fibre may be used.
- b) Attention should be paid for the selection of mastic and caulking materials used for the high-temperature piping, equipment, etc., because they have a risk of burn.

6.3 Execution guideline of hot insulation works

6.3.1 General matters

General matters shall be as follows.

- a) Surfaces to be worked shall be free from adhesion of foreign substances such as dust/water/ice.
- b) Attention should be paid that the hot insulation materials are not wetted with rain-water and the like during storage, transportation and execution thereof.
- c) The support rings and the piping supports shall be attached prior to the hot insulation execution.

6.3.2 Execution

6.3.2.1 Piping and joints

The hot insulation execution on piping and joints shall be as follows.

- a) Stick the pipe insulation fast to the surface to be hot-insulated, and tightly bind it with the binding material. The binding shall be made at two or more positions per one piece of pipe insulation (see Figure 1).

- b) Generally, attach the pipe insulation by single layer if the thickness is 75 mm or under, and by two or more layers if over 75 mm (see Figure 1 and Figure 2).
- c) In the case of two or more layers, arrange the seams not to be placed at the same position in circumferential direction and longitudinal direction of the first layer and the second layer, and their above layer (see Figure 2).
- d) In the case of vertical piping, attach the support rings at appropriate positions to prevent the pipe insulation from slipping down. Provide an expanding part beneath the pipe insulation, and stuff the compressed man made mineral fibre thermal insulation material (see Figure 3 and Figure 4).
- e) In the case where the metal covering material specified in **6.2.1.1** is used, the seam in longitudinal direction shall employ a seam-jointing, tapping screw stop or button punch seaming. The overlap in circumferential direction shall be beaded and overlapped (see Figure 5).
- f) The overlap of the covering of vertical piping in circumferential direction shall be made downward to prevent the ingress of rainwater, generally overlapped by 25 mm to 50 mm in longitudinal direction, and beaded. The execution should be conducted by hanging it with a cleat after beading (see Figure 6 and Figure 7).
- g) When attaching the hot insulation material to an elbow part, process the pipe insulation to fit the shape of elbow joint, cut the board insulation or the pipe insulation into the parts to be finished along the curving part, or attach a moulding. When using the man made mineral fibre thermal insulation material, stick it fast not to make a clearance, and bind it with the binding material (see Figure 8, Figure 9 and Figure 10).
- h) For the covering of elbow part, process the metal covering material specified in **6.2.1.1** to the shape of elbow joint, or mitre joint beaded in circumference direction, and seam-joint it in the longitudinal direction; or attach a moulding (see Figure 8, Figure 9 and Figure 11).
- i) When using other covering materials, they shall be determined upon the agreement between the parties concerned with delivery depending on the execution site, execution method, part, etc.

6.3.2.2 Valve

The method of hot insulation execution on a valve shall be selected from the following.

- a) Prepare the hot insulation cover having a detachable shape, and attach it. Attach the man made mineral fibre hot insulation material to the inner surface of hot insulation cover or directly to the valve, and bind it with hexagonal wire netting, etc. specified in **6.2.2** (see Figure 12 and Figure 13).
- b) Directly attach the man made mineral fibre thermal insulation material on the valve, and bind it with a wire rod, hexagonal wire netting, etc. Apply an insulating cement, etc. by a trowel, and finish it (see Figure 14).
- c) Cut the pipe insulation to meet the valve, attach it, fill the gap with the man made mineral fibre thermal insulation material, and bind it with steel wire, hexagonal

wire netting, etc. Apply an insulating cement, etc. by a trowel, and finish it (see Figure 15).

- d) Attach the thermal insulation mattress to a valve directly, and bind it with a steel wire, belt, hook and loop fastener, etc. (see Figure 16).

6.3.2.3 Flange

The hot insulation execution on a flange shall be selected from the following.

- a) In the case of the hot insulation execution on a flange, prepare the hot insulation cover having a detachable shape, and attach it. Attach the man made mineral fibre hot insulation material to the inner surface of hot insulation cover (see Figure 17) or directly to the flange, and bind it with hexagonal wire netting, etc. (see Figure 18).
- b) Attach the thermal insulation mattress to a flange directly, and bind it with a steel wire, belt, hook and loop fastener, etc. (see Figure 19).

6.3.2.4 Equipment/tower tank, etc.

The hot insulation execution on equipment/tower tank, etc. shall be as follows.

- a) Stick the board insulation fast to the surface to be worked, and bind it tightly with the binding material specified in **6.2.2.1**. At the top and the end plates, fit the board insulation to the curved surface, cut and attach, set a float-ring, and bind it radially with the binding material specified in **6.2.2.1**. After the board insulation is attached, reinforce it with hexagonal wire netting, and apply an insulating cement, etc. by a trowel, as required. Finish this with the covering material specified in **6.2.1** (see Figure 20, Figure 21 and Figure 22).
- b) Attach the board insulation and the covering material, utilizing the bolts welded on the surface to be worked, or nuts (in the case of nuts, attach bolts, etc. to nuts) (see Figure 21).
- c) For the flange and manhole parts, process the hot insulation cover having a detachable shape, and attach it (see Figure 23 and Figure 24).

6.3.2.5 Smoke duct

The hot insulation execution on a smoke duct shall be as follows.

- a) Weld the rivets and supports to the body of smoke duct for attaching the hot insulation material and the covering material.
- b) Attach the hot insulation material to the surface to be worked, and bind it with a wire rod, etc. specified in **6.2.2.1**.

An air layer may be provided between the body of smoke duct and the hot insulation material.

- c) Some inclination shall be provided to the covering material of ceiling for the outdoor smoke duct (see Figure 25).

7 Execution methods for cold insulation works

7.1 Cold insulation materials

7.1.1 General matters

General matters shall be as follows.

- a) An appropriate cold insulation material shall be determined by referring to Clause 4 and considering the safety and workability. If the moisture permeability of cold insulation material is large, the water vapour retarder and the like shall be used.
- b) The material shall be selected, which is not liable to generate cracks due to heat contraction, clearances at seam parts, etc. at the service temperature.
- c) The material capable of withstanding the load shall be used for the position to which a load is applied.
- d) The method for the execution at an extreme low temperature of -100°C or lower shall be individually investigated, considering the low temperature characteristics of the material to be used and the surface to be worked.

7.1.2 Selection of material

An appropriate material and type of the cold insulation material shall be selected in accordance with Clause 4.

7.1.3 Execution thickness

The execution thickness of cold insulation material shall be in accordance with **c)** and **d)** of 5.3.

7.2 Main subsidiary materials

7.2.1 Covering materials

The covering materials to be used shall be selected from 6.2.1.1 or 6.2.1.2, considering the requirements specified in 6.2.1.

7.2.2 Other materials

7.2.2.1 Binding materials

The binding materials used to fix or support the cold insulation material and the covering material at the prescribed position shall be as given in Table 1, or those having the quality equal or superior thereto shall be used, considering the temperature/corrosion resistance/strength, etc.

7.2.2.2 Reinforcing material

The reinforcing materials used for the slip-prevention, etc. of cold insulation material and covering material shall be appropriately selected from “Other materials” of Table 1.

7.2.2.3 Adhesive

The adhesives used for the adhesion of the cold insulation materials each other shall be as given in Table 1, or those having the quality equal or superior thereto shall be

used. These adhesives may be used to fix the cold insulation material to the surface to be cold-insulated, or for the temporary adhesion.

7.2.2.4 Joint sealer

The joint sealers shall be as given in Table 1, which are used for the purpose of water vapour proof of the seams between the cold insulation materials, the seams with the protrusions, etc.

7.2.2.5 Water vapour retarder

The water vapour retarders used for the outer surface of cold insulation materials shall be as given in Table 1.

7.2.2.6 Waterproof material

The waterproof materials used around the fitting, etc. penetrating the covering material, on the overlap of covering material, on the cold insulation end part, etc. shall be the caulking materials specified in “Other materials” of Table 1.

7.3 Execution guideline of cold insulation works

7.3.1 General matters

General matters shall be as follows.

- a) Surfaces to be worked shall be free from adhesion of foreign substances such as dust/water/ice.
- b) Attention should be paid that the cold insulation materials are not wetted with rainwater and the like during storage, transportation and execution thereof.
- c) The slip-prevention fitting, support, etc. for the cold insulation material shall be attached prior to the cold insulation execution.
- d) The injection and foaming of rigid urethane foam in site requires the high degree technique for quality control; therefore, the applicable site is restricted.

Refer to the following for the recommended handling for injection and foaming of the stock solution of rigid urethane foam used for the cold insulation works.

- 1) Confirm the specifications (mixing ratio/mixing time/reactivity/free foaming density) of stock solution of rigid urethane foam for injection and forming, beforehand. Follow the instruction manual, etc. from the manufacturers of stock solutions at the time of the execution.
- 2) Weigh out the stock solution of rigid urethane foam for injection and forming using a measuring instrument such as a balance to attain the specified mixing ratio.
- 3) Care should be taken so that the stock solution of rigid urethane foam for injection and forming is not contaminated by water. Also, confirm that there is no moisture such as dew condensation and rainwater at the position to be worked.
- 4) Mix the stock solution of rigid urethane foam for injection and forming to be uniform, taking an appropriate mixing time. The stock solution should be mixed using an electric agitator, etc.

- 5) Before the execution, carry out the test foaming in a plastic bag, a container for exclusive use, etc. under the foaming condition confirmed in 1).
- 6) Using the test sample of 5), check the quality based on the measurement of the free foaming density of rigid urethane foam and the appearance inspection by visual observation.
- 7) The acceptance criteria shall be determined upon the agreement between the parties concerned with delivery.

NOTE The rigid urethane foam for injection and forming should have the performance comparable to that of the board or cylindrical cold insulation material used for the same cold insulation execution.

7.3.2 Execution

7.3.2.1 Piping and joints

The cold insulation execution on piping and joints shall be as follows.

- a) Attach the cylindrical cold insulation material to piping, and bind it with a steel strip, steel wire or pressure sensitive adhesive tape specified in 7.2.2.1 (see Figure 26). It may be closely contacted to piping using an adhesive specified in 7.2.2.3, which does not interfere with the cold insulation material.

In the case where the rigid urethane foam is injected and formed in the gap of seam part, a clearance should be provided in the seam part beforehand (see Figure 27).

- b) If the execution thickness of cold insulation material is over 75 mm, attach the insulation material by two or more layers, in general, for the execution (see Figure 28).
- c) Conduct the execution so that the longitudinal and lateral seams of each layer of cold insulation material are not be placed at the same position.
- d) In the case of the execution by a single layer, apply the joint sealer specified in 7.2.2.4 or the adhesive specified in 7.2.2.3 well to all the seam parts of the cold insulation material not to make a gap, when the temperature of piping is about 0 °C or lower. If the temperature of piping is over about 0 °C, the joint sealer or the adhesive need not be applied to the seam parts of cold insulation material.
- e) In the case of the execution by two or more layers, for the attachment of the cold insulation material of the first layer, take a measure to absorb the contraction or to prevent the generation of clearances due to the contraction.
- f) When attaching the cold insulation material to an elbow part, process the pipe insulation into the elbow joint shape (see Figure 29), cut the pipe insulation into the parts to be fitted along the curving part, or attach a moulding (see Figure 30).
- g) Execute the covering of elbow part in the same way as 6.3.2.1 h).
- h) When the cold insulation material of which the contraction amount is smaller than that of the pipe, insert the cold insulation material having good cushioning property at appropriate intervals.

- i) In the case of the execution on an outermost layer of the cold insulation material, apply the joint sealer specified in **7.2.2.4** or the adhesive specified in **7.2.2.3** well to all the seam parts of the cold insulation material not to make a gap. The rigid urethane foam may be injected in seam parts.
- j) Incorporate a water vapour retarder to the outer surface of cold insulation material beforehand, or apply the water vapour retarder specified in **7.2.2.5** on the surface of cold insulation material which does not have a water vapour barrier on the outer surface, and provide the covering specified in **7.2.1**.
- k) Refer to the following for the execution of slip-prevention fitting of cold insulation material (see Figure 31).
 - 1) The cold insulation thickness for the slip-prevention fitting of cold insulation material (hereafter referred to as an additional cold insulation) shall be about half the general cold insulation thickness.
 - 2) The cold insulation material of the additional cold insulation part and the general cold insulation material shall be closely contacted using an adhesive and/or joint sealer by taking into account the displacement.
- l) Refer to the following for the execution of hanger of cold insulation material (see Figure 32).
 - 1) The cold insulation thickness of the hanger shall be about half the general cold insulation thickness.
 - 2) The cold insulation length of the additional cold insulation part shall be three times or more the general cold insulation thickness.
 - 3) Also for the cold insulation of metal part that penetrates the cold insulation layer such as the measuring tube, the execution shall be conducted in the same way.

7.3.2.2 Valve and flange

The cold insulation execution on a valve or a flange should be selected from the following based on the execution method determined according to the temperature condition.

- a) Attach a fibre cold insulation material to a valve or a flange to cover the whole, and bind it with a wire rod, tape, etc., specified in **7.2.2.1**. Use the cold insulation material already provided with the water vapour retarder on the outer surface. Attach the water vapour retarder specified in **7.2.2.5** to the cold insulation material afterward, if not provided on the outer surface.
- b) Attach a board or cylindrical cold insulation material to a valve or a flange using an adhesive, and make it into a box-shape or a cylinder-shape to cover the whole. Fill the gap inside with the fibre cold insulation material (see Figure 33 and Figure 34) or inject the rigid urethane foam (see Figure 35 and Figure 36). Attach the water vapour retarder on the outer surface of board or cylindrical cold insulation material.

If the rigid urethane foam is injected, attach the fibre cold insulation material and the water vapour retarder specified in **7.2.2.5** to the surface of a valve or a flange beforehand.

- c) Attach the fibre cold insulation material and the water vapour retarder specified in **7.2.2.5** to the surface of a valve or a flange, and bind it with a wire rod, tape, etc. specified in **7.2.2.1**. Process the covering material specified in **7.2.1** into a box shape or a cylinder shape, attach it to cover the whole valve or flange, and inject the rigid urethane foam to fill the gap inside (see Figure 37 and Figure 38).

7.3.2.3 Equipment/tower tank, etc.

The cold insulation execution on the equipment/tower tank, etc. shall be as follows (see Figure 39 and Figure 40).

- a) In the case of the execution by a single layer, stick fast the seams of the cold insulation material not to make a clearance with a joint sealer or adhesive suitable for the cold insulation material to be used, and bind it with a steel strip or steel wire, when the temperature of equipment/tower tank, etc. is about 0 °C or lower. If the temperature of equipment/tower tank, etc. is over about 0 °C, the joint sealer or the adhesive need not be applied to the seam parts of cold insulation material. The cold insulation material may be closely contacted to the equipment, using an adhesive that does not interfere with it.
- b) If the thickness of cold insulation material is over 75 mm, attach the insulation material by two or more layers, in general, for the execution. At this time, conduct the execution in accordance with **7.3.2.1 i)** so that the longitudinal and lateral seams of adjacent layers of cold insulation material are not be placed at the same position.
- c) In the case of the execution on an outermost layer of the cold insulation material, apply the joint sealer or the adhesive well to all the seam parts of the cold insulation material not to make a gap. Also, the rigid urethane foam may be injected.
- d) Cover the outer surface of the cold insulation material with any of the water vapour retarder specified in **7.2.2.5** suitable for the cold insulation material to be used, and execute the following covering, as required.
 - 1) In the case of an outdoor installation, use the covering material specified in **7.2.1**. When using the metal covering material, attach it by seam-jointing, or bind it with blind rivets or bands making the overlap of 50 mm or over.

In the case of the blind riveting, pay attention not to give damage to the water vapour retarder of the lower layer.
 - 2) In the case of an indoor installation, use the covering material specified in **7.2.1** in the same way as the outdoor installation. In some cases, it may be finished only with the water vapour retarder.

8 Execution methods for hot insulation/cold insulation/dew proofing works of building utility

8.1 Hot insulation/cold insulation/dew proofing materials

8.1.1 General matters

General matters shall be as follows.

- a) Refer to **6.1.1** and **7.1.1**, and select an appropriate material, considering the safety and workability.
- b) For the objects that require both the hot insulation and the cold insulation (cold/hot water pipe, etc.), select the material which satisfies both performances.

8.1.2 Selection of material

An appropriate material and type for the hot insulation/cold insulation/dew proofing shall be selected in accordance with Clause 4. The materials shall be selected to meet the countermeasures against the sick building syndrome, considering the restriction on the amount of formaldehyde emission especially for the indoor utilities.

8.1.3 Execution thickness

The execution thickness of hot insulation/cold insulation/dew proofing material shall be in accordance with **5.3 i)**.

8.2 Main subsidiary materials

8.2.1 Covering materials

8.2.1.1 Metal covering materials

The metal covering materials shall be selected from **6.2.1.1**.

8.2.1.2 Other covering materials

Other covering materials shall be in accordance with Table 1.

8.2.2 Other materials

8.2.2.1 Binding materials

The binding materials shall be used to fix or support the hot insulation material/cold insulation material/dew proofing material and the covering material to the predetermined positions, and shall be determined in accordance with Table 1, considering the temperature/corrosion resistance/strength, etc.

8.2.2.2 Adhesives

The adhesives used for the adhesion of the hot insulation material or the cold insulation material shall be as given in Table 1. The major component of adhesives used for bonding rivets shall be the synthetic rubber system, epoxy resin system, etc.

8.2.2.3 Sealing materials

The sealing materials used for the penetrated parts, end parts, junctures of covering plates, etc. shall be those specified in **JIS A 5758** or the rubber system sealing materials, which are listed in "Other materials" of Table 1.

8.2.2.4 Water vapour retarders

The water vapour retarders used for the outer surface of cold insulation materials shall be as given in Table 1.

8.2.2.5 Forming materials

The forming materials used for the appearance improvement of indoor exposed parts shall be the base paper given in “Other materials” of Table 1, or the formed resin elbows given in “Other covering materials” of Table 1.

8.3 Execution guideline of hot insulation work/cold insulation work/dew proofing work

8.3.1 General matters

General matters shall be as follows.

- a) The covering work shall be carried out using materials specified in Building Standards Act and Fire Service Act on the important portions of pipe/duct, etc. which require the thermal insulation work, penetrating the areas enclosed for fire protection, fire walls and partitions specified by laws and regulations, walls/floors, etc. of the buildings.
- b) The equipment and piping/duct part on which a hot insulation work is to be carried out shall be delivered in a state without the interference to the hot insulation work.

8.3.2 Execution

8.3.2.1 Hot water supply pipe/hot water pipe/steam pipe

The hot insulation execution on the hot water supply pipe/hot water pipe/steam pipe, and the finish of covering thereon shall be as follows.

- a) **Hot insulation execution** The execution of hot insulation on piping, joints, valves, flanges, etc. shall be as follows.
 - 1) Stick fast the pipe insulation to piping, and bind it tightly with the binding material specified in **8.2.2.1** at one or more positions per one piece of pipe insulation not to generate clearances in the juncture of the pipe insulation.
 - 2) Generally, attach the pipe insulation by a single layer if the necessary thickness is 75 mm or under, and by two or more layers if over 75 mm. In the case of two or more layers, arrange the seams not to be placed at the same position in circumferential direction and longitudinal direction of the first layer and the second layer, and the above layer.

For the execution, Figure 1 and Figure 2 should be referred to.

- 3) As the hot insulation of joints, use the moulded hot insulation material such as the prefabricated elbow, bind the board insulation, strip insulation, felt, etc. with the zinc-coated low carbon steel wire spirally by a pitch of 50 mm or under to fasten, or cut and attach the pipe insulation.
- 4) As the hot insulation execution on a valve or a flange, use the hot insulation material of moulding, or use cylindrical, board or strip hot insulation material, and bind it with zinc-coated low carbon steel wire specified in **8.2.2.1**.

The execution of hot insulation on the parts other than the outdoor exposed parts of valve or flange shall be upon the agreement between parties concerned with delivery.

b) **Finish of covering of each part** The finish of covering of each part shall be as follows.

- 1) If the covering material such as aluminium laminated glass cloth base paper specified in **8.2.1.2** is used as a sheet, which is to be attached on the hot insulation material, the overlap width shall be 30 mm or over. Or when other covering material specified in **8.2.1.2** is used in tape-shape and wound spirally to finish, the overlap width shall be 15 mm or over.

When winding the vertical pipe with the tape such as aluminium laminated glass cloth and coloured aluminium laminated glass cloth, wind it from the bottom to the top.

- 2) The finish of covering of indoor exposed part shall be selected from the following.
 - 2.1) Attach the aluminium laminated glass cloth base paper, etc. specified in **8.2.1.2** on the hot insulation material, fix it temporarily with decorative pins or staples specified in **8.2.2**, and adhere the seams with aluminium laminated glass cloth adhesive tapes, etc. to finish (see Figure 41).
 - 2.2) Attach the base paper specified in **8.2.2.5** on the hot insulation material and finish it with aluminium laminated glass cloth tape specified in **8.2.1.2**, or attach the decorative resin cover specified in **8.2.1.2** and fix it with the button punch seaming or decorative pins specified in **8.2.2** to finish (see Figure 42).
 - 2.3) In the case of a machine room, book storeroom and warehouse, use the finish specified in **2.1**) or **2.2**), or the pipe insulation with sheathing material, adhere it with the pressure sensitive adhesive tape of the same material as the sheathing material specified in **8.2.1.2**, and bind it with the hexagonal wire netting specified in **JIS G 3554** (hereafter referred to as hexagonal wire netting) to finish (see Figure 43).

Other covering materials specified in Table 1 may be attached on the hot insulation material and finished with the hexagonal wire netting (see Figure 44).

- 2.4) If the pipe insulation or the cut thereof is used for the joints, finish it with other covering materials specified in **8.2.1.2**.

When a board insulation, strip insulation or felt is attached, attach the formed resin elbow specified in **8.2.1.2** to finish.

- 2.5) If the hot insulation is executed on a valve or a flange of 65A or over in nominal diameter, put a detachable covering using the metal covering material specified in **8.2.1.1** or conduct the same execution as that of piping.

- 3) The finish of covering of indoor unexposed part shall be selected from the following.

- 3.1) Attach the covering material such as aluminium foil paper specified in **8.2.1.2** on the hot insulation material, adhere the seams with the pressure sensitive adhesive tape of the same material as the covering material, and bind it with the hexagonal wire netting specified in **8.2.2.1** to finish (see Figure 45).
- 3.2) Finish with the tape of aluminium laminated glass cloth, etc. specified in **8.2.1.2** by winding it on the hot insulation material spirally (see Figure 46).

- 3.3) When using the pipe insulation with sheathing material, if there is any overhang of the sheathing material at the seam in the longitudinal direction, adhere that part with a pressure sensitive adhesive double coated tape, and stick all the other seams with the pressure sensitive adhesive tape of the same material as the sheathing material. If there is no overhang of the sheathing material, adhere all the seams with the pressure sensitive adhesive tape of the same material as the sheathing material. Further, finish it with the pressure sensitive adhesive tape of the same material as the sheathing material by winding it on one or more positions in the circumferential direction (see Figure 47).
- 4) For the places under floor and the conduits, attach the water vapour retarder specified in **8.2.2.4** on the hot insulation material, wind the coloured and tape-shape aluminium laminated glass cloth specified in **8.2.1.2** around it, and bind it with the coloured aluminium laminated glass cloth adhesive tape at intervals of 2 m to finish (see Figure 48).
- 5) For the places that may be wetted by water such as an outdoor exposed part, bathroom and kitchen, attach the water vapour retarder on the hot insulation material, and further attach the metal covering material specified in **6.2.1.1** on it (see Figure 49).

The seam of the metal covering material in the longitudinal direction shall employ the seam-jointing or the button punch seaming. Also, the seam in the circumferential direction shall be beaded and overlapped. Apply the sealing material specified in **8.2.2.3** to the juncture of beading, as required.

8.3.2.2 Cold water pipe/cold and hot water pipe/brine pipe

The cold insulation execution/hot insulation execution on the cold water pipe/cold and hot water pipe/brine pipe, and the finish of covering thereon shall be as follows.

- a) The cold insulation execution or the hot insulation execution on piping, joints, valve and flange shall be in accordance with **8.3.2.1 a)**. In the cold insulation work, after attaching the cold insulation material, attach the water vapour retarder specified in **8.2.2.4** to the outer surface of cold insulation material.
- b) The finish of covering of each part shall be in accordance with **8.3.2.1 b)**.

8.3.2.3 Water supply pipe/drain pipe

The dew proofing execution and the finish of covering on water supply pipe/drain pipe shall be as follows.

- a) The dew proofing execution of piping, joints, valves and flanges shall be in accordance with **8.3.2.1 a)**.
- b) The finish of covering of each part shall be in accordance with **8.3.2.1 b)**.

8.3.2.4 Equipment

The hot insulation execution/cold insulation execution/dew proofing execution on the equipment, etc., and the finish of covering thereon shall be as follows.

- a) The hot insulation execution, cold insulation execution and dew proofing execution of equipment using the board insulation shall be as follows.

- 1) Attach the board insulation with the adhesives specified in **8.2.2.2** or the rivets specified in **8.2.2**. Bind the circular large-sized equipment with the zinc-coated low carbon steel wire specified in **8.2.2.1** so that the lower part does not sag.
- 2) Attach the hexagonal wire netting specified in **8.2.2.1** on the board insulation, and bind it tightly so as not to be loosened.

When carrying out the cold insulation of the cold source equipment, attach the water vapour retarder specified in **8.2.2.4** on the cold insulation material attached with an overlap width of 30 mm or over, and bind it with the zinc-coated low carbon steel wire specified in **8.2.2.1**.

b) The finish of covering of equipment shall be as follows.

- 1) Attach the metal plate specified in **8.2.1.1** on the hexagonal wire netting in the case of the heat source equipment, and on the water vapour retarder in the case of the cold source equipment. Seam-joint or overlap the seams, and fix them with tapping screw as specified in **8.2.2** (see Figure 50 and Figure 51). Finish the spherical end plate to a radiated shape (chrysanthemum-shape) (see Figure 52).
- 2) For the square equipment, set up a steel frame specified in **8.2.2**, as required, and attach the metal plate on it. The corner shall employ the seam-jointing or the button punch seaming.

8.3.2.5 Air conditioning duct

The hot insulation execution/dew proofing execution on the air conditioning duct, and the finish of covering thereon shall be as follows.

a) The hot insulation execution/dew proofing execution on a rectangular duct, and the finish of covering thereon shall be as follows.

- 1) Attach one or more rivets specified in **8.2.2** on every 300 mm × 300 mm area of the duct by means of an adhesive specified in **8.2.2.2** or spot welding.
- 2) Attach the hot insulation material to the rivets, put the washers to the pins protruded from the hot insulation material, and bend their tips.

The welding rivets with washers may be inserted and spot welded after sticking the hot insulation material fast to the duct.

- 3) In the case of the execution using the board insulation, wave insulation of man made mineral fibre thermal insulation material and felt, attach the board insulations by sticking them fast each other. In the case of the execution of the flange using the rolled hot insulation material of man made mineral fibre thermal insulation material or felt, attach it as it is. In the case of the execution using the board insulation or the wave insulation, if the hot insulation thickness is smaller than the height of flange face, pile it up in two layers.
- 4) When using the hot insulation material equipped with sheathing material, attach them by sticking fast each other, and adhere the seam part with the pressure sensitive adhesive tape of which the material is the same as the sheathing material.
- 5) For the indoor exposed part, select the execution from the following.

- 5.1) When attaching the hot insulation material equipped with sheathing material such as aluminium laminated glass cloth, adhere the seam part with the pressure sensitive adhesive tape of the same material to finish (see Figure 53).
- 5.2) When attaching the hot insulation material or the hot insulation material equipped with sheathing material, install the metal covering material on the hot insulation material or on the steel frame base, as required (see Figure 54).

The corner parts of metal covering material shall employ the seam-jointing or the button punch seaming. The seam shall employ the inserting seam or vertical seam. Fix the important positions with the tapping screws specified in **8.2.2**.

- 5.3) In the case of a machine room, book storeroom and warehouse, attach the hot insulation material equipped with sheathing material, adhere the seam part with the pressure sensitive adhesive tape of the same material as the sheathing material, and bind it with the hexagonal wire netting specified in **8.2.2.1** to finish (see Figure 55).
- 6) Attach the hot insulation material with sheathing material on the indoor unexposed part, adhere the seam part with the pressure sensitive adhesive tape of the same material, and bind it with the hexagonal wire netting specified in **8.2.2.1** to finish (see Figure 55).
- 7) For the places that may be wetted by water such as an outdoor exposed part, bathroom and kitchen, attach the water vapour retarder specified in **8.2.2.4** on the hot insulation material with an overlap width of 30 mm or over, and further attach the metal covering material specified in **8.2.1.1** on it (see Figure 56).

The metal covering material shall employ the seam-jointing for the seam part, and fix the important positions with the tapping screws specified in **8.2.2**.

- b) The hot insulation execution/dew proofing execution on a circular duct, and the finish of covering thereon shall be as follows.
 - 1) When using the board insulation, wave insulation, felt and strip insulation, attach the hot insulation materials by sticking them fast each other, and bind it tightly with the zinc-coated low carbon steel wire specified in **8.2.2.1** spirally at intervals of 150 mm or under.
 - 2) When using the hot insulation material equipped with sheathing material, attach them by sticking fast each other, and adhere the seam part with the pressure sensitive adhesive tape of which the material is the same as the sheathing material.
 - 3) When attaching the sheet of aluminium laminated glass cloth base paper, etc. specified in **8.2.1.2** on the hot insulation material, the overlap width shall be 30 mm or over. When finishing with the tape such as aluminium laminated glass cloth by winding spirally, the overlap width shall be 15 mm or over.
 - 4) When attaching the metal covering material, employ the seam-jointing or the button punch seaming with an overlap seam of 25 mm to 50 mm in the longitudinal direction to finish.

- 5) For the indoor exposed part, select the execution from the following.
 - 5.1) Attach the hot insulation material equipped with sheathing material, and adhere the seam part with the pressure sensitive adhesive tape of the same material to finish (see Figure 57).
 - 5.2) Attach the hot insulation material equipped with sheathing material, adhere the seam part with the pressure sensitive adhesive tape of the same material, and finish it with the metal covering material specified in **8.2.1.1** or decorative resin cover specified in **8.2.1.2** (see Figure 58).
- 6) For the indoor unexposed part, select the execution from the following.
 - 6.1) When using the hot insulation material equipped with sheathing material, adhere the seam part with the pressure sensitive adhesive tape of the same material, and bind it tightly with the hexagonal wire netting specified in **8.2.2.1** to finish (see Figure 59).
 - 6.2) Wind the tape such as aluminium laminated glass cloth spirally on the hot insulation material to finish (see Figure 60).
- 7) For the places that may be wetted by water such as an outdoor exposed part, bathroom and kitchen, attach the water vapour retarder on the hot insulation material equipped with sheathing material and further attach the metal covering material specified in **8.2.1.1** on it (see Figure 61).

9 Inspections

9.1 Classification of inspections

The inspections shall include the items voluntarily confirmed by a contractor and the performance confirmation inspections after the completion of thermal insulation work or at the time of consignment.

9.2 Voluntary confirmation items

The necessity/format/items, etc. of records should be determined upon the agreement between the parties concerned with delivery.

- a) **Before execution** The confirmation before execution shall be as follows.
 - 1) Confirm that the main hot insulation material to be used is conforming to the requirements in this Standard or as described in the specification.
 - 2) Confirm that other materials to be used are as described in the specification.
 - 3) Confirm that materials to be used are free from taints and damages.
 - 4) Confirm that the hot insulation materials, cold insulation materials, dew proofing materials, etc. are not wetted by water.
 - 5) Confirm that the slip-prevention fitting of cold insulation material/anchor, etc. are attached according to the specified dimensions.
 - 6) Confirm that the surfaces to be worked are free from adhesion of foreign substances such as dust/water/ice.

- b) **During execution** The confirmation items during execution shall be as follows.
- 1) Confirm that the hot insulation materials, cold insulation materials, dew proofing materials, etc. are not wetted by water.
 - 2) Confirm that the execution is conducted based on the prescribed execution specification or the execution guideline on the type/thickness/fixing method of respective materials to be used, the treatment of grouts, the forming method of water vapour barrier, the installing method of covering, etc.
 - 3) Confirm that the water vapour proof treatment of the covering material at the penetration part of hot insulation material, etc. is carried out in the cold insulation work.
- c) **At completion of work** At the completion of work, check the appearance visually and confirm the good finish.

9.3 Performance confirmation inspection

The confirmation items after the completion of thermal insulation work or at the time of consignment shall be as follows. However, they are omissible upon the agreement between the parties concerned with delivery. The measuring locations, measuring positions and measuring conditions, etc. shall be determined in detail upon the agreement between the parties concerned with delivery.

- a) **Based on radiating quantity of heat** In the case of the hot insulation work designed based on the radiating quantity of heat, measure the radiating quantity of heat by a heat flowmeter after the start of operation or during the test operation.
- b) **Based on surface temperature** In the case of the hot insulation work designed based on the surface temperature, measure the surface temperature and the ambient temperature after the start of operation or during the test operation.
- c) **Based on thermal insulating economical thickness** In the case of the thermal insulation work designed based on the thermal insulating economical thickness, the confirmation items shall be in accordance with those for the hot insulation work designed based on the radiating quantity of heat.
- d) **Based on cold insulation/dew proofing work** In the case of the cold insulation/dew proofing work, confirm that there is no dew condensation or frost formation on the outer surface after the start of operation.

9.4 Acceptance criteria

The acceptance criteria after the completion of thermal insulation work or at the time of consignment shall be as follows. The acceptance criteria may be determined in detail upon the agreement between the parties concerned with delivery.

- a) **Based on radiating quantity of heat** In the case of the hot insulation work designed based on the radiating quantity of heat, the measurement result shall be within +20 % of that specified in the specification or the heat calculation sheet as the acceptance criteria.

- b) **Based on surface temperature** In the case of the hot insulation work designed based on the surface temperature, the measurement result shall be within +20 % of the temperature difference between the designed surface temperature and the ambient temperature specified in the specification or the heat calculation sheet as the acceptance criteria.
- c) **Based on burn prevention** In the case of the hot insulation work designed based on the surface temperature for the purpose of burn prevention, the measurement result shall be the surface temperature or under specified in the specification or the heat calculation sheet as the acceptance criteria.
- d) **Based on cold insulation/dew proofing work** In the case of cold insulation/dew proofing work, the requirements of **9.3 d)** shall be satisfied as the acceptance criteria. The case where the ambient condition is largely different from that in the specification, if dew condensation or frost formation is recognized, shall be upon the agreement between the parties concerned with delivery.

9.5 Measuring instruments

The measuring instruments to be used shall be determined upon the agreement between the parties concerned with delivery. For each instrument, the following should be referred to.

- a) **Heat flowmeter** Heat flowmeter specified in **2.3** of **JIS A 1412-2** or that having the accuracy equal or superior to.
- b) **Thermometer** Measuring instrument using thermocouples specified in **JIS C 1602** or solid-stem general purpose liquid-in-glass thermometer specified in **JIS B 7414**.
- c) **Hygrometer** Aspiration psychrometer specified in **8.3** or electronic hygrometer specified in **10.1** of **JIS Z 8806**, or that having the accuracy equal or superior to.