CHAPTER II

R A W M A T E R I A L S

The Building Blocks of Gasketed Joint PVC Pipe are PVC and Elastomeric Compounds

CHAPTER II

RAW MATERIALS

PVC pipe with gasketed joints derives its physical properties and performance characteristics from the basic properties of its raw material components. There are essentially two polymeric materials -- PVC compounds and elastomeric seal compounds. A brief summary of the material properties for these compounds provides a solid foundation for understanding and appreciation of PVC pipe properties, capabilities, and limitations.

PVC PIPE COMPOUNDS

PVC pipe manufacturers purchase raw materials in one of two forms. They purchase either preblended PVC extrusion compound, or basic PVC resin and other ingredients for preparation of their own compounds. Most major manufacturers purchase PVC resin and commence their manufacturing processes with the preparation of PVC pipe extrusion compounds.

PVC resin, the basic building block of PVC pipe, is derived essentially from natural gas or petroleum, salt water, and air. Prior to processing into PVC pipe compound, PVC resin resembles granulated sugar in appearance and texture. PVC resin offers excellent physical, chemical, mechanical, and electrical properties for PVC pipe; however, without additional processing into extrusion compound, it cannot be extruded successfully into finished PVC pipe. PVC resin, produced by any of the common manufacturing processes -- bulk, suspension, or emulsion processes -- is useless until compounded (i.e., combined with heat stabilizers, lubricants, and other ingredients).

In general, compounds made from PVC resins comprise three types -- plastisols, flexibles and rigids. Each compound type is used in the manufacture of different types of PVC products. Plastisols may be used in production of footwear. Flexibles, which contain plasticizers, may be used in production of hose. Rigids do not contain plasticizers. Rigids are used in the production of PVC pipe.

Rigid PVC compounds are a mixture of PVC resin and some combination of stabilizers, extenders, lubricants, pigments, and modifiers. Rigid compounds prepared for PVC pipe extrusion are carefully designed

and developed to provide specific properties, which are application dependent. For example, relatively high tensile strength is required for PVC pressure pipe. Non-pressure pipe performance relies more critically on modulus of elasticity. Formulating compounds for a specific application is an integral part of PVC pipe production.

Rheology testing of compounds grades the flow characteristics

Rigid PVC pipe compounds designed for transport of potable water must additionally meet criteria based on toxicological properties and design stress properties. Design stress properties are demonstrated by long-term testing under hydrostatic pressure. Hydrostatic design stress ratings are established after long-term hydrostatic testing in accordance with ASTM D 2837. Certification of potable quality by an independent laboratory is provided with PVC water pipe as assurance to the user of this inherent health benefit. To define the basic properties of PVC compounds, the American Society for Testing and Materials (ASTM) established standard specification D 1784, the "Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds." This specification defines a five-digit cell class designation system which describes minimum characteristic physical properties for a particular compound, as is shown in Table 2.1.

TABLE 2.1

Class Requirements for Rigid Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds for ASTM D1784

Note—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell.

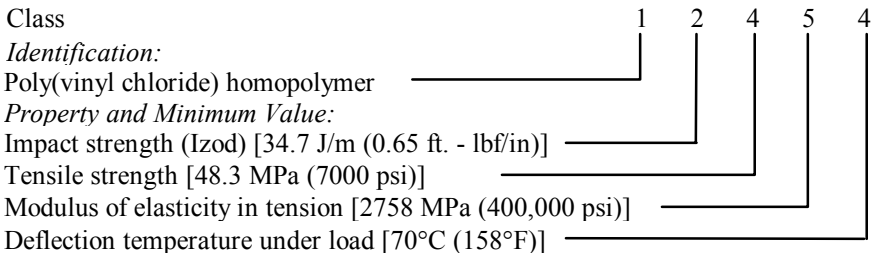
Desig-nation Order No.	Property and Unit	Cell Limits											
		0	1	2	3	4	5	6	7	8	9	10	11
1	Base resin	unspecified	poly(vinyl chloride) homo-polymer	chlorinated poly(vinyl chloride)	vinyl copolymer								
2	Impact strength (lzod), min:												
	J/m of notch	unspecified	<34.7	34.7	80.1	266.9	533.8	800.7					
	ft-lb/in. of notch		<0.65	0.65	1.5	5.0	10.0	15.0					
3	Tensile strength, min:												
	MPa	unspecified	<34.5	34.5	41.4	48.3	55.2						
	psi		<5 000	5 000	6 000	7 000	8 000						
4	Modulus of elasticity in tension, min:												
	MPa	unspecified	<1930	1930	2206	2482	2758	3034					
	psi		<280 000	280 000	320 000	360 000	400 000	440 000					
5	Deflection temperature under load, min, 1.82 MPa (264 psi):												
	ºC	unspecified	<55	55	60	70	80	90	100	110	120	130	140
	ºF		<131	131	140	158	176	194	212	230	251	266	284
	Flammability	A	A	A	A	A	A	A	A	A			

[A] All compounds covered by this specification, when tested in accordance with Test Method D 635, shall yield the following results: average extent of burning of 25mm; average time of burning of < 10 s.

The five properties designated are: (1) base resin, (2) Izod impact strength, (3) tensile strength, (4) elastic modulus in tension and (5) deflection temperature under loading. Figure 2.1 shows how this classification system can describe minimum properties for a compound.

FIGURE 2.1
EXAMPLE - CLASS REQUIREMENTS FOR ASTM D 1784

The manner in which selected materials are identified by this classification system is illustrated by a Class 12454 rigid PVC compound having the following requirements (see Table 2.1):



NOTE: The cell-type format provides the means for identification and close characterization and specification of material properties, alone or in combination, for a broad range of materials. This format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted.

Prior to the development of the current cell classification system for PVC compounds defined in ASTM D 1784, PVC pipe compounds were specified by means of a four-digit plastic pipe material code.

The former plastic pipe material code essentially defined three properties of a designated PVC compound: (1) Izod impact strength, (2) chemical resistance and (3) hydrostatic design stress, in units of 100 psi. Figure 2.2 shows how the material code described the specific properties for a given PVC pipe compound.

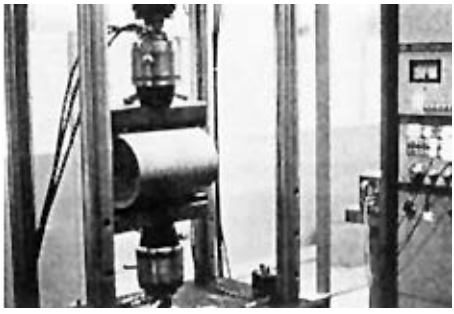
FIGURE 2.2
EXAMPLE - PVC PIPE MATERIAL CODE

The manner in which selected materials are identified by this material code is illustrated by a PVC 1120 compound having the following requirements:

Material Code PVC 1 1 2 0

IDENTIFICATION

Polyvinyl Chloride homopolymer
Type 1 -- impact strength (1200) [34.7 J/m (0.65 ft. lbf/in)] minimum
Grade 1 -- chemical resistance -- as defined under Suffix B in ASTM D1784, prior to 1995
Hydrostatic Design Stress, units of 100 psi



PVC compounds can be produced in vast variety; however, the properties afforded by specific compounds may be easily identified and compared with standard requirements by defining the appropriate cell classifications for the compounds.

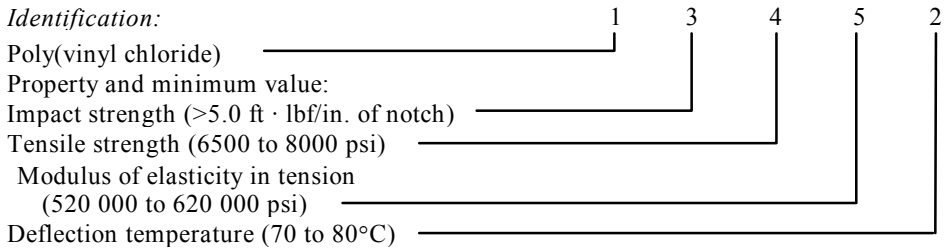
As PVC compounds are frequently designed for specific end-uses, so are the cell classification systems which define the needed physical properties of those compounds. The use of these systems allows the product standards to directly address the performance characteristics of concern in the product end-use.

ASTM standard specification D 3915, the "Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride)

(CPVC) Compounds for Plastic Pipe and Fittings Used in Pressure Applications," defines a cell classification specific to PVC pressure pipe applications. This specification uses a six-digit cell class designation system as defined in Table 2.2. The first five digits identify the same properties numerically classified in ASTM D 1784. However, the cell limits are not necessarily identical. The sixth digit of an ASTM D 3915 cell class defines the parameter for designing specific pressure piping applications with a desired safety factor. This is discussed in detail in Chapter V: Pressure Pipe Design and Selection.

Likewise ASTM D 4396, "Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds for Plastic Pipe and Fittings Used in Nonpressure Applications," describes the classification of compounds specifically for PVC non-pressure pipe. This specification uses a five-digit classification system as described in Figure 2.3.

FIGURE 2.3 - (ASTM D 4396)



The cell-type format provides the means for classification and close characterization and specification of compound properties, alone or in combination, for a broad range of compounds. This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available compounds. The manufacturer should be consulted.

To summarize, pipes marked with a four-digit material code were manufactured with a compound as defined in an earlier version of ASTM D 1784 (i.e., ASTM D 1784-65 T). Pipes having a five-digit cell classification were made from a compound defined by the more recent editions of ASTM D 1784. For specific applications, it may be necessary to consult ASTM D 3915 or ASTM D 4396. The current edition of

ASTM D 1784 provides the most commonly used cell classification system for PVC pipe. All of these standards provide for quality control in the manufacturing of compounds for pipe and fittings.

TABLE 2.2

Class Requirements for Poly(Vinyl Chloride) (PVC) and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds for ASTM D3915

Note—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell.

Desig-nation Order No.	Property and Unit	Cell Limits								
		0	1	2	3	4	5	6	7	8
1	Kind of resin in compound	unspecified	poly(vinyl chloride) (PVC)	chlorinated poly(vinyl chloride) (CPVC)	vinyl chloride copolymer (CVC)					
2	Impact resistance, min: J/m of notch (ft-lbf/in of notch)	unspecified	<40.0 (<0.65)	40.0 (0.65)	80.1 (1.50)	266.9 (5.00)				
3	Tensile strength, min: MPa (psi)	unspecified	<34.0 (<5 000)	34.0 (5 000)	41.0 (6000)	48.0 (7000)	55.0 (8000)			
4	Modulus of elasticity in tension, min MPa (psi)	unspecified	<1930 (<280 000)	1930 (280 000)	2210 (320 000)	2480 (360 000)	2760 (400 000)	3310 (480 000)	3860 (560 000)	
5	Deflection temperature under load, 1.82 MPa (264 psi) min ºC (ºF)	unspecified	60 (140)	70 (158)	80 (176)	100 (212)	110 (230)	120 (248)	130 (266)	140 (284)
6	Hydrostatic design basis: MPa (psi)	unspecified	13.80 (13.25 to 16.50) (2000) (1920 to 2390)	17.25 (16.55 to 20.75) (2500) (2400 to 3010)	21.70 (20.80 to 26.35) (3150) (3020 to 3820)	27.60 (20.40 to 33.05) (4000) (3830 to 4790)	34.50 (33.10 to 41.60) (5000) (4800 to 6030)			

PVC pipe is an engineering-designed product. Many of the important properties of PVC pipe are predetermined by the design of the PVC compound from which the pipe is extruded. Familiarity with the classification of PVC pipe compounds is useful in proper system design and product application.

GASKET MATERIALS

Gasket materials should comply in all respects with the physical requirements specified in ASTM F 477, "Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe."

ASTM F 477 specifies elastomeric seals used to seal joints of plastic pipe used for gravity, or low-pressure, and high-pressure applications. Table 2.3 defines physical requirements of elastomeric seals for plastic pipe. Elastomeric materials with more specific properties are generally used by each pipe manufacturer. (See Table 2.4 - Typical Properties of Elastomeric Compounds.)

TABLE 2.3 - (ASTM F 477)

Tests	Low-Head Application (Below 150 kPa or 50-ft Head)	High-Head Application (150 kPa or 50-ft Head and Above)
Original Properties:		
Tensile strength, min, MPa (psi)	8.3 (1200)	13.8 (2000)
Elongation, min, %	325	400
Hardness, Type A durometer	40 to 60	40 to 60
Low-temperature hardness, Type A durometer, max increase, points	15	15
Compression set, max %	25	20
Ozone resistance	no cracks	no cracks
Accelerated aging (air oven test):		
Decrease in tensile strength, max % of original	15	15
Decrease in elongation, max % of original	20	20
Hardness, Type A durometer, max increase, points	8	8
After water immersion:		
Change in volume max %	5	5

TABLE 2.4
TYPICAL PROPERTIES OF GASKET MATERIALS

	1	2	3	4	5	6
	Styrene butadiene	Butadiene	Ethylene propylene terpolymer	Chloroprene (neoprene)	Nitrile butadiene (high-ethylene)	Nitrile butadiene (low (nitrile)
ASTM D 1418 designation	SBR	BR	EPDM	CR	NBR	NBR
ASTM D 2000 SAE J200 type, class	AA, BA	AA	AA, BA, CA	BC, BE	BF, BG, BK, CH	BF, BG
Specific gravity, base polymer	0.94	0.91	0.86	1.24	1.00	1.00
Tensile strength, max. reinf. (psi)	3,500	3,000	3,000	4,000	4,000	3,500
Elongation, max. reinf (T)	600	600	600	600	600	600
Hardness, Store A	40-90	40-80	30-90	30-90	40-90	40-90
Brittle point (F)	-80	-100	-90	-80	-40	-90
Resilience at 73°F	B	A	B	B-A	B	B
Compression set	A	B	B-A	B-A	B-A	B-A
Electrical properties	A	A	A	A	D-C	D-C
Adhesion to metal	A	A	C-B	B-A	B-A	B-A
Resistance to:						
Tearing	C	C	C	C-B	B	B
Abrasion	A	A	B	A	A	A
Flame	D	D	D	B-A	D	D
Ozone	NR	NR	A	A	D-C	D-C
Weather	D	D	A	A	D	D
Oxidation	C	C	A	A	B	B
Water	B-A	B	A	B	A	B-A
Steam	C	C	B-A	C	C-B	C-B
Acids						
(dilute)	C-B	C-B	A	A	B	B
(conc)	C-B	C-B	A	A	B	B
Alkalies						
(dilute)	C-B	C-B	A	A	B	B
(conc)	C-B	C-B	A	A	B	B
Synthetic lubricants	NR	NR	NR	D	B-A	D
Lubricating oils						
(high aniline)	NR	NR	NR	A	A	A
(low aniline)	NR	NR	NR	B	A	A
Animal, vegetable oils	D-B	D-B	B-A	B	B	B
Aliphatic hydrocarbons	NR	NR	NR	C	A	B
Aromatic hydrocarbons	NR	NR	NR	D	B	D
Gas permeability	C	C	C	B	B-A	B

A = Excellent; B = Good; C = Fair; D = Use with caution; NR = Not recommended

CHAPTER II

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