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EXPERIMENTAL RESEARCH CONCERNING POLYPROPYLENE TUBES ASSEMBLING

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Abstract: this paper shows experimental research concerning dismountable and non-dismountable assemblies of polypropylene tubes which are used in household and industrial installation, the connecting pieces (fittings), the devices used, as well as the flaws and welding control.

1. INTRODUCTION

The polypropylene tubes systems are more and more important in household water and industrial piping systems. The superior material features, easy handling and installation and the excellent quality-price ratio are major advantages of this system, mainly in high-pressure appliances.

Polypropylene tubes are used in: drinkable water distribution networks, anti-fire networks, transport of alimentary and industrial fluids, urban sewage piping systems, water treatment systems, drainage systems in normal and special conditions, telephone lines protection systems, special ventilation pipes, abrasive liquid transport piping.

2. PROPERTIES OF POLYPROPYLENE

Tab.1 ÷ tab.2 show the properties of polypropylene.

Tab.1. Mechanical properties of polypropylene.

Characteristic	*Testing method according to*	*Measurement unit*	*Value*
Extension	ISO R 527 / DIN53455	N/mm^2	>20
Elongation	DIN53455	%	>8
Elasticity modulus	ISO R 527 / DIN53457	N/mm^2	>800
Hardness	ISO2039 / DIN53456	N/mm^2	45
Impact test at 23°C	ISO180 / 1C	KJ/mp	no breaking
Impact test at 0°C	ISO180 / 1C	KJ/mp	160
Impact test at –30°C	ISO180 / 1C	KJ/mp	28
Impact test at 23°C	ISO180 / 1A	KJ/mp	30
Impact test at 0°C	ISO180 / 1A	KJ/mp	3
Impact test at –30°C	ISO180 / 1A	KJ/mp	1.8

Tab.2. Physical and thermal properties of polypropylene.

Characteristic	*Testing method according to*	*Measurement unit*	*Value*
Density at 23°C	ISO1183	g/cm^3	0.909
Creep stress at 190°C / 5kg	ISO1133	g/10min	0.55
Creep stress at 230°C / 2.16kg	ISO1134	g/10min	0.30
Creep stress at 230°C / 5kg	ISO1135	g/10min	1.30
Creep volume at 230°C / 2.16kg	ISO1133	cm^3/10min	0.38
Softening point (VST / A / 50)	ISO306 / DIN53460	°C	132
Softening point (VST / B / 50)	ISO306 / DIN53461	°C	69
Thermal stability HDT A	ISO75 / DIN534561	°C	49
Thermal stability HDT B	ISO75 / DIN534562	°C	70
Thermal transfer coefficient	DIN52612	W/mK	0.24

Polypropylene tubes comply with the international standards that refer to drinkable water transport; the elements of the piping system may be assembled by means of either polyfusion or electrofusion. The piping elements may also be assembled by means of threads, using injected fittings; all threads inserted in these fittings are made of nickel – OT58. Due to their low specific mass, the polypropylene pipes and fittings are easy to handle; their internal surfaces are smooth, which prevent the formation of chalkstone or other residues. The elasticity and isolation capacity considerably reduce the operating noise and, in case of frost, the pipe section may slightly increase without cracking. The abrasion resistance is very good, which allows fluid transport at speeds greater than 7 m/s, even when transporting highly acid or alkaline substances (ph between 1 ÷ 14). Even at high temperatures (110 ÷ 115°C), the polypropylene pipes are resistant to many chemical agents. Due to their flexibility and elasticity, the polypropylene pipes are suitable for use in seismic areas, and the perforation phenomena caused by electric flows are practically inexistent due to the exceptionally low electric conductivity. Also, the sweat and heat dispersion of the fluids are considerably diminished than when using metal pipes.

Due to these characteristics, polypropylene may be used for various appliances, as sanitary pressurized installations in factories or urban areas, air-pressure ducts, drinkable water or alimentary fluids transportation systems, ducts for gardens or green-houses, acid or other aggressive fluids transportation systems, traditional heating systems etc.

3. FITTINGS USED FOR POLYPROPYLENE PIPES ASSEMBLING

Fig.1 and fig.2 show some fittings (connecting elements) that may be used for assembling various polypropylene pipes systems and for solving various situations that are met in their design and installation. These fittings are made by means of injection in special moulds. Fig.1 shows some fittings used for non-dismountable assembling (polyfusion welding) and fig.2 shows some fittings used for dismountable assembling by means of threads on one side and by means of welding on the other side.

Fig.1. Fittings used for non-dismountable assemblies.

Fig.2. Fittings used for dismountable assemblies.

4. EXPERIMENTAL RESEARCH

The experimental research has been carried out at the University of Oradea, by means of a polyfusion welding installation from the instrumentation of the Non-Conventional Technologies Laboratory, TCM Department. Fig.3 shows the polyfusion welding principle and fig.4 shows the welding installation and its interchangeable heads, which are used for various diameters of the pipes and fittings to be welded.

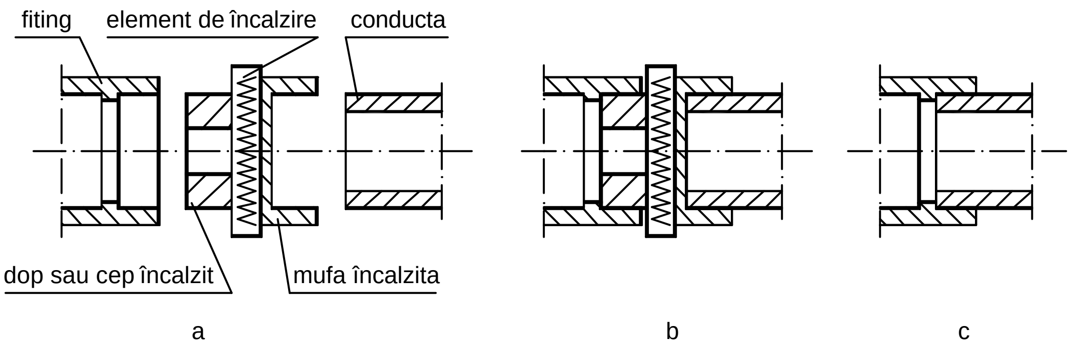


Fig.3. Polyfusion welding principle:
a – elements; b – heating of fitting and pipe; c – welded assembly.

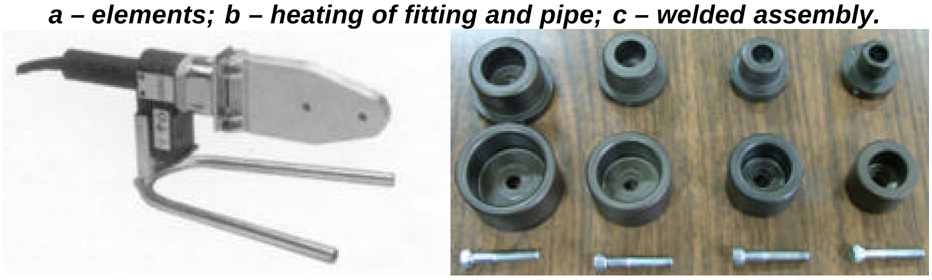


Fig.4. Polyfusion welding installation and its interchangeable heads pairs.

Polypropylene pipes welding can be achieved either by polyfusion or by electrofusion. Polyfusion welding applies to 16 ÷ 125 mm diameter polypropylene pipes; the thermal energy that is necessary for welding is produced by the installation and is transmitted to the elements to be welded by pairs of calibrated interchangeable heads. The welding temperature must be kept in the range of 250 ÷ 270°C. After the removal of the heating element, the pipe end is introduced in the fitting and they cool down together. The pipe outer diameter, the fitting inner diameter and the size of the heating heads are all dimensionally matched, so that the welding pressure is evenly distributed and the welding comes out homogeneous.

The following paragraphs show the polypropylene pipes welding technology, using non-dismountable and dismountable connecting elements.

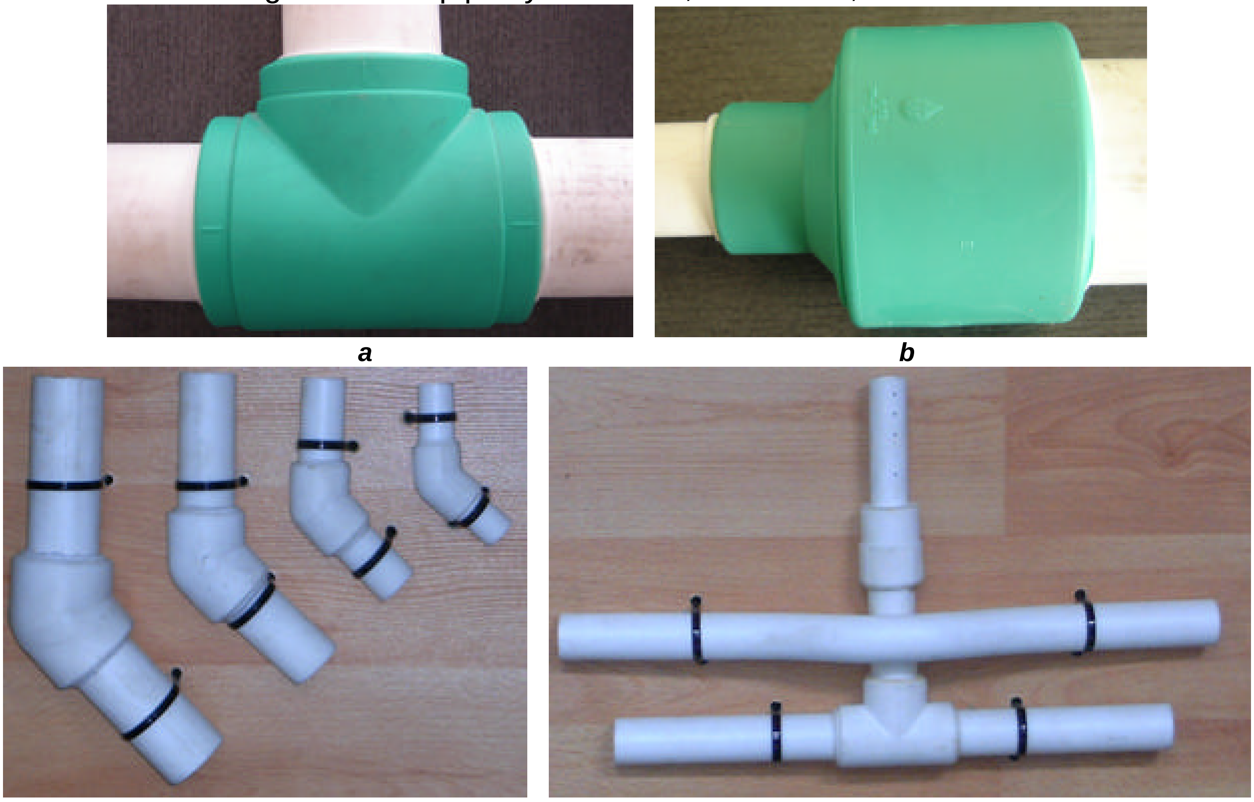
The pipe outer surface and the fitting inner surface must be both clean and impurity-free. Also the pipe end must be clean and cut under the appropriate angle. In order to prevent the presence of micro-fissures caused by transport or mishandling, it is recommended that a portion of 2 cm of the pipe end to be cut off. The use of flames is absolutely forbidden! Before the beginning of welding process, the welding installation must be checked for correct operation and for the achievement of the adequate welding temperature (260°C).

The pipe and the fitting are introduced in the corresponding heating heads and are kept immobile, without any rotation. It is very important that the heating, assembling and cooling times from tab.3 are respected, according to DVS2207.

Tab.3. Heating, assembling and cooling times recommended for welding of polypropylene pipes and fittings (DVS2207).

Pipe diameter [mm]	*Heating time (minim) [s]*	*Assembling time (maxim) [s]*	*Cooling time (minim) [s]*
20	5	4	2
25	7	4	2
32	8	6	4
40	12	6	4
50	18	6	4
63	24	8	6

Fig.5 shows non-dismountable assemblies that were made by means of this installation, observing the DVS2207 standards and recommendations for various diameters and configurations of pipe systems: “T”, reductions, elbows etc.



a *b* *c* *d*

Fig.5. Non-dismountable assemblies; a – “T”, b – reduction, c – elbows, d – overpass.

Fig.6 shows pipe-fitting non-dismountable assemblies which will allow further dismountable assemblies by means of threads.

Fig.6. Dismountable threaded assemblies (left).

Another way of quick making dismountable assemblies between polypropylene and other materials pipes is by means of gaskets. The pipes and the fittings are provided with elastomer gaskets, so that the assembly is made by simply inserting the pipe end in the socket of the other tube or fitting (fig.7). More than that, the gaskets have the same properties and resistance to chemical agents and high temperatures as polypropylene. This assembling method is to be used exclusively by hand.

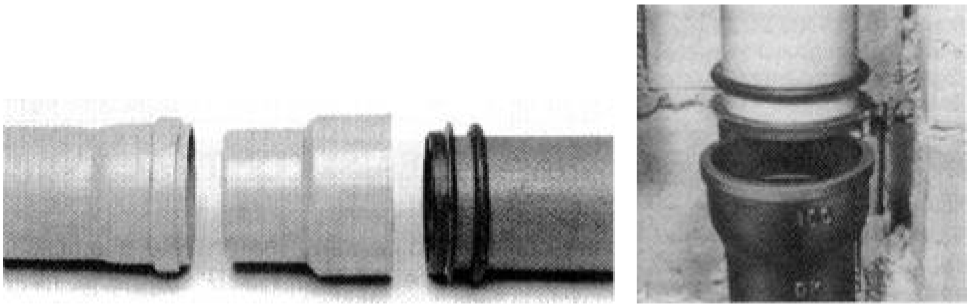


Fig.7. Dismountable assemblies of polypropylene pipes and other pipes, made of different materials.

The experimental research was carried out on the occasion of replacement of the old metallic pipes system from the basements and rooms of the DACIA 113 block of flats (Oradea), under the guidance of the paper authors, by means of the above-shown technologies and devices. Fig.8 shows the new room heating system, made of polypropylene pipes, put together by means of both non-dismountable (welded) and dismountable (threaded) assemblies.

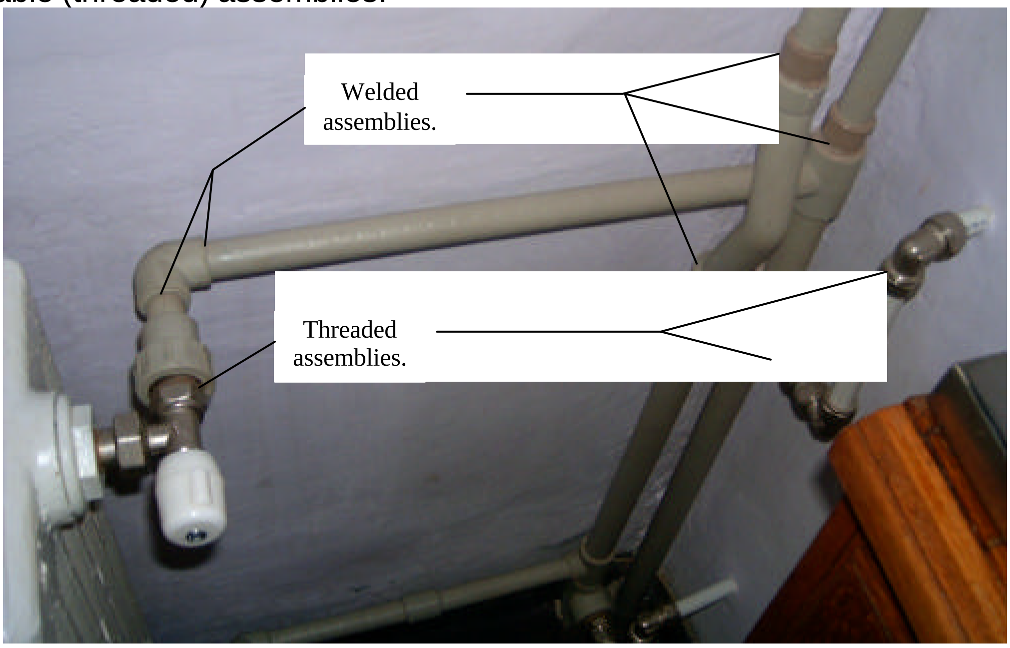


Fig.8. Room heating system made of polypropylene pipes.

5. FLAWS AND WELD CONTROL

The penetrating radiation non-destructive welding control will be carried out in compliance with European and international standards.

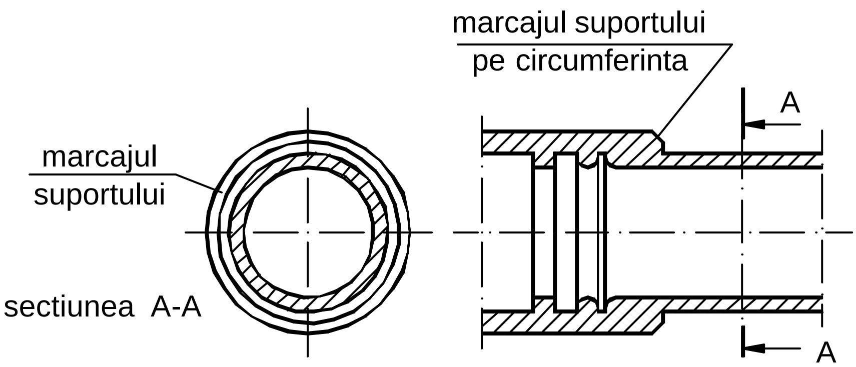


Fig.9. Aligned welded joint, according to the mark on the support.

The control is carried out also visually. The pipe and the coupling element must be aligned and to bear evident marks on the coupling element surface (fig.9). The fitting end must be visible all around its circumference.

The welded seams must be proportional, as shown in fig.10.a and b; cases c and d are not admitted unless for small pressure values.

The joint between the coupling element and the pipe end must be proportioned at both ends, as shown in fig.11.a and b; case c is admitted for a max.2 mm no-penetration.

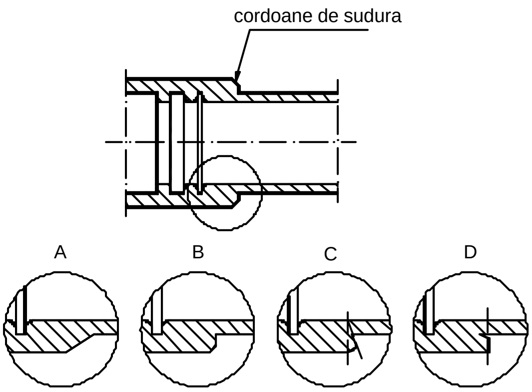


Fig.10. Welded seam at the end of the fitting.

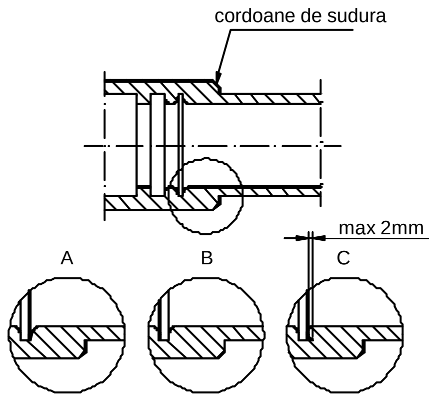


Fig.11. Welded seam between pipe and fitting.

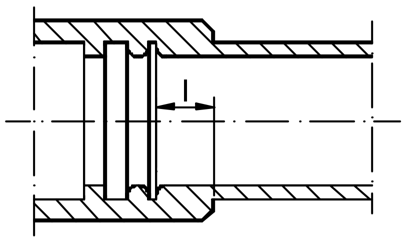


Fig.12. Penetration depth at polyfusion welding.

The penetration depth *l*, measured from the coupling element end to the pipe terminal edge (fig.12), must comply with tab.4, within a +1/-2 mm margin. The penetration depth is measured with a venire depth gauge.

Tab.4. Penetration depth versus pipe diameter.

Nr..	Pipe diameter [mm]	Penetration depth [mm]	
		A-type	B-type
1	20	12	14
2	25	13	16
3	32	14,5	18
4	40	17	20
5	50	–	23
6	63	24	27
7	75	–	31
8	90	29	35
9	110	–	41
10	125	35	44

The range between l_{min} and l_{max} (minimum and maximum penetration depth), noted as ?l, must not exceed 2 mm (fig.13):

$$\Delta l = l_{max} - l_{min} \leq 2 \text{ mm} \quad (1)$$

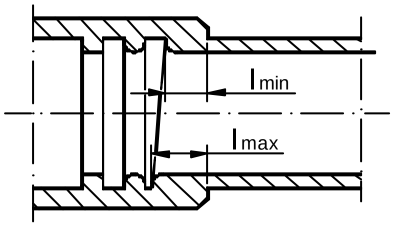


Fig.13. Penetration depth limits for polyfusion welding.

The welding absence between the pipe and the coupling element chamfering must not extend under the coupling element end (fig.14).

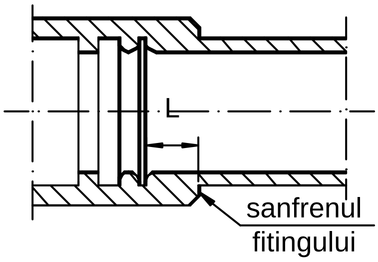


Fig.14. Welded seam length for polyfusion welding.

No solid or gaseous inclusions are admitted in welded joints (fig.15).

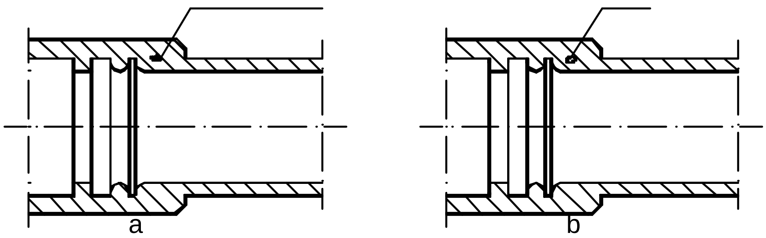


Fig.15. Internal flaws at polyfusion welding: a – solid inclusions; b – gaseous inclusions.

The interior burr *y* must be 5% of the internal medium diameter (fig.16):

$$y = 0.05 \cdot d_i \qquad (2)$$

Inside the coupling element, the pipe must be evenly welded, with no deformations (fig.17).

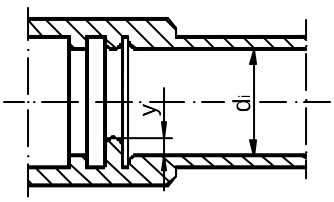


Fig.16. Burr height* y *in polyfusion welding.

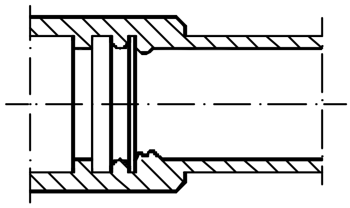


Fig.17. Pipe deformation inside the coupling element, in polyfusion welding.

According to the results of the experimental research, the observation of the welding temperatures and times and of the technological hygiene leads to correct and homogeneous welding, and the flaws that may occur are caused only by material defects, inclusions or impurity. Fig.18 shows a section of a correctly assembled "T" joint; the homogeneous welding is clearly visible, featuring no discontinuity, voids or other flaws. The internal and external burrs are also visible, which correspond to the international standards and recommendations.

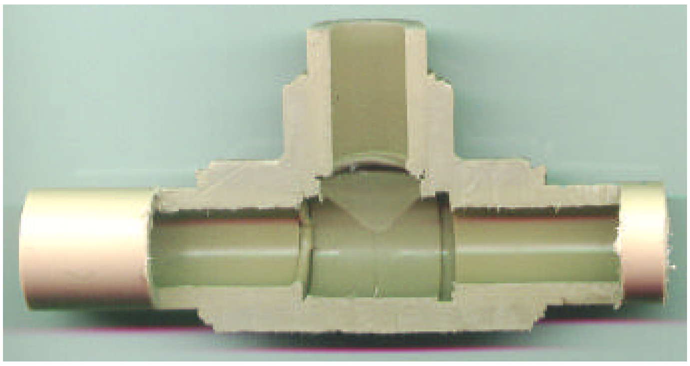


Fig.18. Section of a "T" joint, made by polyfusion.

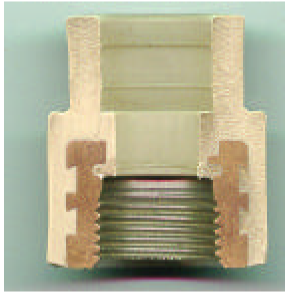


Fig.19. Section of a threaded fitting, made by injection.

Threaded fittings made by injection are very important in dismountable assemblies used in pressurized fluid transportation systems. These fittings must be perfectly tight at the polypropylene-metal internal interface. Fig.19 shows a section through such a fitting.

6. CONCLUSIONS

The polypropylene pipe systems are the best and the most convenient economical solution, considering the low costs, the durability, the easy installation and inexpensive future maintenance and repairs. Because they don't corrode, the polypropylene pipes are more lasting than the steel pipes. Also, due to polypropylene excellent properties, the repairs are more infrequent. Polyfusion and electrofusion welding can easily make safe, durable and homogeneous joints. The products are light and flexible, thus allowing easy transport and long tubes installation.

The advantages of polypropylene pipes allow its use in hot water and thermal agent transportation systems (100 – 110°C). Using portable devices, the positioning and welding of pipes can be carried out on the spot, even in rough conditions.

The cost-analysis was made on different parameters, considering the pipe cost, transportation, deploying, special devices, welding etc.; the results indicate that the cost is approx. 65% relative to the case of using steel tubes.

7. REFERENCES

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[10] ***, DVS2208 – echipamente si utilaje pentru sudarea materialelor termoplastice;
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