NEW TECHNOLOGY APPLICATION

PROPOSED REPLACEMENT/REHABILITATION OF A 6 INCH TRANSMISSION LINE UTLIZING A REINFORCED THERMOPLASTIC PIPE

(RTP)

FOR

NGO TRANSMISSION, INC'S TENNESSEE PIPELINE SEGMENTS 9A and 9B

From

NGO TRANSMISSION, INC TAP TO THE TENNESSEE EASTERN PIPELINE (SPRATT STATION)

IN RICH HILL TOWNSHIP IN MUSKINGUM COUNTY OHIO

To

NGO TRANSMISSION, INC's _new McDonald Rd Station__________________

IN SALT CREEK TOWNSHIP IN MUSKINGUM OHIO

Submitted By:

NGO TRANSMISSION, INC.

August 7, 2017

BACKGROUND INFORMATION AND CALCULATIONS

NGO transmission, Inc. proposes to replace a portion of its six-inch Tennessee Line which was installed in 1955. The current steel line was installed with a design pressure of 225 creating a design SMYS of 11.09%. Currently this pipeline operates at an MAOP of 175PSI and the proposed replacement would include approximately 28,500ft of pipe. This replacement would involve a combination of the insertion of a reinforced thermoplastic pipe (RTP) inside of the existing six-inch steel pipe, boring of reinforced thermoplastic pipe (RTP), or plowing of reinforced thermoplastic pipe (RTP). The method used to install the RTP pipe will be determined by the depth of the current active pipe and the terrain encountered along the existing easement. All bored, plowed or open ditch installation of RTP pipe will provide a minimum of three foot of burial depth.

NGO Transmission's six-inch Tennessee line is supplied from Kinder Morgan's Tennessee Gas Pipeline. Currently, the Tennessee Gas Pipeline company operates the inlet piping of NGOT's Spratt Station at a7 90PSI MAOP. NGO Transmission will design and install all equipment including the RTP pipe rated for a 1,000PSI continuous maximum operating pressure (MAOP). All installed RTP pipe will be a 4-inch OD with a 3.45 inch ID. A map of the pipeline layout is attached as Reference 1.

(i) Description of the Reinforced Thermoplastic Pipe (RTP) – overview:

Specialty RTP, LLC's reinforced thermoplastic pipe (RTP) is comprised of three distinct layers. The inner liner is designed as a corrosion and low permeation barrier layer for the flow of natural gas, a reinforcement layer that provides the static and cyclic load strength to withstand the pressure environment and an outer jacket to provide an abrasion resistant jacket to protect the reinforcement layer. The pipe is terminated with metallic stainless steel couplings swaged onto the RTP to "lock" the reinforcement layer in place. The RTP pipe and couplings must be combined to create a system and one cannot work without the other.

References:

2. Pull Through Case Study
3. Picture of RTP Pipe
4. Picture of a Coupling Swaged onto the Pipe
5. Specialty RTP Brochure

(ii) Description of the Specialty RTP Pipe – Components:

Inner Liner:

The inner liner will be comprised of a Nylon 6 Polymer because of its inherent resistance to hydrocarbons. The primary objective is to withstand the influence of Methane gas. The attached report details the performance of the Nylon used for this application for chemical compatibility and low permeation. The result is no de-rating of the pipe when a Nylon liner is required.

References:
6. Chemical Compatibility
7. Nylon Specification Sheet
8. Nylon Permeation Data

Reinforcement Layer:
Aramid Twaron Aramid fiber provides the reinforcement with a triaxial braid design where by a cross braid pattern provides the hoop strength to maintain the pressure requirements of the pipe and longitudinal fibers running parallel to the pipe length provides resistance against tensile loads.

Aramid fiber is chosen because of its strength, cyclic loading resistance, and its resistance to oilfield environments.

References:
9. Twaron Spec Sheet 2300
10. Twaron Technical Performance Manual

Outer Jacket:
The outer jacket is an abrasion resistant cover designed to protect the braid and resist the gathering line production flow stream. It is Polypropylene with a UV inhibitor additive. In addition to chemical compatibility and permeation resistance, abrasion testing is provided below. The Taber abrasion testing protocol uses an abrasive wheel with one kilogram of weight exerted on to the test sample. The weight of the sample is compared both before and after 1,000 revolutions of the abrasive wheel.

References:
11. Taber Abrasion Data
12. Sand Abrasion Test
13. Specification Sheet

(iii) Maximum source pressure (MSP) for the Line

The input source is from the Tennessee Gas Transmission pipeline. The input pressure varies but has been derated to 790PSI maximum allowable operating pressure (MAOP).

(iv) Maximum allowable operating pressure (MAOP) of the RTP and calculations:

Summary: MAOP for the proposed pipeline is 1,000 psig at 140°F.

Calculations:

a. 4” RTP pipe:

The design strength of the RTP pipe is determined by the stress rupture characteristics of the aramid fiber. This can be defined as:

$$P = 2*F*n*\sin(\theta)/D*L$$

Where:

P = Burst pressure of the Pipe
F = Strength of each Cross Fiber
n = Number of Cross Fibers
D = Outside Diameter of the Inner Liner
P = Pitch or length reinforcement travels along pipe after 1 360 degree revolution around the pipe
Θ = Angle of Braid

The long-term strength regression data for Specialty RTP's tubing is:

Log(stress) = 2.1826- 0.05402(log time)
Stress is in bars of pressure and time is in hours

	Hours	Pressure (Bar)	Pressure(PSI)
Short Term Burst Strength	0.1	172.43	2,500.28
Medium Term Strengh	1,000.0	104.84	1,520.23
20 Year Strength	175,200.0	79.31	1,150.04

In addition, the pipe strength is increased by using a 95% confidence interval and divided by a .67 safety factor. The result is a short term burst pressure as follows:

Design Pressure (PSI)	Short Term Burst (PSI)	ST/Design Pressure Multiplier
1,000	3,300	3.3X

Short term testing is in accordance with ASTM D-1599 at Design Temperature (in this case testing was performed at 140F)

<u>Reference:</u>

14. Creep and Stress Rupture of Aramid Fibre

b. <u>Connections</u>:

Specialty RTP connectors will consist of two types:

1. Union couplings to join two sections of RTP pipe together of an approximate length of 2,800 ft. individual spool lengths

2. End terminations will be double raised face ANSI 600 flanges when connecting to flanges and weld style termination couplings designed

for Schedule 40 pipe with a reducer to match up with the existing 6 inch pipe for certain sections of the line

All unions will utilize Duplex 2205 Stainless in accordance with the operating environments spelled out in NACE MR 0175 Specification and will be in accordance to the existing ANSI flange rating currently on the 6” and 4” steel pipe terminations.

The end terminations will be zinc chromate plated carbon steel.

The pipe is designed to withstand a maximum tensile load of 16,000lbs as the pipe coupling system. A two mile pull of RTP pipe requires 8,300lbs of pull force. A tensile test of the actual pipe coupling system will be part of the factory acceptance testing to assure the pipe will not be damaged during pulling. In addition, load sensors are applied to the pulling ropes to assure maximum tensile loads are not exceeded.

The only expansion of the pipe is due to pressure. The ability to withstand pull out from the coupling due to expansion from pressure is determined by the longitudinal reinforcement braids which resist the elongation. The pictures below show the cross braid which provides the hoop strength and the longitudinal reinforcement, which resist elongation. Thermal expansion or contraction is not an issue with flexible reinforced thermoplastic pipe.

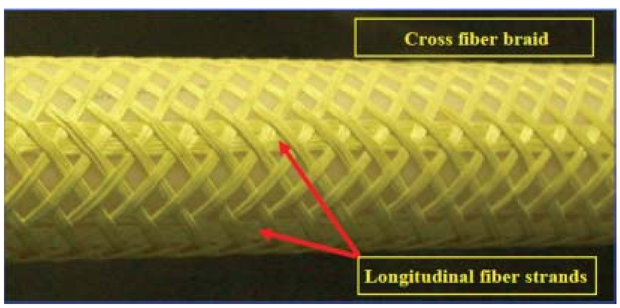

Figure 1:

By adjusting the number of longitudinal braids, Specialty RTP can adjust the tensile load required for the application. For the application applied for, Specialty RTP has taken the MAOP of the line which is 750PSI and multiplied it by 1.5 for the hydrotest pressure and then determined the tensile load on the pipe. (Cross sectional area times pressure). The chart below summarizes the calculations.

Tensile Load Calculations		
ID of RTP (in)	3.45	
Cross Sectional Area of 4" (in^2)	9.35	
Tensile Load at 750PSI (lbs)	701	
Tensile Load at 1,125PSI (lbs)	10,517	

The pipe should not see more than 10,517 lbs. of tensile load and it has been designed to withstand 16,000lbs of tensile load.

Existing Steel Pipeline Requirements:

The existing 6 inch steel line currently operates at 500PSI and has a pressure regulator a the connection to the Tennessee Gas Transmission line which has a maximum pressure rating of 790PSI. The regulator will be set to 790PSI for the the RTP line inserted into the existing 6 inch steel line

(v) <u>Hydrostatic test pressure (HTP), test medium, and period of time:</u>

Hydrostatic test pressure for the Specialty RTP pipeline and risers: 1,500 psig

Test medium: Water
Test period: 8 hours
Calculation:
HTP = 1.50 x MAOP
= 1.50 x 1,000
= 1,500 psig

<u>References:</u>

15. Specialty RTP Hydrostatic Test Procedure

(vi) <u>MAOP of tie-in piping:</u>

Any steel tie in piping requirements will be Schedule 40 Steel

(vii) <u>Summary of the installation procedure:</u>

The installation procedure is as follows:

1. Pig the line to clean out any debris
2. Pig a pulling synthetic rope with 5X the maximum pulling force tensile rating through the existing pipeline.
3. Pull the Thermoflex pipe through the existing pipeline
4. Flange off against the existing termination flanges for the existing pipe
5. Hydro-test
6. Commission

<u>Reference:</u>

16. Case Studies (2)
17. Texas RR Commission approval of a very similar system
18. DOT approval of an RTP gas line in Mobile Bay

(viii) <u>Proposed date for commencing installation and estimated time for construction:</u>

Construction will be performed in two phases. The first is approximately 1-2 miles adjacent to the Tennessee Gas Transmission connection. It will be comprised of some trenching, Bores and Pull Throughs in accordance with the 49 CFR Part 192 Regulations for construction. Commence construction date: October 2017

The balance of the line will be a pull through and finished in the spring of 2018.

Estimated construction time:

Phase 1: 10 Days
Phase 2: 15 Days

(ix) <u>Type of protection to the offended crossing pipelines:</u>

The Specialty RTP pipe shall be incased inside of the existing 6” pipeline except for sections in phase one where bores are required because the existing steel is exposed on the surface.

The 6” pipeline serves as a conduit/casing for the RTP pipe

The Bores will be below 3 ft. minimal burial depth

(x) <u>Additional design precautions</u>

There will be a pressure sensor on the line to assure integrity of the pipeline

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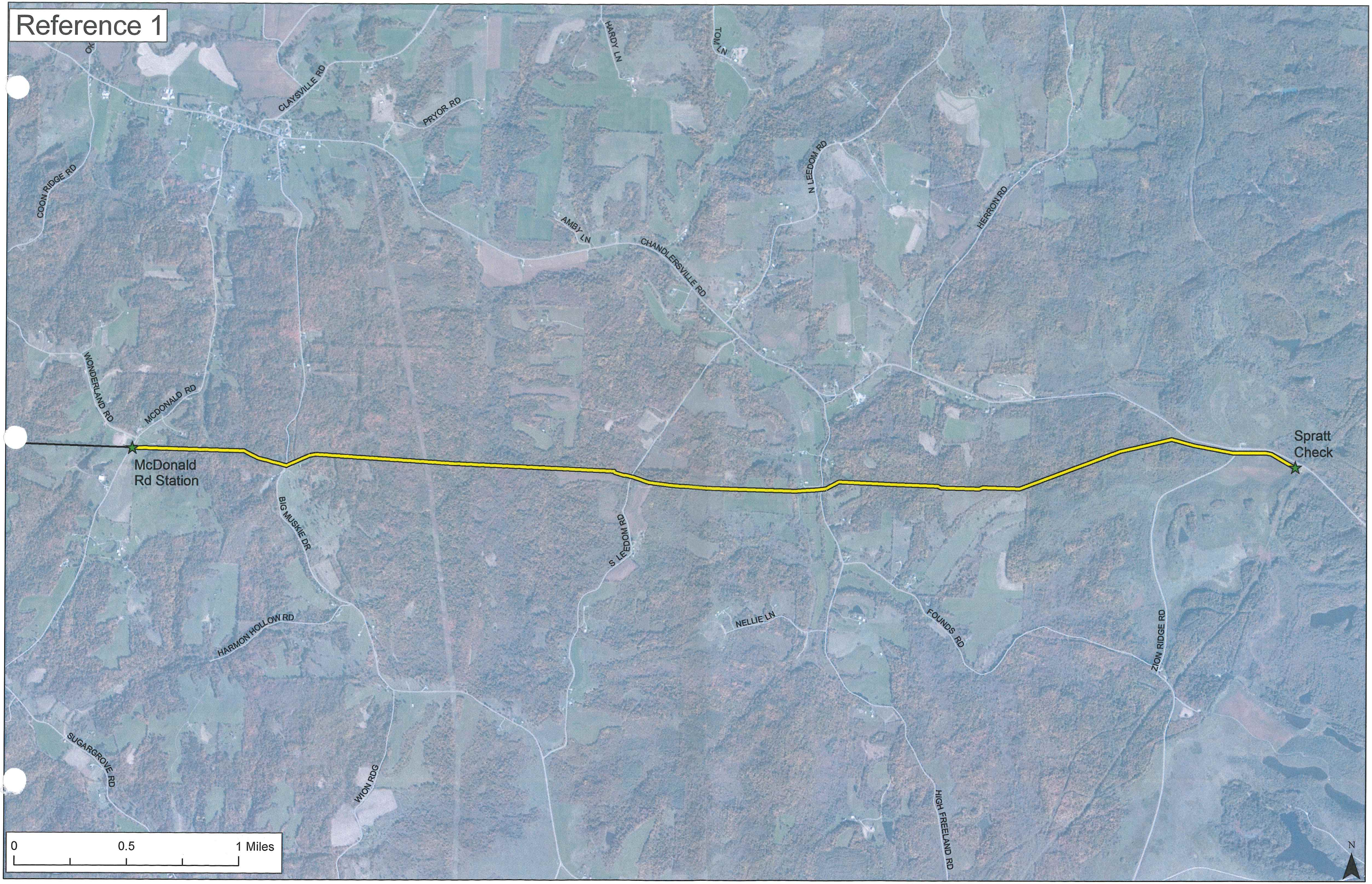


Reference 1
CLAYSVILLE RD
PRYOR RD
HARDY LN
TOM LN
COON RIDGE RD
N LEEDOM RD
HERRON RD
AMBY LN
CHANDLERSVILLE RD
WONDERLAND RD
MCDONALD RD
McDonald Rd Station
Spratt Check
BIG MUSKIE DR
S LEEDOM RD
NELLIE LN
FOUNDS RD
ZION RIDGE RD
HARMON HOLLOW RD
SUGARGROVE RD
WION RDG
HIGH FREELAND RD
0
0.5
1 Miles
N

SPECIALTY RTP
Technology to Flow Mature Wells

RTP-Rehab™ Case Study

Installation of 3" RTP Pipelines Inside Corroded Steel Flow Lines Under a Ship Channel in the Gulf of Mexico

Background

An operator in the Gulf of Mexico had several gas wells shut in due to multiple corroded pipelines. The two lines to be rehabilitated were approximately 1.7 miles (~ 9,300 ft) in length and between two platforms (Figure 1. shows view of one platform across ship channel). One line will flow gas the other line is for flow of produced liquids containing H2S levels as high as 4,000 PPM. The gas line was DOT jurisdictional. The company selected Specialty RTP's reinforced thermoplastic pipe (RTP) as the best option to take advantage of rapid low cost installation and to minimize ongoing maintenance costs.

Figure 1. View of Platform Across Ship Channel

Figure 2. RTP on 12 ft OD Spools

RTP-Rehab™ System Selected

Due to the high levels of H2S:

- The RTP selected was comprised of a polyphenylene sulfide (PPS) liner, aramid reinforcement and a polypropylene jacket
- The union couplings to join two long lengths of RTP were constructed Alloy 625 inserts

In order to maintain critical velocity to move solids (sand) in the produced liquids line, and minimize pressure drop for the gas line, the optimal RTP size was determined to be 3" OD; with a design pressure of 1,600 PSI to be consistent with original steel line design pressure.

Installation

The 3” RTP for each line was supplied on three 12 ft OD spools (see Figure 2), with one spool placed in an A-frame positioned on the mezzanine deck and the remaining two spools were staged on the platform’s helideck (Figure 3 shows lifting RTP spool onto mezzanine deck).

A synthetic rope was utilized to pull the 3” RTP between platforms, through 6” steel pipelines from riser flange to riser flange (Figure 4 shows RTP being pulled from spool on mezzanine deck to riser flange). All work was performed from the decks of the platforms.

The total time required for pull through of each RTP line was 1 day.

A hydro test was performed on each RTP at 2,400 PSI for 24 hours, per the state regulators.

Figure 3. Lifting RTP Spool onto Platform

Figure 4. RTP Being Pulled from Platform

Benefits of the RTP-Rehab™ System

- Rapid, safe installation
- No chemical treatment to prevent corrosion of the line
- Generally, no maintenance pigging required
- Simple light duty installation equipment
- No lift boats or barges required as there was sufficient space on both platforms
- All gas wells **Returned to Production**
- > 70% lower cost compared to other options
    - For onshore, typically >50% cost savings
- Return on Investment > 900% (payback < 2 months) for this project

Contact Specialty RTP to Learn How RTP-Rehab™
Can Cost Effectively Rehabilitate your Corroded Pipelines
And Help “Return to Production” your Marginal Fields

Specialty RTP, LLC PO Box 7111 Wayne, PA 19087

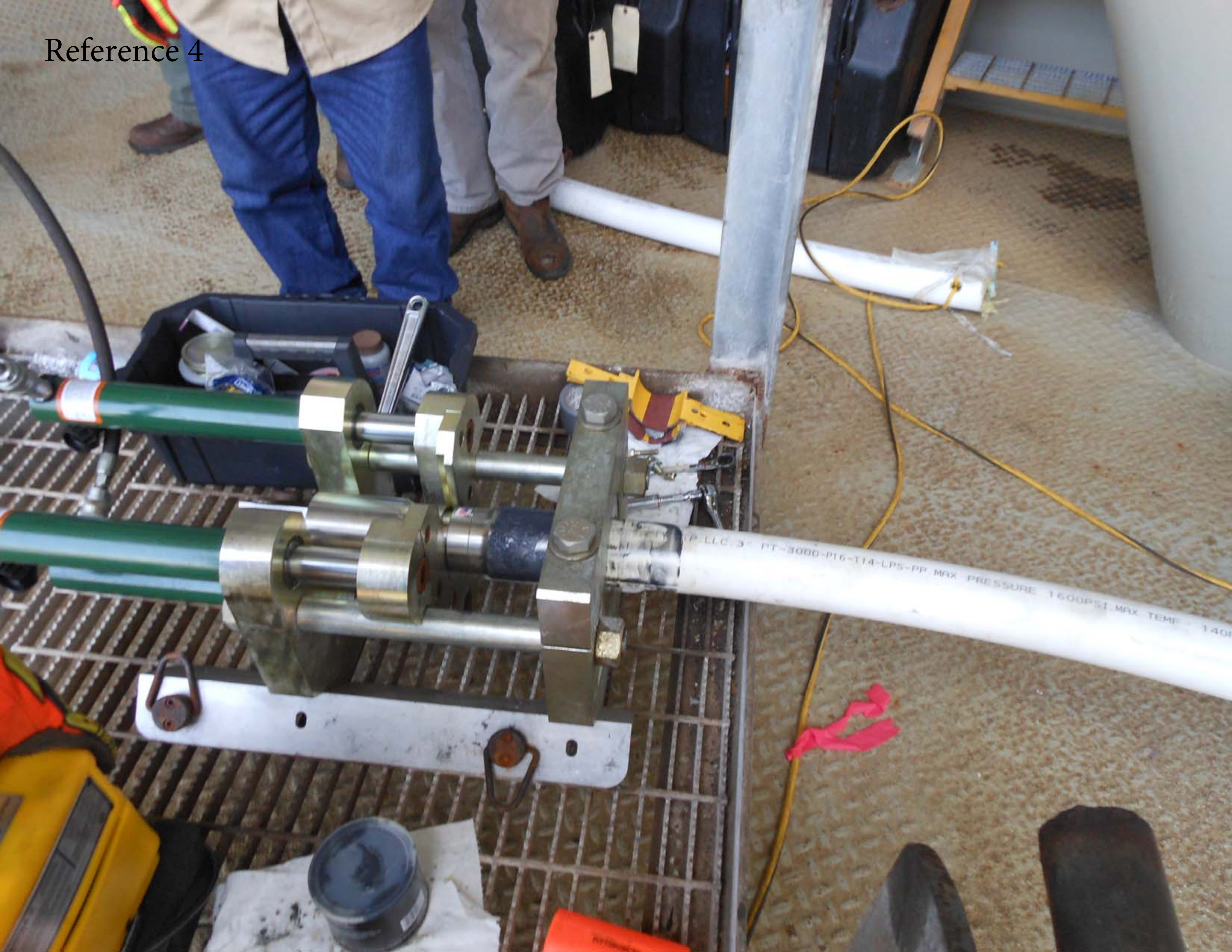
(610) 557-1020

RTP-Rehab@SpecialtyRTP.com

October 2015

Reference 3

Reference 4



Reference 5

SPECIALTY RTP

Technology to Flow Mature Wells

RTP-Rehab™ Profitably **Return** Wells **to Production**

Keep Marginal Fields Flowing
For a Fraction of Traditional Costs

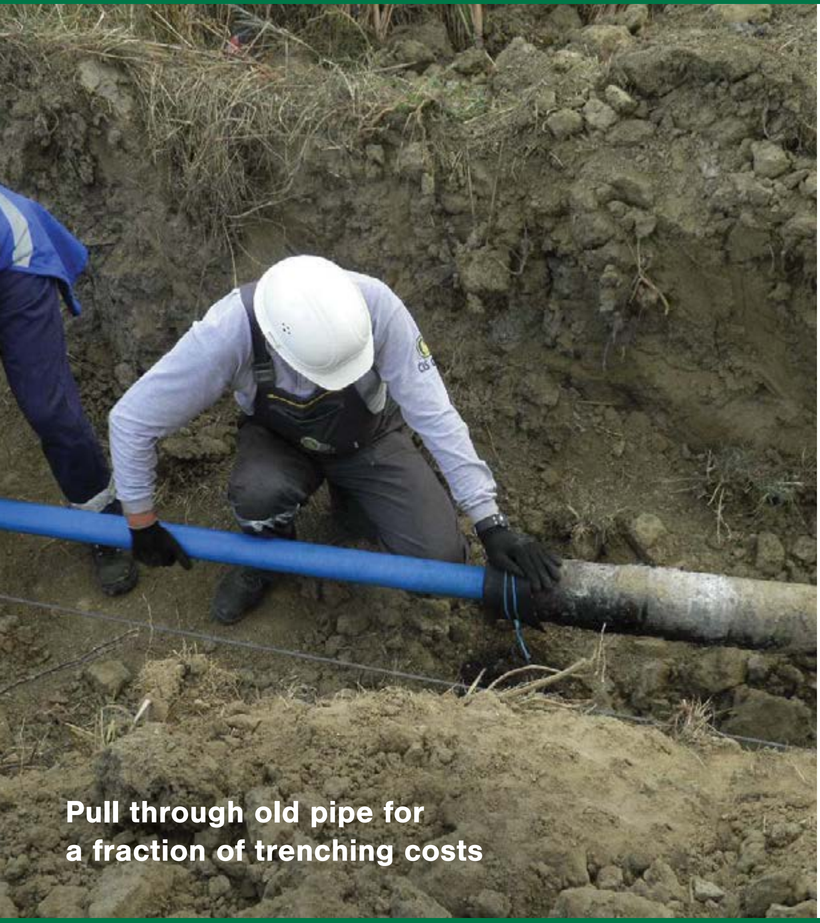
The Specialty RTP Difference

Low Production in Mature Fields?

Operators close mature fields when:

- Capital spending on traditional means of pipeline and downhole tubular rehabilitation is cost-prohibitive
- Operating costs exceed production revenues
- Pipelines and tubing are too large for today's production

Digging new pipeline trenches in mature fields can be time consuming and expensive



Pull through old pipe for a fraction of trenching costs

The Answer is RTP Rehab™

Specialty RTP provides a comprehensive solution that optimizes production rates with minimal capital costs while assuring all safety standards and reqirements are met.

- Return pipelines and tubulars to "new" for 50-70% less capital than traditional rehabilitation
- Minimize operating expenses by right sizing tubing with inert polymers to eliminate corrosion inhibitors, maintenance pigging
- Keep fields flowing for less than plugging and abandonment costs
- Introduce secondary recovery and artificial lift systems at a low cost

RTP REHAB™ ELIMINATES COST WHILE RE-ESTABLISHING SAFETY

How is it Used?

- Bring leaking pipelines back up to standards
- Create continuously monitored secondary containment for environmentally sensitive areas
- Convert production wells into injector wells
- Facilitate artificial lift
- Enable multi-line flowing from one line

Specialty RTP's Turnkey Process

- Analyzes the issues and develops an answer to solve cost issues
- Designs an end-to-end solution to ensure the best productivity for the entire system
- Uses Reinforced Thermoplastic Pipe – RTP – designed for severe environments including:
  - High Temperatures
  - Severe Environments
  - Pressure
- Manages the project to ensure proper installation

About Specialty RTP

Specialty RTP delivers solutions that dramatically lower your capital and operating costs and keep mature fields flowing profitably. We work with you from analysis to testing to ensure attractive returns on fields historically determined to be unattractive.

Ready to Return Your Wells and Fields to Production? Contact Us.

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SPECIALTY RTP
Technology to Flow Mature Wells

Reference 6

Technical Information

TI-KTE/AS-28 e
136709 November 2005

Supersedes edition TI-KTU/AS-28 e
October 2000

BASF Plastics
key to your success

BASF
The Chemical Company

® = Registered trademark of BASF Aktiengesellschaft

Resistance of Ultramid®, Ultraform® and Ultradur® to chemicals

1 General information

The information given in this publication is based on our current knowledge and experience. In view of the many factors that may affect processing and application, these data do not relieve processors of the responsibility of carrying out their own tests and experiments; neither do they imply any legally binding assurance of certain properties or of suitability for a specific purpose.

The information given relates to unreinforced, unmodified base grades (eg, Ultramid® A3K and B3S, Ultraform® N 2320, Ultradur® B 4250). Reinforced and impact-modified grades may behave slightly differently. For example, glass-fibre reinforced Ultraform® is less resistant to hot water than unmodified grades, or impact-modified Ultra products may be more prone to swelling in polar solvents, fuels and oils than unmodified ones.

If you cannot find the information you require here, please contact our Technical Centre.

2 Column headings

wt. %: Figures under this heading refer to the concentration in wt. % of (unless otherwise stated) an aqueous solution of the substance; **SS** re fers to a saturated solution of the substance; a blank means the information given relates to the pure substance.

°C: The temperature at which the given data is valid. RT means "room temperature" which is taken to be between 15 °C and 35 °C.

Notes: Miscellaneous information such as references to other publications, figures, permeability data (diffusion coefficient at 20 °C, D_{20}; permeability at 50 °C, P_{50}) is given here. Values are written in scientific notation, eg, 2.5E-9 means 2.5 x 10^{-9}.

The degree of saturation w_t/w_s of a specimen after a given time can be found from the expression:

$$\frac{w_t}{w_s} = \frac{2.256}{s}\sqrt{Dt}$$

where:

w_t = increase in mass at time t (in s)
w_s = increase in mass at saturation
s = wall thickness in cm
D = diffusion coefficient in cm^2/s
t = time in seconds

The above formula can also be used to determine the diffusion coefficient for a particular chemical substance by measuring the rate of absorption.

3 Symbols used to describe the chemical resistance

+ : Resistant. Only slight changes to weight, dimensions, properties. According to current knowledge, the medium causes no irreversible damage to the polymer.

○ : Limited resistance. Noticeable change in properties. Prolonged exposure to the medium may cause irreversible damage (eg, polymer degradation).

– : Not resistant. Medium attacks polymer and/or causes environmental stress-cracking within a short time. Irreversible damage.

S : Plastic dissolved by the chemical.

Number after the resistance symbol: This number refers to the mass increase after the polymer specimen has been saturated. The values given are only rough values and refer to unreinforced grades. The actual weight change depends on the grade of plastic and its crystallinity. The percentage change in length can be taken as being roughly a quarter of the percentage weight change.

Overview of the chemical resistance of Ultramid®, Ultraform® and Ultradur®

Rating	Ultramid®	Ultraform®	Ultradur®
Very resistant	Aliphatic and aromatic hydrocarbons Alkalis Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Lubricants Detergent	Aliphatic and aromatic hydrocarbons Alkalis Alcohols Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Detergent Water up to approx.100 °C	Aliphatic and aromatic hydrocarbons Brake fluids Ethers, esters Greases Ketones Fuels (gasoline, diesel) Paints Acids (dilute) Lubricants Detergent Water up to approx. 40 °C
Not resistant	Halogens (fluorine, chlorine, bromine, Iodine) Mineral acids and certain organic acids Oxidants Phenols Zinc chloride solutions	Halogens (fluorine, chlorine, bromine, iodine) Nitrous gases Oxidants Acids Sulfur dioxide Concentrated zinc chloride solutions at elevated temperature	Alkalis Halogens (fluorine, chlorine, bromine, Iodine) Water above approx. 60 °C
Solvent for the resin			
1. Room temperature	Formic acid (> 60 %) Fluorinated solvents m-Cresol Phenol Sulfuric acid (96 %)	Fluorinated solvents (eg, hexafluoroisopropanol)	Fluorinated solvents (eg, hexafluoroisopropanol)
2. Elevated temperature	Benzyl alcohol Glycols Formamide	N-methylpyrrolidone Dimethylformamide	Phenol Dichlorobenzene

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Acetaldehyde soln.	40	RT	○ (12 %)	+		
Acetamide soln.	50	RT	○ (7 %)	+		[2], [11]
Acetamide soln.	50	> 140	S			
Acetic acid	95	RT	–	–	–	
Acetic acid	10	RT	○	+	+	POM: up to 1000 h no damage
Acetic acid	5	RT	+ (10 %)	+	+	PA: D_{25} = 1.4E-8 cm^2/s
Acetone		RT	+ (2 %)	+	○	PA: creep strength see fig. 2; P_{20} = 0.01 (g.mm/m^2h)
Acetone		60	+	+	–	
Acetophenone		RT	+	+	+	
Acetyl chloride		RT	–	–		
Acetylene		RT	+	+	+	
Acrylic acid		> 30	S	–		[11]
Acrylic acid (soln. in aliphatic hydrocarbons)	3	80	○ (2 %)	–		
Air		RT	+	+	+	
Alcohols: see “Methanol”, “Ethanol” etc.						
Aliphatic hydrocarbon blend		RT	+	+	+	
Alkylbenzenes (Shellsol® A)		RT	+	+		
Allyl alcohol		RT	○		+	
Aluminium acetate soln.	SS	RT	+	+	+	
Aluminium hydroxide soln.	SS	RT	+	+	+	
Aluminium salts of mineral acids in soln. (eg, chloride, sulfate, nitrate)	20	RT	○	○	+	PA: may cause stress cracking [6]
Aluminium salts of mineral acids in soln. (eg, chloride, sulfate, nitrate)	SS	50	–	–		
Amines, aliphatic		RT	+ (≤8 %)	+	+	
Amino acids	SS	RT	+	+	+	
Ammonia soln.		RT	+	+	○	PA 6 (10 bar/50 °C): D_{50} = 2E-8 cm^2/s [9]; PA: P_{20} = 1E-10 ($cm^2/s \cdot mbar$)
Ammonia soln.		70	○	+	–	
Ammonia soln.	20	RT	+	+	+	PA: P_{20} = 0.06 ($g \cdot mm/m^2 \cdot h$)
Ammonia soln.	20	60	+	+	–	
Ammonium thiocyanate soln.	SS	RT	+	+		
Ammonium hydrogen carbonate soln.	SS	RT	+	+	+	
Ammonium salts of minerals acids in soln.	10	RT	+	+	+	
Ammonium salts of minerals acids in soln.	10	50	○	○		

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Amyl acetate		RT	+	+	+	
Amyl acetate		100	–		–	
Amyl alcohol		RT	+ (≤ 5 %)	+	+	PA: creep strength see fig. 1
Aniline		RT	○	○		
Anodizing baths (30 % nitric acid/10 % sulfuric acid)		RT	○	–	○	
Anthraquinone		85	○	+		
Antifreeze: see “Coolants”						
Antimony trichloride soln.	SS	RT	–	–		
Aqua regina (HCl/HNO_3)		RT	–	–	–	
Argon		RT	+	+	+	
Aromatic hydrocarbon blend		80	+	+	○	
Asphalt		RT	+	+	+	
Asphalt		> 100	○	○	○	
Bacteria (DIN 53739)		RT	+	+	+	
Baking enamels		150	+	○	+	Baking up to 30 min; particularly suitable for glass-reinforced grades
Barium salts of mineral acids		RT	○	+	+	PA: conc. solns. of barium thiocyanate cause stress cracking [9]
Benzaldehyde		RT	○	+		
Benzene		RT	+	+	+	PA: $P_{20} = 0.5$ (g · 100 μm/m^2 · h)
Benzene		80	+	+	–	
Benzoic acid soln.	20	RT	○	○	+	
Benzoic acid soln.	SS	RT	–	–	+	
Benzyl alcohol		RT	○ (3 – 30 %)	+		
Beverages		RT	+	+	+	See also “Fruit juices”, “Brandy”, “Wine”
Bitumen (DIN 51567)		RT	+	+	+	
Bitumen (DIN 51567)		> 100	○	○	○	
Bleaching agent (aqueous; 12.5 % active chlorine)		RT	–	–	○	
Boric acid soln.	10	RT	○	○	+	
Boron trifluoride		RT	–	–	–	
Brake fluids		RT	+ (3 – 10 %)	+	+	
Brake fluids: (DOT 3 – 5, FMVSS 116)		125	○	+	+	Weight change after 14 days' immersion at 120 °C: Ultramid® A3WG6 +3 % POM at 120 °C stable over 2000 h

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Brake fluids: (SAE J 1703; DIN 53521)		150	–	–		
Brake fluids: Hydraulan® (BASF)		60	+	+	+	
Brake fluids: Hydraulan® (BASF)		120	+	+		Weight change after 14 days' immersion: Ultramid® A3WG6 + 3 %; Ultraform® N 2200G53 + 6 %
Brandy		RT	+ (10 %)	+	+	
Bromine vapour		RT	–	–	–	
Bromine water	SS	RT	–	–	–	
Bromochlorodifluoromethane		RT	+	+	+	
Bromotrifluoromethane		RT	+	+	+	
Butadiene		RT	+	+	+	
Butane		RT	+	+	+	PA 66: P_{20} < 10 ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Butanediols		RT	+	+	+	
Butanediols		> 140	○	–	–	
Butanols		RT	+ (2 – 9 %)	+	+	PA: P_{20} approx. 2E-12 mol/cm · s; D_{20} = 3E-12 cm^2/s
1-Butene, cis-2-butene, (liquefied gas DIN 51622)		RT	+	+	+	
Butene glycol		RT	+	+	+	
Butene glycol		> 160	○	○	–	
Butter, buttermilk		RT	+	+	+	
Butyl acetate		RT	+	+	○	
Butyl acrylate		RT	+	+	○	
n-Butyl ether		RT	+	+	+	
n-Butyl glycol (glycol monobutyl ether)		RT	+	+	+	
Butyl glycolate		RT	+	+	+	
Butyl phthalate		RT	+	+	+	
Butyric acid soln.	20	RT	○	○	+	
γ-Butyrolactone		RT	+ (2 %)	+		[16]
γ-Butyrolactone		> 90	○	○		[16]
Calcium chloride soln.	SS	RT	+ (10 %)	+	+	
Calcium chloride soln.	SS	60	○			
Calcium chloride soln. (alcoholic)	20	RT	○	+		Dissolves PA
Calcium hydroxide soln. (lime water)	SS	RT	+	+	+	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Calcium hypochlorite and bleaching powder soln.	SS	RT	–	–	○	
Camphor soln. in alcohol	50	RT	+	+	+	Weight increase owing to alcohol uptake
ε-Caprolactam (aqueous solution)	50	RT	+	+	+	
ε-Caprolactam (aqueous solution)	50	> 150	○			Dissolves PA 6 above 150 °C, PA 66 above 170 °C
ε-Caprolactam (molten)		> 120	○	–	–	[2]
Carbon dioxide		70	+	+	+	PA: P_{20} = 40 – 60 ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Carbon disulfide		RT	+	+		PA: P_{20} = 0.02 ($g.mm/m^2 \cdot h$)
Carbon disulfide		60	–			
Carbon monoxide		70	+	+	+	
Casein		RT	+	+	+	
Caustic soda soln.: see “Sodium hydroxide soln.”						
Cellulose lacquers		RT	+	+	+	see also “Paint solvents”
Cement		RT	+	+	+	[1], [8]
Ceresin		RT	+	+	+	
Chloral hydrate		RT	–			[11]
Chloramines	< 10	RT	–		–	
Chlorinated biphenyls		80	○			see also “Clophen A 60/petroleum ether”
Chlorine, chlorine water		RT	–	–	–	see also “Bleaching agent”
Chloroacetic acid soln.	10	RT	–	–	–	
Chlorobenzene		20	+	+	+	PA: P_{50} = 1.0 ($g \cdot mm/m^2 \cdot 10^3\ h$)
Chlorobenzene		50	+	+	–	
Chlorobromomethane		RT	○ (3 – 30 %)		+	
Chlorodifluoroethylene		RT	+	+	+	
Chlorodifluoromethane, chlorodifluoroethane		RT	+	+	+	
Chloroform		RT	○ (5 – 25 %)	○	–	PA: P_{20} = 0.1 ($g \cdot mm/m^2 \cdot h$)
Chlorosulfonic acid soln.	<10	RT	–	–	–	
Chlorothene®: see 1,1,1-Trichloroethane						
Chromic acid	10	RT	–	–	○	
Chromic acid	1	RT	○	○	+	
Chromyl chloride		RT	–	–		
Citric acid soln.	10	RT	+ (≤ 10 %)	○	+	PA: D_{25} = 1E-8 cm^2/s
Citric acid soln.	10	50	+	–	○	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Citric acid soln.	20	80	+	–		
Citrus fruit juices		RT	+	+	+	
Citrus oils		RT	+	+	+	
Cleaning agent: all-purpose cleaner		RT	+	+	+	
Cleaning agent: household cleaner (Ajax, ATA, Domestos, Rilan)	10	RT	+	+	+	
Cleaning agent: toilet cleaner (pH < 3)		RT	◯	–	+	
Cleaning agent: window cleaner		RT	+	+	+	
Clophen A 60/petroleum ether (1 : 1)		RT	+	+	+	
Cobalt salt solns.	20	RT	◯	+		PA: stress cracking possible eg, with $CoCl_2$, $Co(SCN)_2$; [6], [15]
Concrete		RT	+	+	+	PA: [1]
Coolants: Glysantin®/Water 1 : 1		106	◯	+	–	PA: see figs. 3 & 4
Copper (II) salt solns.	10		◯	+	+	PA: nitrate and chloride cause stress cracking; [6], [10]
Coumarone and coumarone resins		RT	+	+	+	
Cresols		RT	S		S	
Crude oil: see “Petroleum”						
Cutting oils: see Lubricating oils						
Cycloalkanes		RT	+	+	+	
Cyclohexane, cycloheptane		RT	+	+	+	
Cyclohexanol (and esters thereof)		RT	+ (2 – 6 %)	+	+	
Cyclohexanone		RT	+	+	+	
Decontaminating agent (MIL-D-50030 F)		RT	+	+	+	= diethylenetriamine/NaOH/ethylene glycol monoethyl ether (70 : 2 : 28)
Dekalin®		RT	+ (1 – 2 %)	+	◯	
Descaler (based on formic, acetic, citric acids)	10	RT	+	◯	+	
Descaler (based on formic, acetic, citric acids)	10	50	◯	–	◯	
Descaler (based on sodium hydrogen sulfate)	10	RT	+	◯	+	
Detergent soln, heavy-duty	< 10	RT	+	+	+	
Detergent soln, heavy-duty	< 10	80	◯	+	◯	POM: oxidizing detergent may cause corrosion
Developer soln. (Rodinal®, Agfa, pH 11)		RT	+	+	+	
Dibutyl phthalate		RT	+	+	+	
Dibutyl phthalate		60	+	+	◯	
p-Dichlorobenzene		RT	+ (2 %)		–	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
1,2-Dichloroethane		RT	+ (2 – 5 %)	+	–	
Dichloroethylene		RT	+	–	–	
Dichlorofluoromethane		RT	+	+	+	
Dichloromethane: see “Methylene chloride”						
Dichlorotetrafluoroethane		RT	+	+	+	
Diesel fuel: see “Fuels”						
Diethyl ether		RT	+ (3 %)	+	+	PA: $P_{20} = 0.03$ (g · mm/m² · h)
Diethylene glycol		> 140	S		–	See also “Glycol”
Difluoromethane		RT	+	+	+	
Dimethyl ether		RT	+	+	+	
Dimethylacetamide		RT	+	+		PA 6 and POM on prolonged exposure: ○; [11]
Dimethylacetamide		> 150	–			
Dimethylamine		RT	+			
Dimethylformamide		RT	+ (5 %)	+	+	
Dimethylformamide		90	○ (15 %)			
Dimethylformamide		> 140		S		
Dimethylsilane		RT	+			
Dimethylsulfoxide (DMSO)		RT	+		+	
Dimethylsulfoxide (DMSO)		125	S			
Dioctyl phthalate		RT	+	+	+	
Dioxan		RT	+	+	+	PA: $P_{20} = 0.001$ (g · mm/m² · h)
Dioxan		60	+		–	
Diphyl® (biphenyl and diphenyl ether)		80	+	+	–	
Disopropyl ether		RT	+	+	+	PA: $P_{20} = 0.005$ (g · mm/m² · h)
Dishwasher detergent soln.	< 10	95	+	○	–	POM: oxidizing detergents may cause corrosion
Disinfectant (alcohol-based)	< 10	RT	+	+	+	[3], [4]
Disinfectant (aldehyde-based)	< 10	RT	+	+	+	[3], [4]
Disinfectant (based on phenols)	< 10	RT	○	○	○	PA is however resistant under normal conditions of use
Disinfectant (based on quaternary ammonium compounds)	< 10	RT	+	+	+	[3], [4]
Disinfectant (based on quaternary phosphonium compounds)	< 10	RT	+	+	+	[3], [4]
Disinfectant (chlorine-based)	< 10	RT	○	–	+	[3], [4]
Disinfection by boiling		100	+	+	○	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Disinfection by fractional vacuum process			+	+		
Disinfection by gas sterilization: see "Ethylene oxide"						
Disinfection by hot air/steam/hot air			+	+	○	See also "Steam (sterilization over 50 cycles)"
Disinfection by irradiation (25 kGy for 6 h)			+	○	+	PA: slight yellowing
Dispersions, aqueous (BASF Acronal®, Propiofan®)			+	+	+	
Edible fats and oils		100	+	+	+	
Electroplating baths, acidic		RT	–	–	+	see also: "Anodizing baths" and solutions of metal salts
Electroplating baths, alkali (cyanides)		RT	+	+	○	
Engine oils: see "Lubricating oils"						
Epichlorhydrin		RT	○			
Ethane		RT	+	+	+	PA: $P_{20} < 10$ ($cm^3 \cdot 100$ μm/$m^2 \cdot d \cdot bar$)
Ethanol		RT	+ (15 %)	+	+	PA: $P_{20} = 0.2$ (g.mm/$m^2 \cdot h$)
Ethanol, dilute	40 vol.	RT	+	+	+	
Ethereal oil		RT	+	+	+	
Ethyl acetate		RT	+ (1 %)	+	○	PA: $P_{20} = 0.008$ ($g \cdot mm/m^2 \cdot h$)
Ethyl chloride		RT	+	+		
Ethylene		RT	+	+	+	PA: $P_{20} < 10$ ($cm^3 \cdot 100$ μm/$m^2 \cdot d \cdot bar$)
Ethylene carbonate		50	+		–	
Ethylene carbonate		100	–		–	
Ethylene chlorohydrin		RT	○			
Ethylene oxide		RT	+	+	+	PA: $P_{20} < 100$ ($cm^3 \cdot 100$ μm/$m^2 \cdot d \cdot bar$)
Ethylene oxide		> 80	–			
Ethylene oxide (gas sterilization)			○	+		PA: 30 – 70 °C up to 8 h: +
Ethylenediamine		RT	+ (8 – 15 %)			
Exhaust fumes from internal combustion engine		RT	+	+	+	
Fats and waxes, edible fats		RT	+	+	+	see also "Edible fats and oils"
Fatty acids		RT	+	+	+	
Fatty alcohols		RT	+	+	+	
Fatty alcohols, sulfonated		RT	+	+	+	
Fluorinated hydrocarbons, fluorocarbons		70	+	+	+	POM: $P_{20} = 50 - 150$ ($cm^3 \cdot 100$ μm/$m^2 \cdot d \cdot bar$)

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Fluorine		RT	–	–	–	
Formaldehyde		RT	+	+	+	
Formaldehyde solution	30	RT	+ (5–15 %)	+	+	
Formamide		RT	+	+		
Formamide		> 150	S			
Formic acid soln.	10	RT	○	○	+	POM: no damage after 1000 h Conc. acid dissolves nylons (50 % for PA 6, 80 % for PA 66); [2]
Formic acid soln.	10	50	–	–	○	
Fruit juices		RT	+	+	+	
Fuel, engine: Diesel		85	+	+	+	PA: P_{40} = 0.001 (g · mm/m^2 · h)
Fuel, engine: FAM test fuel (5 % ethanol)		55	+ (9–14 %)	+	+	
Fuel, engine: Gasoline (normal & premium grade)		RT	+	+	+	PA: P_{40} = 0.006 (g · mm/m^2 · h); POM: see figs. 24–25
Fuel, engine: Gasoline (normal & premium grade)		85	+	+		
Fuel, engine: High-performance fuels (Dekalin®, perhydrofluorene)		85	+	+	○	
Fuel, engine: M15 mixture (15 % methanol)		55	+ (9–14 %)	+	+	PA: see figs. 8–10; D_{20} = 1E-8 cm^2/s; POM: see figs. 24–25
Fuel, engine: M15 mixture (15 % methanol)		70	○	+	○	PA: see figs. 8–10; PBT: see figs. 26–27
Fungi (DIN 53739; ISO 846)			+	+	+	[19]
Furfural		RT	+ (2–7 %)	+	+	
Furfuryl alcohol		RT	+	+	+	Solvent for PA 610 above 90 °C
Gas sterilization: see “Ethylene oxide (gas sterilization)”						
Gasoline: see Fuels						
Gear oils (EP, hypoid, ATF, manual transmission)		≤ 110	+	○	+	See also “Lubricating oils”; PA: temperature/time limits see fig. 13
Gelatine		RT	+	+	+	
Glue		RT	+	+	+	
Glycerol		RT	+	+	+	PA: creep strength see fig. 5
Glycerol		170	S	–	–	
Glycolic acid soln.	30	RT	–	–		
Glycols, alkyl glycol ethers		RT	+ (2–10 %)	+	+	See also “Brake fluids”, “Coolants”; [11]
Glysantin® (BASF): see “Coolants”						
Grease (based on ester oils, diester oils, phosphoric acid esters, synthethic oils)		≤ 110	○	+	+	[5]

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Grease (based on polyphenylester)		≤ 110	+	+		
Grease (based on silicone oils): see “Silicone oils”						
Grease: antifriction bearing grease DIN 51825 (based on metal soaps)		≤ 110	+	+	+	PA: temp./time limits correspond to fig. 13; Lithium grease may cause increased swelling under some circumstances.
Hair dyes		RT	○ (≤ 11 %)	+		
Hardening oils		RT	+	+	+	
Heating oil (DIN 51603)		RT	+	+	+	
Helium		RT	+	+	+	
Heptane		RT	+	+	+	PA: P_{20} = 0.1 (g · mm/m^2 · h)
Hexachloroethane		RT	+	+		
Hexachlorobenzene		80	+ (1 %)	+		
Hexafluoroisopropanol		RT	S	S	S	
Hexamethylenetetramine		RT			+	
Hexane		RT	+	+	+	
Humic acids		RT	○	○	+	PA, POM: chemical attack possible under extreme conditions
Hydraulic fluids		100	+	+	+	
Hydraulic oil (DIN 51525)		100	+		+	
Hydraulic oil (MIL-H 5606)		100	+		+	
Hydraulic oil (VDMA 24318)		100	+		+	
Hydrazine		RT		+		
Hydriodic acid, hydrogen iodide soln.		RT	–	–	○	
Hydrobromic acid soln.	10	RT	–	–	○	
Hydrochloric acid	> 20	RT	–	–	○	
Hydrochloric acid	2	RT	–	○	+	PA: figs. 1 & 12; [17]
Hydrofluoric acid	40	RT	–	–	–	
Hydrofluosilicic acid	30	RT	–	–	–	
Hydrogen		RT	+	+	+	PA: P_{20} = 300 – 400 (cm^3 · 100 µm/m^2 · d · bar)
Hydrogen chloride gas		RT	–	–	–	see also “Hydrochloric acid”
Hydrogen fluoride		RT	–	–	–	
Hydrogen peroxide soln.	0.5	RT	+	+	+	
Hydrogen peroxide soln.	30	RT	–	–	+	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Hydrogen sulfide	< 10	RT	○	○	+	PA & POM: possible damage by sulfuric acid formed by oxidation
Hydrogen sulfide (dry)		RT	+	+	+	PA: P_{20} = 2.4E-12 ($cm^2/s \cdot mbar$)
Hydroquinone soln.	5	RT	–		+	
Hyraulan® (BASF): see “Brake fluids”						
Impregnating oils		RT	+	+	+	
Ink		RT	+	+	+	
Iodine (alcoholic solution)		RT	–	–		
Iron (III) chloride	SS	RT	–			
Iron (III) chloride soln., acidic	10	RT	–	–		
Iron (III) chloride soln., neutral	10	RT	+ (4 – 10 %)		+	
Iron (III) thiocyanate soln.	10	RT	○		+	
Isocyanates, aromatic		RT	+	+	+	
Isooctane		80	+	+	+	
Isopropanol		RT	+ (5 – 15 %)	+	+	PA: P_{20} = 20 ($g \cdot 100\ \mu m/m^2 \cdot d$); D_{20} = 1E-11 cm^2/s
Isopropanol		60	+	+	○	PA: creep strength see fig. 7
Ketones (aliphatic)		RT	+	+	○	
Lactic acid		10	+	+	+	
Lactic acid		90	–	–		
Laughing gas: see “Nitrous oxide”						
Lead acetate soln.	10	RT	+	+	+	
Lime: see “Cement”						
Linseed oil		RT	+	+	+	
Lithium bromide, lithium chloride soln. (aqueous)	10	RT	○	+	+	PA: environmental stress-cracking in saturated solutions
Lithium chloride soln. (alcoholic)	20	RT	S	+		
Lithium hydroxide	10	20	+	+	+	
Lithium hydroxide	10	80	–	+	–	
LPG (DIN 516222): see “Propane, propene”						
Lubricating oils						
Lubricating oil: gear oil (eg, ATF)		≤ 130	+	+	+	PA: temperature/time limits see fig. 13

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Lubricating oil: HD engine oils, hydraulic oils, transformer oils		≤ 130	+	+	+	PA: temperature/time limits see fig. 13; PBT see fig. 28.
Lubricating oil: hypoid gear oil (with EP additives, MIL-L 2105 B)		≤ 110	+	○	○	PA: see fig. 13
Lubricating oil: hypoid gear oil (with EP additives, MIL-L 2105 B)		120	–			
Lubricating oil: without HD or EP additives (ASTM reference oil)		100	○	○	+	Possible attack by acids formed by oxidation
Lutensit®, Lutensol® (BASF)		RT	+	+	+	
Magnesium salt solns. (chloride, nitrate, sulfate)	10	RT	+ (5 – 10 %)	+	+	
Maleic acid soln.	25	RT	○	–		
Malic acid	SS	RT	+	○	+	
Malt		RT	+	+	+	
Manganese salt solns (chloride, sulfate)	10	RT	+	+	+	
MAPP gas (C_3, C_4 aliphatic hydrocarbons)		RT	+	+	+	
Mercury		RT	+	+	+	
Mercury (II) chloride	SS	RT	–			
Mersolates®		RT		+	+	
Methane		RT	+	+	+	
Methanol		RT	+ (9 – 14 %)	+	+	PA: P_{20} = 0.2 (g · mm/m^2 · h); D_{20} = 1E-8 cm^2/s; creep strength see fig. 11
Methyl acetate		RT	+ (2 %)	+	○	
Methyl chloride		RT	+	+		
Methyl chloroform: see “1,1,1-Trichloroethane”						
Methyl ethyl ketone		RT	+ (2 %)	○	+	PA: P_{20} = 0.001 (g · mm/m^2 · h)
Methyl formate		RT	+	+	+	
Methyl glycol		RT	+			
Methylamine		RT	+ (7 %)	+		
Methylaniline		RT	+ (3 – 15 %)			
Methylbromide		RT	+	+		PA: P_{60} = 6E-13 (cm^2/s · mbar)
Methylene chloride		RT	○	○	–	
N-methylpyrrolidone		RT	+	+		
N-methylpyrrolidone		> 150		S		
Microbes		RT	+	+	+	
Milk		RT	+	+	+	
Mineral oils: see “Lubricating oils”						

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Molasses		RT	+	+	+	
Mortars: see “Cement”						
Moulds (DIN 53739; ISO 846 A, B; MIL-T 18404)		RT	+	+	+	[19]
Naphtha		RT	+	+	+	
Naphthalene		RT	+	+	+	
Naphthalenesulfonic acids		RT	–	–		
Naphthenic acids		RT	+	+	+	
Naphthols		RT	–			
Natural gas		RT	+	+	+	
Nekanil®, Nekal® surfactants (BASF)	< 10	50	+	+	+	PA: see fig. 1
Neon		RT	+	+	+	
Nickel nitrate	10	RT	○			PA: environmental stress-cracking possible; [6]
Nickel plating baths: see “Electroplating baths”						
Nickel salt solns. (chloride, sulfate)	10	RT	+	+	+	
Nitric acid	> 50	RT	–	–	○	
Nitric acid	2	RT	–	–	+	
Nitrilotriacetic acid (sodium salt)		RT	+	+	+	
Nitrobenzene, nitrotoluene		RT	○	○	+	
Nitrobenzene, nitrotoluene		> 100	S			[12]
Nitrocellulose lacquers (alcoholic, hazard class A I)		RT	○	+	○	
Nitrocellulose lacquers (alcohol-free, hazard class A II)		RT	+	+	○	
Nitrogen (200 bar)		RT	+	+	+	PA: $P_{20} = 6$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Nitrogen oxides (dinitrogen tetraoxide)		RT	○	–	+	[8]
Nitrogen oxides (under pressure)		RT	–	–		
Nitromethane, nitropropane		RT	○			
Nitrous fumes		RT	○	–	○	
Nitrous oxide		RT	+	+	+	
Noble gases (argon, helium, neon)		RT	+	+	+	PA: for helium $P_{20} = 340$ ($cm^3 \cdot 100\ \mu m/m^2 \cdot d \cdot bar$)
Octane, octene		RT	+	+	+	
Oil, for transformers, switchgear (DIN 51507)		50	+	+	+	PA: creep strength see fig. 1

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Oils (vegetable, ethereal, mineral)		RT	+	+	+	See also “Lubricating oils”
Oleic acid		RT	+	+	+	
Oleum		RT	S	–	–	
Oxalic acid soln.	10	RT	○	–	+	
Oxalic acid soln.	10	80	–	–		
Oxygen (atmospheric pressure)		RT	+	+	+	PA: P_{20} = 10 – 15 (cm^3 · 100 µm/m^2 · d · bar); D_{20} = 1.3E-9 cm^2/s
Oxygen (high pressure)		RT	– (*)	– (*)	– (*)	(*): not BAM-approved (German materials testing institute)
Ozone		RT	–	–	–	
Ozone (1 ppm in water)		RT	+		+	
Ozone (20 ppm in air)		RT	○	○	+	[8]
Paint solvents		RT	+	+	○	Alcoholic solvents cause PA to swell
Paints: see “Paint solvents”, “Baking enamels”						
Palamoll®, Palatinol® grades (BASF)		RT	+	+	+	
Palatal® resins (BASF): see “Polyester resins”						
Palmitic acid		80	+	+	+	
Paraffin wax, liquid paraffin		RT	+ (< 0.2 %)	+	+	
Peracetic acid		RT	–	–		
Perchloroethylene: see “Tetrachloroethylene”						
Perfume (alcoholic solution)		RT	+	+	+	
Perhydrol: see “Hydrogen peroxide soln.”						
Petroleum		RT	+	+	+	
Petroleum ether, petroleum solvents		80	+	+	+	
Phenol		> 43	S	–	–	[11], [12]
Phenol	88	RT	S	–	–	
Phenol (alcoholic soln.)	70	RT	○	–	–	
Phenyl ether (guaiacol, cresol)		RT	–			
Phenylethyl alcohol		RT	○			[11]
Phenylethyl alcohol		> 160	S			
Phosphate (inorganic) solns. (neutral and alkaline)	10	RT	+	+	+	
Phosphate esters: see “Hydraulic fluids”						
Phosphine		RT	+	+	+	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Phosphoric acid	10	RT	–	–	–	
Phosphoric acid	85	RT	S	–	–	
Photographic developer		RT	+	+	+	
Photographic fixer		RT	+	+	+	
Phthalic acid soln.	SS	RT	○	+	+	
Plasticizers: see “Palamoll®, Palatinol®”						
Plastomoll® (adipates, BASF) DDA, NA, DIDA		RT	+	+	+	
Polyester resins (eg, BASF Palatal® resins)		RT	+	+	+	
Polyglycols, polyols		RT	+	+	+	
Potassium bromide soln.	10	RT	○	+	+	
Potassium chloride soln.	10	RT	+	+	+	
Potassium chloride soln.	10	70	+	+	–	
Potassium dichromate soln.	5	RT	○	+	○	
Potassium hydroxide soln.	50	RT	○	○	–	Unfilled PA & POM: +; glass fibres attacked in reinforced grades.
Potassium nitrate soln.	10	RT	+	+	+	
Potassium permanganate soln.	1	RT	–	+	+	
Potassium thiocyanate soln.	SS	RT	–			
Propane, propene		RT	+	+	+	PA: $P_{20} < 10$ (cm$^3 \cdot$ 100 µm/m$^2 \cdot$ d $\cdot$ bar) for propane
Propanol (n-, iso-)		RT	+ (5–15 %)	+	+	PA: D_{20} = 1E-11 cm^2/s; P_{20} = 20 (g $\cdot$ 100 µm/m$^2 \cdot$ d); creep strength see fig. 7
Propanol (n-, iso-)		> 100	S		–	
Propionic acid soln.	5	RT	+	+	+	
Propionic acid soln.	10	RT	–	○	+	
Propionic acid soln.	50	RT	–	–		
Protein solutions		RT	+	+	+	
Pulp slurries		≤ 60	+			
Pulp slurries		95	–		–	
Pyridine		RT	+	○		PA: P_{20} = 0.0002 (g $\cdot$ mm/m$^2 \cdot$ h)
Pyridine		80	○ (15–20 %)			
Pyrocatechol soln.	6	RT	–			
Pyrrolidone		RT	+			
Pyruvic acid soln.	10	RT	○	–	+	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Rainwater (acidic)		RT	+	+	+	
Refrigerator oil		RT	+	+	+	
Resorcinol (alcoholic soln.)	50	RT	○	○	–	
Resorcinol/methanol/benzene/water (40 : 35 : 10 : 5)		RT	○	○	–	adhesive solvent
Road salt, road-salt solutions		RT	+	+	+	PA and POM may be attacked by any zinc chloride that forms
Salicylic acid soln.	SS	RT	+	–	+	
Seawater: see “Water”						
Silane (tetramethylsilane)		RT	+		+	
Silicone oils		≤ 80	+	+	+	PA: see figs. 14 – 15
Silicone oils		> 100	○			PA: see fig. 15
Soap solution	< 10	80	+	+	+	
Soda soln.	10	RT	+ (3 – 10 %)	+	+	
Sodium bromide soln.	10	RT	○			
Sodium chlorate soln.	10	RT	+	+	+	
Sodium chlorite soln.	10	RT	○			
Sodium dodecylbenzenesulfonate soln.		RT	+	+	+	
Sodium hydrogen carbonate soln.	10	RT	+	+	+	
Sodium hydrogen sulfate soln.	10	RT	+		+	
Sodium hydrogen sulfite soln.	10	RT	+	–	+	
Sodium hydroxide soln.	10	RT	+	+	–	
Sodium hydroxide soln.	50	RT	○	○	–	Unfilled PA & POM: +; glass fibres attacked in reinforced grades.
Sodium hydroxide soln.	10	80	–	○	–	
Sodium hypochlorite soln.	10	RT	○	○	○	POM: damage after more than 1000 h
Sodium hypophosphite soln.	10	RT	+	+	+	
Sodium lauryl sulfate paste	30	RT	+	+		
Sodium lignosulfonate		RT	+	+	+	
Sodium nitrilotriacetate soln.	10	RT	+	+	+	
Sodium oleate		RT	+	+	+	
Sodium pentachlorophenolate		RT	+			
Sodium perborate soln.	3	RT		+		
Sodium pyrosulfite soln.	10	RT	+			

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Sodium salt solns. (neutral, eg, chloride, nitrate, sulfate)	10	RT	+	+	+	
Soil (acidic: pH 3)		RT	+	○	+	see also “Humic acids”
Soil (neutral; alkaline: pH 10)		RT	+	+	+	see also “Bacteria”, “Moulds”
Soldering fluid		RT	–	–	+	
Steam		100	○	+	–	
Steam (50-μm film)		116	–			Evidence of molecular degradation after 5 cycles
Steam (sterilization over 50 cycles)		134	○	+	○	Sterilization (DIN 58946 parts 1 – 5): PA 66: +; PA 6: –
Stearic acid, stearate, alkyl stearate		RT	+	+	+	
Sterilization, sterilizing agent see “Disinfectant”						
Stoving enamels: see “Baking enamels”						
Styrene		80	+	+	+	
Sulfolane (tetramethylenesulfone)		RT	+ (1 %)	+	+	
Sulfolane (tetramethylenesulfone)		> 80	S			
Sulfonates (eg, alkyl aryl sulfonate)	<10	RT	+	+	+	
Sulfur		RT	+	+	+	
Sulfur dioxide (dry)		RT	+	–	+	PA: P_{20} = 2.3E-11 ($cm^2/s \cdot mbar$) [13]; high absorption under high pressure [16]
Sulfur dioxide (moist)		RT	○	–	+	
Sulfur hexafluoride (20 bar)		RT	+	+	+	
Sulfuric acid	> 80	RT	S	–	–	
Sulfuric acid	2	RT	–	○	+	POM: no damage caused by 5 % solution up to 1000 h
Sulfurous acid soln.	SS	RT	○	○	+	
Sweat (DIN 54020)		RT	+	+	+	[7]
Tall oil		RT	+	+	+	
Tallow		RT	+	+	+	
Tar: see “Bitumen”						
Tartaric acid	10	RT	+ (4 – 10 %)	+	+	
Tartaric acid	50	RT	○		+	
Termites		RT	+	+	+	Surface may be eaten into slightly
Tetrachloroethylene		RT	○	+	○	[18]
Tetrachloroethylene		80	–	○	–	[18]

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Tetrachloromethane		RT	+ (1 – 4 %)	○	+	PA: P_{20} = 0.08 (g · mm/m²h)
Tetrafluoromethane		RT	+	+		
Tetrafluoropropanol		RT	–			
Tetrahydrofuran		RT	+ (2 – 10 %)	○	+	PA: P_{20} = 0.001 (g · mm/m²h)
Tetralin®		RT	+ (2 – 3 %)	+	+	
Tin (II) salts of mineral acids	10	RT	○	+	+	
Toluene		RT	+	+	+	PA: P_{20} = 0.005 (g · mm/m²h)
Toluene		100	+	+	–	
Town gas		RT	+	+	+	
Trichloroacetic acid ethyl ester		RT	○	–	–	PA 66: limited resistance; PA 6: not resistant
Trichloroacetic acid soln.	50	RT	–	–	–	
1,1,1-Trichloroethane (Chlorothene®)		45	+		+	[18]
Trichloroethanol, trifluoroethanol		RT	–		–	[11]
Trichloroethylene		RT	○ (4 – 10 %)	–	–	PA: P_{50} = 0.02 (g · mm/m² · d)
Trichloroethylene		> 40	–	–	–	
Trichlorotrifluoroethane		RT	+	+	+	
Triethanolamine		RT	+	+	+	
Trilon® A, B (BASF)	10	RT	+	+	+	
Trilon® A, B (BASF)	10	60		+		
Trimethylamine		RT	+	+		
Tri-p-cresyl phosphate		RT	+	+	+	
Turpentine oil		RT	+ (1 %)	+	+	
Turpentine substitute (white spirit)		RT	+	+	+	
Uranium fluoride		RT	–	–	–	
Uric acid soln.	20	RT	+	+	+	
Urine		RT	+	+	+	
Vacuum		RT	+	+	+	
Vaseline		RT	+	+	+	
Vinyl chloride, bromide, fluoride		80	+	+	+	
Vulcanization		≤ 180	+	○	–	

	Wt. %	°C	Ultramid®	Ultraform®	Ultradur®	Notes
Water (including seawater)		RT	+	+	+	PA: see figs. 1, 17, 18, 19; POM: see figs. 22 & 23
Water (including seawater), chlorinated (≤ 0.5 mg/l)		80	+	+	○	
Water glass		RT	+	+	+	
Wax		80	+	+	+	
Wax polishes		RT	+	+	+	
WC cleaner (pH < 3)		RT	○	–	+	
Wine		RT	+	+	+	
Xylene		RT	+	+	○	
Xylene		100	+	+	–	
Yeast		RT	+	+	+	
Zinc (galvanized metal surfaces) exposed to weather		RT	+	+	+	Formation of zinc chloride possible on exposure to salt water (see "Zinc chloride")
Zinc chloride		RT	+	+	+	
Zinc chloride soln.	10	RT	○	+	+	PA: stress cracking under certain circumstances (see figs. 20 – 21); POM: corrosion under certain circumstances above 60 °C
Zinc chloride soln.	37	RT	–	○	+	POM: corrosion possible above 60 °C
Zinc thiocyanate, bromide, iodide, nitrate	30	RT	–		+	

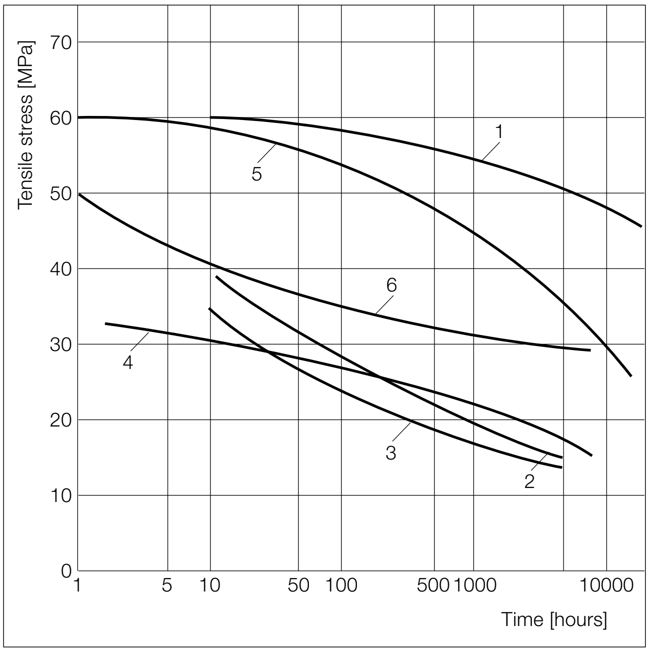

Fig 1: Creep behaviour of Ultramid® B5 in air and various chemicals at 23, 40 and 50 °C.
Test specimens: DIN 53455, no. 3, made from extruded sheet.
1 air, 23 °C/50 r.h.
2 water (distilled), 23 °C
3 hydrochloric acid, pH 1.5, 23 °C
4 Nikanil W Extra, 5 %, 50 °C
5 transformer oil, 50 °C
6 amyl alcohol, 23 °C

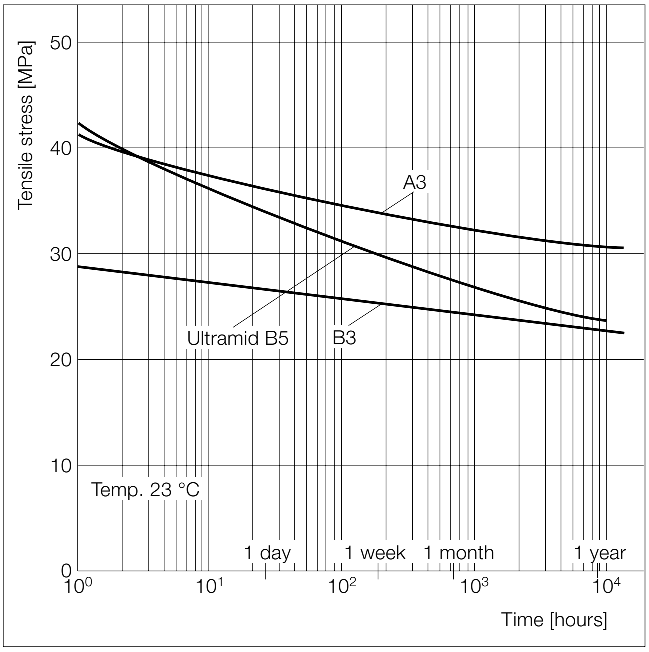

Fig 2: Creep behaviour of Ultramid® A and B grades in acetone at 23 °C.
Test specimens: DIN 53455, no. 3.

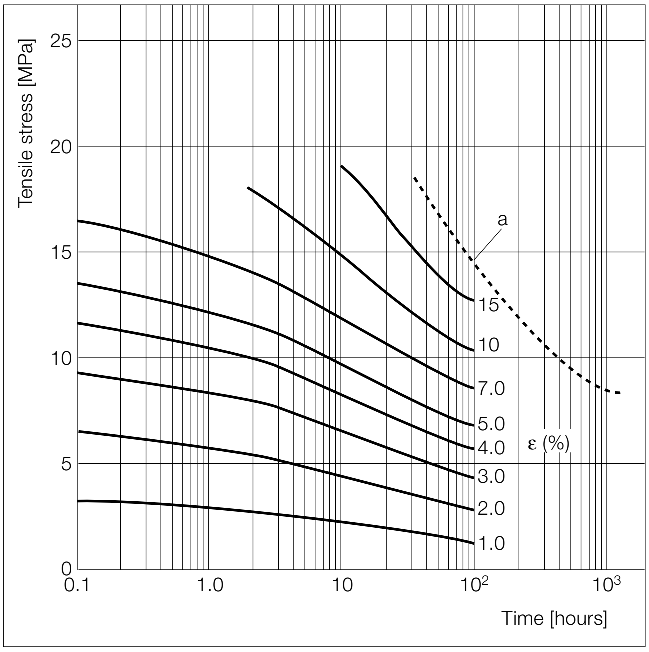

Fig 3: Creep behaviour of Ultramid® A4K in a boiling 1 : 1 Glysantin®/water mixture at 106 °C.
Test specimens: 118 mm x 13 mm x 8 mm (initially dry).
Weight increase at saturation (150 h): 11.5 %.
a = creep-to-rupture curve; ε = strain

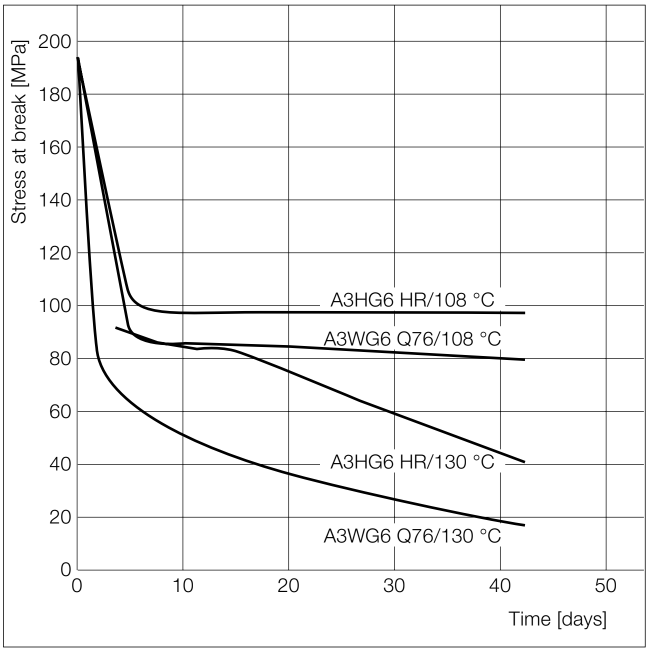

Fig. 4: Mechanical data after immersion in 1 : 1 Glysantin/water mixture at 108 °C and 130 °C.

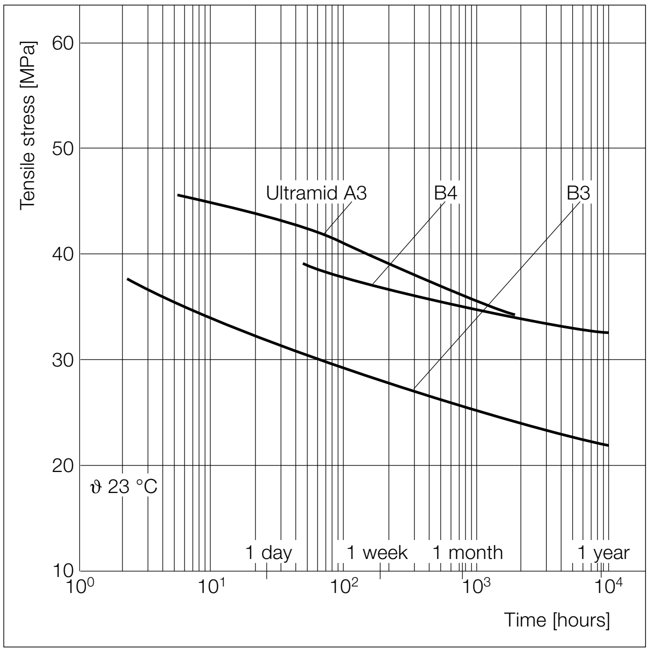

Fig 5: Creep behaviour of Ultramid® A and B grades in glycerol at 23 °C.
Test specimens: DIN 53455, no. 3

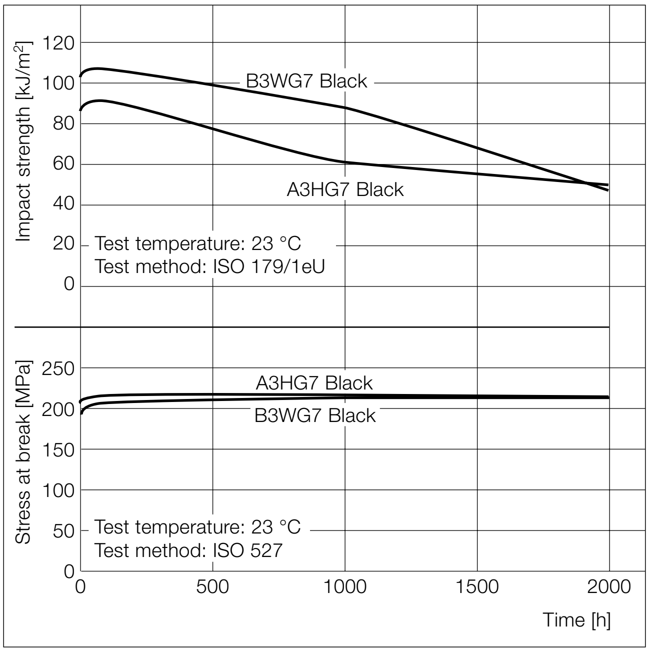

Fig. 6: Ultramid® A3HG7 Black and B3WG7 Black Resistance to engine oil (Elf XT 3341) at 150 °C

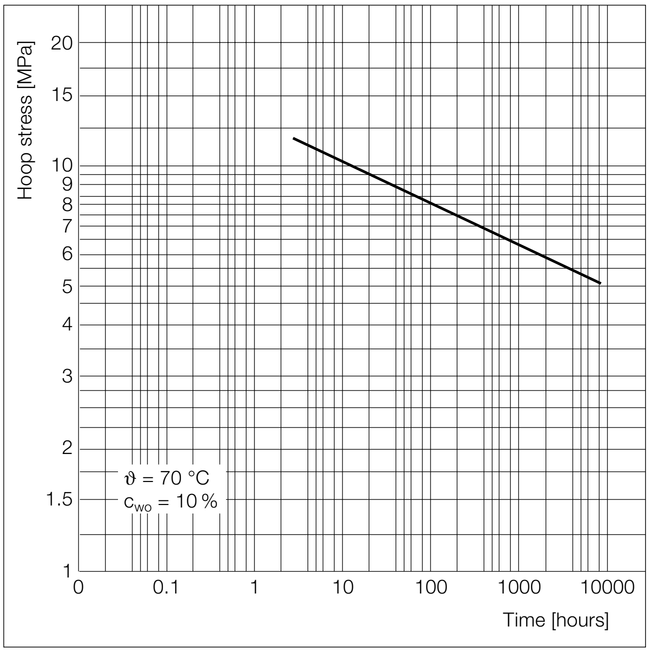

Fig. 7: Creep behaviour of water-saturated Ultramid® B5 pipes in isopropanol at 70 °C

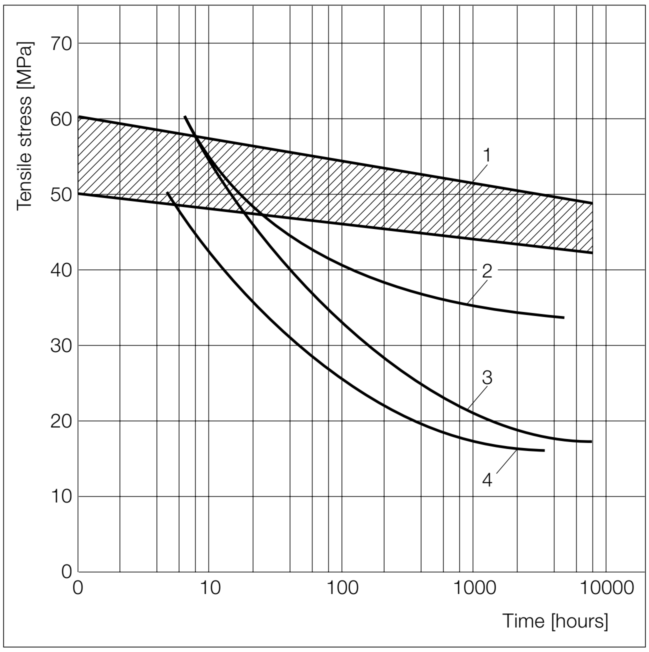

Fig. 8: Creep behaviour of Ultramid® B grades in M15 fuel (85 : 15 gasoline/methanol), in water and in 23/50 standard atmosphere.
Test specimens: DIN 53455, no. 3
1 Ultramid® B3S, B5 (conditioned at 23 °C/50 r. h.)
2 Ultramid® B3S (dry) in premium-grade gasoline at 23 °C
3 Ultramid® B3S (dry) in M15 fuel at 23 °C
4 Ultramid® B3S (initially dry) in water at 23 °C

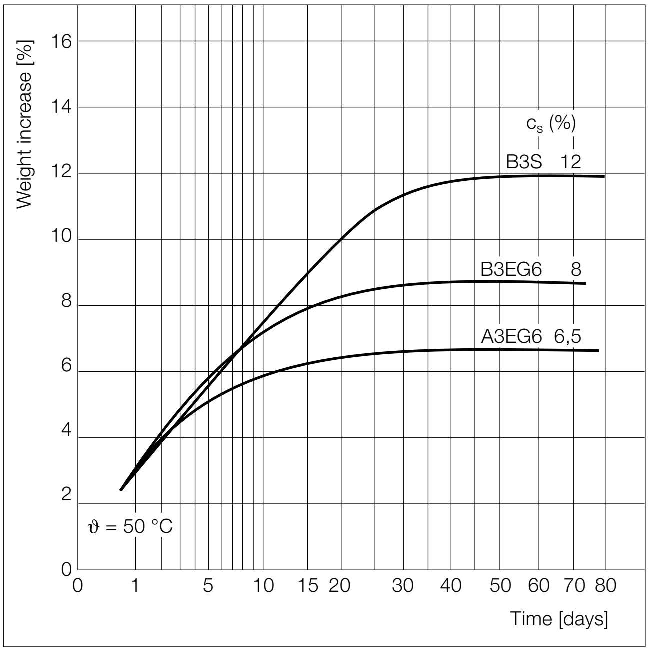

Fig. 9: Relative increase in weight of Ultramid® grades in M15 fuel (85 : 15 gasoline/methanol) at 50 °C. C_s (%) is the relative increase in weight at saturation. Test specimens: DIN 53455, no. 3

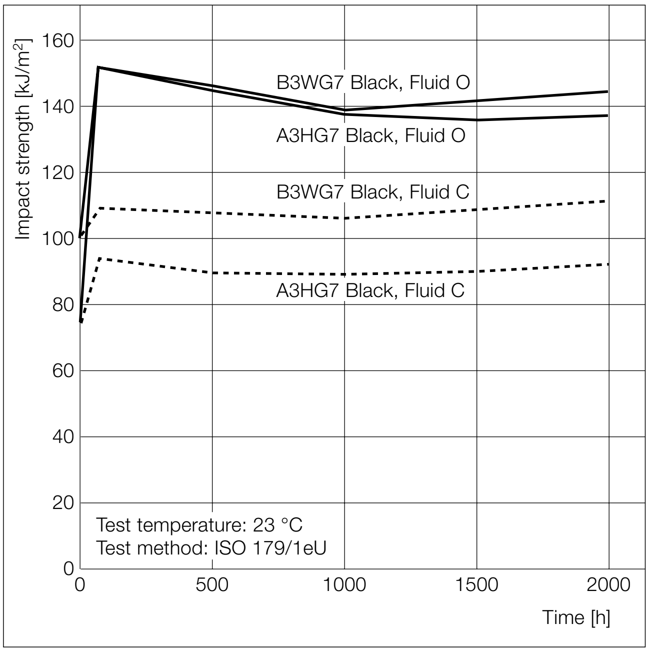

Fig. 10: Ultramid® A3HG7 Black and B3WG7 Black Resistance to fuel mixtures at 70 °C: Fluid C (50 % isooctane + 50 % toluene); Fluid O (85 % Fluid C + 15 % methanol).

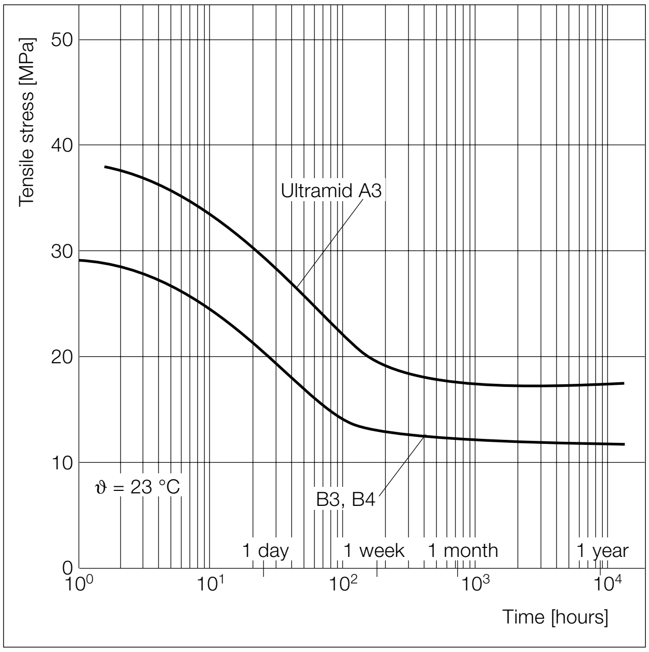

Fig. 11: Creep behaviour of Ultramid® A and B in methanol. Test specimens: DIN 53455, no. 3; temp.: 23 °C

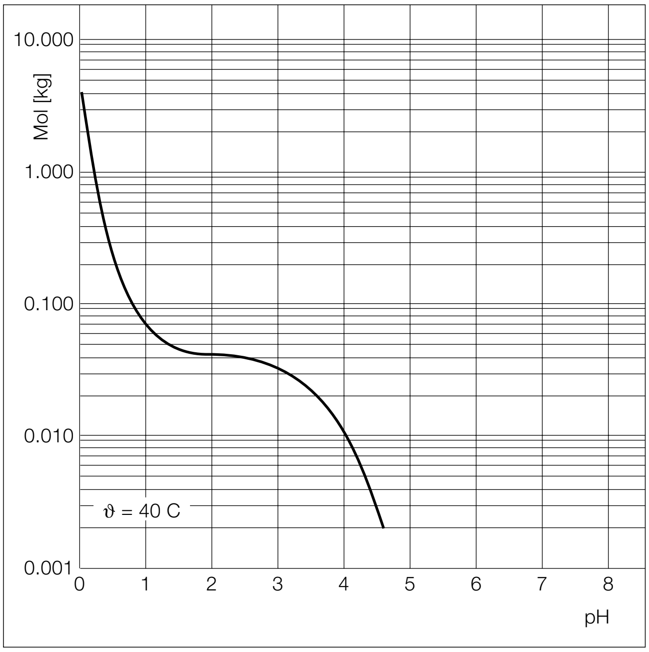

Fig. 12: Absorption of hydrochloric acid by Ultramid® B3 as a function of the pH at 40 °C. Test specimens: disks (Ø 60 mm x 1 mm) injection-moulded with a cold mould

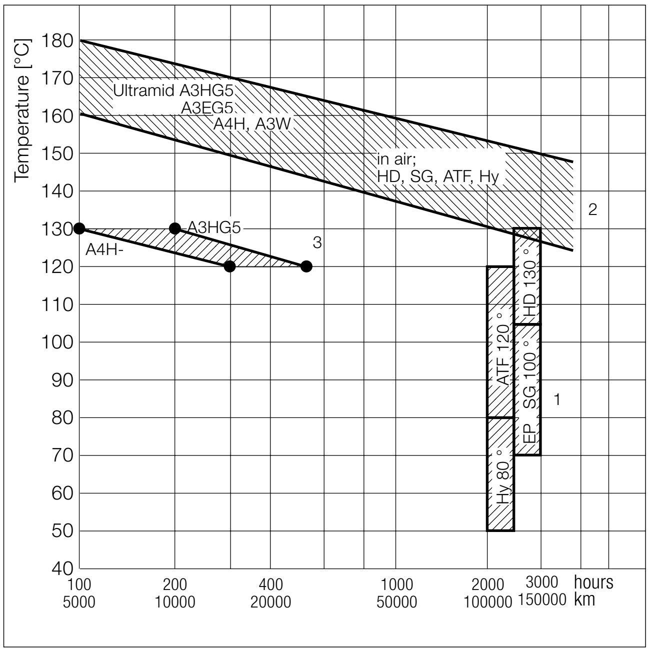

Fig. 13: Typical temperature and endurance data for Ultramid® in contact with automotive lubricants
HD = HD engine oil
SG = Transmission oil (mechan.)
ATF = Transmission oil (autom.)
EP = EP hypoid-gear oil SAE90
Hy = Hydraulic oil (corresp. HD)

1 Long term temp. in driving operation (Peak temp. approx. + 130 °C)
2 In accordance with IEC-216
3 In EP hypoid-gear oil

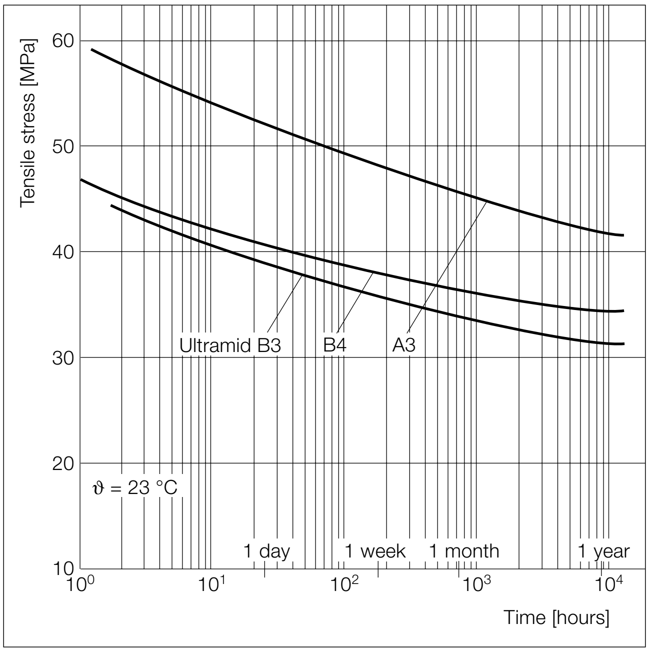

Fig. 14: Creep behaviour of Ultramid® in silicone oil AK 1000 (Wacker)
Test specimens: DIN 53455, no. 3

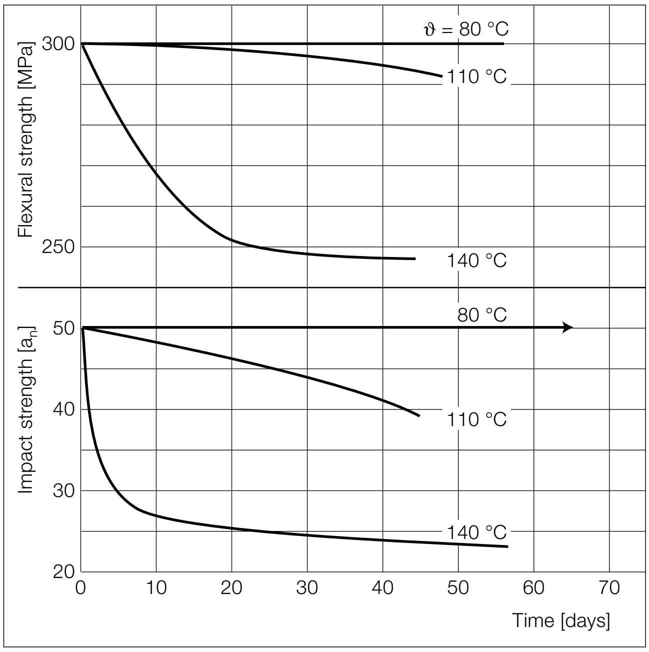

Fig. 15: Change in impact and flexural strength of Ultramid® A3EG10 Black 564 in contact with silicone oil at 80, 110 and 140 °C (measured at 23 °C)

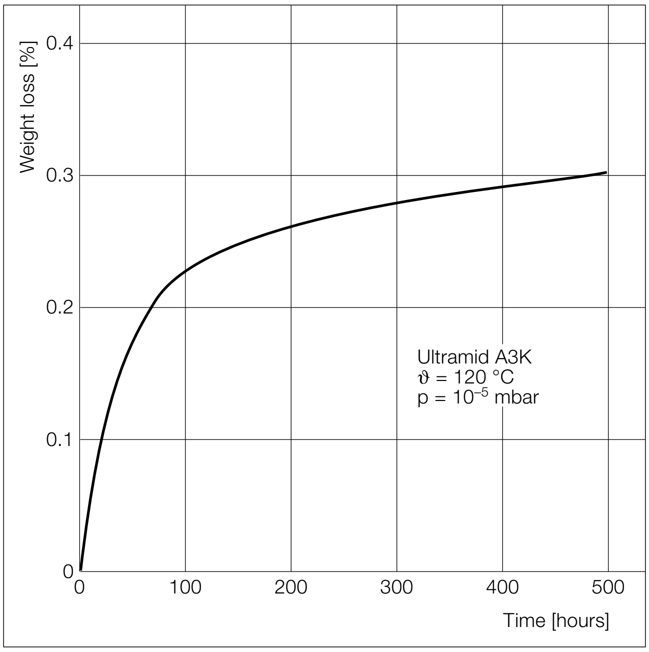

Fig. 16: Relative loss in weight of Ultramid® A3K Black 464 (dry) at 120 °C in a 10^{-5}-mbar vacuum.
(GLC analysis of volatile matter: 80 % oligomers, 7 % water).

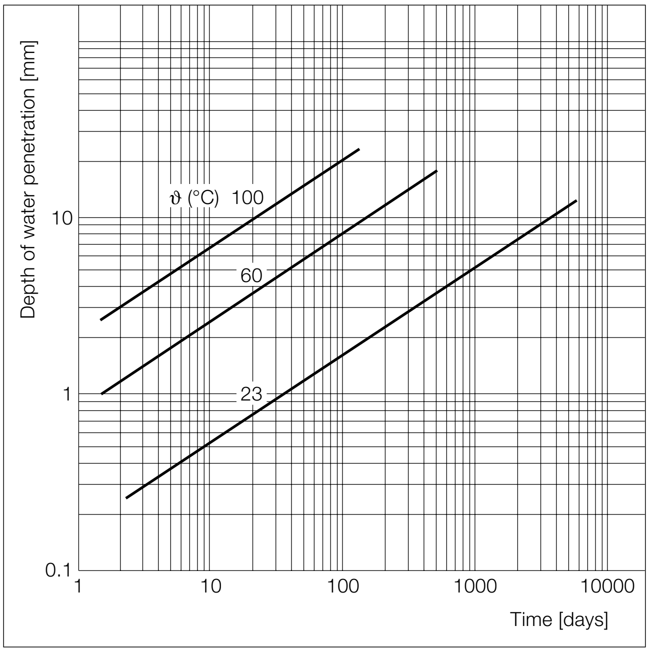

Fig. 17 Penetration of water into Ultramid® B at 23, 60 and 100 °C

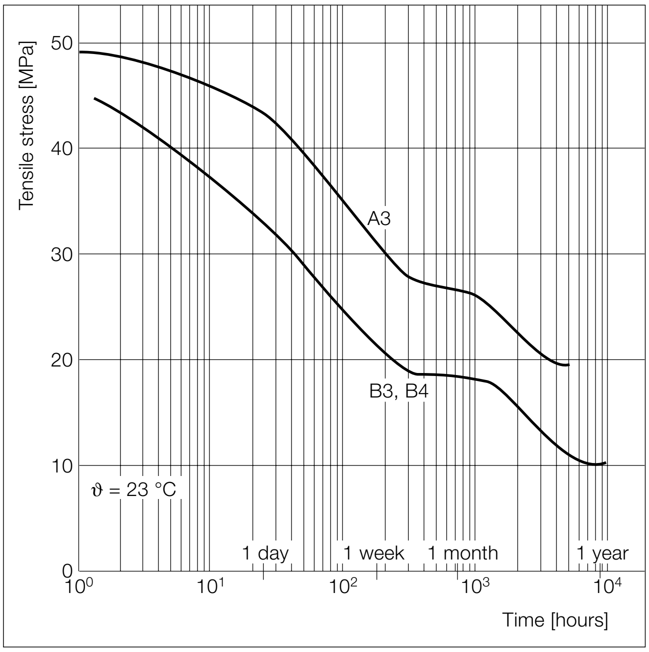

Fig. 18 Creep behaviour of Ultramid® in distilled water at 23 °C
Test specimens: DIN 53455, no. 3

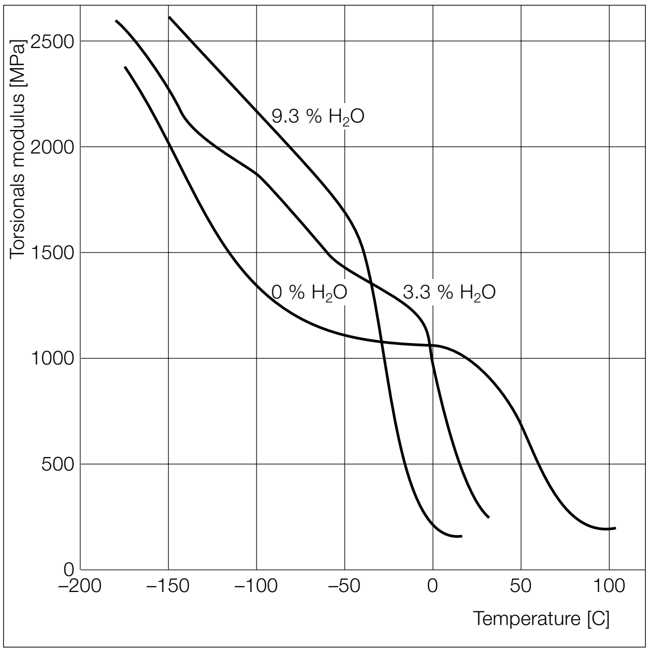

Fig. 19: Variation in torsional shear modulus of Ultramid® B3 as a function of temperature. Water content of specimens: 0 %, 3.3 % and 9.3 % (DIN 53445)

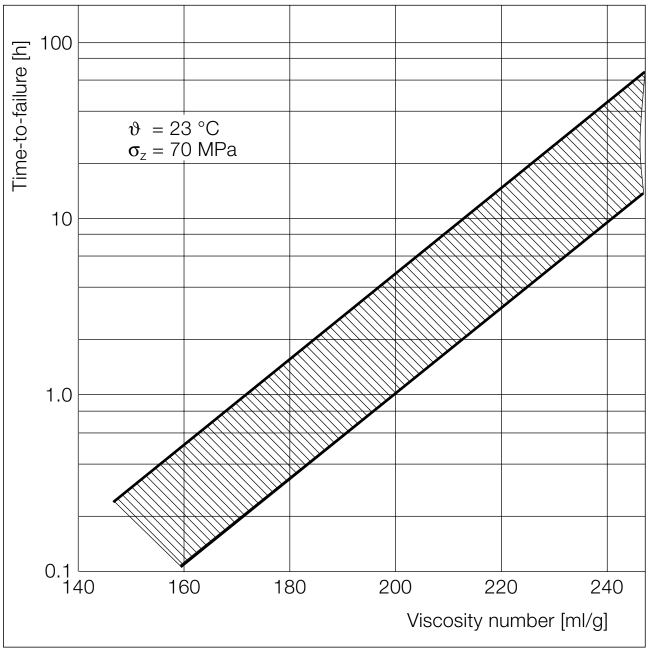

Fig. 20: Time-to-failure of dry PA 66 in 37.5 % zinc chloride solution under a tensile stress of 70 MPa as a function of the viscosity number (DIN 53727, H_2SO_4 96 %).

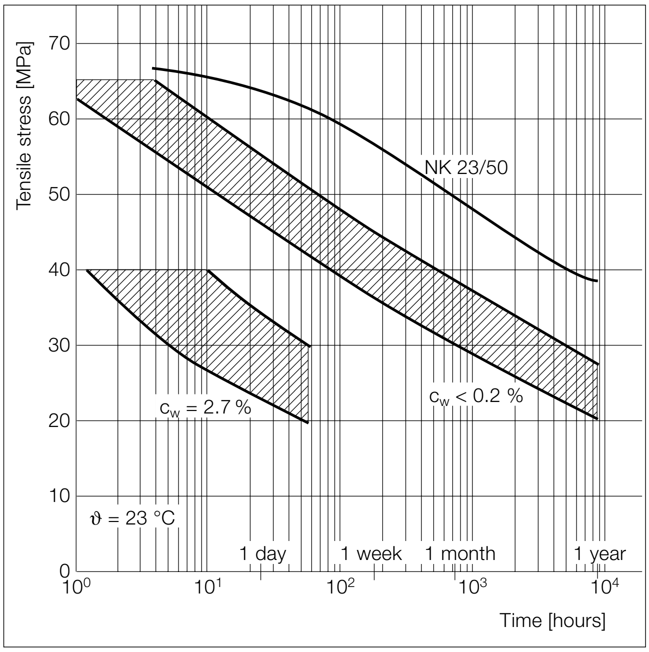

Fig. 21: Creep behaviour of stabilized high-molecular-weight PA 66 (dry and 2.7 % water content) in 37.5 % aqueous zinc chloride solution at 23 °C
Test specimens: DIN 53455, no. 3

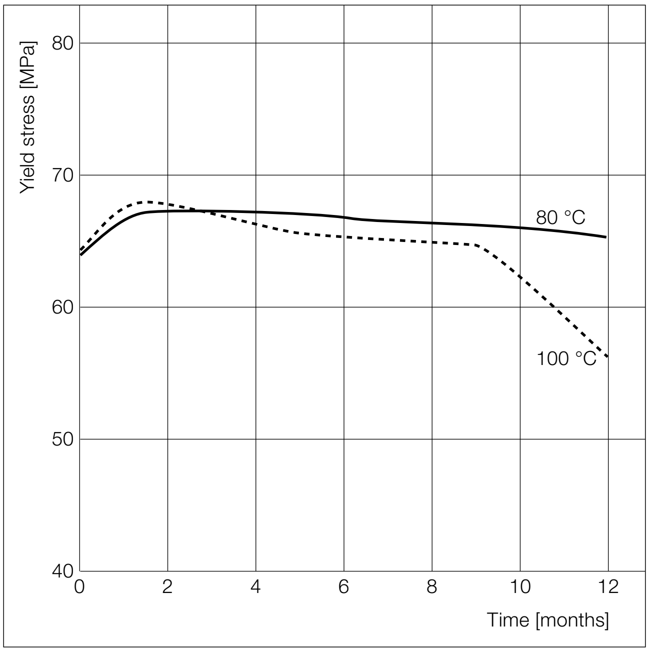

Fig. 22: Immersion of Ultraform® N 2320 003 in water.

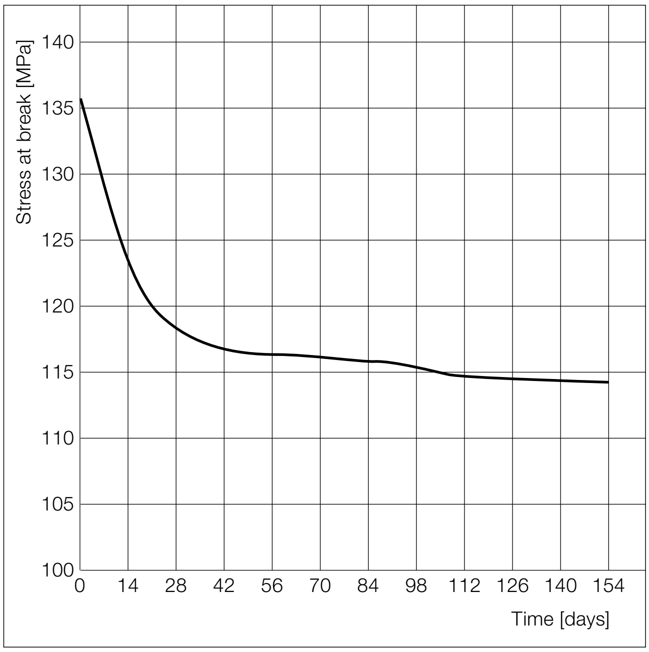

Fig. 23: Immersion of Ultraform® N 2200 G53 in water at 40 °C

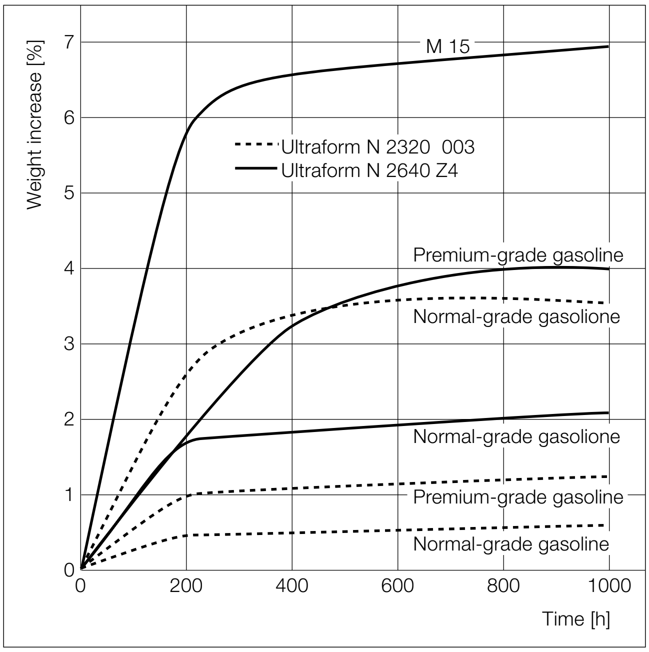

Fig. 24: Immersion of Ultraform® in engine fuels at 50 °C

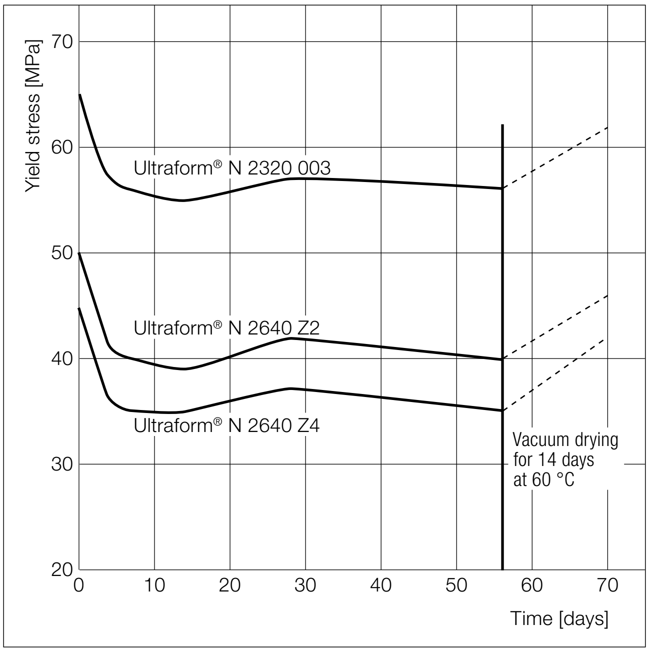

Fig. 25: Stress at yield after immersion in M15 fuel at 60 °C

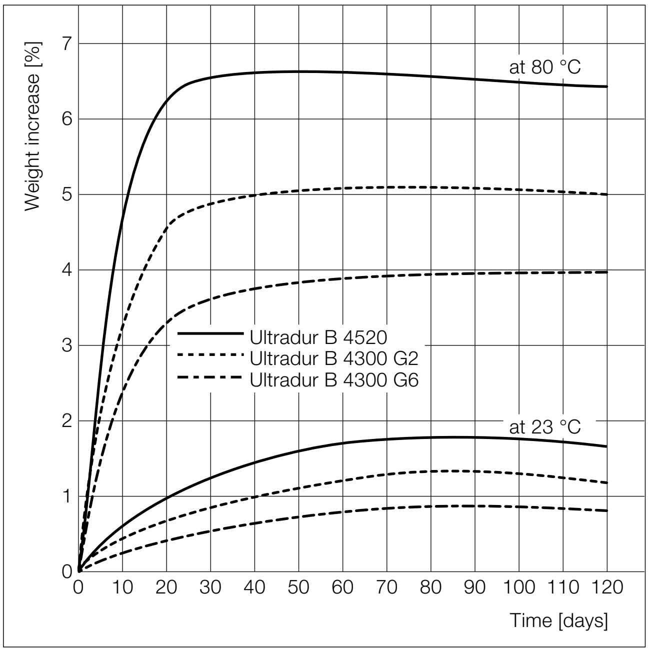

Fig. 26: Relative increase in weight of Ultradur® after immersion in M15 fuel at 23 °C and 80 °C

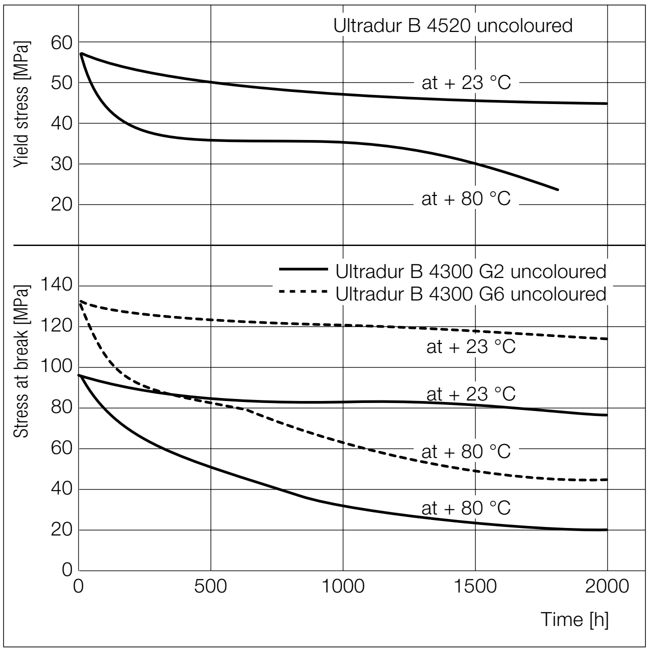

Fig. 27: Yield and breaking stress of Ultradur® after immersion in M15 fuel at 23 °C and 80 °C

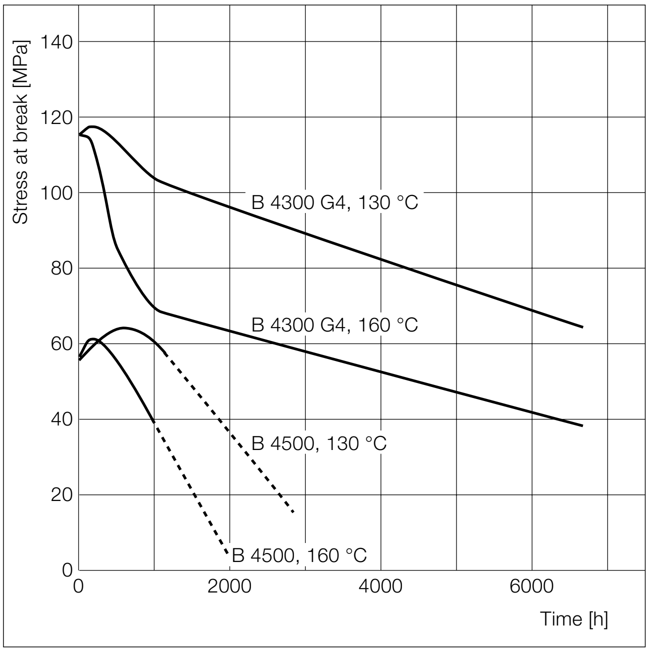

Fig. 28: Stress at break of Ultradur® after immersion in synthetic engine oil (Castrol TXT Softec 10W-40)

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Product Information

Nov 2011

Ultramid®
Polyamide 6

BASF
The Chemical Company

Product Description

Ultramid is a polyamide specialty extrusion resin combining high flexibility, outstanding chemical resistance and enhanced heat stability.

Applications

Ultramid is recommended for pipe and tubing applications requiring high melt strength and flexibility.

PHYSICAL	ISO Test Method	Property Value	
Density, g/cm	1183	1.13	
MECHANICAL	**ISO Test Method**	**Dry**	**Conditioned**
Tensile Modulus, MPa	527		
23C		1,180	-
Tensile stress at yield, MPa	527		
23C		48	-
Tensile strain at yield, %	527		
23C		30	-
Nominal strain at break, %	527		
23C		200	-
Flexural Modulus, MPa	178		
23C		1,050	-
IMPACT	**ISO Test Method**	**Dry**	**Conditioned**
Charpy Notched, kJ/m^2	179		
23C		12	-
THERMAL	**ISO Test Method**	**Dry**	**Conditioned**
Melting Point, C	3146	220	-
HDT A, C	75	48	-

Processing Guidelines

Material Handling
Max. Water content: 0.1%
Product is supplied in sealed containers and drying prior to molding is not required. If drying becomes necessary, a dehumidifying or desiccant dryer operating at 65 degC (149 degF) is recommended. Drying time is dependent on moisture level, but 2-4 hours is generally sufficient. Further information concerning safe handling procedures can be obtained from the Material Safety Data Sheet. Alternatively, please contact your BASF representative.
Typical Profile
Melt Temperature 225-245 degC (437-473 degF)
Typical Barrel Profile (degC):
Rear 225-245 degC (437-473 degF)
Middle 225-250 degC (437-482 degF)
Front 225-245 degC (437-473 degF)
Head 230-245 degC (446-473 degF)
Flange 230-245 degC (446-473 degF)
Die 230-245 degC (446-473 degF)
Screw Parameters

Metering Section	40%

BASF Corporation
Engineering Plastics
1609 Biddle Avenue
Wyandotte, MI 48192

General Information: 800-BC-RESIN
Technical Assistance: 800-527-TECH (734-324-5150)
Web address: http://www.plasticsportal.com/usa

Transition Section	3 to 4 flights
Feed Section	balance of screw length
Compression Ratio	3.5:1 to 4.0:1
L/D Ratio	20:1 to 24:1

Tooling & Sizing
Die to Finished Tube dia. 1.5-2.0:1

Selection of pin and die size will be dependent on the material viscosity. In general, the ratio of die size to finished tube diameter is about 1.5-2.0:1. The mandrel (pin) size is determined the same way in relation to the inner tube diameter.

Free (open tank) extrusion is recommended when producing tube diameters 9.5mm and below. For larger diameters, a differential pressure vacuum tank is recommended.

Tooling draw ratio is generally higher with free extrusion versus sizing, but will depend on melt viscosity. The vacuum sizer entrance should be about 3-9% larger than the finished tube outer diameter. Selection will depend on melt viscosity and die swell of the extrudate.

Quenching
For diameters less than or equal to 9.5mm (.37") O.D., open tank quenching with normal tap water is suggested. Depending upon line speed, quenching distance can vary from 7.5 to 12 meters (24.6 -39.4 feet). A short air gap (die to quench water) is recommended for both tubing and cable jacketing for best flexibility.

Note

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Reference 8

Ultramid® Nylon 6

Permeability Coefficients

BASF
The Chemical Company

Permeability Coefficient (P) x 10^{11} [mL (STP) cm cm^{-2} sec^{-1} $(cm\ Hg)^{-1}$]

Temperature (deg C)	**Carbon dioxide**	**Methane**
23	0.2	<0.3
55	4.9	0.6
65	8.5	1.3

Sample thickness = 480 um

Reference 9

TEIJIN

TEIJIN ARAMID BV
Velperweg 76
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6802 ED ARNHEM
The Netherlands
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TWARON® YARN SPECIFICATION

Product : Twaron ® 2300 1680 dtex f1000
Measured at twist level : Z80

			Batch average	
		Target	Minimum	Maximum
Linear density	(dtex)	1730	1692	1768
Breaking force	(N)	390	360	420
Elongation at Break	(%)	3,70	3,35	4,05
Chord Modulus	(GPa)	75	65,3	84,7

The physical properties are determined in accordance with the standard test-methods as laid down in the document TA standard 004: 'Test Methods of p-aramid filament yarns and cords of Teijin Aramid'.

The above specification of the physical properties - defined by minimum and maximum values - is based on process capability studies covering a long production period. The mean values of the deliveries will spread around the average of the min - max values given; the probability that this mean value will be within the indicated min - max values is 99%.

We emphasize that this information serves to reflect the actual standard of measures taken by us in order to permanently improve the safety of our products and not to confirm additional contractual liabilities, in particular within the meaning of Article 9, of General Terms and Conditions of Sale.

Date: August 08, 2016 August 10, 2016

Issued by: Sander Nieuwenhuijzen Henk Kerkdijk

Product Manager Quality Assurance Manager