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(54) IMPROVEMENTS IN OR RELATING TO PIPES

(71) We, YORKSHIRE IMPERIAL PLASTICS LIMITED, a British Company, of Haigh Park Road, Stourton, Nr. Leeds, Yorkshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to pipes and has particular reference to thermoplastics material pipes, for example soil pipes and rainwater down pipes.

Such pipes are in common use today and are normally manufactured from unplasticised PVC, and are used because of their lightness, their ease of handling, their rigidity and their resistance to corrosion which means that they can often be considered suitable for at least 50 years use once properly installed in the case of soil pipes. However, the cost of the material of the pipe is relatively expensive and at present their use largely depends on the fact that their properties are good, and the ease of installation reduces the installation costs to make up for the initial expense of the material.

According to the present invention, there is provided a method of producing a self-supporting cellular thermoplastics pipe comprising placing a foamed thermoplastics pipe in a cylindrical former, subjecting the pipe to an internal fluid pressure whilst heated to a temperature above its glass transition temperature and below the melting point, the said fluid pressure, distending the pipe into contact with the internal wall of the former to increase the internal and external diameters and reduce the wall thickness of the pipe whereby orientation of the thermoplastics material is effected and, whilst maintaining the fluid pressure, cooling the pipe to a temperature at which the thermoplastics material sets.

By "self-supporting" is meant that the pipe will retain its cross-sectional shape at ambient temperatures when laid on its side.

It is well known in the art that thermo-

plastics materials, at temperatures above their glass transition temperatures can extend by relatively large amounts under the influence of a tensile stress. This extension has an elastic and a viscous component, the proportions of which are temperature dependent. By "elastic" is meant that the deformation is wholly recoverable on removing the applied force, or on removing the force and subjecting to a higher temperature. By "viscous" is meant that the deformation is wholly irrecoverable by these means.

As temperature is increased beyond the glass transition temperature, the tendency is for the proportion of viscous deformation to increase, though at the lower end of the range, there is a band of temperatures relatively narrow in the case of amorphous plastics, wider in the case of semi-crystalline plastics, within which the proportion of viscous deformation is insignificantly small. Orientation is associated with elastic extension only, and for the purposes of the present invention, therefore, the temperature range over which orientation occurs, is the band of temperatures, above the glass transition temperature, within which extension is predominantly elastic. For a given material this orientation temperature range can be defined on the basis of a simple test designed to measure recoverability.

The foamed pipe may be heated externally and/or internally prior to distention and may be distended by inflating with a pressurised gas which may be nitrogen or air, or by using pressurised liquid, e.g. water. The pressurised liquid is maintained at the temperature at which the pipe is distended so that orientation of the plastics material occurs.

Inflation is at a rate sufficiently slow to prevent local rupturing of the pipe occurring as a result of localised over-thinning of the pipe. For a 2" diameter 0.2" thick foamed pipe in the non distended condition, the inflation may take place for a period of the order of 5 minutes.

The foamed pipe may be inflated into a

[Price 33p]

female former, which former may include recesses and/or annular projections into or onto which the distending pipe can be located for supporting and sealing the pipe. The invention is particularly applicable to unplasticised PVC.

An advantage of the present invention is that it facilitates the production of a self-supporting pipe of thermoplastics material having a closed cell foamed wall, the wall being oriented circumferentially, the circumferential strength being greater than the longitudinal strength.

The pipe is formed by extruding a mixture of a thermoplastics material and a foaming agent and allowing the extruded material to expand to a cellular structure. The mixture may be maintained prior to extrusion at a temperature below that at which foaming occurs until immediately prior to extrusion and then heated to a temperature at which the foaming agent is activated; the mixture is then extruded and after extrusion is allowed to foam to form the pipe. By this method a closed cell foam is produced.

By way of example, embodiments of the present invention will now be described with reference to the accompanying drawings of which:

Figure 1 is a cross-section of a former;

Figure 2 is an enlarged portion of Figure 1; and

Figure 3 is a cross-section on a smaller scale along the line III—III of Figure 2.

A mixture of PVC and a suitable foaming agent, for example azodicarbonamide, is extruded in a conventional manner with a final temperature in the range 170 to 200°C to produce a foamed pipe of 1.9" OD with a wall thickness of 0.140". The foamed pipe is then cut into lengths and the particular example used was cut into one metre lengths and located inside the former illustrated in the drawings which has an internal diameter of 3.65". The former comprises a cylinder 1 threaded at both ends 2 and 3 and having fixed to the ends 2 and 3 by means of a threaded collar 4 a hollow plug 5 which has an interrupted flange 6 and an internally conically chamfered portion 7 which flares outwardly towards the inner surface 8 of the cylinder 1. The narrower end of the chamfered portion 7 terminates in a cylindrical portion 9 which is stepped into a wider portion at 10 to form a ledge 11 and the stepped portion 10 is threaded as at 12. Located inside and screwed into the threaded portion 12 is a further hollow plug 13 which has an annular recess 14 and a central bore 15. The annular recess 14 defines an outer peripheral wall 16 which has an O-ring 17 contacting the bore 10 to form a seal therewith and has an end face 18. The inside of the annular recess 14 extends for a greater distance than the peripheral wall 16 to form an outwardly

directed face 19, the function of which will be explained further below.

When assembled, there is located between the end face 18 and the ledge 11 a series of chevron cross-section rings 20 which are formed from polytetrafluoroethylene and which are located at either end by brass rings 21 and 22. The recess 14 accommodates the thermoplastics pipe 23 and when the cylinder 13 is tightened onto the rings 20, they spread laterally to clamp the pipe between themselves and the wall 19 to form an effective seal between the interior of the pipe and the exterior.

A slight gap 24 exists between the tube 1 and the plug 5, the gap being bridged by the flanges 6 over a small part of its circumference. The purpose of this gap is to permit water to pass into and out of the annular space 25 between the pipe 23 and the cylinder 1.

The metre length of pipe is thus assembled within the former with its ends not touching the depths of the recess 14 which would otherwise impose an unwanted longitudinal stress along the length of the pipe. The assembly is then immersed in a bath of hot water at 86°C and the temperature of the pipe is allowed to become equal to that of the water. In the Example now to be described, this temperature was reached in 20 minutes by which time the bath had fallen to a temperature of 84°C. It is believed that the orientation temperature for PVC is in the range of approximately 80 to 105°C for practical purposes, and for this particular composition reversion tests showed it to be 80—90°C. Thus the temperature attained by the pipe was such that orientation on distension would occur.

Compressed nitrogen was then fed inside the pipe through the bore 15 and in the present case nitrogen was fed in from both ends to equalise pressure throughout the pipe in the most efficient manner. The pressure was raised at a rate of 10lb/sq in per minute until a pressure of 60psi was reached, after a period of 6 minutes. Because the gas inside the pipe increased its buoyancy, it tended to bow upwardly and it was found necessary to use a hollow mandrel inside the pipe to prevent the bowing. However, such a mandrel would be unnecessary if pressurised hot water were used instead of pressurised nitrogen. The reason for inflating the pipe slowly is that there is a tolerance of 10% in the pipe wall thickness and the slow rate of pressurisation enabled a steady inflation of the pipe to occur without localised thinning and consequent danger of rupture as the pipe distended. Small weep holes of approximately 0.025" diameter at 2" centres were located in the walls of the cylinder 1 to enable hot water to be bled throughout the length of the pipe as the foamed pipe distended into con-

tact with the walls. Hot water also of course was displaced through the gap 24 at either end. Once the pipe had been fully inflated, the nitrogen pressure was maintained at 60lbs/sq in and the cylinder was removed from the hot bath and placed into a bath of cold water at 10°C for approximately 10 minutes and allowed to cool under pressure until the wall temperature was reduced to 50°C so that the orientation of the pipe was frozen in. The nitrogen pressure was then released and the sample of the pipe was extracted from the former. Details of tests on the distended pipe are set out below.

It will be appreciated that grooves could be formed in the wall of the former, or if necessary internally directed projections could be so formed that the external and consequently the internal shape of the pipe would be altered and made to conform to the grooves. In use, the tapered ends of the pipe formed by contact with the portions 7 of the former would be cut off and rejected. The thickness of the final product is, of course, dependent upon the thickness of the pipe originally extruded, the amount of forming and the amount of distension. These three factors can be varied to produce a final pipe of the correct thickness, but distension to about twice the original diameter will normally be used.

There are many advantages in the production of a pipe by this route but the principal advantages are that for a given size of pipe, less plastics material is required and hence the expenditure on material is reduced leading to an economic saving. Also when compared with unoriented foamed pipe, it is envisaged that the orientation which has occurred will somewhat alter the failure mechanisms of the pipe when subjected to impact and tests have shown that the type of failure in a distended pipe is ductile and localised whereas in foamed and undistended pipe the fracture is brittle and extensive. Attempts have been made to increase the

impact strength of foamed pipe by modifying the structure chemically. This does tend however to be expensive and thus reduces the cost advantage of using a foamed pipe.

A further advantage of the present invention is that very large diameter pipes can be manufactured using dies of a much smaller size. Thus for example a 20" pipe can be manufactured by using a 10" die and then distending the pipe to 20" after foaming.

It has been established that the distension of the pipe does not cause a significant breakdown of the cellular structure of the foamed pipe. This result is contrary to what may have been expected. It would have seemed almost certain that when distending foamed PVC having a density of 0.65 g/cc (compared with solid PVC density of 1.4 g/cc) the foamed structure would have broken down completely, with the cell walls being ruptured, and the cells collapsing. Alternatively it may have been thought that the material would have proved impossible to distend at all at such a low density, and that the structure would merely have failed. However, it has been discovered that this is not so, and that the material can be distended without a significant change in the wall density, and that the cellular wall can be oriented to produce an increase in the tensile strength of the material in the direction of orientation. This unexpected result can be seen by looking at the structure of the pipe before and after distension and orientation. Orientation can also be proved by comparing the tensile strengths of the material in the circumferential and in the longitudinal directions and by the reversion of the pipe to its normal size on heating after distension and orientation.

Comparing the tensile properties; initially, in an experiment a 1.9" OD foamed pipe having 0.14" wall thickness was distended to 3.65" OD and five test pieces were cut in the circumferential direction in the longitudinal direction and were tested to give the following results:

TABLE I

Circumferential Test Pieces				Breaking Load		Tensile strength
Specimen no.	Width in	Thickness in	Area in ²	Newtons	lbf	lbf/in ²
1	.137	.082	0.01123	201	45.2	4025
2	.136	.084	0.01142	189	42.5	3722
3	.138	.081	0.01118	181	40.7	3640
4	.137	.081	0.01110	210	47.2	4252
5	.137	.083	0.01137	199	44.7	3931
						Av. 3914
Longitudinal Test Pieces				Breaking Load		Tensile strength
Specimen no.	Width in	Thickness in	Area in ²	Newtons	lbf	lbf/in ²
1	.496	0.067	0.0332	312	70.1	2111
2	.498	0.079	0.0393	340	76.4	1944
3	.493	0.091	0.0449	378	85.0	1893
4	.495	0.076	0.0376	336	75.5	2008
5	.500	0.077	0.0385	342	76.9	1997
						Av. 1991

5 This gave a ratio of circumferential tensile strength to longitudinal tensile strength of 1.97:1, indicating the presence of orientation in the circumferential direction.

Relaxation tests were then performed on samples of pipe 1" long which were heated

in hot water to 90°C for 15 minutes. 90°C is the upper-limit of the orientation temperature of the PVC formulation used in the above examples, and is sufficient to give relaxation of the pipe. Results are given in Tables II and III.

TABLE II
Dimensions of samples before heat treatment.

Thickness at one end in	Thickness at the other end in
.073	.075
.077	.081
.068	.066
.063	.064
.087	.085
.092	.093
.090	.089
.087	.085

The measurements were made at eight points around the periphery of the tube and the average was 0.080". The diameter at one end was 3.627", the diameter at the other end was also 3.627" giving an average of 3.627", compared with a distended diameter of 3.65", a small amount of contraction having occurred.

TABLE III
Dimensions of samples after heat treatment.

Thickness at one end in	Thickness at the other end in
.133	.132
.133	.137
.121	.120
.120	.123
.153	.155
.157	.158
.157	.158
.149	.150

Arithmetic Mean 0.141"

The diameter was measured at both ends at two positions at right-angles giving the following results: 2.330", 2.135", 2.282", 2.242", giving an average diameter of 2.247".

The relaxation on the wall thickness was therefore from 0.080" to 0.141" and on the OD from 3.627" to 2.247". The original pipe OD was 1.9" and the original wall thickness was 0.14" and the distension ratio was 2.03:1. This relaxation confirms that the material was oriented to a significant degree.

If polypropylene is used instead of PVC, a temperature of about 150°C is required for orientation distension and this can be pro-

duced by using hot air or radiant heat rather than hot water.

WHAT WE CLAIM IS:—

1. A method of producing a self-supporting, as hereinbefore defined, cellular thermoplastics pipe comprising placing a foamed thermoplastics pipe in a cylindrical former, subjecting the pipe to an internal fluid pressure whilst heated to a temperature above its glass transition temperature and below the melting point, the said fluid pressure distending the pipe into contact with the internal wall of the former to increase the internal

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and external diameters and reduce the wall thickness of the pipe whereby orientation of the thermoplastics material is effected and, whilst maintaining the fluid pressure, cooling the pipe to a temperature at which the thermoplastics material sets.

2. A method as claimed in claim 1 in which the thermoplastics material is PVC.

3. A method as claimed in claim 1 or claim 2 in which the pipe is subjected to fluid pressure at a temperature in the range 80—90°C.

4. A method as claimed in claim 1 in which the thermoplastics material is polypropylene.

5. A method as claimed in claim 1 or claim 4 in which the pipe is subjected to fluid pressure at a temperature of 150°C.

6. A method as claimed in any of the preceding claims in which the pipe is heated internally prior to distension.

7. A method as claimed in any of claims 1—5 in which the pipe is heated externally prior to distension.

8. A method as claimed in any of claims 1—5 in which the pipe is inflated by nitrogen.

9. A method as claimed in any of claims 1—5 in which the pipe is inflated by air.

10. A method as claimed in any of claims 1—5 in which the pipe is distended by liquid.

11. A method as claimed in claim 10 in which the pipe is distended by water which is at a temperature at which orientation of the thermoplastics material occurs.

12. A method as claimed in any of the preceding claims in which the pipe is produced by extruding through a 10 inch OD die and is distended to 20 inch OD.

13. A method as claimed in claim 1 comprising locating a length of foamed thermoplastics pipe co-axially in a tubular female former having an inner diameter larger than the outer diameter of the pipe, supporting the pipe at its ends, sealing the ends, coupling at least one of the ends to a source of fluid

pressure, immersing the former and pipe in water at a temperature at which orientation of the thermoplastics material can occur, distending the pipe from the fluid pressure source at the said temperature until the outer surface of the pipe is constrained by the inner surface of the former, cooling the pipe whilst maintaining the fluid pressure to a temperature at which the thermoplastics material sets and removing the former from the pipe.

14. A method as claimed in claim 13 in which the former and pipe after distention are immersed in cold water to effect cooling.

15. A method as claimed in claim 13 or claim 14 in which the foamed pipe is of PVC which is heated to a temperature in the range 80—90°C, inflated with nitrogen at a rate of 10lb/sq in per minute up to a maximum pressure of 60lb/sq in, and the former then immersed in water at 10°C and cooled whilst maintaining the pressure in the pipe until the pipe is at a temperature of 50°C.

16. A method as claimed in any of claims 13—15 in which the former includes recesses and/or annular projections into or onto which the ends of the pipe are located for support and for sealing.

17. A pipe when manufactured according to a method claimed in any one of the preceding claims.

18. A self-supporting pipe according to claim 17 having a closed cell foamed wall, the wall being oriented circumferentially, the circumferential strength being greater than the longitudinal strength.

19. A method of manufacturing a pipe substantially as herein described with reference to and as illustrated by the accompanying drawings.

20. A pipe when manufactured substantially as described herein.

M. A. KERR,
Agent for the Applicants.



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