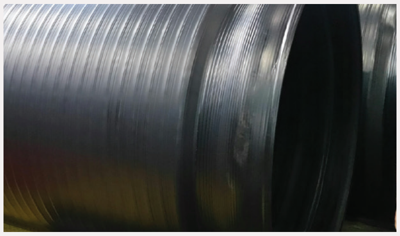

Spirolite

BULLETIN No. 910 –
TECHNICAL DESIGN GUIDE
ASTM F894

Profile wall high-density polyethylene pipe and fittings

PLASSON®
USA

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TECHNICAL DESIGN GUIDE

This section explains a generic design methodology for the Spirolite Pipe System. Described in Chapter 6 of the second edition of the Plastic Pipe Institute's Handbook of PE Pipe, the design methodology covers the gravity flow of liquids and standard installation design. For further reading on Standard Burial, Shallow Cover Design, Deep Fill Design (not included in this guide), please consult Chapter 6 of PPI's Handbook of PE Pipe or contact Plasson USA.

DEFLECTION CONTROL

A realistic approach to deflection control in flexible pipe installations involves assessment of the deflection occurring during installation and due to the service loads, i.e. soil and superimposed loading.

The placement and compaction of bedding material tend to deform plastic pipe, at times causing more deflection than the service load. The lateral forces acting on a pipe during the compaction of the embedment material between the pipe's invert and springline tend to produce a slight increase in the pipe's vertical diameter ("rise"). Rise can offset load deflection.

Because a flexible conduit interacts with the surrounding soil, the nature of the pipe embedment material and the quality of its placement are important to the control of deflection. Some conduit deflection is natural and essential to the development of necessary soil support. The maximum deflection at any point along a pipe must be limited to safeguard its performance capabilities (such as joint tightness) and to protect pipe walls from excessive straining. One of the key objectives in the selection and installation of a flexible pipe is deflection control. Spirolite pipe can

FIGURE 1: **VALUES OF E' FOR SPIROLITE PIPE** (TAKEN FROM USBR M-25 2ND EDITION)

TRENCH WALL SOIL CLASSIFICATION (USCS)	STIFFNESS OF TRENCH WALL (E' IN LB/IN2)		
	SLIGHT (<85%C)	**MODERATE (≥85%C TO <95%)**	**HIGH (≥95%C)**
Highly compressible fine-grained soils: CH, MH, OH, OL. Peat swamps, bogs or other unsuitable material	DO NOT USE		
Fine-grained soils: Soils with medium to no plasticity and with less than 30% coarse- grained particles CL, ML (or CL-ML, CL/ML, ML/CL)	200	500	1500
Sandy or gravelly fine-grained soils: Soils with medium to no plasticity and with 30% or more coarse-grained particles CL, ML (or CL-ML, CL/ML, ML/CL) Coarse-grained soils with fines: Sands, gravels with more than 12% fines GC, GM, SC, SM (or any soil beginning with one of these symbols [i.e., SC/CL])	400	700	2500
Clean coarse-grained soils: Sands, gravels with 12% or less fines GW, GP, SW, SP, or any soil beginning with one of these symbols (i.e., GP-GM). Does not apply to SP soils with ≥ 50% fine sand (passing No. 40 sieve). Treat as ML soils.	700	1000 for Sands; 2000 for Overconsolidated Sands	4000
Rock, sandstone, shale: Highly cemented soils, etc	1000	>>4000	

withstand large amounts of deflection because of its ductility and ability to relieve stress under load. Common design practice is to limit long term deflection to 7.5%.

The primary contributor to deflection control is the support provided by the embedment material. Support is the result of mobilization of passive resistance in the embedment material during horizontal deflection of the pipe. The amount of support is measured by and directly proportional to a constant known as the modulus of soil reaction (E') Values of the modulus of soil reaction are given in Figure 1.

FIGURE 2: **VERTICAL DEFLECTION (%)**

	E' = 1000	E' = 2000	E' = 3000
DEPTH OF COVER = 10'	%	%	%
CLASS 63	1.7	0.9	0.6
CLASS 100	1.7	0.9	0.6
CLASS 160	1.6	0.9	0.6
DEPTH OF COVER = 16'	%	%	%
CLASS 63	2.8	1.4	1.0
CLASS 100	2.7	1.4	1.0
CLASS 160	2.6	1.4	0.9

**(1) 36" Pipe* **(2) Soil Weight=120 lb/ft^3* **(3) With H2O loading*

In situ soil stiffness may influence the modulus of soil reaction value. The designer should consider this for applications in soils having a low capacity for lateral resistance. The effect of pipe deflection of various levels of side support versus pipe ring stiffness is illustrated in Figure 2. Note that, with a modulus of soil reaction of 1000 psi at a burial depth of 10 feet, there is virtually no difference in the amount of anticipated deflection regardless of pipe class. A Class 160 pipe buried to a depth of 10 feet may, depending on the quality of the pipe's embedment (E') deflect substantially more than a Class 63 pipe buried to a depth of 16 feet. The greater E' enables the more flexible pipe, under substantially greater load, to see considerably less deflection. Studies and extensive field experience show this to be the case and indicate that the vertical deflection of buried flexible pipes is about equal to the vertical compression (soil strain) of the pipe's sidefill.

RING STIFFNESS CONTSTANT (RSC)

Pipe's sensitivity to deflection rise during installation is controlled by the pipe's ring stiffness. Ring stiffness is defined in terms of the deflection resulting from the load applied between parallel plates. The Ring Stiffness Constant (RSC) is the value obtained by dividing the parallel plate load in pounds per foot of pipe length by the resulting deflection in percent, at 3% deflection (as described in ASTM F-894).

EQUATION 1: RING STIFFNESS CONSTANT

$$RSC = \frac{6.44EI}{D_m^{\ 2}}$$

Where:

RSC = ring stiffness constant (parallel plate load in pounds per foot of pipe which causes a 1% reduction in diameter

I = moment of inertia of wall section $(\frac{in^4}{in})$

E = short term modulus of pipe material (130,000 typical f or PE4710) $(\frac{lb}{in^2})$

D_m = Mean Diameter (Di + 2z)(in)

D_i = Inside Diameter (n)

Z = distance from pipe ID to centroid of wall section (in)

The nominal ring stiffness constant of a specific Spirolite pipe can be directly related to the pipe's class designation. That is, a Class 63 pipe has a nominal ring stiffness constant of 63, the RSC of Class 100 is 100, and so forth. The minimum RSC for any diameter of pipe within a class is 90% of the class nominal value.

The classes are shown in Figure 4. All sizes of pipe in the same class will deflect uniformly under parallel plate load, i.e. the same parallel plate load will produce approximately the same percent of deflection in all pipe of a given class. For example, any Class 100 pipe will deflect approximately 1% under a 100 lb./lineal ft. load.

To further illustrate this, consider a Class 63 pipe, which is the most flexible Spirolite pipe. Although the exact force applied to a flexible pipe during compaction is not easily calculated, it is known that, for ordinary levels of compactive effort, Class 63 pipe possesses adequate stiffness to achieve a beneficial amount of rise while not impeding the installation or creating significant stresses in the pipe wall. Field observation indicates a typical rise of one or two percent in the vertical diameter. However, variations in embedment materials, their placement, and in compactive techniques make it difficult to estimate rise prior to the actual installation.

Beyond initial installation, pipe stiffness plays an insignificant role in controlling deflection.

PIPE SELECTION

This section provides an approach to selection of the proper size and class of pipe for a specific subsurface installation.

The following considerations apply in the selection of Spirolite pipe as well as other flexible pipes: hydraulic flow, resistance to crush, resistance to buckling, and resistance to deflection due to construction and service loads.

Selection of a class of Spirolite pipe generally depends on the crushing resistance of the pipe wall rather than on the anticipated deflection of the pipe. In cases where the pipe is buried beneath the ground-water table, the constrained buckling resistance of the pipe must also be considered. Pipe class has little influence on long term service load deflection in most installations. Deflection is controlled by the enveloping soil stiffness, as shown in the section "Deflection Control."

The Class of Spirolite pipe selected for a given application should have allowable crush and buckling loads in excess of the service load. The service load includes traffic loads, earth load, and surcharge load.

The design guidelines in this brochure are contingent upon the pipe being installed according to recognized principles and standards for flexible pipe installation such as ASTM D-2321 Standard Practice for underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications, ASTM D-2774 Standard Practice for Underground Installation of Thermoplastic Pressure Pipe, Plasson USA Bulletin 914 Spirolite Installation Guide, and The Handbook of Polyethylene Pipe by the Plastic Pipe Institute. Because of complexities in soil-pipe interaction, this guide should not be substituted for the judgment of a professional engineer for achieving specific project requirements. Some cases may require more exact solutions than can be obtained from the equations and methods in this guide.

HYDRAULIC/FLOW PERFORMANCE

When a designer is preparing a specification an appropriate sized pipe based upon hydraulic calculations should be selected. Being made of high-density polyethylene, all Spirolite pipe products result in excellent hydraulics, superior to those of conventional materials. Spirolite pipe products minimize flow disturbance due to sedimentation and slime build-up by providing a smooth, non-polar and anti-adhesive inner surface. Thus, Spirolite pipe offers the potential for use of smaller diameter and/or reduced slopes to accomplish given flow requirements. The Manning coefficient of Spirolite pipe for clean water at ambient temperature is 0.009.

FIGURE 3: TYPICAL VALUES OF N FOR USE WITH MANNING EQUATION

SURFACE	N, TYPICAL DESIGN
SPIROLITE PIPE	0.009
UNCOATED CAST OR DUCTLE IRON PIPE	0.013
CORRUGAED STEEL PIPE	0.024
CONCRETE PIPE	0.015
VITRIFIED CLAY PIPE	0.013
WOOD STAVE	0.011
RUBBLE MASONRY	0.021
FRP	0.011
STEEL REINFORCED HDPE	0.013

EQUATION 2: GRAVITY FLOW

$$Q = \frac{1.486\ A}{n}$$

Where:

Q = flow (ft.^3/sec.)

N = Manning roughness coefficient

A = flow area of pipe (ft.^2)

R = hydraulic radius (ft.) = D/4

Where:

D =pipe inside diameter (ft.)

S = slope (feet/foot)

When sliplining failed or deteriorating gravity flow pipes, with Spirolite it is useful to compare flow for slipliners. Sliplining involves inserting a Spirolite pipe inside the bore of the host pipe. Prior to sliplining, it is recommended to measure the deteriorated pipe's bore to ensure the OD of the Spirolite pipe can be inserted without obstruction. Typically, there should be a 5% to 10% clearance between the OD of the Spirolite and the bore of the host pipe. Comparative flow capacities of circular pipes may be determined by the following:

EQUATION 3: COMPARATIVE FLOW

$$\%\ \text{Flow} = 100\,\frac{Q_1}{Q_2} = 100\,\frac{\left[\dfrac{D_{ii}^{8/3}}{n_1}\right]}{\left[\dfrac{D_{12}^{8/3}}{n_2}\right]}$$

WHERE:

D_{ii} = ID of the liner

D_{12} = Original Host pipe Bore

n_1 = Manning' Coefficient for Liner Pipe

n_2 = Manning' Coefficient for Host Pipe

STRUCTURAL PERFORMANCE

Once the designer has selected the appropriate sized pipe, the designer should select the appropriate class of pipe. Spirolite pipe is manufactured in several standard ring stiffness classes per ASTM F894. In preparing a specification, the designer selects a class of pipe appropriate for the application. It is important that the designer perform all necessary calculations to verify the adequacy of a given class of pipe and be acquainted with all assumptions and installation requirements. The basis for these calculations for standard installations are described in the Plastic Pipe Institute's Handbook of PE Pipe, Chapter 6 Section 3. Other types of installations, not covered in this guide including Deep Burial and Shallow Burial, are covered in Chapter 6, Section 3 of the Handbook of PE Pipe. Other design methods may be applicable.

The standard design of Spirolite pipe (burials less than 50 ft.) for subsurface applications is, typically, based on the following performance limits: (1) vertical deflection, (2) wall crush strength, and (3) constrained buckling resistance where the soil cover is the larger of 18" or 1 pipe diameter. The suitability of a class of pipe for installation at a given depth depends on the installation achieving the design E' and on the pipe being installed in accordance with ASTM D-2321 and the Spirolite Pipe Installation Guide. The designer is advised to review the applicability of these equations to each use of Spirolite pipe.

FIGURE 4: SPIROLITE SIZES & CLASSES

PIPE ID	STANDARD CLASSES	AVERAGE OD CLASS 63	AVERAGE OD CLASS 400
18	63, 100, 160, 250, 400	21.3	21.9
21	63, 100, 160, 250, 400	24.3	24.9
24	63, 100, 160, 250, 400	27.3	28.2
27	63, 100, 160, 250, 400	30.5	31.3
30	63, 100, 160, 250, 400	33.3	35.3
33	63, 100, 160, 250, 400	36.4	37.5
36	63, 100, 160, 250, 400	39.3	41.2
39	63, 100, 160, 250, 400	42.7	44.6
42	63, 100, 160, 250, 400	45.4	47.6
48	63, 100, 160, 250, 400	52.2	53.9
54	63, 100, 160, 250, 400	57.4	60.2
57	63, 100, 160, 250, 400	60.7	62.6
60	63, 100, 160, 250, 400	64.2	66.5
66	63, 100, 160, 250, 400	69.3	74.6
72	63, 100, 160, 250, 400	75.5	80.6
78	63, 100, 160, 250, 400	82.6	85.5
84	63, 100, 160, 250, 400	88.2	94.1
90	63, 100, 160, 250, 400	94.6	97.6
96	63, 100, 160, 250, 400	100.4	106.5
120	63, 100, 160, 250, 400	125.2	130.5

VERTICAL DEFLECTION

Total deflection of a flexible pipe includes both the deflection incurred during installation and the deflection due to soil and superimposed loads. Most proposed relationships for estimating deflection deal only with the latter loads. However, sufficient empirical data exists to make reasonable estimates of total deflection.

A well-known relationship for calculating the average vertical deflection in a buried flexible pipe resulting from soil loading only is Spangler's Modified Iowa Equation. This equation, as shown is modified and expressed in terms of RSC values.

The U.S. Bureau of Reclamation (USBR) and others have investigated the load/deflection relationship of buried flexible pipe. As a result of hundreds of field measurements, and computer analysis, a series of soil reaction (E') values were developed for use with the above Equation. These E' values are useful in estimating the initial deflection resulting from soil loading. They are presented in Figure 1 in terms of the embedment materials.

EQUATION 4:

$$\frac{\Delta X}{D_i} = \frac{P_t}{144}\left[\frac{K*L}{\frac{1.24\,(\text{Class})}{D_i} + 0.061E'}\right]$$

ΔX = horizontal deflection, in

K = bedding factor, typically .13

L = deflection lag factor

P_t = pipe crown vertical pressure, lbs/ft^2

E' = soil reaction modulus, lbs/ft^2

Typical use 75% of E' value

Class = Pipe RSC Class

D_i = Inside Diameter, in

$$\%\ \text{Deflection} = \frac{\Delta X}{D_i} * 100$$

COMPRESSIVE RING THRUST

Wall crushing occurs when the compressive ring stress in the pipe wall exceeds the compressive yield stress of the pipe material. The crushing load for a confined conduit is determined by the compressive strength of its walls. The compressive ring thrust should be less than 1150 psi for PE4710 materials and is determined by:

EQUATION 5: COMPRESSIVE RING THRUST

$$S_t = \frac{P_t * D_o}{288A}$$

S_t = Total Wall Stress, lbs/ft^2

P_t = Total Vertical Load, lbs/ft^2

D_O = Ouside Diameter, in

A = Profile Cross – section area

COMPRESSIVE RING THRUST

Occasionally, when pipe is buried below the groundwater table, wall buckling resistance will govern the class selection of Spirolite pipe. Constrainment of pipe in a trench greatly increases its resistance to wall buckling under hydrostatic load. For a constrained pipe buried to a depth of cover greater than 4 feet, the following equation from AWWA C-950 may be used to determine the allowable buckling pressure:

EQUATION 6: CONSTRAINED BUCKLING

$$P_{wc} = \frac{5.65}{N}\sqrt{RB'E'\frac{EI}{D_m{}^3}}$$

P_{wc} = allowable constrained buckling pressure, psi

K = bouancy reduction factor

$R = 1 - 0.33\,\frac{H'}{H}$

B'= elastic support factor

$B' = \frac{1}{1 + 4e^{-0.065H}}$

E' = soil reaction modulus, lbs/ft^2

1 = Moment of Inertia, in^4/in

D_m = Mean Diameter, in

E = Mid Term modulus of elasticity of pipe material

(Where the water table is perminently above

the crown of pipe use 28,200, $\frac{lbs}{in^2}$

N = Safety Factor (2 is typical)

CASINGS, TUNNELS AND SLIPLINERS

When Spirolite pipe is placed in casings or tunnels the annular space between the pipe and the casing is normally filled with cementatious grout. Grouting is necessary to keep bell and spigot joints together and to enhance the pipe's resistance to buckling. The enhancement depends on the quality of the grout, its placement and grout strength. One method to determine the allowable unconstrained pipe wall buckling is given by using Equation 7: Unconstrained Buckling.

Plasson USA Technical Bulletin Guidelines for Grout Encasement describes installation guidelines for casings and tunnels. The designer should insure that the pipe will not float, buckle, or deflect excessively during the placement of grout. Resistance to grout pressure may be calculated using Equation 7: Unconstrained Buckling.

Grout is normally placed in lifts. Flotation and buckling may be prevented by properly blocking the pipe, placing struts in the pipe, filling it with water, and placing grout in lifts.

For more information about unconstrained buckling equation refer to PPI's Handbook of PE Pipe 2nd Ed. Chapter 6. Please consult Plasson USA for more details.

EQUATION 7: UNCONSTRAINED BUCKLING

$$(3\text{-}40)\quad P_{wu} = \frac{f_o}{N_s}\,\frac{24EI}{(1 - \mu^2)\,D^3_M}$$

WHERE

P_{wu} = allowable constrained buckling pressure, psi

DR = Dimension Ratio

E = apparent modulus of elasticity of pipe material, psi

f_o= Ovality Correction Factor, Figure 3-9

N_s = safety factor

I = Pipe wall moment of inertia, in4/in

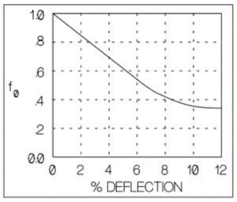
μ = Poisson's ratio

D_M = Mean Diameter, (DI + 2z or DO -[), in

D_i = pipe inside diameter, in

Z = wall-section centroidal distance from inner fiber of pipe, in (obtain from pipe producer)

FIGURE 5 : OVALITY CORRECTION FACTOR



LIVE AND DEAD LOADS

In the design of buried pipelines, both earth loads and live loads must be considered for the proper selection of pipe classes.

The work of Marston and recent developments with finite element analysis have shown that at a given depth, the vertical soil pressure at the crown of a buried flexible pipe is generally less than the pressure in the soil if no pipe were present (prism condition). This phenomena occurs because the flexible pipe deflects under load and allows part of the load to be absorbed by soil factional forces (soil arching).

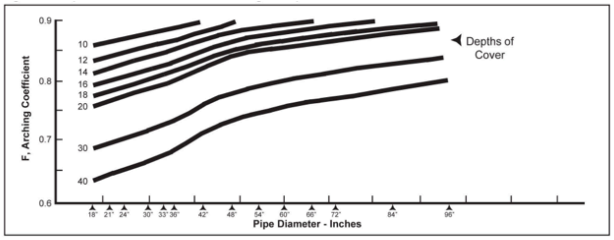
EQUATION 8:

Total Load = (Prism Load) • Arching Coefficient + Live Load
= WHF + L

Where:

P = total load (lbs. / ft.)
W = design unit weight of soil (lbs. / ft.)
H = height of cover (ft.)
F = Arching Coefficient (See Figure 6)
L = live load (See Figure 11)

FIGURE 6 : Graphical Solution to Marston Soil Arching Concept



The values in Figure 10 were obtained as follows.

(1) The Marston Load is calculated. Since specific soil conditions are not always known, ordinary clay ($k\mu = 0.13$) was assumed for the calculations, The assumed trench width was ID + 3' for 18" - 42" and ID + 4' for 48" - 96" (Marston's formula is given in ASCE Manual No. 60, Gravity Sanitary Sewer Design and Construction.)

(2) The prism load is calculated. The prism load equals the product of the unit weight of soil and the depth of cover (ft.)

(3) Add 40% of the difference between the prism load and the Marston load to the Marston load.

(4) The arching coefficient is obtained by dividing the quantity obtained in Step 3 by the prism load.

(5) If the arching coefficient exceeds 0.9 use 1.0 instead. For example, a 36" **Spirolite**® pipe with 18' of cover in a 6 ft. wide trench with a 120 lb./ft³ soil design weight. Therefore, the arching coefficient equals:

$$F = \frac{1500 \text{ psf} + 0.4\,(2160-1500)}{2160 \text{ psf}} = 0.82$$

Plasson USA recommends the use of the soil arching concept for calculating the soil load for analysis of Spirolite pipe wall crush strength. The soil load as defined in Equation 8 is the product of the prism load and the arching coefficient. The arching coefficient reduces the prism load to a conservative arched soil load value. For evaluations involving the Constrained Buckling and Spangler's Iowa Equation the value for the modulus of soil reaction (E') was derived using the prism load. Therefore, for evaluations employing the Spangler and Constrained Buckling Equation an arching coefficient, F, of 1.0 should be used.

TRAFFIC LOADS

The vehicular load applied to a buried pipe depends on the depth of cover and the pavement type. Figure 8 gives the theoretical amount of load transferred to the pipe by a standard 20 ton truck (H20 loading) passing over 12" thick, rigid pavement. For flexible pavement or unpaved roads, loads may be calculated using a suitable point load or distributed load equation. The Handbook of PE Pipe gives a number of calculation methods for finding vehicular loads on pipe. Load intensity varies somewhat with the different methods based on the engineering assumptions made when deriving the equations.

FIGURE 8: H20 & HS20 HIGHWAY LOADING (AISI)

COVER, ft	TRANSFERRED LOAD, lb/ft²
1	1800
2	800
3	600
4	400
5	250
6	200
7	175
8	100
10	†

Simulates 20 ton truck traffic + impact. †Negligible live load influence.

SHALLOW COVER

Where traffic loads are present, a minimum depth of cover of 18" or one-half the pipe diameter (whichever is greater) is recommended for Spirolite pipe. However, where the depth of cover is less than 3 feet or one pipe diameter (whichever is greater), the combined bending resistance of the pipe and soil must be sufficient to handle the live load. Thus, the Watkins Shallow Burial equation, which gives the upper limit on the live load, must be satisfied or the depth of cover and/or the pipe class increased. In addition to checking for bending capacity, the designer should also check resistance to crush, buckling, and deflection due to the total load.

FLOTATION OF SPIROLITE PIPE

Where pipe is installed with less than one and a half diameters of cover and the groundwater or water level in the pipe trench can rise above the pipe, there is a potential for pipe flotation. The buoyant uplift acting on the pipe due to the displaced volume of water must be less than the hold-down forces due to the soil above the pipe and the weight of the pipe and its contents by a sufficient safety factor. Where there is insufficient cover to prevent flotation, a continuously poured concrete cap can be used to hold the pipe down. For a conservative calculation, the designer may equate the displaced volume of water with the outside diameter of the Spirolite pipe and ignore the pipe weight. Consult Plasson USA for dimensions and weights, if a more exact calculation is required.

QUALITY CONTROL

RAW MATERIALS

Prior to the launch of a new product, all tests laid down in the requirement specifications are carried out and documented. Before the materials are used in production, a trial manufacturing run is completed and the pipes and fittings undergo long-term tests. If our factory standards and criteria, which are significantly more stringent that the standard requirements, are met, we, then, will release the product for production.

A material is only approved for production after an extensive production trial phase has been completed successfully. All incoming raw materials and semi-finished products are carefully inspected before they are released for use in production. In the inspection process, the suitability of the goods for the intended purpose is verified.

PRODUCTS

Buried pipes for the transport of wastewater need to withstand media that tend to contain ever more aggressive components. At the same time, the requirements regarding the protection of the environment have become much more stringent than in the past. This means that modern pipe systems must meet extremely high quality standards as regards their production, development and installation.

As part of our internal quality assurance system, all in-process tests and inspections that are required by the relevant standards are performed at regular intervals by qualified staff. Our laboratory technicians take samples from each production batch, which are used for more detailed physical tests. All these procedures are performed according to the relevant product standards.

The following routine tests are carried out as part of our internal quality assurance system:

INCOMING INSPECTION OF RAW MATERIAL BATCHES

- Melt flow index
- Material density
- Homogeneity of material

IN-PROCESS CONTROL

- Color
- Identification
- Surface properties
- Delivery condition
- Dimensions

QUALITY INSPECTION OF SPIROLITE PIPE

- Dimensions
- Melt flow index
- Density
- Color
- Ring stiffness

PRE-DELIVERY INSPECTION

- Packaging
- Delivery condition
- Dimensions

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