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MOULDING AND EVALUATION OF WATER METER TOP-PLATES FROM SHORT GLASS FIBRE REINFORCED CARILON POLYMERS

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(July 1993 - March 1995)

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K. Van Poppel and A. Wakker

Team member: E.M. Esselens

Approved by: J.A. Verhave

SUMMARY

Short glass fibre reinforced CARILON polymers have been evaluated by Schlumberger-Massy for a potential application in cold water meters. At the same time two alternative materials, PPA and PA66.6 have been investigated against PPS, the material currently used for the water meter top-plates.
The top-plates have been successfully injection moulded from CARILON DP R1130 and RDP R1150. Compared to PPS, a 30% cycle time reduction could be established for CARILON polymer. The main requirements are static and dynamic burst pressure performance upon accelerated water ageing. These tests have been carried out by Schlumberger for the five materials. CARILON polymers were found to be technically suitable for the water meter top-plates.

August, 1995.

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1 INTRODUCTION

Mid 1993, CARILON polymer was introduced to Schlumberger Industries at the Massy location. Schlumberger-Massy (Appendix 1) is the central Schlumberger laboratory for all electricity-, gas- and water meters for domestic as well as industrial use. The prime activity is the manufacture of plastic parts for water meters.
The main performance criteria are static and dynamic burst pressure performance upon accelerated water ageing. Based on its water insensitivity, hydrolytic stability and its good balance of mechanical properties, CARILON polymer was thought to be an attractive candidate for water meter top-plates. It was decided to test CARILON polymer in one of Schlumbergers most demanding top-plates (Figure 1, Table 1), which was at that time moulded from PPS GF/MF 60.

Schlumberger were sampled with two CARILON grades: standard GF 30% black coloured DP R1130-9000 and a GF 50% RDP R1150. The latter research grade was compounded at CRCSL. At the same time Schlumberger tested two other alternative new materials, being PPA GF 40/MF 25 and PA66.6 LGF 60. In the present work the relevant test results are reported and a technical judgement of the potential of CARILON polymers in water meters is made.

2 THERMOPLASTIC WATER METERS

In water meters one always has to distinguish between the actual meter part and the housing part. Housings of cold water meters are from PPO or PPS, those of hot water meters (used in heating systems) are from PPS. In general, the parts are designed based on mineral or glass filled grades.
Two different types of meters are used, the plunger type and the propeller type. The plunger type is the most accurate because volume flow of water is determined directly. In cold water, these meters are out of mineral filled PS or SAN. These materials have low shrinkage, good dimensional stability and low coefficient of thermal expansion (10^{-6}). In hot water, mineral filled PPS and PES are used. Propeller type meters only work if the material density is lower than or equal to that of water. In cold water PP fulfils, in hot water PA11/12 needs to be used. PA6/66 cannot be used because of water absorbtion.
Currently, PPS is used for the most demanding water meter top-plates. However, because PPS is extremely brittle, difficult to process and expensive, Schlumberger-Massy are investigating alternative materials. If the relevant requirements for these top-plates were to be achieved, a potential of 700.000 water meters per year produced in France, equalling 42 T/annum, could possibly be realized.

3 EXPERIMENTAL

3.1 Injection Moulding

CARILON DP R1130 (lot 07QAD0002) was initially used for injection moulding of the water meter top-plates at Schlumberger. The clamping side of the Netstal Neomat 350 with a 150 ton clamping force was provided with a 3 cavity mould and a hot runner system.
Mouldings were made at melt temperatures of 240°C and 260°C which resulted in a marginally improved surface appearance at the higher melt temperature. However, since appearance was not a prerequisite, it was decided to mould the water meter top-plate at the lower temperature to avoid potential effects of crosslinking.

The cycle time was optimized by reducing the cooling time with 50% which necessitated an increase in screw speed of 20% to prepare a full shot. In addition, the holding pressure time could be lowered with 6 seconds. As a result the total cycle time was reduced to 76 seconds for CARILON polymer compared to 107 seconds for PPS. Injection moulding conditions are listed in Table 2.
The dimensions of the DP R1130 parts were somewhat smaller than those of the PPS part but apparently acceptable. The lower density of CARILON polymer (1.45 versus 1.98 g/cm^3 for PPS) provides an additional advantage over PPS. In addition, Schlumberger commented that CARILON polymer was much easier to mould than PPS.
CARILON RDP R1150 was moulded without problems under similar conditions, see also Table 2. No information was available concerning the mouldability and cycle time of PPA and PA66.6.

3.2 Evaluation

The performance of CARILON DP R1130, RDP R1150 and the PPA and PA66.6 grades have been evaluated against PPS for cold water meters. An overview of their glass content, price and density can be found in Table 3. Note that the density of PPA is similar to CARILON polymer and that of PA66.6 is somewhat higher.

Schlumberger have subjected the water meter top-plates to two in-house tests i.e. a static burst pressure test and a dynamic pressure or fatigue test. These tests have been carried out as a function of ageing in water at 90°C upto 90 days full immersion of the top-plates in Paris water (chlorinated). The life time of cold water meters appears to be 20 years. Schlumberger uses this accelerated ageing test for life time extrapolation.

3.2.1 Static burst pressure test

The burst strength resistance has been measured on the moulded top-plates fixed in a metal frame and filled with cold water, simulating the water meter. The entire meter was brought under a burst pressure within 20 seconds pressure increase until the plastic part failed.
This measurement has been carried out before and after immersion of the top-plates in 90°C water for 90 days. The specification for the initial static burst pressure is minimal 50 bars before and minimal 40 bars after ageing.

3.2.2 Dynamic pressure test

The dynamic pressure test or fatigue test consists of a top-plate fixed in a water meter housing filled with water at 85°C, which is submitted to intermittent pressure shocks of 25 bars at a frequency of 1 Hz. The number of cycles have been determined before and after ageing. The requirement for the fatigue test is minimal 12.500 cycles after ageing in 90°C water for 90 days.

4 RESULTS AND DISCUSSION

4.1 Static Burst Pressure

The results of the burst strength resistance generated by Schlumberger are shown in Figure 2. The burst pressure is presented for the five materials before and after ageing.
Apparently CARILON, PPS and PPA perform similarly, while PA66.6 gives better results. All materials have reached an initial burst pressure of minimal 50 bar. After ageing for 90 days in 90°C water, all materials retain a burst pressure of minimal 40 bars. Note that the static burst pressures of RDP R1150 are systematically lower than these of DP R1130.
It is clear that all materials meet the requirements set by Schlumberger regarding the static burst pressure test.

4.2 Dynamic Pressure

The fatigue performance of the five materials is shown in Figure 3. This bar graph indicates the number of cycles reached before failure of the part before and after 90 days ageing in 90°C water.
PPS and PA66.6 exhibit a good fatigue performance of respectively 85.000 and 100.000 cycles before ageing. However, the water sensitivity of both materials causes a detrimental effect on the dynamic pressure test. After the water ageing the number of cycles dropped to 20.000 for PPS and to 10.000 for PA66.6. PPA performed relatively poor. Upon 90°C water ageing, no fatigue life performance was left after 90 days.
CARILON DP R1130 showed an insufficient life time of 5000 cycles after ageing. Fatigue performance was significantly improved with RDP R1150 both before and after ageing. Fatigue life approximately doubled upto 10.000 cycles after ageing, just below the required level.

Static and dynamic tests have been carried out as a function of ageing in 90°C water upto 90 days full immersion of the top-plate in Paris water. Hence ageing represents only the effects of water, no oxidative ageing.

The fatigue performance of CARILON RDP R1150 has improved versus the DP R1130 grade but at the expense of loss of static burst pressure. Nevertheless, all materials passed the specification for the static burst test.
The improvement of the fatigue can be attributed to a larger stiffness, hence smaller strains. The relatively smaller loss in static burst pressure is most likely limited to an (unknown) absolute glass fibre loading limit. This limit is determined by the glass fibre volume fraction and the fibre matrix adhesion. It is known that adhesion between the glass fibre currently used (OC 429YZ) and the CARILON matrix is relatively poor when compared to adhesion found in glass filled polyamides[1]. It is expected that a better fibre matrix adhesion will increase the static burst pressure, decrease the sensitivity of static burst pressure to glass fibre loading and will further improve the fatigue life.

Note that the DP R1130 and RDP R1150 top-plate surfaces had turned dark brown and black respectively. Possibly, the fast discolouration is caused by degraded CARILON polymer around the glass fibres. The above is a surface effect only and thought not to be detrimental to mechanical integrity. Psychologically it may be wise to sample black GF CARILON in the future for such applications.

5 CONCLUSION

CARILON DP R1130 and RDP R1150 water meter top-plates have been successfully injection moulded at Schlumberger. Compared to PPS, a reduction in cycle time of 30% has been established for DP R1130.

Schlumberger concluded that CARILON compounds are technically suitable for cold water meters. It was confirmed that CARILON polymer was the least water sensitive of all materials investigated. However, for the PPS top-plate, Schlumberger have decided to return to a metal design due to a change of technology requiring thinner parts. Schlumberger advised that CARILON polymers could compete in a lower ranged class of top-plates from PPO.

Louvain-la-Neuve, August, 1995.

References

1. A. Wakker, "Fatigue performance of CARILON R1130 polymer and competing reinforced engineering polymers: a scouting study", LVGR.95.037.

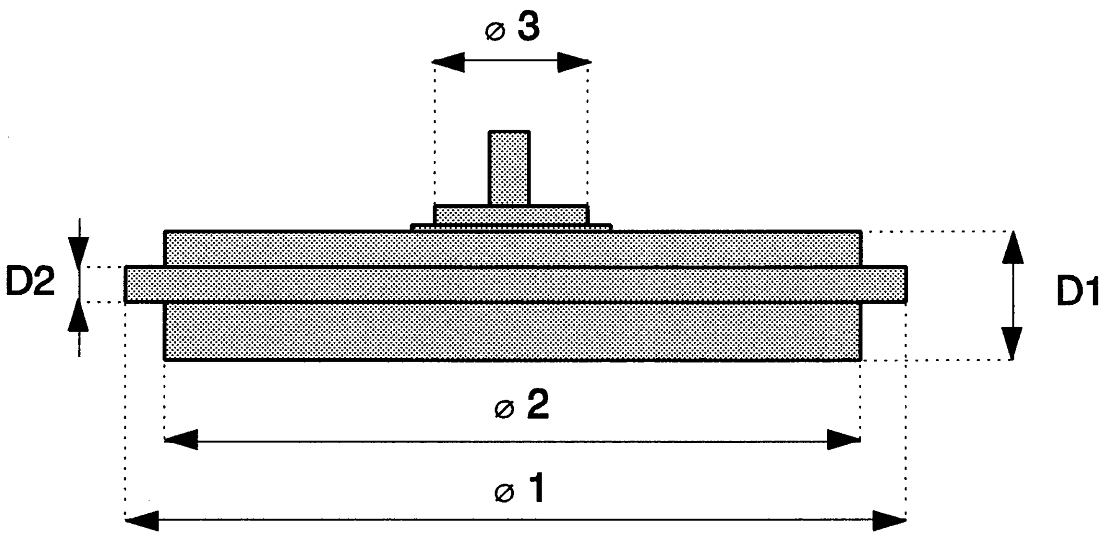

Figure 1: Water meter top-plate

		DP R1130
Weight,	g	58.6
Density,	g/cm^3	1.45
D1,	mm	15.35
D2,	mm	4.53
∅1,	mm	78.24
∅2,	mm	69.77
∅3,	mm	20.22

Table 1: Dimensions of the water meter top-plate

	DP R1130-9000	RDP R1150-1000	PPS
Machine	Netstal Neomat 350	Netstal Neomat 350	Netstal Neomat 350
Nozzle type	open	open	open
Mould	multi-cavity (3) hot runner system	multi-cavity (3) hot runner system	multi-cavity (3) hot runner system
Temperature settings, (from hopper to die) °C	230 -> 240	200 -> 260	190 -> 260
Temperature hot runner, °C	250		260
Mould temperature, °C	80	90	80
Injection pressure, bar	1100	1100	1100
Injection time, s	3.82	1	3.82
Injection speed, mm/s	30		30
Holding pressure, bar	750 -> 800	1100 -> 900	650
Holding time, s	39	30	45
Cooling time, s	25	30	50
Total cycle time, s	76	68	107

Table 2: Injection moulding conditions

Polymer type	Grade	Filler content	Density g/cm^3	Price FF/kg
PK	CARILON DP R1130-9000	30% GF	1.45	35
PK	CARILON RDP R1150-1000	50% GF*	1.59	
PPS	Ryton BR 111	60% GF/MF	1.98	30
PPA	Amodel APXM 92-136	40% GF, 25% MF	1.43	50
PA 66.6 (copol.)	Verton RF 700-12 FVL	60% LGF	1.7	30

* : GF = Owens Corning 429 YZ ; R1000 lot 28

Table 3: General information of the materials used

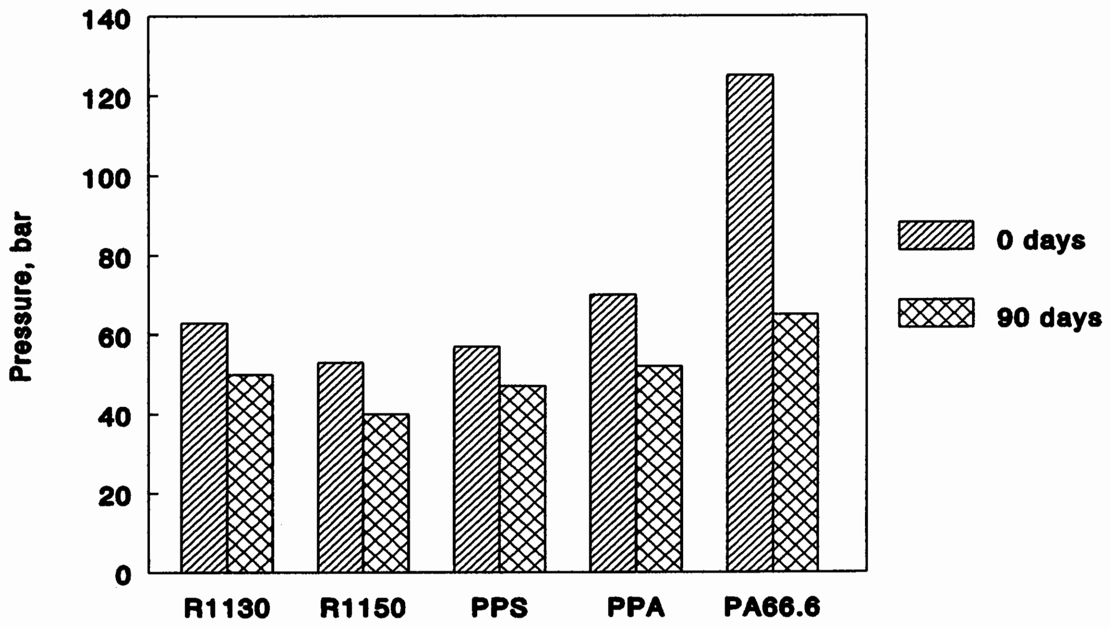

Figure 2: Static burst pressure measured before and after ageing in 90°C water for 90 days

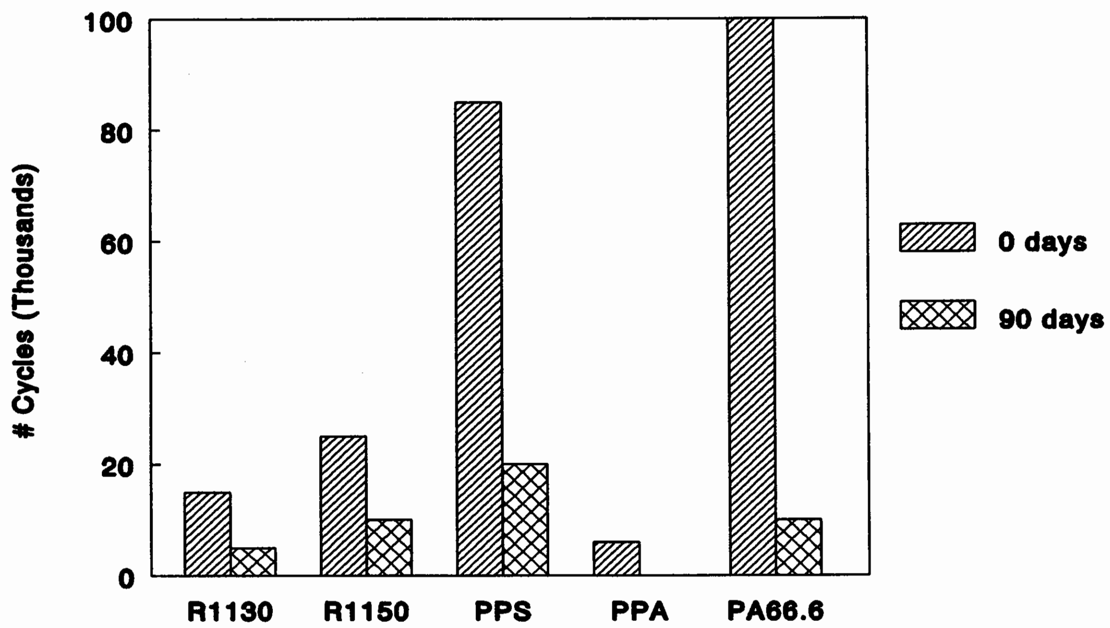

Figure 3: Dynamic burst pressure measured before and after ageing in 90°C water for 90 days

APPENDIX 1

Schlumberger Industries

Schlumberger Industries has grown from originally a French company only involved in the drilling and pumping of oil to a large multinational with head offices in Paris and New York with a variety of very specialised activities.
They are organised in two main sectors, i.e. 'oil and services' and 'systems and measurement'. The oil and services sector, with an annual turnover of 3.5 billion dollar, is mainly involved in contract oil exploration and production activities for the major oil companies. The second sector, with an annual turnover of 2.5 billion dollar, is subdivided in two sections referred to as 'industry' and 'technology'. The main activities in the industry section is the manufacture of water, gas and electricity meters for domestic as well as industrial use. This is done on a global basis with plants in various countries. The technology section covers a variety of activities ranging from the manufacture of credit cards and parking meters to petrol pump meters.

The prime activity at the Schlumberger-Massy-site plant is the manufacture of plastic parts for water meters. A large number of parts are also subcontracted under their supervision to custom moulders. Schlumberger-Massy have 45 moulding machines varying in clamping pressure form 30 to 300 ton (Arburg, Demag and Netstal). Approximately 700 different moulds are being used, with 1 to 20 cavities and shot weights ranging from 1g to 1kg. Production sizes range from 10 to several million parts. Some 150 grades cover the total scala of thermoplastic materials used.

Schlumberger-Massy are also the central R&D resource for the use of plastics for the Schlumberger group. The laboratory is very well equipped for material characterisation, e.g. high temperature GPC, IR, HPLC, DSC, TMA and dynamic rheology equipment. Performance testing equipment at Massy is concentrated specifically on the use of plastics in water meters. Schlumberger-Massy have access to performance testing equipment specific to other areas of their activities at each specific plant, e.g. for gas meters at the plant in Reims.

Contact person at Massy was Mr. E. Lavrut. He has been very enthusiastic about CARILON polymer, but unfortunately will move to another Schlumberger location as from August 1995. Mr. Lavrut has reported relevant results obtained with CARILON polymers internally. No other contacts within Schlumberger have been established. During the two years collaboration with Schlumberger, despite the enthusiasm of Mr. Lavrut, it became clear that Schlumberger are a traditional metals oriented company rather than a more innovative plastics user.

APPENDIX 2

List of abbreviations

DP	Development product
GF	Glass filled
LGF	Long glass fibre
MF	Mineral filled
PA6/66	Polyamides 6 and 66
PA66.6 copol.	Polyamide 66 polyamide 6 copolymer
PA11/12	Polyamides 11 and 12
PES	Polyethersulfone
PK	Polyketone
PP	Polypropylene
PPA	Polyphthalamide
PPO	Polyphenyleneoxide
PPS	Polyphenylenesulfide
PS	Polystyrene
R1130	CARILON polymer R1000 filled with 30% glass fibres
R1150	CARILON polymer R1000 filled with 50% glass fibres
RDP	Research Development Product
SAN	Styrene-acrylonitrile

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