Design Technical Manual
for Steel Mesh Reinforced Polyethylene Pipe

Contents

I. Main Performance Parameters of Steel Mesh Reinforced Polyethylene Pipe

As a type of pressure bearing pipe, the steel mesh reinforced polyethylene pipe with its unique structure has both the advantages of steel and thermoplastics and has outstanding performance features.

1.1 Crack Stability Under Pressure

Take a pipe sample with a length of 100±10mm for test. Place the sample between the pressing plates of the hydraulic machine, slowly press it down to 50% of the diameter of the pipe in 10-15s, and maintain the pressure for 10 minutes. There shall be no crack on the pipe.

1.2 Longitudinal Dimension Shrinkage (1h at 110°)

To test in accordance with *Determination of Longitudinal Shrinkage Rate of Thermoplastic Pipes* GB / T6671-2001.

1.3 Short-term Hydrostatic Strength Test

To test in accordance with *Internal Pressure Withstand Test Method for Thermoplastic Pipes for Fluid Transportation* GB6111-2003

Test temperature: 20□; test duration: 1h; test pressure: 1.5 times the nominal pressure; test result: no crack or leakage.

Test temperature: 70□; test duration: 165h; test pressure: 1.5×0.76 times the nominal pressure; test result: no crack or leakage.

1.4 Weathering Test

According to *Test Method for Plastics with Exposure to Natural Weathering* GB/T3681-2000, after receiving accumulative aging energy of ≥3.5kMJ/m^2, the pipe still meets the performance requirements specified in Article 2.3 and maintains good welding performance.

1.5 Roundness

Measure the maximum and minimum inner diameters on the same section using the measuring tool with a precision within 1mm. The difference between the two diameters is the roundness deviation of the pipe, which is not more than 0.05DN.

1.6 Nominal Pressure Correction Factor

The nominal pressure shall be corrected if the temperature of the conveyed liquid medium is higher than 20□. Refer to Table 1.1 for the correction factors:

Table 1.1:Temperature-wise Nominal Pressure Correction Factor for Conveying Water

Temperature t (□)	0＜t≤20	20＜t≤30	30＜t≤40	40＜t≤50	50＜t≤60	60＜t≤70	70＜t≤80
Nominal pressure correction factor	1	0.95	0.90	0.86	0.81	0.70	0.60

The nominal pressure shall be corrected if the temperature of the conveyed fuel gas medium is higher than 20□. Refer to Table 1.2 for the correction factors:

Table 1.2: Temperature-wise Nominal Pressure Correction Factor for Conveying Fuel Gases

Temperature t (□)	-20 < t≤0	0 < t≤20	20 < t≤25	25 < t≤30	30 < t≤35	35 < t≤40
Nominal pressure correction factor	0.9	1	0.93	0.87	0.8	0.74

1.7 Linear Expansion Coefficient

The linear expansion coefficient of the pipe is 35.4-35.9×10^{-6} (1/□).

1.8 Allowable Bending Radius of the Pipe

Table 1.3: Allowable Bending Radius of the Pipe

Specification (inner diameter d)	65~150	200~300	350~400	500
Allowable bending radius R, mm	≥80d	≥100d	≥110d	≥120d

Note: R shall not be less than 200d if there is any joint on the pipe section.

1.9 Overhead Spacing for the Pipe

Table 1.4: Support Spacing for Overhead Installation

Specification	50	60	80	100	125	150	200	250	300	350	400	500
Support spacing (m)	3.0	3.5	4.0	4.2	4.5	5.0	5.4	5.7	6.0	6.0	6.0	6.0

1.10 Burst Pressure of the Pipe

Burst pressure of the pipe ≥ nominal pressure ×3

1.11 Ring Stiffness of the Pipe

Table 1.5: Ring Stiffness of the Pipe

Specification	150	200	250	300	400	500
Ring stiffness (KPa)	47.52	21.26	16.05	9.28	7.32	5.52

1.12 Applicable Medium Temperature for the Pipe

The temperature of the conveyed medium is preferred to be not more than 80□.

1.13 Electrical Properties of the Pipe

Surface resistance ＞10^{13}Ω

Volume resistivity ＞10^{16}Ω×cm

Dielectric strength 700KV/cm

Dielectric constant 2.33F/m

Dielectric loss: 6×10^{-4} at 50Hz

8×10^{-4} at 10^{3}Hz

7×10^{-4} at10^{4}Hz

6×10^{-4} at 10^{5}Hz

1.14 Heat Conducting Performance of the Pipe

The heat conductivity at 20□ is 0.43W×$(m\times k)^{-1}$.

1.15 Roughness of the Pipe

Equivalent roughness of the pipe: 0.010

1.16 Abrasion Resistance of the Pipe

Take an HDPE pipe and a steel pipe with a diameter of 50mm for test at a water speed of 7-8m/s and water temperature of 30□-35□ (with 15% sand mixed in the water). The result shows that the degree of corrosion of the HDPE pipe in 1600 hours is 4mm, while it takes less than 1000 hours to reach the same degree of corrosion for the steel pipe.

1.17 Refer to Annex I for Chemical Stability

II. Calculation of Nominal Pressure of Steel Mesh Reinforced Polyethylene Pipe

Based on the stress distribution law of steel mesh reinforced polyethylene pipe, the pipe wall is within the allowance of elastic deformation under nominal pressure. The following formula is deduced from mid-diameter formula. Refer to Figure 2.1:

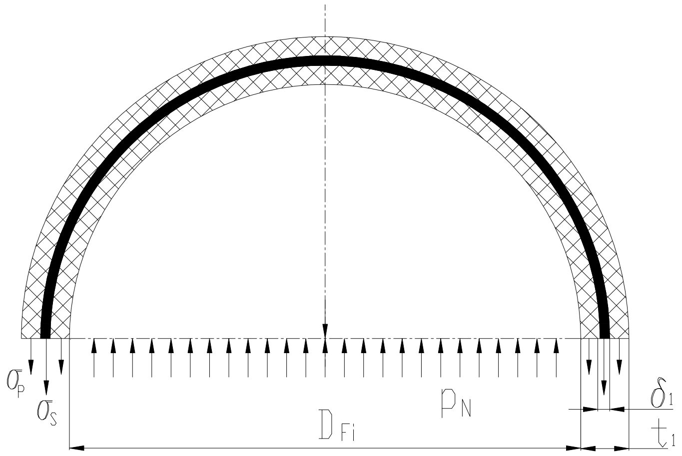

Figure 2.1: Stress Distribution Diagram of Steel Mesh Reinforced Polyethylene Pipe

$$2(t_1\sigma_P + \delta_1\sigma_S) = 2(t_1\sigma_p + \delta_1 \times 235.3\sigma_P) = P_N(D_{Fi} + 2a + \delta_1)$$

This formula is evolved from common mid-diameter formula. The only difference is that the product of the wall thickness of the reinforced pipe with the stress is resolved into the products of the respective stresses of the transverse steel wire and the plastics with the wall thickness. As "a" is an unknown number and "δ_1"is a small value having little influence on the calculation result, these two can be ignored. Therefore,

$$P_N \approx \frac{2(t_1\sigma_p + \delta_1\sigma_s)}{D_{Fi}}$$

For a straight pipe:

$$t_1 = e - \delta_1 - \delta_2$$

$$\delta_1 = \frac{\pi d_1^2}{4s}$$

$$\delta_2 = \frac{Nd_1^2}{4(D_{Fi} + e - d_2)}$$

For the convenience of calculation, δ_2 can be ignored as it takes up very little proportion. Substitute t_1, δ_1 and $\sigma_p = \sigma_s / 235.3$ into the formula and get the nominal pressure P_{CN}:

$$P_{CN} \approx \frac{2\sigma_s(e + 234.3 \times \frac{\pi d_1^2}{4s})}{235.3 \cdot D_{Fi}}$$

For an FG pipe conveying fuel gases, in view of possible influence of the components of the gases on the plastics and risk of the gases, the above formula shall be further divided by 1.6 to get the nominal pressure in accordance with international standards.

$$P_{CN} \approx \frac{2\sigma_s(e + 234.3 \times \frac{\pi d_1^2}{4s})}{1.6 \times 235.3 \times D_{Fi}}$$

This coefficient 1.6 is based on the rated design stress (6.3MPa for PE80), and the plastic stress is only 0.6MPa for FG pipe. Obviously the coefficient is too large and quite conservative for the strength of FG pipe. Therefore, how to determine the coefficient is a question of great value for improving the pressure withstand potential and has yet to be further discussed in the FG pipe strength calculation.

For pipe fitting:

$$t_1 = e - \delta_1$$

$$\delta_1 = \delta \frac{s - d_0}{s}$$

$$t_1 = e - \delta \frac{s - d_0}{s}$$

The nominal pressure is calculated as follows:

$$P_{CN} = \frac{2\sigma_s(e + 234.3 \times \delta \times \frac{s - d_0}{s})}{1.6 \times 235.3 \times D_{Fi}}$$

δ : wall thickness of skeleton of steel plate, mm

e : nominal wall thickness of FG pipe, mm

P_N : nominal pressure, MPa

D_{Fi} : inner diameter of FG pipe, mm

d_1 : diameter of transverse steel wire, mm

s: center distance of transverse steel wire or spacing of longitudinal holes on the skeleton of steel plate, mm

t_1 : converted wall thickness of cylinder of pure PE pipe, mm

σ_{sb}: tensional limit of steel skeleton, MPa

σ_s : allowable stress of steel skeleton, MPa (i.e. $\sigma_{sb}/3$)

σ_p : design stress of PE, MPa (σ_p = σ_s/235.3 for PE80)

δ_1 : converted wall thickness of steel cylinder of transverse steel wire or steel mesh, mm

δ_2 : converted wall thickness of steel cylinder of longitudinal wire, mm

N: number of longitude lines

In the above formula, D_{Fi}, e, d_1 and d_2 are pre-determined based on the specifications of the FG pipe and process possibility. On such a basis, the material of PE and steel mesh is further determined. Through repetitive calculations and adjustment of the center distance s, the value of s is selected meeting the requirements of the nominal pressure P_N and the safety coefficient n as well as the process requirement of clear spacing $s - d_1 \geq 2.5$. The calculated nominal pressure P_{CN} of the FG pipe is further rounded and serialized to bring forward the final nominal pressure P_N.

The calculation for a pipe fitting is similar to that for a straight pipe.

Based on this P_{CN} calculation formula, the pressure respectively borne by the steel mesh and PE under nominal pressure can be further calculated as follows:

Pressure borne by steel mesh:

$$\frac{2\delta_1 \cdot \sigma_s}{D_{Fi}} = 2\delta_1 \cdot \frac{\sigma_{sb}}{3D_{Fi}}$$

Pressure borne by PE:

$$\frac{2t_1}{D_{Fi}} \cdot \frac{\sigma_{sb}}{3 \times 235.3}$$

Ratio of the two values:

$$\frac{\delta_1}{t_1} \times 235$$

Based on the values of δ_1 and t_1 of FG pipes of various specifications, the average ratio is calculated to be about 1/11. The pressure that can be borne by PE is about 8% of the nominal pressure.

In terms of bearing strength, the PE material bears much less pressure than the steel mesh. This is the decisive factor why the FG pipe is close to steel pipe in mechanical properties.

III. Hydraulic Calculation for Steel Mesh Reinforced Polyethylene Pipe

3.1 Hydraulic Calculation for Fuel Gas Pipeline of Steel Mesh Reinforced Polyethylene Pipe

The fuel gas conveying pressure P of urban fuel gas pipelines in China is divided into 5 grades, and the requirements in the table below shall be satisfied:

Table 3.1: Grading of Urban Gas Conveying Pressure (Gauge Pressure)

Name		Pressure (MPa)
High pressure gas pipeline	A	0.8＜P≤1.6
	B	0.4＜P≤0.8
Medium pressure gas pipeline	A	0.2＜P≤0.4
	B	0.005＜P≤0.2
Low pressure gas pipeline		P≤0.005

The hourly gas flow for domestic use and public buildings (0□ and 101.325Kpa) is preferred to be calculated as per the following formula:

$$Q_h = \frac{1}{n} Q_a$$

In this formula, Q_h: calculated hourly gas flow (m^3/h);

Q_a: annual gas consumption (m^3/a);

n: utilization time of the maximum gas load (h);

The value is:

$$n = \frac{365 \times 24}{K_m K_d K_h}$$

K_m: monthly peak factor, to calculate the ratio of daily average gas consumption in a month and daily average gas consumption in a year;

K_d: daily peak factor, to calculate the ratio of daily maximum gas consumption in a month and daily average gas consumption in the month;

K_h: hourly peak factor, to calculate the ratio of hourly maximum gas consumption in the day with the maximum gas consumption in a month and hourly average gas consumption in the day.

3.1.1 The unit frictional resistance loss of the fuel gas pipeline of low pressure steel mesh reinforced polyethylene pipe is preferred to be calculated as per the following formula:

$$\frac{\Delta P}{l} = 6.26 \times 10^7 \lambda \frac{Q^2}{d^5} \rho \frac{T}{T_0}$$

In this formula,

ΔP: frictional resistance loss of fuel gas pipeline of steel mesh reinforced polyethylene pipe (Pa);

λ: frictional resistance coefficient of fuel gas pipeline of steel mesh polyethylene plastic pipe;

l: calculated length of fuel gas pipeline of steel mesh reinforced polyethylene pipe (m);

Q: calculated flow of fuel gas pipeline of steel mesh reinforced polyethylene pipe (m^3/h);

d: inner diameter of fuel gas pipeline of steel mesh reinforced polyethylene pipe (mm);

ρ: density of fuel gas (Kg/m^3);

T: fuel gas temperature in the design (K);

T0: 273.16K.

There are different calculation formulas for λ subject to different states of motion of the gas in the pipeline.

Substitute the values into the above formula to get the calculation formula for the frictional resistance loss per practical unit length for different flow states:

$$\mathrm{Re}=dv/\mu$$

Re: Reynolds number

d: inner diameter of steel mesh reinforced polyethylene pipe (mm);

v: calculated flow rate of fuel gas pipeline of steel mesh reinforced polyethylene pipe (m/s);

μ: kinematic viscosity of fuel gas at 0□ and 101.325Kpa (m^2/s)

(1) Laminar flow state: (Re≤2100)

$$\lambda = 64/\mathrm{Re}$$

$$\frac{\Delta P}{l} = 1.13\times10^{10}\frac{Q}{d^4}v\rho\frac{T}{T_0}$$

(2) Critical state: (2100＜Re≤3500)

$$\lambda = 0.03 + \frac{\mathrm{Re}-2100}{65\,\mathrm{Re}-10^5}$$

$$\frac{\Delta P}{l} = 1.9\times10^{6}\left(1+\frac{11.8Q-7\times10^4 dv}{23Q-10^5 dv}\right)\frac{Q^2}{d^5}\rho\frac{T}{T_0}$$

(3) Turbulent state: (Re＞3500)

$$\lambda = 0.11\left(\frac{k}{d}+\frac{68}{\mathrm{Re}}\right)^{0.25}$$

$$\frac{\Delta P}{l} = 6.9\times10^{6}\left(\frac{k}{d}+192.2\frac{dv}{Q}\right)^{0.25}\frac{Q^2}{d^5}\rho\frac{T}{T_0}$$

In this formula,k: equivalent absolute roughness of inner surface of fuel gas pipeline of steel mesh reinforced polyethylene pipe (mm). 0.01 is taken herein.

3.1.2 The unit length frictional resistance loss of medium and high pressure steel mesh reinforced polyethylene pipes is preferred to be calculated as per the following formula:

$$\frac{P_1^{\,2}-P_2^{\,2}}{L} = 1.27\times10^{10}\lambda\frac{Q^2}{d^5}\rho\frac{T}{T_0}Z$$

In this formula,P_1: starting point pressure of steel mesh reinforced polyethylene pipe (absolute KPa);

P_2: end point pressure of steel mesh reinforced polyethylene pipe (absolute KPa);

Z: compressibility factor; when the gas pressure is less than 1.2MPa (gauge pressure), 1 is taken;

L: calculated length of steel mesh reinforced polyethylene pipe (km).

The hydraulic calculation method for steel mesh reinforced polyethylene pipe is the same as that for polyethylene pipeline. The difference lies in the value of K, which is 20 times different between the steel mesh reinforced polyethylene pipe and steel pipe. Therefore, the gas conveying capacity of the steel mesh reinforced polyethylene pipe is higher than that of the steel pipe with the same pipe diameter, length and pressure drop.

There will be static electricity when the fuel gases, especially the ones with dust, flow inside the polyethylene pipe, due to friction with the pipe wall. To prevent excessive accumulation of the static electricity, besides necessary measures, the flow rate of the medium inside the steel mesh reinforced polyethylene pipe shall also be restricted. In the industrial standard of China, *Technical Specification for Polyethylene Fuel Gas Pipeline Engineering* (CJJ63-95), it is specified that “the allowable pressure drop of medium pressure pipeline can be determined by the pressure difference between the inlet pressure of the pipeline and the minimum inlet pressure allowed by the pressure regulator of the secondary pipe network; the flow rate is preferred to be not more than 5m/s”. If this flow rate is taken in the design of steel mesh reinforced polyethylene pipe network, the economical efficiency of medium conveying will be greatly reduced, and the advantages of steel mesh reinforced polyethylene pipe cannot be reflected. The following are some foreign regulations on the flow rate of gas pipeline:

(1) Pressure pipeline of oil refining equipment V=15～30m/s;

(2) Natural gas pipeline in *Chemical Installations* of the U.S. V≤30.5m/s;

(3) LPG pipe V=8～15m/s;

(4) Coke oven gas pipe V=4～8m/s.

According to the unique performance of the steel mesh reinforced polyethylene pipe and relevant foreign documents on the design flow rate of polyethylene pipe, based on the above mentioned data, the flow rate of the medium of the reinforced pipe is recommended to be not more than 15m/s.

3.2 Hydraulic Calculation for Water Supply Pipeline of Steel Mesh Reinforced Polyethylene Pipe

3.2.1 Basic hydraulic calculation formula for water supply pipeline:

$$h_f = \lambda \frac{L}{d_i} \cdot \frac{v^2}{2g}$$

In this formula, h_f : frictional head loss of steel mesh reinforced polyethylene pipe (m)

d_i : inner diameter of steel mesh reinforced polyethylene pipe (m)

L : pipe section length (m)

g : acceleration of gravity ($9.81 m/s^2$)

v : average water flow rate inside the steel mesh reinforced polyethylene pipe (m/s)

λ : hydraulic frictional resistance coefficient

$$\frac{1}{\sqrt{\lambda}} = -2\log\left[\frac{2.51}{\mathrm{Re}\sqrt{\lambda}} + \frac{\Delta}{3.72 d_i}\right]$$

Re: Reynolds number

$$\mathrm{Re} = \frac{v d_i}{\upsilon}$$

υ: kinematic viscosity of water (cm^2/s)

$$\upsilon = \frac{0.01775}{1 + 0.0337t + 0.00022t^2}$$

t: water temperature (□)

Δ: equivalent roughness of pipeline; 0.010 is taken herein

3.2.1 The local head loss is calculated as per certain percentage of the frictional head loss in the following pipe networks:

(1) Urban water supply pipe network: 8％-12％;

(2) Water supply pipe network for residential buildings: 12％-18％;

(3) Production water supply network, production and firefighting public water supply pipe network, and sanitary, production and firefighting common water supply pipe network: 20% for each network;

(4) Fire hydrant system firefighting water supply pipe network: 10%;

(5) Production and firefighting common water supply pipe network: 15%.

Due to smooth inner surfaces, compared to a metal pipe with the same through-flow area, length and starting point pressure, the steel mesh reinforced polyethylene pipe has less head loss, higher flow capacity and less noise. Therefore, when the steel mesh reinforced polyethylene pipe is used, the water flow rate can be increased as appropriate according to the actual utilization of the pipe. Refer to Table 3.2 for the recommended design flow rate.

Table 3.2: Recommended Design Flow Rate for Water Pipe

Pipeline type	Suction pipe of water pump	Outlet pipe of water pump	Common water supply main	Indoor water supply riser
Recommended flow rate (m/s)	1.2~2.1	2.4~3.6	1.5~3.0	0.9~3.0

IV. Pipeline Design for Steel Mesh Reinforced Polyethylene Pipe

There are two installation methods to be decided as per the actual laying situation in the design of the steel mesh reinforced polyethylene pipe, i.e. underground installation and above ground installation.

4.1 Above-ground Installation Design for steel mesh reinforced polyethylene pipe

4.1.1 Introduction

The above-ground installation of steel mesh reinforced polyethylene pipe is to fix or suspend the pipe onto supporting structures. The specific method is to be decided as per the actual situation. One type is temporary pipeline system, which is economical in installation; one is convenient for installation and maintenance; and another is to prevent pipeline cooling according to specific installation conditions.

As this type of reinforced pipeline has the advantages of good structure, adequate toughness and light weight, it can be widely used in above ground manner.

This section introduces the design specifications and installation methods for steel mesh reinforced polyethylene pipe, discusses in detail the influence of temperature limit, chemical irradiation, ultraviolet radiation and mechanical stress, enumerates the two types of above-ground installation methods for steel mesh reinforced polyethylene pipe classified as per the project design classification method, i.e. suspended installation and ground installation. Based on the design classification method, all the calculation formulas come from published design reference documents, and the designers can make specific designs according to the listed reference documents.

4.1.2 Design specifications

The design specifications having influence on the performance of the steel mesh reinforced polyethylene pipe installed above ground include:

(1) Temperature

(2) Chemical resistance

(3) Ultraviolet radiation

(4) Stress and load

4.1.2.1 Temperature

Due to factors of sunshine, changes of seasons and shifts from day to night, the steel mesh reinforced polyethylene pipe installed above ground is influenced by the changes of temperature of the pipe. In principle, polyethylene can be safely used within the range of -60℃ to 70℃; extreme temperatures however do affect the engineering performance of the pipeline. Therefore, when the temperature is below 0℃, strong impact load shall be avoided, and the recommended service temperature for the steel mesh reinforced polyethylene pipe is -20℃ to 70℃.

The changes of temperature also greatly affect the performance of the steel mesh reinforced polyethylene pipe. Along with the increase of temperature, the nominal pressure and modulus of elasticity will decrease. The nominal pressure of the pipe while conveying media above 20℃ shall be corrected. Refer to Table 1.2 and Table 1.3 for the correction factors.

The expansion coefficient of the steel mesh reinforced polyethylene pipe is 35.4×10^{-6}～35.9×10^{-6} (1/℃). Along with the changes of temperature, the length of the pipeline also changes. Compared to steel and concrete pipes, the polyethylene pipe has greater thermal expansion and contraction changes but much less modulus of elasticity, indicating significantly less stress required for restricting such expansion and contraction and thus very simple fixing methods for controlling such expansion and contraction.

4.1.2.2 Chemical resistance

There will be no rust, corrosion or sand holes, etc. on the steel mesh reinforced polyethylene pipe due to chemical, electrolysis or electroplating reasons. The substances having severe influence on the reinforced pipeline are strong oxidizing agents and some hydrocarbon compounds. These harmful substances will affect the service features of the reinforced pipeline installed above ground. Long time exposure of the pipeline to strong oxidizing agents may lead to breaking of the pipeline or cracks on the surfaces of the pipeline, while accidental or instantaneous exposure to such solvents will not have severe influence on the long term performance of the pipeline. Refer to Annex I for the chemical stability of the pipeline.

Hydrocarbon compounds usually have only temporary influence on the polyethylene material of the steel mesh reinforced polyethylene pipe, the degree of influence depending on the time of exposure. As the result of exposure to some hydrocarbon compounds, the pressure bearing capacity of the polyethylene material of the pipeline will be weakened. After absorbing hydrocarbon compounds, polyethylene will have weakened toughness and enlarged physical dimensions (swelling). Long time exposure will lead to permeation of the wall of the pipe, the degree of permeation depending on the pressure, temperature and types of the hydrocarbon compounds. All such factors shall be taken into consideration for above-ground installation of the pipeline.

4.1.2.3 Ultraviolet radiation

When steel mesh reinforced polyethylene pipe is used above ground in outdoor environment, the ultraviolet in the sunshine is harmful to polyethylene due to long time direct sunshine, unless good protection materials are used. Study on natural aging shows that 2.0% to 2.5% carbon black with good dispersion and uniform distribution added into the raw materials for production of the pipeline has the function of long term protection against harmful ultraviolet radiation.

4.1.2.4 Mechanical stress and load

Any pipeline installed at exposed places shall be suitable for the severe surrounding conditions. The common damages to the pipeline during handling and transportation include scratches, bending and loss of luster on the surfaces of the pipeline. If the pipeline has to be installed above ground at places with heavy traffic or messy machineries (e.g. along roads), extra protection measures shall be taken for the pipeline, for example, to set up a platform, wrap the pipe, or use other equipment to protect the pipeline. The pipeline shall be buried underground as much as possible in such areas.

In common cases, if any place of the steel mesh reinforced polyethylene pipe is scratched during installation, so long as the scratching depth does not reach the steel wire or just reach the wire but without damage to the wire, the pipe can continue to be used after simple repair and protection. If the bending of the pipeline exceeds the allowable range or if there are cracks or other visible damages, the pipeline can also be replaced.

4.1.3 Design classification method

As discussed hereinabove, the changes of temperature will affect the pressure performance of the steel mesh reinforced polyethylene pipe system. The thermal expansion and contraction properties of the reinforced pipeline subject to the changes of temperature therefore must be indicated, and the installation features of the pipeline above ground shall be further analyzed.

4.1.3.1 Pressure performance

As discussed hereinabove on the influence of temperature on the pressure performance of the steel mesh reinforced polyethylene pipe, along with the increase of temperature, the pressure performance of the reinforced pipeline is weakened, and the modulus of elasticity also decreases.

4.1.3.2 Thermal expansion and contraction

The design specifications in this section show that the changes of temperature can lead to physical dimension changes of the steel mesh reinforced polyethylene pipe, the linear expansion coefficient of which is between those of steel and pure plastic pipes. The potential of thermal expansion and contraction shall be taken into consideration for the design classification of above-ground installation. The amount of deformation can be calculated as per the following formula:

$\Delta L = a(T_2 - T_1)L$

ΔL: theoretical change in length, m;

$\Delta L > 0$: thermal expansion;

$\Delta L < 0$: thermal contraction;

a: linear expansion coefficient, 1 /□;

T_1: initial temperature, □;

T_2: final temperature, □;

L: pipeline length at temperature T_1, m.

The expansion and contraction due to temperature changes is of much importance. However, such calculation of pipeline length along with the changes of temperature is based on the assumption of non-fixed pipeline and instantaneous drop of temperature. Actually, temperature does not drop instantaneously. When placed on the ground, the theoretical motion of the pipeline is also slowed down due to friction. According to experience in site installation of the pipeline, the actual amount of thermal expansion and contraction of the pipeline due to the changes of temperature is about half of the total theoretical motion, and the consequent longitudinal stress of the pipeline is also about half of the theoretical value. Besides, the thermal properties or heat dissipation performance of the fluids in the pipeline often further alleviate the changes of physical length. However, in conservative engineering designs, the influence of the changes of temperature on the pipeline in case of static fluids or even non-fluids shall be considered.

The steel mesh reinforced polyethylene pipe is prone to be influenced by the changes of temperature. The common method for such cases is to provide a suitable fixing device, such as concrete fixing device and hard block. Be noted that the stress on the wall of the pipeline is the result of the estimated changes of temperature, and the value of the stress can be determined as per the following formula.

$\sigma_T = a(T_2 - T_1) \times E$

σ_T: axial stress, MPa;

a: linear expansion coefficient, 1 /□;

T_1: initial temperature, □;

T_2: final temperature, □;

E: modulus of elasticity, MPa;

The theoretical longitudinal force of the pipeline due to the changes of temperature is as follows:

$F_T = \sigma_T \times A = a(T_2 - T_1) \times E \times A$

F_T: theoretical longitudinal force, N;

σ_T: theoretical longitudinal stress, MPa;

a: cross sectional area of pipe wall, m^2.

The influence of temperature on the reinforced pipeline installed above ground is briefed hereinabove. However, other factors having influence on the thermal expansion and contraction are not included, such as the weight of the pipeline, frictional resistance between the pipeline and the ground.

4.1.4 Installation features

There are two types of above-ground installation methods for the steel mesh reinforced polyethylene pipe: one is to place the pipeline directly on the ground, and the other is supported or suspended installation of the pipeline. The two types are classified as per different designs and are respectively discussed hereinafter.

4.1.4.1 Sectional installation

As mentioned hereinabove, there is thermal expansion and contraction along with the changes of temperature. The designers propose two options accordingly. One is that the installation is not restricted in any sense, that is, the pipeline can have free motion along with the changes of temperature; the other is that the pipeline is fixed in a way to control the changes of physical dimensions.

4.1.4.1.1 Non-fixed (movable) type installation

This type of installation requires the steel mesh reinforced polyethylene pipe be placed on a base or the land for passages. As the pipeline not fixed is prone to be scratched or damaged on the outside, to be placed on a base or the land for passages can ensure its free motion and no external damage. The pipeline usually has to be laid in the shape of snake so that the pipeline can have free motion without axial stress in case of changes of temperature.

4.1.4.1.2 Fixed type installation

Fixing is taken as the method to control the motion of the pipeline in the design of fixed type above-ground installation of the steel mesh reinforced polyethylene pipe. The force for fixing or restricting the pipeline is used to compensate or control the estimated thermal expansion or contraction stress. The common fixing methods include the use of supports and concrete racks, etc.

The use of continuous small earth platform to fix the pipeline can not only restrict motion of the pipeline but also alleviate the changes of temperature. Along with small temperature changes, the amount of deformation is also reduced. When intermittent small earth platform is used to fix the pipeline, it can be divided into different fixing sections as per the length of the pipeline, and each fixing point is wrapped with earth (with the distance of 1-3 pipe diameters). This is an economical method.

When the pipeline is fixed intermittently, there will be horizontal displacement of the pipeline if the temperature changes, generating stress on the wall of the pipe. The specific calculation formula is as follows:

$\Delta Y = L[0.5a\times(\Delta T)]^{1/2}$

ΔY: amount of horizontal displacement, m;

L: spacing between fixing points, m;

a: linear expansion coefficient, 1 /□;

ΔT: temperature variation, □.

Bending strain:

$\varepsilon = D[96a\times(\Delta T)]^{1/2} / L$

ε: strain of pipe wall;

D: pipe outer diameter, m;

a: linear expansion coefficient, 1 /□;

ΔT: temperature variation, □;

L: spacing between fixing points, m.

The general principle is that the cost depends on the number of the fixing points. If it is necessary to limit the displacement of the pipeline, there has to be more fixing points, while if displacement within a certain range is allowed, there can be fewer fixing points as appropriate, and the installation cost of the pipeline will certainly be reduced.

The horizontal displacement of the steel mesh reinforced polyethylene pipe is limited by the allowable maximum stress of the pipe wall.

The above two formulas are used for determining the theoretical displacement and stress of the steel mesh reinforced polyethylene pipe installed above ground. However, as most temperature changes are not instantaneous, and the factors of friction, gravity and gas flow all reduce the stress during temperature changes, the displacement and stress are actually smaller than the theoretical values.

The above formulas indicate that the values of horizontal displacement and stress depend on the spacing of fixing points of the pipeline.

4.1.4.2 Supported or suspended type installation

The characteristics of temperature and relative displacement of the steel mesh reinforced polyethylene pipe installed in supported or suspended manner are similar to those of the pipeline installed in intermittently fixed manner without support. However, there are two additional parameters: bending strain due to the dead weight of the pipeline and the gravity of the conveyed media, and structure of support and fixing device.

The spacing between the supporting points of the steel mesh reinforced polyethylene pipe is determined with the aim to restrict the bending strain. Simply supported beam type or continuous beam type is used in the installation. The spacing between the supporting points shall meet the requirement of the following formula:

$$L = \left[\frac{3(OD^4 - ID^4)\sigma_m \pi}{8qOD}\right]^{1/2}$$

L: spacing between supporting points, m;

OD: pipeline outer diameter, m;

ID: pipeline inner diameter, m;

σ_m: maximum bending strain, MPa;

q: pipeline unit load, Kg/m;

$q=(w/12)+(\pi\times\rho\times ID^2)/6912$

q: pipeline unit load, Kg/m;

w: pipeline dead weight, Kg;

ρ: density of conveyed media, Kg/m.

The obtained data of the spacing of the supporting points from this formula is conservative for the non-fixed steel mesh reinforced polyethylene pipe (with free motion on the supports). During the complicated analysis on the bending strain of the pipeline, the pipeline can be viewed as a load beam with terminals, and the actual displacement can be calculated as per the following formula:

$d=5qL^4/384E_LI$

d: pipeline displacement, m;

L: spacing between supports, m;

q: pipeline unit load, Kg/m;

E_L: modulus of elasticity, MPa;

I: moment of inertia $=(\pi/64)(OD^4-ID^4)$, m^4.

The analysis on the simply supported beam shows that the displacement is related to the spacing between the supports, and the modulus of elasticity at the given temperature is analyzed. However, the relation between the amount of displacement and thermal expansion and contraction is not considered. If this is also taken into consideration, the amount of displacement will be as shown in the following formula:

Amount of displacement= amount of beam displacement+ amount of displacement due to thermal expansion

$=d+\Delta Y$

$=(5qL^4/384E_LI)+L\times(0.5a\Delta T)^{1/2}$

The object of analysis on the simply supported beam is the pipe section of the length of one spacing at the end of the pipeline. The length of spacing between the supporting points of the pipeline is usually the same. Furthermore, a pipeline with multiple lengths of spacing is analyzed. The analysis is conservative to most pipelines with multiple lengths of spacing. The displacement with a continuous beam is analyzed as follows:

$d=fqL^4/E_LI$

d: amount of displacement, m;

f: displacement coefficient; function of span and pipe fixing method;

q: unit length load, N;

L: spacing between supports, m;

E_L: modulus of elasticity, MPa;

I: moment of inertia $=(\pi/64)(OD^4-ID^4)$, m^4.

Based on the analysis on the simply supported beam, the result of analysis on the displacement with a continuous beam is that the spacing is polygon shaped at the given temperature. In this formula, other displacements due to factors like thermal expansion and contraction along with the changes of temperature are not included, while in the following formula, the displacements due to the polygon shaped spacing and thermal expansion are integrated:

The displacement with consideration to a continuous beam and thermal influence is as follows:

Total displacement $=fqL^4/E_L+(0.5a\times\Delta T)^{1/2}$

f: displacement coefficient;

q: unit length load, N;

E_L: modulus of elasticity, MPa;

I: moment of inertia $=(\pi/64)(OD^4-ID^4)$, m^4;

ΔT: temperature variation, □.

4.2 Underground Installation Design for Steel Mesh Reinforced Polyethylene Pipe

4.2.1 Introduction

The common application method of steel mesh reinforced polyethylene pipe is underground installation. The procedure of underground installation of the pipeline is as follows: (1) excavation of pipe ditches; (2) laying of the pipeline into the ditches; (3) backfill of the ditches. The design method for underground installation of the reinforced pipeline will be detailed hereinafter.

4.2.2 Underground installation theory for flexible pipeline

Though the steel mesh reinforced polyethylene pipe shares some characteristics of the steel pipe, it remains a flexible pipeline, which is subject to deformation due to overload in underground installation. Therefore, the designers and installation personnel shall make use of the surrounding soil to set up a layer of supporting materials to keep the deflection within the allowed range of flexible deflection of the pipe.

The supporting layer, called "packing layer", is usually made of hard and stable materials around the pipe. The supporting force of the packing layer is in direct proportion to its rigidity. Thus the packing is often compacted. Besides, the arching of the packing greatly reduces the load on the pipeline. In other words, the re-distribution of the packing stress on and around the pipeline deviate the load from the pipeline. The larger the rigidity of the packing, the better the arching will be.

The designers and installation personnel shall consider not only the packing but also the undisturbed soil around the packing and the underground water. In case of soft clay, wet and loose silt or sand, the ditches will be unstable, leading to collapse and loosening during excavation. If the underground water level exceeds that of the pipe top, in order to provide the best support to the pipeline, the secondary backfill shall be conducted immediately after the primary backfill. So long as proper measures are taken for these factors, the pipeline can be installed with the deflection controlled within the allowed range.

4.2.3 Deflection control

The bearing capacity of the steel mesh reinforced polyethylene pipe is greatly improved by the backfill. The horizontal outward motion of the pipe wall during load bearing of the pipeline transfers the load to the backfill outside the pipeline and generates passive soil resistance, which prevents further deflection of the pipeline and provides supporting force for vertical load. The value of the resistance of the backfill is directly affected by the situation of installation. The harder the packing, the smaller the deflection of the pipe will be. Such combination of packing and pipe is called pipe/soil system.

The deflection of the steel mesh reinforced polyethylene pipe consists of service deflection and installation deflection. Service deflection refers to the reduction of the vertical diameter of the pipeline, reflecting the adjusting degree of the established pipe/soil system subject to soil and other loads, while installation deflection refers to the increase or reduction of the vertical diameter. The increase of the vertical diameter usually is the result of compaction of the packing around the pipeline. The installation deflection to a certain degree offsets the service deflection. The installation deflection can be controlled if care is taken during filling and compaction of the arched packing.

The pipe usually can achieve a stable deflection after being buried for 1 to 2 years. The deflection can be calculated as per the following formula:

$$\Delta X = \Delta X_w - \Delta X_q$$

ΔX : total pipeline deflection;

ΔX_w: deflection under vertical load;

ΔX_q : deflection under resilient resistance.

About the distribution pattern and range of the resilient resistance, Prof. Spangler in the U.S. pointed out after many studies that the distribution pattern of the resistance is quadratic parabola and the range of action of β=100º is suitable for actual cases. Refer to Figure 4.1 for the calculation diagram recommended by Prof. Spangler.

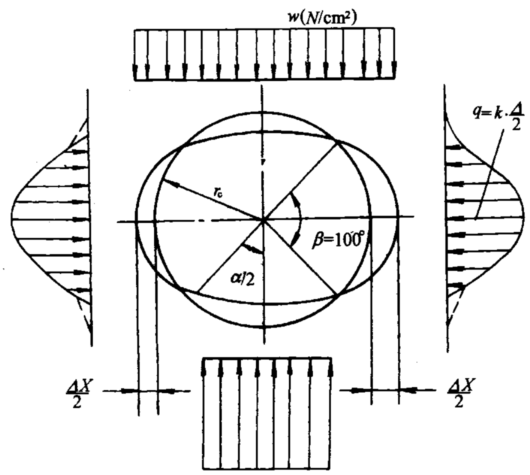

Figure 4.1

The radial deformation of the pipeline subject to vertical load is calculated using the elastic center method of structural mechanics:

$$\Delta X_w = 2K_a \frac{\omega r_c^{\ 4}}{EI}$$

In this formula, K_a is the subgrade coefficient relevant to the wrap angle of the curved foundation. Refer to Table 4.1.

Table 4.1: Subgrade Coefficient K_a

Half angle α of foundation support	0°	15°	22.5°	30°	45°	60°	90°
K_a	0.110	0.108	0.105	0.102	0.096	0.090	0.083

The radial deformation of the pipeline subject to resilient resistance is as follows:

$$\Delta X_q = 2 \times 0.061 \frac{q \times r_c^{\ 4}}{EI}$$

The coefficient 0.061 is for the range of action of β=100º and the distribution pattern of quadratic parabola.

And as $q = \frac{E_0}{r_c} \cdot \frac{\Delta X}{2}$,

$$\Delta X_q = 2 \times 0.061 \frac{qr^4}{EI} = 0.061 \frac{\Delta X E_0 r_c^{\ 3}}{EI}$$

$$\Delta X_w = \Delta X + 0.061 \frac{\Delta X E_0 r_c^{\ 3}}{EI}$$

$$\Delta X = \frac{\Delta X_w}{1 + 0.061\dfrac{E_0 r_c^{\ 3}}{EI}} = \frac{2K_a \dfrac{\omega r_c^{\ 4}}{EI}}{1 + 0.061\dfrac{E_0 r_c^{\ 3}}{EI}}$$

$$G = 2\omega r_c$$

$$\Delta X = \frac{K_a G r_c^{\ 3}}{EI + 0.061 E_0 r_c^{\ 3}}$$

In actual applications, ΔX shall be multiplied by the deformation lag coefficient λ of the backfill, and the formula is often presented in relation to the deformation rate of the pipe diameter. The deformation rate of the diameter of the plastic pipeline is usually specified as not more than 5% in deformation checking, and thus the deformation checking condition is as follows:

$$\Delta X = \frac{\lambda K_a G r_c^{\ 3}}{EI + 0.061 E_0 r_c^{\ 3}} \le 5D\%$$

Or $\dfrac{\Delta X}{D}\% = \dfrac{\lambda K_a G r_c^{\ 3} \times 100}{EI + 0.061 E_0 r_c^{\ 3}} \le 5\%$

K_a: subgrade coefficient as shown in Table 4.1;

r_c: average pipeline radius (cm);

E: modulus of elasticity;

I: moment of inertia per unit length on the cross section of pipe wall (cm^4/cm);

δ: pipe wall thickness (cm);

G: total external load borne by the pipeline (N/cm); G=2ωr;

λ: soil settlement lag coefficient 1.5;

E_0: modulus of deformation of backfill (N/cm^2);

ΔX: pipe diameter deformation (cm).

EI in the formula is the ring stiffness. When the ring is subject to concentrated load, the deformation of the ring is $\Delta = 0.149\dfrac{p r_c^{\ 3}}{EI}$. The formula thus can be written as follows:

$$P_S = \frac{p}{\Delta} = \frac{EI}{0.149 r_c^{\ 3}}$$

Or $EI = 0.149 P_S r_c^{\ 3}$

$$\Delta X = \frac{\lambda K_a G}{0.149(P_S) + 0.061 E_0}$$

P_S : pipe ring stiffness (KN/m^2).

4.2.4 Pipeline packing material

Packing material is the material around the pipeline. The material can be supplied from elsewhere or can be the material excavated from the ditches. The packing material shall be of enough strength, rigidity, contact uniformity and stability to minimize the deformation caused by pressure on the packing. The pressure on the packing varies around the pipeline; the pressure on the top of the arch is significantly smaller than that at the pipe bottom. Normally, the maximum pressure may horizontally act on the springing line of the pipe, as a result of passive pressure and arching of the packing.

V. Pipeline Layout of Steel Mesh Reinforced Polyethylene Pipe

5.1 The layout and arrangement of water supply pipeline of steel mesh reinforced polyethylene pipe shall be in accordance with *Design Code for Building Water Supply and Drainage* (GB50015－2003).

5.1.1 The outdoor water supply pipeline in residential areas shall be laid along roads in the plant area, parallel to the buildings, and is preferred to be under pavements, slow lanes or lawns. The outer wall of the pipeline shall have a clear distance of not less than 1m from the outer walls of buildings, and shall have no interference to the foundations of buildings. The clear distance from the outdoor water supply pipeline in residential areas to other underground pipelines and trees shall meet the requirements in Table 5.1.

Table 5.1: Minimum Clear Distance from Outdoor Water Supply Pipeline in Residential Areas to Other Pipelines/Structures, m

<table>
<tr><th>Type</th><th>Water supply pipe</th><th>Sewage pipe</th><th>Rainwater pipe</th><th>Low pressure gas pipe</th><th>Directly buried heat supply pipe</th><th>Thermal pipe ditch</th><th>Tree center</th><th>Power cable</th><th>Communication cable</th><th>Communication and lighting cable</th></tr>
<tr><td>Horizontal</td><td>0.5～1.0</td><td>0.8～1.5</td><td>0.8～1.5</td><td>0.5～1.0</td><td rowspan="2">Note 2</td><td rowspan="2">Note 2</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.5</td></tr>
<tr><td>Vertical</td><td>0.1～0.15</td><td>0.1～0.15</td><td>0.1～0.15</td><td>0.1～0.15</td><td>—</td><td>Directly buried 0.5; Through tube 0.15</td><td>Directly buried 0.5; Through tube 0.15</td><td>—</td></tr>
</table>

Note: 1. The clear distance is calculated from the outer wall of the pipe; if casing is provided at pipeline intersections, from the outer wall of the casing; for directly buried thermal pipe, from the outer wall of heat insulation tube.

2. For the conveying of fuel gases with reference to Table 5.2 and Table 5.3, the distance is fixed as specified; when proper heat insulation measures are taken, the distance can be reduced.

5.1.2 When the water supply pipeline is laid in buried manner, the depth of the overlaying soil shall be determined upon the frozen depth of the soil, vehicle load and pipeline intersections, etc. The minimum depth of the overlaying soil at the pipe top shall be 150mm below the local frozen line. If it is necessary to be laid above the frozen line, reliable heat insulation measures shall be taken. In non-frozen areas, when the pipeline is laid in buried manner, the burial depth of the overlaying soil shall be not less than 500mm at the pipe top and not less than 700mm at places crossing roads.

5.1.3 The water supply pipeline shall not directly go through pollution sources like sewage wells, septic tanks and public toilets.

5.2 The layout and arrangement of fuel gas pipeline of steel mesh reinforced polyethylene pipe shall be in accordance with *Design Code for Urban Fuel Gases* (GB50028－2002).

5.2.1 The fuel gas pipeline of steel mesh reinforced polyethylene pipe shall not go past under buildings and large structures, neither under areas with inflammable, explosive materials or corrosive liquid, and shall not be laid in the same ditches with other pipelines or cables.

5.2.2 The horizontal clear distance between the reinforced pipe conveying fuel gases and heat supply pipe shall not be less than the values specified in Table 5.2. The horizontal clear distance between the reinforced pipe and the foundations of other buildings and structures as well as between neighboring pipelines shall be in accordance with *Design Code for Urban Fuel Gases* (GB50028－2002).

Table 5.2: Horizontal Clear Distance between reinforced Pipe Conveying Fuel Gases and Heat Supply Pipe

Type of heat supply pipe	Clear distance (m)	Remarks
t＜150□ directly buried heat supply pipeline Heat supply pipe Water return pipe	 3.0 2.0	Burial depth of reinforced pipe less than 2m
t＜150□ hot water heat supply pipe ditch Steam heat supply pipe ditch	1.5	
t＜280□ steam heat supply pipe ditch	3.0	Working pressure of reinforced pipe not more than 0.1MPa; burial depth of reinforced pipe less than 2m

5.2.3 The vertical clear distance between the reinforced pipe conveying fuel gases and various underground pipelines or facilities shall not be less than the values specified in Table 5.3.

Table 5.3: Vertical Clear Distance between Steel Mesh Reinforced Polyethylene Pipe and Various Underground Pipelines or Facilities

Type of underground pipeline or facility		Clear distance (m)	
		Pipeline above facility	Pipeline below facility
Water supply pipe Fuel gas pipe	--	0.15	0.15
Drainage pipe	--	0.15	0.20 with casing
Cable	Directly buried	0.5	0.5
	Inside conduit	0.20	0.20
Heat supply pipe	t ＜150□ Directly buried heat supply pipe	0.5 with casing	1.30 with casing
	t ＜150□ Hot water heat supply pipe ditch Steam heat supply pipe ditch	0.20 with casing or 0.40	0.30 with casing
	t ＜280□ Steam heat supply pipe ditch	1.0 with casing; reducible if temperature lowering measures are taken for casing	Not allowed
Rail bottom of railway	--	--	1.20 with casing

5.2.4 The minimum thickness of overlaying soil on the top of the reinforced pipe conveying fuel gases shall be in accordance with the following regulations:

(1) When the pipe is buried under roadways, it is preferred to be not less than 1m;

(2) When the pipe is buried under non-roadways, it is preferred to be not less than 0.6m;

(3) When the pipe is buried under paddy fields, it is preferred to be not less than 0.8m.

The above mentioned requirements can be lowered if effective protective measures are taken.

5.3 The subgrade for the steel mesh reinforced polyethylene pipe is preferred to be composed of undisturbed soil without sharp and hard stone or earth and without halogen rocks. If there are such matters in the undisturbed soil, fine sandy soil shall be laid as the bedding course. At the sections where there may be uneven settlement of the pipeline, the subgrade shall be treated or provided with other anti-settlement measures.

5.4 If the steel mesh reinforced polyethylene pipe conveying fuel gases is used for medium pressure main pipe, valves along with bleeding pipes on both sides shall be provided on different sections. Valves are also required at the starting points of branch pipes. If the pipe is used for low pressure pipeline, valves are not required. The required valves shall be installed on valve pits.

5.5 The steel mesh reinforced polyethylene pipe conveying fuel gases shall not be led into buildings directly or into pressure regulating boxes on the walls of buildings directly. In case the pipe is led in directly, the section of the pipe going through foundations or outer walls and the section on the ground must be protected with casing. If the reinforced pipe is used for conveying other media, the section of it going through foundations or outer walls, or across main roads shall also be protected with casing.

5.6 The section of the steel mesh reinforced polyethylene pipe going through river bottoms must be protected with casing or other protective measures. The reinforced pipe conveying fuel gases shall be in accordance with the current national standard *Design Code for Urban Fuel Gases* (GB50028－2002).

5.7 The spacing of supports for overhead steel mesh reinforced polyethylene pipe shall be in accordance with Table 1.5.

VI. Material Inspection, Storage, Handling and Transportation

6.1 General Regulations

6.1.1 The pipes and fittings shall be provided with quality inspection reports from the quality inspection department and Quality Certificate from the manufacturer.

6.1.2 During storage, handling and transportation, the pipes shall be bundled with non-metal ropes or bundled with metal and protected with cushions.

6.1.3 During storage, handling and transportation, the pipes and fittings shall not be thrown or subject to severe impact.

6.1.4 During storage, handling and transportation, the pipes and fittings shall have end covers or straw ropes at the places of seals and flange joints for protection.

6.1.5 During long term storage, the pipes and fittings shall not be exposed to sunshine and shall not have contact with chemical substances like oil, acid, alkali, and salt. The pipes and fittings shall also be kept away from open fire.

6.2 Material Inspection

6.2.1 Inspect the pipes and fittings before accepting. Check the Quality Certificate, Quality Guarantee, performance inspection reports, specifications, quantity, packing, and documents related to the quality of the pipes and fittings.

6.2.2 Take samples of 5%-10% from the same batch of the pipes and fittings to check the specifications, sizes and visual characteristics according to current industrial standards, and if necessary, conduct an overall test.

6.2.3 Upon delivery of the pipes and fittings, take samples of 3%-5% of electro-fusion couplers to fit with the pipes to see whether the fit clearance is proper.

6.2.4 Upon delivery of the pipes and fittings, check whether the seals and flange joints are in good condition. The defected ones shall be repaired or discarded in time.

6.2.5 Upon delivery of the pipes and fittings, mark the following information on the tag in detail: raw materials, production date (batch no.), resistance value of the electro-fusion couplers, etc.

6.3 Storage

6.3.1 The pipes and fittings shall be stored in warehouses or on simply constructed yards with good ventilation and a temperature of not more than 40℃. No contact is allowed with flame or high temperature matters, and covering shall be provided in case of long time storage.

6.3.2 The pipes shall be stacked horizontally on smooth and leveled supports or ground (if possible, soft matters like straw mattresses shall be laid on the ground). The stacking height is preferred to be not more than 1.5m. The pipes of Dn200 and above are better stacked not more than 5 layers, and Dn300 and above not more than 3 layers.

6.3.3 The pipes to be stored, especially the electro-fusion couplers, shall be sealed with plastics or tied up with plastic bags.

6.3.4 The flange connected pipes shall be stacked with battens in between rows, the thickness of which shall prevent contact of the joints of the upper and lower rows. The pipes shorter than 6m shall have battens at two points, and the ones longer than 6m shall have battens at three points at least.

6.4 Handling

6.4.1 During handling, the pipes shall be lifted with non-metal ropes.

6.4.2 During handling, the pipes and fittings shall be handled with care and placed neatly, and shall not be thrown, dragged along roads, or subject to severe impact. The fittings with small diameters (especially the electro-fusion couplers) shall be put into packing boxes as many as possible.

6.4.3 During handling of the pipes and fittings, special care shall be taken to avoid knocking against the seals and flange joints.

6.4.4 In cold weather (below -4℃), the pipes and fittings shall be handled with care to avoid severe impact.

6.5 Transportation

6.5.1 For transportation by vehicles, the pipes shall be placed on flat cars; for shipping, the pipes shall be placed in flat cargo holds. During transportation, the straight pipes shall be bundled and fixed to prevent collision. There shall not be any protruded matters that may damage the pipes at the stacking places.

6.5.2 During transportation, the fittings shall be stacked neatly layer by layer, box by box, in a stable and reliable manner.

VII. Pipeline Connection of Steel Mesh Reinforced Polyethylene Pipe

7.1 General Regulations

7.1.1 Before connecting the steel mesh reinforced polyethylene pipe, check the pipes, fittings and auxiliary facilities according to the design requirements, and conduct visual inspection at the installation site to ensure conformity with the requirements.

7.1.2 Use the method of electric fusion connection if the reinforced pipeline is laid underground, and the method of electric fusion connection or flange connection if laid on the ground.

7.1.3 Use corresponding special tools and tackles subject to different connection methods of the steel mesh reinforced polyethylene pipe.

7.1.4 The operators for the connection of the reinforced pipeline shall undergo special training and pass examination and technical assessment before going on duty.

7.1.5 During connection of the steel mesh reinforced polyethylene pipe, the pipe ends shall be clean. Each time after work, the ends of the pipe shall be temporarily blocked.

7.1.6 Preparation for connection of the steel mesh reinforced polyethylene pipe

(1) Check the electro-fusion couplers to be used one by one to see whether there is any apparent deformation and whether the resistance value is the same as that mentioned on the tag.

(2) The pipes and fittings damaged during transportation must be repaired before use.

(3) Check whether there is any dirt like oil stain on the installation machines and tools, and take corresponding measures.

(4) Arrange installation machines and tools that are already commissioned and get the machines and tools ready (e.g. welding machine, angle grinder, centralizer, cutting saw and welding gun).

(5) Arrange sufficient auxiliary materials (e.g. steel brushes, grinding wheels, plastic welding rods and ropes).

7.2 Electric Fusion Connection

7.2.1 Welding procedure test at site

(1) Before connecting the pipeline, conduct a process test at site with reference to the basic process parameters;

(2) Adjust the welding process parameters according to the climatic changes at site;

(3) Adjust the welding process parameters in case the voltage at the input side of the welding machine at site cannot reach the requirement;

(4) Adjust the welding process parameters in case of changes of material of the pipes and fittings;

(5) Take at least two test pieces for tearing test to observe the welding effect;

(6) Decide the welding process based on the tearing test.

7.2.2 Pipe laying

(1) Before laying, check the pipe especially the heads, and repair the welding immediately in case of cracks or damages. If it is not possible to repair the welding at the moment, make distinct markings on the pipe for the convenience of repair later when possible;

(2) Have the pipe-laying workers carry the pipes to the site and place the pipes along the pipe ditches as required. Keep the heads and ends linked up;

(3) The pipe shall be handled with care to prevent damages and must not be dragged on the ground. Bear safety in mind when carrying the pipe with a large diameter to prevent personal injuries.

7.2.3 Preparation

(1) Check whether there is any mud, sand or oil stain on the welding places of the pipe to be laid, and whether the pipe is placed in conformity with the direction of the pipeline;

(2) Remove the sand and soil from inside the pipe;

(3) After cleaning the welding surfaces, use electric steel brush or steel brush to roughen the surfaces for fusion connection (the inner surfaces of the electro-fusion couplers and seals). Thoroughly remove the oxide layer;

(4) Remove the dirt near the wiring terminals of the electro-fusion couplers;

(5) Test the resistance of the electro-fusion couplers.

7.2.4 Trial installation

Push the sleeves up to proper depth in the pipe by hand, with the long and short axes corresponding to those of the pipe accordingly. If a sleeve is found too tight or too loose, put it aside and select the ones with suitable tightness.

7.2.5 Hammer the surrounding of the electro-fusion couplers lightly. Put the sleeves onto the seals. It is forbidden to hammer on the wiring terminals of power.

7.2.6 Installation of centralizer

(1) Adjust the two clamp rings of the centralizer to suitable positions;

(2) The connection pipe shall be kept on the same axis in case of above ditch connection, and there shall not be obvious angle of intersection by visual inspection;

(3) Install the centralizer onto the straight pipe or the pipe fitting. Pay attention to the positions of the power socket and the centralizer. When in place, the clamp rings of the centralizer shall push against the electro-fusion couplers;

(4) Tighten the bolts of the clamp rings. Tighten the two screws on the diagonal to pull and tighten the pipe to be laid in place;

(5) Remove the mud, sand and sweat, etc. spilt onto the welding area during installation in time.

7.2.7 Welding

(1) Check whether the power line is in good contact, whether there is any deformation with the plug at the output side, and whether there is mud, sand or oxide layer;

(2) Measure the voltage at the input side of the welding machine using a multimeter to see whether it is within the range of 220 (380) ±10％. If not, welding shall not be conducted;

(3) Plug the output side of the welding machine onto the wiring terminals of the electro-fusion couplers tightly to ensure good contact;

(4) Select the welding grade on the welding machine subject to the diameter of the pipe;

(5) Check the heating time, switch on the welding machine and regulate it to the required voltage;

(6) Observe the changes on the observation holes of the electro-fusion couplers, and check whether there is any abnormal sound, and whether the joint deformation and temperature changes on the surfaces are normal. Switch off the machine immediately in case of any abnormality, analyze the cause, take correction measures and put the information on records;

(7) Fill in the installation records carefully as required.

7.2.8 Cooling

The cooling method is natural cooling or artificial cooling. Shock cooling shall be avoided. During the process of cooling, the connecting places shall be free from external forces.

7.2.9 Dismantling of centralizer

The centralizer can be dismantled only when the surface temperature of the electro-fusion couplers drops close to the environmental temperature. In case the installation progress is affected due to lack of the centralizer, the centralizer can be dismantled when the four screws of it are loosened. However, the joint must be kept free from any external force to ensure no damage to the fusion surfaces during contraction.

7.3 Flange Connection

(1) Place the pipe with the opposing ends matched well, align the pipe under the natural condition, remove the mud and sand from inside the seal grooves and the flange end faces, put the seal rings flat into the grooves, and put on the lap joint flanges.

(2) Tighten the screws on the diagonal. Pay attention to keep the two flanges parallel. The leveling standard is that

the end face parallel misalignment of the flanges of the pipe is less than 2mm. No item (e.g. washer, gasket) is allowed to be missed out in the connection.

(3) Tighten the screws with uniform force. Tighten all the screws repetitively to ensure complete fitting of the end faces of the flange joints (i.e. the seal rings are compressed), while in the meantime, there is no local plastic deformation of the plastics.

7.4 Machines and Tools for Pipeline Installation

7.4.1 Machines and tools for installation of pipeline with flange connection

Wrench, band tape and angle grinder, etc.

7.4.2 Machines and tools for installation of pipeline with electric fusion connection

7.4.2.1 Special machines and tools for installation of pipeline with electric fusion connection

Welding power, straight pipe centralizer, cutting saw and plastic welder, etc.

7.4.2.2 Common machines and tools for installation of pipeline with electric fusion connection

Wrench, band tape, knife, hammer and tightening tool, etc.

VIII. Pipeline Layingof Steel Mesh Reinforced Polyethylene Pipe

8.1 General Regulations

8.1.1 The installation of earthwork for the steel mesh reinforced polyethylene pipe shall be in accordance with the current standards.

8.1.2 The bottom width of the ditches for the reinforced pipeline can be determined as per the following formula.

(1) Laying of a single pipe at the edge of a ditch in assembled state:

a=D+0.5 (DN50～DN125)

a=D+0.7 (DN150～DN300)

a=D+0.8 (DN350～DN500)

(2) Laying of two pipes in the same ditch:

a=D1+D2+S+0.5 (DN50～DN125)

a=D1+D2+S+0.7 (DN150～DN300)

a=D1+D2+S+0.8 (DN350～DN500)

In this formula,

a: bottom width of ditch (m);

D: nominal outer diameter of pipeline (m);

D1: nominal outer diameter of the first pipeline (m);

D2: nominal outer diameter of the second pipeline (m);

S: design clear distance between two pipes (m).

8.1.3 During excavation of the ditches, the undisturbed soil 0.1-0.2m above the design elevation of the ditch bottom shall be kept. Before pipe laying, clearing work shall be done manually according to the status of connection and alignment. Generally, over excavation is inadvisable. If there has to be over excavation, sand soil or undisturbed soil shall be backfilled and compacted. The accumulated water in the ditches shall be drained in time. If there are hard matters like rocks and gravels on the bottom of the ditches, dig them out till 0.15-0.2m below the design elevation, then fill in sand soil, level and compact the sand soil up to the design elevation. At the sections where there may be uneven settlement of the pipeline, the subgrade shall be treated or provided with other anti-settlement measures.

8.1.4 For installation on the bottom of the ditches, there shall be operation pits at the locations of joints, the depth and size of which shall be convenient for operation.

8.1.5 The steel mesh reinforced polyethylene pipe can be laid only after the bottom elevation of the ditches and the pipe foundations are checked and found qualified.

8.1.6 When the pipeline is laid in the ditches, it shall be laid on undisturbed soil, unless foundations of other materials are specified in the design. After installation of the pipeline, the blocks (e.g. wood) used for the installation shall be removed in time.

8.1.7 The steel mesh reinforced polyethylene pipe is preferred to be laid in the shape of snake and can be bent along with bending of the landform. The allowed bending radius of the pipeline shall be in accordance with Table 3.4.

8.1.8 The reinforced pipeline shall not be laid on frozen soil. During the process of pipeline laying and pressure test, measures shall be taken to prevent freezing of the bottom of the ditches.

8.1.9 Measures shall be taken where there is significant day and night temperature difference to prevent damage to the pipeline and joints due to stress caused by the temperature difference.

8.1.10 The time schedule, procedure and installation scheme for the steel mesh reinforced polyethylene pipe crossing railways, roads and rivers shall be approved by the relevant management departments. The reinforced pipeline going through walls or across roads, railways and rivers shall be protected with casing. In such cases, if there are joints inside the casings, the laying can only be conducted after pressure test.

8.1.11 If an excavator is used during execution of the crossing work of the reinforced pipeline, the buildings and structures around the crossing sections must be free from settlement, displacement and damages.

8.2 Pipeline Laying in the Ditches

The steel mesh reinforced polyethylene pipe can be connected in the ditches, or connected above the ditches and then put into the ditches.

8.2.1 Multiple pieces of pipes that are connected above the ditches can be put into the ditches only after getting cooled;

8.2.2 In case of large pipe diameters or deep ditches, use ropes to slowly drop the pipe onto the bottom of the ditches. Pay attention to avoid large bending of the pipeline and excessive local force on the connecting places. In no cases can be pipeline be thrown down. In case of large diameters, the centralizer shall be dismantled after the pipeline is put into the ditches.

8.3 Backfill

8.3.1 The backfill of the pipe ditches is generally done in two steps. Before pressure test of the pipeline, reserve the places for the joints first. To avoid movement of the pipeline during pressure test, the backfill thickness above the pipe top shall not be less than 0.5m.

8.3.2 Conduct backfill after satisfactory pressure test. The two sides of the pipeline and the part above the pipe top are preferred to be backfilled with fine soil or sand. When the backfill is up to about 0.3m above the pipe top, compact the soil and then continue backfill. The gap between the lower part of the pipeline and the bottom of the pipe must be fully filled in. In case of mechanical backfill, it shall be done simultaneously from two sides of the pipe, and the machineries must not run on the pipeline.

8.3.3 Due to internal pressure of the reinforced pipeline, there will be axial thrust at the places of tees, elbows, reducers and end sockets, etc., which can be balanced by the backfill soil pressure and the frictional force of the outer wall of the pipe. The frictional force is related to the height of the overlaying soil, soil properties, underground water, and friction coefficient between the soil and the pipe wall, etc. Besides, certain pipe length is required to balance the thrust of the pipeline. The backfill and compaction at the places generating the axial thrust shall be enhanced. At the sections passing places with weak backfill stability, such as swamps and pools, thrust blocks with sufficient supporting area can be set to provide adequate thrust. The thrust blocks shall be made of concrete of not lower than the grade of C15, and shall be cast at site on the excavated undisturbed soil subgrade and grooves. Refer to Table 8.1 for the soil bearing capacity.

Table 8.1: Soil Bearing Capacity

Soil type	Safety bearing load KPa	Soil type	Safety bearing load KPa
Soft clay	24	Mixed clay and gravel	96
Sand soil	48	Shale	240
Gravel	72		

8.3.4 In case of connection of the reinforced pipe with other rigid structures, the joints shall not be warped or displaced. The backfill soil within the range of several times of the diameter of the pipeline at the connecting places shall be compacted to 90% Proctor density or above.

8.3.5 The minimum thickness of the overlaying soil on the top of the steel mesh reinforced polyethylene pipe shall be in accordance with relevant regulations.

8.3.6 When laying the steel mesh reinforced polyethylene pipe conveying fuel gases, warning strips with distinct words shall be provided at the places not less than 300mm from the pipe top

8.4 Reinforced Pipeline Above-ground Installation Requirements

Buttress or support design shall be considered for above-ground installation of the steel mesh reinforced polyethylene pipe, which is of the same importance as the design of other kinds of pipelines. The influence of various factors on the pipeline shall be taken into consideration. The pipes of some pipelines are directly placed on the ground, but there shall not be pebbles, cracks or unevenness on the ground; otherwise there will be point load, leading to increased friction on the surfaces of the pipes and consequent displacement due to temperature changes.

The supports shall be of enough strength to fix the pipe to prevent horizontal or longitudinal displacement. The intermittent supports shall be of adequate spacing. In case of supernormal temperature or load, continuous supporting method shall be considered. If movable supports are required due to thermal expansion, a guiding device shall be installed on the supports. Each section bearing the pipe shall be of the size of 0.5 to 1 times of the diameter of the pipe, and shall bear the pipe with an angle of at least 120°. If the supports are designed to clamp the pipe, the supports must be flexible and installed well with sufficient strength to bear the expected stress. Figures 8.1, 8.2 and 8.3 are typical suspended support structures, and Figure 8.4 is a typical fixed support structure.

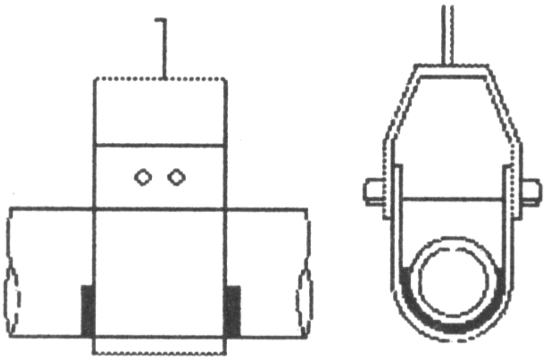

Figure 8.1: Pedal Type Support

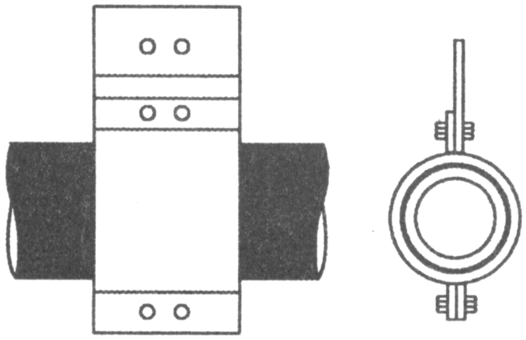

Figure 8.2: Suspended Beam Support

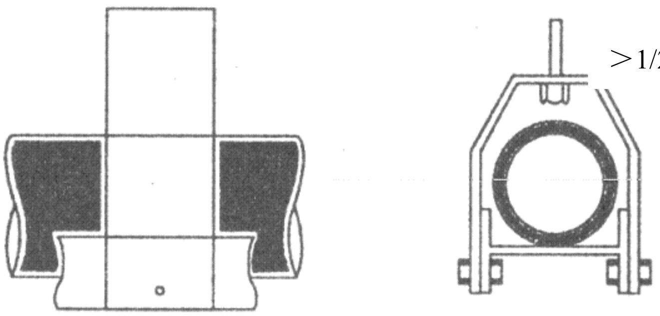

Figure 8.3: Clam Type Support

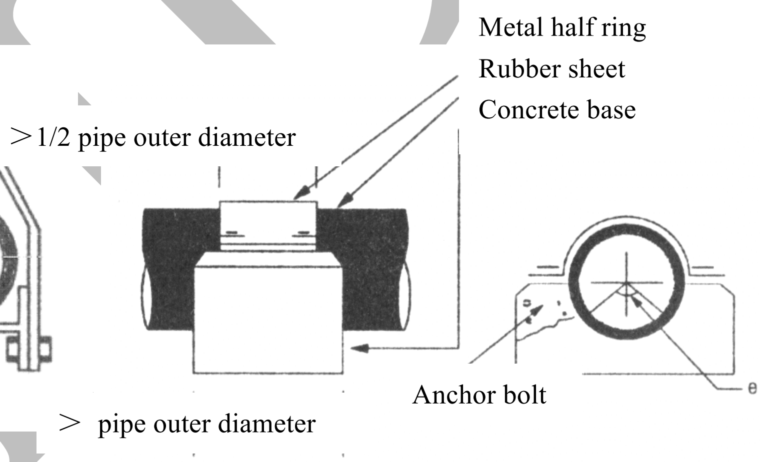

Figure 8.4: Fixed Support

IX. Pressure Test and Inspectionof Steel Mesh Reinforced Polyethylene Pipe

The pressure test and inspection of the steel mesh reinforced polyethylene pipe shall be in accordance with the current national standards and industrial standards.

9.1 Pressure Test and Inspection of Water Supply Pipeline of Steel Mesh Reinforced Polyethylene Pipe

9.1.1 General regulations

9.1.1.1 If the working pressure of the pipeline is not less than 1.0MPa, check the strength of the pipeline and the fittings, and conduct water pressure test at site to check the leakage.

9.1.1.2 The hydrostatic pressure for strength test is 1.5 times the design working pressure and not less than 0.8MPa.

9.1.1.3 During leakage test, the water delivery and distribution pipelines not less than DN100 shall be judged by the water seepage amount; pipelines with a total length of less than 100m can be judged by pressure drop; pipelines less than DN100 are usually judged by pressure reducing method.

9.1.1.4 Leakage and strength tests of the pipeline shall be done by means of water pressure test with water as the medium.

9.1.1.5 The length of the pipe section to be tested is preferred to be not more than 1.0km if the pipeline has no connections like valves. If the pipeline has connections, pressure test can be done in sections according to the positions of the middle connecting parts. If a pipeline is composed of two or more than two types of materials, test shall be done in sections according to the corresponding test requirements of the different materials.

9.1.1.6 For the long distance water supply pipeline of steel mesh polyethylene pipe, if required by the User, water pressure test shall be conducted by the installation unit immediately when the length of the laid pipeline reaches 400m. Only after passing the inspection can the pipeline be further laid.

9.1.1.7 Before conducting water pressure test at site, make proper design of the connection line from the water source and the drainage line. For water pressure test in cold areas in winter, take anti-freezing measures, and after finishing the test, conduct drainage in time to reduce the pressure.

9.1.2 Preparation before test

9.1.2.1 A layer of overlaying soil not less than 0.5m shall be backfilled on the top of the pipe section under pressure test except that the connecting places of the pipe are exposed.

9.1.2.2 The water pressure test shall be designed covering the following:

(1) Design of the back cover plates and the supports;

(2) Design of the water inlet pipeline, exhaust vent holes and drainage holes;

(3) Selection of the pressurizing equipments and pressure gauges and design of installation;

(4) Drainage measures;

(5) Safety measures.

9.1.2.3 The supports shall be placed on undisturbed soil or artificial back soil. Reinforcing measures shall be taken if the soil is soft. The back wall surfaces shall be smooth and vertical to the axis of the pipeline.

9.1.2.4 If spring pressure gauge is used, the precision shall not be less than the grade of 1.5. The maximum measuring range is preferred to be 1.3-1.5 times the test pressure, and the nominal diameter of the dial shall not be less than 150mm. The gauges shall be calibrated before use.

9.1.2.5 The water pump and pressure gauge shall be installed on the water inlet at the lower end of the experimental section, where it is vertical to the axis of the pipe.

9.1.2.6 The buttresses of the pipeline shall reach the design strength, and the fastness of the anchoring facilities shall be carefully checked. Reinforcing measures shall be taken for the pipe fittings without buttresses or anchoring facilities.

9.1.2.7 The pipe section under pressure test shall not have gate valves as the cover plates and shall not have accessories like hydrants and water hammer arrestors. Such accessories, if already provided, must be designed with cover plates. All the control valves must be open during the test. All the openings on the pipeline under pressure test shall be blocked tightly without water leakage.

9.1.3 Pipe section water pressure test

9.1.3.1 Watering into the pipeline shall be done slowly from the low point. Exhaust valves shall be provided on the high points of the pipe section to be tested and the salient points to exhaust the gas from the pipeline.

9.1.3.2 After being filled with water, the pipeline is preferred to be soaked for not shorter than 12 hours at a pressure not more than the working pressure before being tested.

9.1.3.3 The gas inside the pipeline shall be exhausted before pressurizing of the pipeline. During the process of pressurizing, in case the spring pressure gauge indicates fluctuating unstable pressure and slow pressure rise, repeat the step of exhausting and then resume pressurizing.

9.1.3.4 The pressure shall be increased step by step. After increasing the pressure by one step, check the back, buttresses, body of the pipe and joints, and continue pressurizing if no abnormality is found. During pressure test, it is forbidden to beat on the body of the pipe and the joints or to repair defects. The defects, if any, shall be marked out and repaired later after the pressure is released.

9.1.3.5 When the pressure reaches the design pressure, pressure test for the strength of the pipeline shall be conducted. Maintain the pressure for one hour (in case of temperature changes or other factors affecting the accuracy of the pressure test, the pressure maintaining time can be prolonged as appropriate), and check all the parts of the pipeline and all the joints and accessories to see whether there is any leakage or abnormality. Water can be made up into the pipeline to maintain the pressure. If there is no leakage or abnormality, the strength pressure test can be deemed as qualified.

9.1.3.6 After successful strength pressure test, stop pressurizing, reduce the pressure to the design service pressure, close all the drainage and exhaust valves, maintain the pressure for two hours and conduct leakage test to check the water percolating capacity.

9.1.3.7 In case of pressure drop within the one hour before pressure maintaining, water shall be made up into the pipeline to keep the regulated test pressure. Within the one hour after pressure maintaining, measure the pressure drop and the water makeup amount. The makeup amount is the actual water percolating capacity of the pipeline.

9.1.3.8 The measured water makeup amount of the pipeline shall not be more than the allowable water percolating capacity calculated as per the following formula:

$$Q = 3 \times \frac{d_i}{25} \times \frac{p_{wd}}{0.3}$$

In this formula,

Q: allowable water makeup amount of pipeline per kilometer in a day (24 hours);

di: inner diameter of pipeline (mm);

pwd: test internal pressure; design internal pressure is taken (MPa).

9.1.3.9 If the diameter of the pipeline is not less than DN100 and the total length of the pipeline is less than 100m, or if the diameter of the pipeline is less than DN100, it is considered qualified if the pressure drop is not more than 0.05MPa within the two hours of pressure maintaining during leakage test.

9.1.4 Pipeline flushing and sterilization

9.1.4.1 After successful pressure test of the pipeline, conduct flushing and sterilization before completion inspection.

9.1.4.2 The flushing water shall be clean with the turbidity below 10ntu. The flow rate must not be less than 1.0m/s. Flushing shall be continuous until the turbidity and color of water at the outlet are the same as those of water at the inlet. Ensure smooth and safe drainage pipeline during flushing.

9.1.4.3 After being flushed, the pipeline shall be soaked in clean water with a chloride ion concentration of not less than 20-50mg/l for 24 hours, and then flushed again until it is found qualified by sample test by the water quality management department.

9.2 Pressure test and inspection of the steel mesh reinforced polyethylene pipe conveying fuel gases shall be in accordance with section 1 in chapter 5 in *Code for Urban Fuel Gas Delivery and Distribution Engineering and Acceptance* (CJJ33-89).

9.2.1 The pipeline shall be purged before pressure test. The purging pressure can be decided as per the source pressure at site or mutually discussed and agreed. The purging point shall be selected at a high place with few people to avoid personal injury. The purging and test medium is preferred to be compressed air with a temperature of not more than 40□.

9.2.2 Inject the pressure test medium slowly into the pipeline. The pressure test can be conducted by section or on the full course of the pipeline as agreed by the Client and the Contractor based on the specific situation.

9.2.3 Conduct strength pressure test. The test pressure is generally 1.5 times the design working pressure. For medium pressure pipeline, it shall not be less than 0.3MPa, and for low pressure pipeline, not less than 0.05MPa. Maintain the pressure for one hour, and if there is no pressure drop, it is considered qualified. During the strength test, use detergent or soap solution to check whether there is gas leakage at the joints, and after the test, flush away the detergent or soap solution in time with water. In case of temperature changes or other factors affecting the accuracy of the pressure test, the pressure maintaining time can be prolonged as appropriate

9.2.4 The leakage test and air tightness test shall be in accordance with section 3 in chapter 7 in *Code for Urban Fuel Gas Delivery and Distribution Engineering and Acceptance* (CJJ33-89).

9.2.4.1 The air tightness test shall be conducted after successful strength test. The test pressure shall be in accordance with the following regulations. Before starting the air tightness test, charge air into the pipeline to make the pressure reach the test pressure, and maintain the pressure for certain time to achieve stable temperature and pressure. Time of the air tightness test is preferred to be 24 hours. It is considered qualified if the pressure drop does not exceed the calculation results of the following formulas.

(1) When the design pressure P≤5kPa, the test pressure shall be 20kPa;

The same pipe diameter: $\Delta P = 6.47T/d$

Different pipe diameters:

$$\Delta P = 6.47\frac{T(d_1L_1 + d_2L_2 + \cdots + d_nL_n)}{d_1^2L_1 + d_2^2L_2 + \cdots + d_n^2L_n}$$

(2) When the design pressure P＞5kPa, the test pressure shall be 1.15 times the design pressure but not less than 100kPa.

The same pipe diameter: $\Delta P = 40T/d$

Different pipe diameters:

$$\Delta P = \frac{40T(d_1L_1 + d_2L_2 + \cdots + d_nL_n)}{d_1^2L_1 + d_2^2L_2 + \cdots + d_n^2L_n}$$

In the formulas,

ΔP: allowable pressure drop (Pa);

T: test time (h);

d: inner diameter of pipe section (m);

d1, d2……dn: inner diameters of pipe sections (m);

L1, L2……Ln: lengths of pipe sections (m).

9.2.4.2 The measured pressure drop shall be corrected as per the following formula based on the changes of atmospheric pressure and temperature inside the pipeline during the pressure test:

$$\Delta P' = (H_1 + B_1) - (H_2 + B_2)\frac{273 + t_1}{273 + t_2}$$

In this formula,

ΔP′: pressure drop correction (Pa);

H1 and H2: pressure gauge readings at the moment of starting and finishing test (Pa);

B1 and B2: barometer readings at the moment of starting and finishing test (Pa);

t1 and t2: temperature inside pipeline at the moment of starting and finishing test (□).

It is considered qualified if the calculation result $\Delta P' \leq \Delta P$.

9.2.5 Conduct pressurizing in sections in case the test pressure is too high. When the pressure reaches two thirds of the test pressure, maintain the pressure for half an hour, and then increase it to the test pressure.

9.2.6 Conduct patrol inspection on the pipeline. Start patrol inspection when the pressure reaches two thirds of the test pressure. If natural gas is taken as the medium for pressure test, apply soapy water onto the joints to test leakage during the period of pressure maintaining in leakage pressure test.

9.3 General Requirements when Steel Mesh Reinforced Polyethylene Pipe is Used for Industrial Pipeline

9.3.1 The medium for pressure test shall be liquid.

9.3.2 The test pressure is 1.5 times the design pressure and not less than 0.4MPa.

9.3.3 Slowly increase the pressure during the pressure test. When it reaches the test pressure, maintain it for 10 minutes, and then reduce it to the design pressure and stop pressurizing for 30 minutes. It is considered qualified if there is no pressure drop and no leakage.

9.4 Discharge water or air from the pipeline after pressure test. The pressure shall be released slowly and evenly.

9.5 Re-tighten the bolts of the pipeline with flange connection after pressure test.

9.6 The following documents shall be submitted for inspection of the pipeline system:

(1) Installation drawing;

(2) Inspection records of concealed work and relevant data;

(3) Pressure test records of the pipeline system.

9.7 Information on the following shall be available for inspection of concealed work:

(1) Setting of buttresses for overground and underground pipelines;

(2) Buried elbows, joints and fittings;

(3) Pipeline crossing railways, roads and rivers.

9.8 Pressure test on the pipeline shall be conducted by the Client and the Contractor jointly. Conduct trial run of the whole course of the pipeline after successful pressure test, and only when there is no abnormality can the pipeline be formally put into use. Other matters during the pressure test not specified herein shall be handled in accordance with the engineering design as well as criteria of the department using the pipeline and relevant national standards, or mutually discussed and agreed.

X. Quality Assurance for Installation of Steel Mesh Reinforced Polyethylene Pipe

10.1 The pipes and fittings shall be provided with quality inspection reports from the quality inspection department and Quality Certificate from the manufacturer.

10.2 The installation personnel at site shall first conduct overall inspection on the steel mesh reinforced polyethylene pipe to prevent entry of the pipes and fittings damaged during transportation and handling, and shall repair the damaged ones.

10.3 Before starting installation, the installation worker shall remove the miscellaneous matters from the inside of each pipe and fitting.

10.4 Each installation team shall conduct self inspection on the installed centralizers to make sure that each step meets the requirements of the installation process.

10.5 During the course of installation, each installation team shall conduct mutual inspection on the completed work according to the installation process to ensure high installation quality.

10.6 During the course of installation, ensure completeness of the installation records to realize quality tracking and quality accountable by each person.

10.7 The technologist for site installation or the project manager bears full responsibility for the quality of the project.

10.8 When electric fusion connection is employed in the project, in case the welding process needs to be modified due to changes of environmental temperature, the technologist or the project manager shall issue a Notice of Modification with its signature to the welding personnel. In no case can anyone change the welding process without permission from the technologist or the project manager.

10.9 In principle, the steel mesh reinforced polyethylene pipe is not allowed to be welded in rainy days. If it has to be done in rainy days in special cases, a tent shall be put up on the operation pit and the connecting places shall be cleaned before welding.

10.10 For installation of the steel mesh reinforced polyethylene pipe in winter, necessary measures shall be taken to ensure the project quality.

(1) When the environmental temperature is below -4℃, it is regarded as installation in winter; when the environmental temperature is below -15℃, it is inadvisable to have installation of the reinforced pipe;

(2) Before installation, check the pipes and fittings again at site to confirm that all the indicators are satisfactory;

(3) The pipes and fittings for installation in winter shall be of better quality out of the qualified ones;

(4) The pipes and fittings shall be handled with extra care in winter, compared to that at normal temperature, to prevent damage to the pipes and fittings. The pipes must not be dragged on the ground during installation;

(5) For installation in winter, the pipe ditches must be excavated with care to have leveled bottom without protruded edges of frozen soil.

(6) For installation in winter, purge and heat the inside of the electro-fusion couplers and the seals with hot air after grinding, clean the inside of the electro-fusion couplers and the seals with dry cloth, and then start grinding. When the oxide layer is thoroughly removed, conduct connection immediately and then welding immediately. Another option is to heat the electro-fusion couplers and the seals to around 20℃ using heating blanket and then grind the sleeves and seals. When the oxide layer is thoroughly removed, conduct connection immediately and then welding;

(7) For installation in winter, welding shall be done in the ditches as much as possible. In case of connection and welding above the ditches, the pipeline shall be put into the ditches along with the centralizer after being cooled;

(8) There shall not be ice, snow or blocks of frozen soil on the inner wall of the pipe near the seals;

(9) For backfill, fine sand or plain soil shall be filled in first. Blocks of frozen soil are not allowed to be backfilled near the pipe;

(10) When the environmental temperature at the installation site is below -10℃, heat preservation shed shall be added if possible;

(11) For installation in winter, operation shall be as much as possible done in the daytime when the temperature is relatively high;

(12) Installation in winter shall be done by skilled workers;

(13) All the weld joints shall be inspected strictly and put on record;

(14) In winter, besides normal pressure test, the reinforced pipe shall also be checked with antifreezing liquid to see whether there is any leakage.

10.11 In case of electric fusion connection under strong sunshine, the connecting places shall be covered before welding to prevent influence to the welding performance due to big temperature difference between the sunny side and the shaded side at the connecting places of the pipe. If possible, avoid welding at noontime.

10.12 In case of electric fusion connection in windy days, the welding places shall be covered with cloth or other materials to prevent dust on the welding surfaces.

10.13 The grinded welding surfaces shall not be touched by hand and shall be free from dirt.

10.14 The installation personnel shall mark all the welded joints with the installation records including the serial number, time of welding and welding process.

XI. Analysis on Thermal Expansion and Contraction of Steel Mesh Reinforced Polyethylene Pipe and Countermeasures

11.1 Polyethylene Pipe: Flexible Pipe

The polyethylene pipe in use is treated as a type of flexible pipe both in China and overseas, in conformity with relevant international and national specialized standards and codes. The linear expansion coefficient of polyethylene pipe is about 170×10^{-6} (1/□), while the modulus of elasticity of high density polyethylene is 200 times smaller than that of common carbon steel, usually less than 1000Mpa (the modulus of elasticity of common carbon steel is 206×10^{3}MPa).

Since the polyethylene pipe is treated as a type of flexible pipe, usually no special compensation measures are taken for its thermal expansion/contraction during installation. During installation, the pipe is laid in the shape of snake deliberately, to eliminate the internal stress caused by temperature difference.

11.2 Problem of Thermal Expansion/Contraction of Steel Mesh Reinforced Polyethylene Pipe

Compared to the linear expansion coefficient of $10.6\text{-}12.2\times10^{-6}$ (1/□) of common carbon steel, the coefficient of steel mesh reinforced polyethylene pipe is 35.9×10^{-6} (1/□), 3 to 3.4 times that of common carbon steel, while the coefficient of polyethylene pipe is 14 to 16 times that of common carbon steel.

In general, as for thermal expansion and contraction, the steel mesh reinforced polyethylene pipe shall also be treated as a type of flexible pipe. For the pipe with a small diameter (＜DN125), try to lay it in a bent shape as far as possible. The pipes laid in such a manner have been in trouble-free service for more than two years in Sichuan Gas Field and Daqing Oilfield, conveying 70□ to 80□ flushing water and 40□ gas field sewage. As for the pipe with a large diameter, DN200 and DN300 pipes have been in trouble-free service in Shengli Oilfield for more than one year, with a straight section of more than 2km and without any compensation measures, conveying 40□ to 50□ oil water mixture.

The installation of DN200 pipeline in Xinjiang in 1999 faced some problems due to thermal expansion and the structure of soil, which indicates that as the reinforced pipe with a large diameter has large sectional area and good rigidity, while the pipe is treated as flexible pipe, the friction of soil to the pipeline shall be fully considered, and some compensation methods for thermal expansion and contraction shall be applied, or stabilizing measures shall be taken, e.g. provision of anchoring blocks.

11.3 Calculation Method for Thermal Expansion/Contraction

The formula for calculating the theoretical thermal expansion/contraction is as follows:

$$\Delta L = L \times a\,(T_2 - T_1)$$

In this formula,

ΔL: change of length, m;

$\Delta L > 0$: thermal expansion;

$\Delta L > 0$: thermal contraction;

a: linear expansion coefficient of pipe, 1/□;

T_1: initial temperature, □;

T_2: final temperature, □;

L: length of pipeline at T_1 (m).

11.4 Compensation Method for Thermal Expansion/Contraction of Steel Mesh Reinforced Polyethylene Pipe

Due to friction between the soil and the surfaces of the pipe, the actual thermal expansion of the steel mesh reinforced polyethylene pipe is smaller than the calculated value from the above theoretical formula.

As the reinforced pipe has small modulus of elasticity, large deformation capacity and small internal stress during thermal deformation, not prone to be damaged due to deformation, it is preferred to be laid in a bent shape along with the landform naturally or deliberately according to the different pipe diameters. The end of the straight section shall be provided with fixing buttresses as per Article 3, so as to prevent damages due to transfer of the deformation to other pipes. Besides, the packing material shall be of adequate uniformity, stability and compaction to be in contact with the pipe.

When the reinforced pipe is laid underground, fixing buttresses shall be provided for the pipeline with a long straight section at the connecting places with valves, elbow tees and fittings (condenser cylinder and filter, etc.) as per Figure 11.1 and Figure 11.2. The expansion/contraction is restricted on the straight section. Or the fittings can be reinforced as per Figure 11.3 (with small temperature difference).

Buttress requirement: the pipe clamps shall be of good rigidity and strength. Between the pipe clamps and the contact surfaces of the pipe, soft materials with a large friction coefficient shall be added, such as rubber sheet. The pipe clamps shall be long enough. The buttresses can be fabricated/cast at site or prefabricated.

If the straight section is short, the pit at the place of the fittings shall be excavated large, and the sand/undisturbed plain soil shall be backfilled to be 100mm-200mm above the pipeline.

When the reinforced pipe is laid above ground, fixed supports shall be provided if it is connected with valves, tanks and water pumps, etc. The straight section shall be provided with sliding (axial and horizontal) supports.

In summary, the solution to the problem of thermal expansion and contraction of steel mesh reinforced polyethylene pipe in theory is similar to that to rigid pipes like steel pipe. With appropriate arrangement and necessary measures by the design and installation personnel, the problem can be well solved.

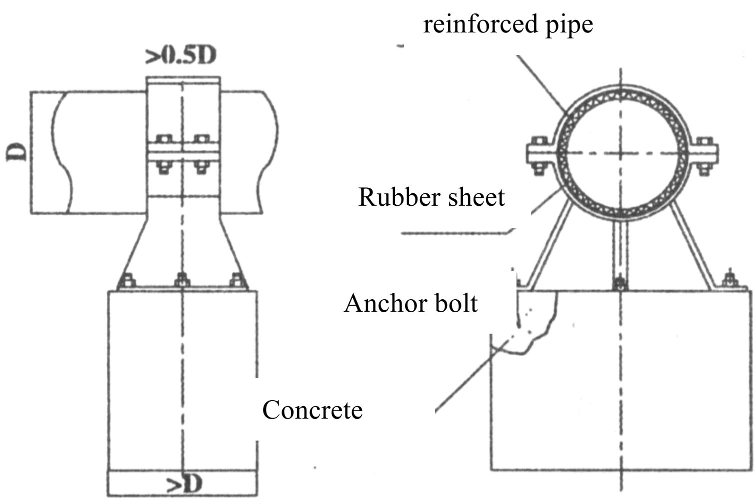

Figure 11.1

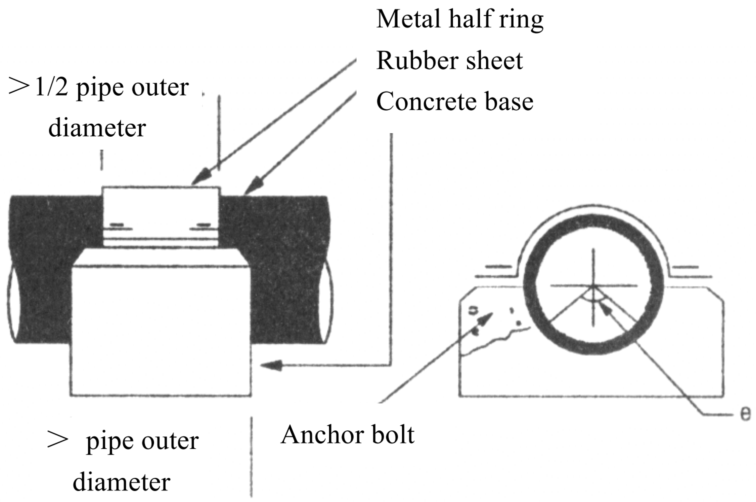

Figure 11.2

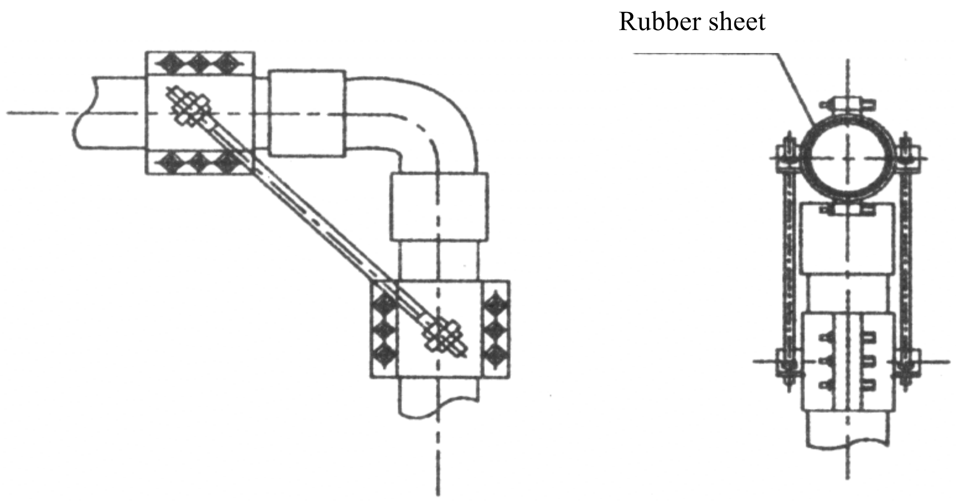

Figure 11.3

Annex I: Chemical Stability of Steel Mesh Reinforced Polyethylene Pipe

The high density polyethylene used in **Huachuang** steel mesh reinforced polyethylene pipe is a crystalline non-polar material with very stable chemical properties, capable to resist corrosion from many types of chemical media as well as no electrochemical corrosion. With smooth inner walls, the steel mesh reinforced polyethylene pipe has small output resistance, good anti-wearing performance, no scaling or wax precipitation, and thus outstanding energy saving effect.

Corrosion resistance of steel mesh reinforced polyethylene **pipe**

Solvent	20□	60□	Solvent	20□	60□	Solvent	20□	60□
Acetaldehyde, in gas state	×	/	Acetic acid (10%)	×	×	Phosphoric acid (95%)	×	/D
Acetic acid (100%) (glacial acetic acid)	×	×	Acetic anhydride	×	/D	Phosphorus trioxide	×	×
Acetone	×	×	Acetylene tetrabromide	**/ to—	—	Negative film developing agent, commercial	×	×
Acid, aromatic	×	×	Acrylonitrile	×	×	Polyethyleneglycol	×	×
Oxalic acid	×	×	Allyl alcohol	×	×	Potassiumchromate, containing water (40%)	×	
Aluminum chloride, containing no water	×	×	Aluminum sulfate	*×	×	Potassium bromide	*×	×
Vitriol	×	×	Ammonia, in gas state (100%)	×	×	Potassium borate, containing water (40%)	×	×
Ammonia, in liquid state (10%)	×	×	Ammonium chloride	*×	×	Potassium hydro-fluoride (30% solution)	×	×
Ammonium chloride, containing water (reaching 20%)	×	×	Ammonium nitrate	*×	×	Propyl alcohol	×	×
Ammonium sulfate	*×	×	Ammonium sulfide	*×	×	Propionic acid (100%)	×	/
Amyl acetate	×	×	Aniline, pure	×	×	Pseudocumene	/	/
Anisole	/	—	Antimony trichloride	×	×	Seawater	×	×
Aqua regia	—	—	Barium chloride	*×	×	Silicone oil	×	×
Barium hydroxide	*×	×	Beer	×	×	Sodium benzoate	×	×
Beeswax	×	**/ to—	Benzene	—	—	Sodium carbonate	*×	×
Benzenesulfonicacid	×	×	Benzoic acid	*×	×	Sodium chlorite (50%)	×	/
Benzyl alcohol	×	× to—	Borax, all concentrations	×	×	Sodium hypochlorite (containing 12% chlorine)	/	—
Boric acid	*×	×	Brine, saturated	×	×	Sodium silicate	*×	×
Bromine	—	—	Bromine gas	/		Sodium thiosulfate	×	×
Butantriol	×	×	Butanol	×	×	Spindle oil	× to /	/
Butoxy	×	/	Butyl acetate	×	/	Stearic acid	×	/
Butanediol	×	×	Butyric acid	×	/	Syrup	×	×
Calcium chloride	*×	×	Calcium hypochlorite	*×	×	Sulphur	×	×
Camphor	×	/	Carbon dioxide	×	×	Carbon dioxide, wet	×	×
Carbon disulfide	/		Carbon tetrachloride	**/ to—	—	Vitriol (10%)	×	×
Potassium hydroxide	×	×	Caustic soda	×	×	Vitriol (80%)	×	×
Chlorine, in liquid state	—	—	Bleaching solution containing chlorine (containing 12% chlorine)	/	—	Vitriol, in smoke state	—	—
Chlorine, dry	/	—	Chlorine, wet	/	—	Sulphuryl，chloride	—	
Chlorine (mainly for sterilization)	×		Chloroacetic acid (unit)	×	×	Tannin (10%)	×	×
Chlorobenzene	/	—	Chlorohydrin	×	×D	Tetrachloroethane	**/ to—	—
Trichloromethane	**/ to—	—	Chlorosulfonicacid	—	—	Tetrahydronaphthalene	×	/
Chromic acid (80%)	×	—D	Citric acid	×	×	Thiophene	/	/
Coconut oil	×	/	Copper salt	*×	×	Insulation oil	×	/
Corn oil	×	/	Kreosote	×	×D	Trichloroacetic acid (50%)	×	×
Cresol	×	×D	Cyclohexane	×	×	Trichloroethylene	**/ to—	—
Cyclohexanol	×	×	Cyclohexanone	×	/	Rosin, in oil state	× to /	/
Decalin	×	/	Grease drying agent	×	/	Carbamide	*×	×
Synthetic detergent	×	×	Dextrin, containing water (18% saturated solution)	×	×	Vaseline	**× to /	/
Butyl oxide	× to /	—	Dibutyl phthalate	×	/	Vinegar (industrially concentrated)	×	×
Dichloroacetic acid (100%)	×	/D	Dichloroacetic acid (50%)	×	×	Viscose solution	×	×
Methyldichloroacetate	×	×	Dichlorobenzene	/	—	Sodium silicate	×	×
Dichloroethane	/	/	Dichloroethylene	—	—	Paraxylene	/	—

Diesel	×	/	Diethyl ester	× to /	—	Yeast, containing water	×	×
Diisobutyl ketone	×	/ to —	Dimethylformamide	×	× to /	Phosphorous oxychloride	×	/D
Dioxane	×	×	Emulsifier	×	×	Phosphorus trichloride	×	/
Ester, aliphatic series	×	× to /	Diethyl ether	× to /	/	Phthalic acid (50%)	×	×
Ethyl acetate	/	—	Ethanol	×	×	Potassium dichromate (40%)	×	×
Ethyl glycol	×	×	Ethyl hexanol	×	×	Potassium chloride	*×	×
Ethylene chloride (dichloroethane)	/	/	Ethylenediamine	×	×	Zinc chloride	*×	×
Fatty acid (C8)	×	×	Ferric chloride	*×	×	Potassium cyanide	*×	×
Fluorine	—	—	Fluorocarbon (e.g. Frigen)	/	—	Potassium nitrate	*×	×
Chloro silicic acid, containing water (reaching 32%)	×	×	Formaldehyde (40%)	×	×	Propionic acid (50%)	×	×
Formamide	×	×	Formic acid	×		Propylene glycol	×	×
Juice	×	×	Jam	×	×	Pyridine	×	/
Sugar alcohol	×	×D	Gelatin	×	×	Silicic acid	×	×
Glucose	*×	×	Glycerin	×	×	Silver nitrate	×	×
Glycerin chlorohydrin	×	×	Glycol (concentrated)	×	×	Sodium hydrogen sulfite, dilute solution	×	×
Glycolic acid (50%)	×	×	Glycolic acid (70%)	×	×	Sodium chloride	*×	×
Halothane	/	/	Hydrazine hydrate	×	×	Sodium hydroxide (35% solution)	×	×
Chlorine bromate (50%)	×	×	Hydrochloric acid (all concentrations)	×	×	Sodium nitrate	*×	×
Hydrocyanic acid	×	×	Hydrocyanic acid (40%)	×	/	Sodium sulfide	*×	×
Hydrocyanic acid (70%)	/	/	Hydrogen	×	×	Spermaceti wax	×	/
Gas of hydrogen chloride, dry and wet	×	×	Hydrogen peroxide (30%)	×	×	Starch slurry	×	×
Hydrogen peroxide (100%)	×		Hydrogen sulfide	×	×	Succinic acid (50%)	×	×
Iodine tincture, DAB 7	×	/D	Isooctane	×	/	Sulfate	*×	×
Isopropanol	×	×	Isopropyl ether	× to /	—	Sulfur dioxide, dry	×	×
Marmalade	×	×	Ketone	×	× to /	Sulfur trioxide	/	/
Lactic acid	×	×	Lead acetate	*×	×	Vitriol (50%)	×	×
Linseed oil	×	×	Magnesium chloride	*×	×	Vitriol (98%)	/	—
Magnesium sulfate	*×	×	Maleic acid	×	×	Sulfurous acid	×	×
Malic acid	×	×	Menthol	×	/	Tallow	×	×
Mercury chloride (refined)	×	×	Mercury	×	×	Tartaric acid	×	×
Carbinol	×	×	Methyl butanol	×	/	Tetrahydrofuran	**× to /	—
Methylethylketone	×	/ to —	Methyl, glycol	×	×	Thionyl chloride	—	—
Dichloromethane	/	/	Syrup	×	×	Methylbenzene	/	—
Monochloroacetic acid	×	×	Monochloroethyl ether	×	×	Tributylphosphate	×	×
Monochloromethyl ester	×	×	Morpholine	×	×	Trichloroaceticacid（100%）	×	/到— / to—
Naphtha	×	/	Naphthalene	×	/	Triethanolamine	×	×
Nickel salt	×	×	Nitric acid (25%)	×	×	Tween 20 and 80	×	×
Nitric acid (50%)	/	—	Nitrobenzene	×	/	Waste gas, containing:	×	×
0-nitrotoluene	×	/	Octyl cresol	/	—	Carbon dioxide	×	×
Volatile oil	/	/	Vegetable oil, animal oil	×	× to /	Carbon monoxide	×	×
Oleic acid (concentrated)	×	/	Oxalic acid (50%)	×	×	Hydrochloric acid (all concentrations)	×	×
Oxybromide	/	—	Oxybromide, containing water solution (refined)	×		Hydrogen fluoride (micro amount)	×	×
Paraffin oil	×	×	Perchloric acid (20%)	×	×	Nitrous sulfate (micro amount)	×	×
Perchloric acid (50%)	×	/	Perchloric acid (70%)	×	—D	Sulfur dioxide (low concentration)	×	×
Gasoline	×	× to—	Petroleum (product)	×	/	Vitriol, wet (all concentrations)	×	×
Petroleum distillation product	×	/ to —	Petroleum ether	×	×			
Carbonic acid	×	×D	Phosphate	*×	×			
Phosphoric acid (25%)	×	×	Phosphoric acid (50%)	×	×			

Note: * all concentrations refer to those of water solution ** only conducted under low mechanical stress. The data in the table are obtained after 55 days' test on the samples of 50mm×25mm×1mm.

Symbol: x=stable expansion <3% or weight loss <0.5%, breaking elongation generally the same

/ =partially stable expansion of 3-8% or weight loss of 0.55% and/or breaking elongation <50%

—=not stable expansion <8% or weight loss <5% and/or breaking elongation >5%

D=decoloring