



Figure 4 Tough Clear

Production Tough

FIGURE 4

A clear, production-grade material engineered to offer long-term stability, chemical compatibility, and that has thermoplastic-like mechanical properties.

PRODUCTION-GRADE MATERIAL THAT IS DURABLE AND AVOIDS FADING OR DISCOLORATION

Figure 4 Tough Clear delivers a versatile combination of mechanical stability and properties suitable for functional prototyping or end-use parts. It offers high light transmission that can be made fully transparent with post-processing.

3D printing clear components is a cost-effective manufacturing process for product development. Get visibility into the workings of complex assemblies, observe gas or fluid flows and reduce product design cycles. Figure 4 Tough Clear introduces long-term stability which minimizes reprints.



Figure 4 Tough Clear Manifold

APPLICATIONS

- End-use manufacturing of high-volume, small plastic parts
- Load-bearing handles, cranks, knobs and levers
- Structural brackets, snap-fits and fasteners
- Lighting covers, cases, reflectors and light guides
- Fast-moving consumer goods and consumer packaging

BENEFITS

- Excellent clarity that can be further improved with post-processing steps like clear coating
- Long-term environmental stability of mechanical properties and performance
- Ability to go from prototype to production parts using clear or transparent aesthetics
- Prototypes have longer lives and can be reused for longer periods of time
- Supports functional testing in outdoor settings
- Automotive fluid and chemical compatibility

Note: Not all products and materials are available in all countries — please consult your local sales representative for availability.

MATERIAL PROPERTIES

The full suite of mechanical properties is given per ASTM and ISO standards where applicable. Properties like flammability, dielectric properties, and 24-hour water absorption are also provided for better understanding of material capabilities to help design decisions using the material. All parts are conditioned per ASTM recommended standards for a minimum of 40 hours at 23°C, 50% RH.

Solid material properties reported were printed along the vertical axis (ZY-orientation). As detailed in the Isotropic Properties section, Figure 4 material properties are relatively uniform across print orientations. Parts do not need to be oriented in a particular direction to exhibit these properties.

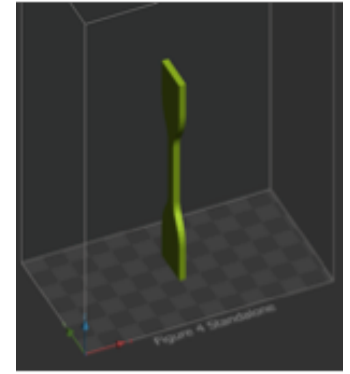
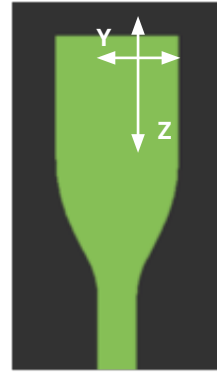
LIQUID MATERIAL						
METRIC	METHOD	METRIC	US			
Viscosity (@25C)	Brookfield viscometer	46 cps	111 lb/ft-hr			
Color		Clear				
Liquid Density (@25C)	Kruss K11 Force Tensiometer	1.11 g/cm ³	0.04 lb/in ³			
Default print layer thickness	Internal	30 µm	0.001 in			
Speed - Standard mode	Internal	17 mm/hr	0.67 in/hr			
Speed - Draft mode	Internal	22.5 mm/hr	0.87 in/hr			
SOLID MATERIAL						
METRIC	ASTM METHOD	METRIC	US	ISO METHOD	METRIC	US
PHYSICAL				PHYSICAL		
Solid Density	ASTM D792	1.2 g/cm ³	0.044 lb/in ³	ISO 1183	1.2 g/cm ³	0.044 lb/in ³
24 Hour water absorption	ASTM D570	0.57%	0.57%	ISO 62	0.57%	0.57%
MECHANICAL				MECHANICAL		
Tensile Strength Ultimate	ASTM D638 Type IV	52 MPa	7500 psi	ISO 527 -1/2	51 MPa	7400 psi
Tensile Strength at Yield	ASTM D638 Type IV	52 MPa	7500 psi	ISO 527 -1/2	51 MPa	7400 psi
Tensile Modulus	ASTM D638 Type IV	2300 MPa	340 ksi	ISO 527 -1/2	2500 MPa	360 ksi
Elongation at Break	ASTM D638 Type IV	12.3%	12.3%	ISO 527 -1/2	11.3%	11.3%
Elongation at Yield	ASTM D638 Type IV	3.8%	3.8%	ISO 527 -1/2	3.7%	3.7%
Flex Strength	ASTM D790	72 MPa	10400 psi	ISO 178	66 MPa	9600 psi
Flex Modulus	ASTM D790	2200 MPa	310 ksi	ISO 178	2100 MPa	308 ksi
Izod Notched Impact	ASTM D256	19 J/m	0.4 ft-lb/in	ISO 180-A	17 J/m ²	0.0079 ft-lb/in ²
Izod Unnotched impact	ASTM D4812	460 J/m	9 ft-lb/in	ISO 180-U	370 J/m ²	0.1769 ft-lb/in ²
Shore Hardness	ASTM D2240	81 D	81 D	ISO 7619	81 D	81 D
THERMAL				THERMAL		
Tg (DMA E")	ASTM E1640 (E"Peak)	50 °C	123°F	ISO 6721-1/11 (E" Peak)	50 °C	123°F
HDT 0.455MPa/66PSI	ASTM D648	49 °C	119°F	ISO 75- 1/2 B	49 °C	119°F
HDT 1.82MPa/264 PSI	ASTM D648	44 °C	110°F	ISO 75-1/2 A	44 °C	110°F
CTE 040 to 15C	ASTM E831	73 um/m-C	41 um/m-F	ISO 11359-2	73 um/m-C	41 um/m-F
CTE 55 to 125C	ASTM E831	184 um/m-C	102 um/m-F	ISO 11359-2	184 um/m-C	102 um/m-F
UL Flammability	UL94	HB				
ELECTRICAL				ELECTRICAL		
Dielectric Strength (kV/mm) @ 3mm thickness	ASTM D149	15.7				
Dielectric Constant @ MkHz	ASTM D150	3.35				
Dissipation Factor @ MkHz	ASTM D150	0.033				
Volume Resistivity (ohm-cm)	ASTM D257	6.29x10 ⁵				

ISOTROPIC PROPERTIES

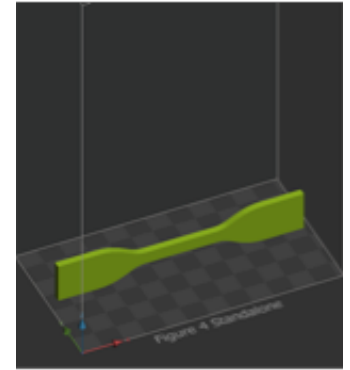
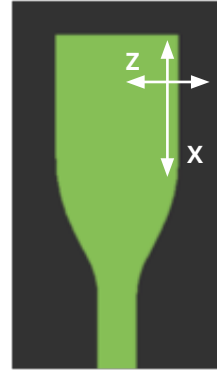
Figure 4 technology prints parts that are generally isotropic in mechanical properties meaning the parts printed along either the XYZ axis will give similar results.

Parts do not need to be oriented to get the highest mechanical properties, further improving the degree of freedom for part orientation for mechanical properties.

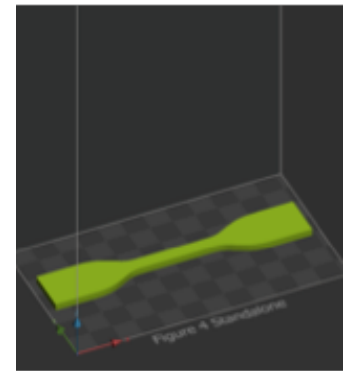
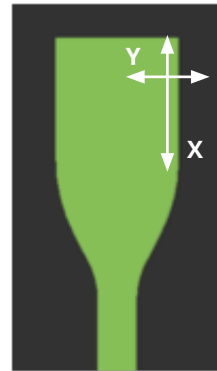
SOLID MATERIAL					
METRIC	METHOD	METRIC			
MECHANICAL					
		ZY	XZ	XY	Z45
Tensile Strength Ultimate	ASTM D638 Type IV	52 MPa	52 MPa	49 MPa	50 MPa
Tensile Strength at Yield	ASTM D638 Type IV	52 MPa	52 MPa	49 MPa	Did not yield
Tensile Modulus	ASTM D638 Type IV	2300 MPa	2400 MPa	3100 MPa	2700 MPa
Elongation at Break	ASTM D638 Type IV	12.3 %	10 %	8 %	6 %
Elongation at Yield	ASTM D638 Type IV	3.8 %	3.9 %	3.6 %	Did not yield
Flex Strength	ASTM D790	72 MPa	75 MPa	75 MPa	79 MPa
Flex Modulus	ASTM D790	2200 MPa	2200 MPa	2200 MPa	2300 MPa
Izod Notched Impact	ASTM D256	19 J/m	21 J/m	21 J/m	20 J/m
Izod unnotched impact	ASTM D4812	460 J/m	506 J/m	473 J/m	482 J/m
Shore D Hardness	ASTM D2240	81 D	80 D	80 D	81 D



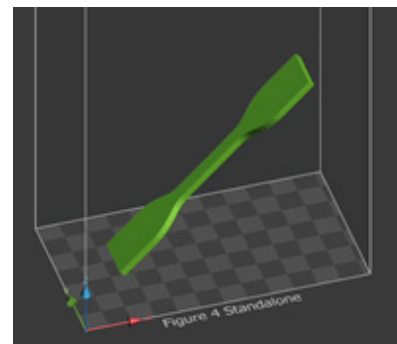
ZY - orientation



XZ - orientation



XY - orientation

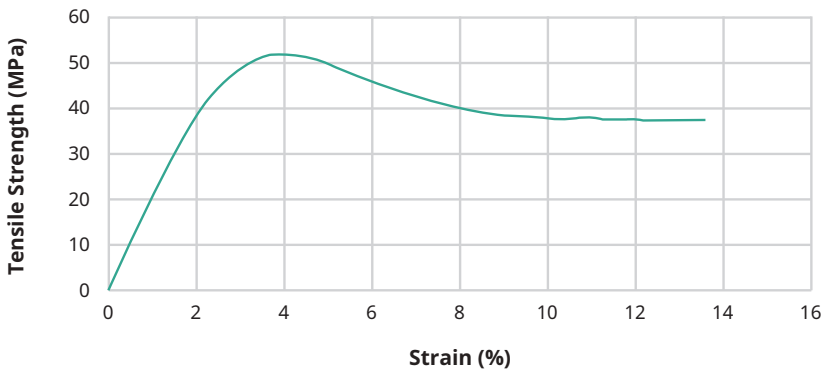


Z45-Degree - orientation

STRESS-STRAIN CURVE

The graph represents the Stress-Strain curve for Figure 4 Tough Clear per ASTM D638 testing.

FIGURE 4 TOUGH CLEAR STRESS-STRAIN CURVE

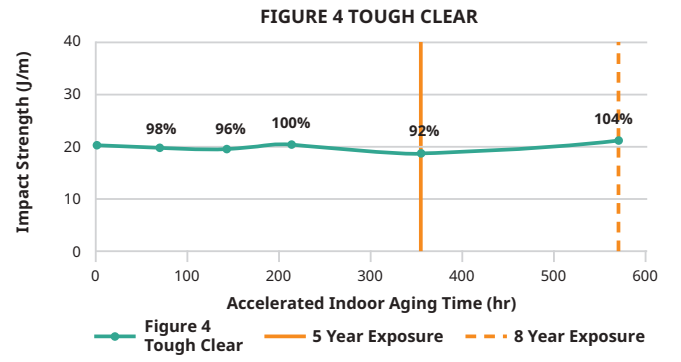
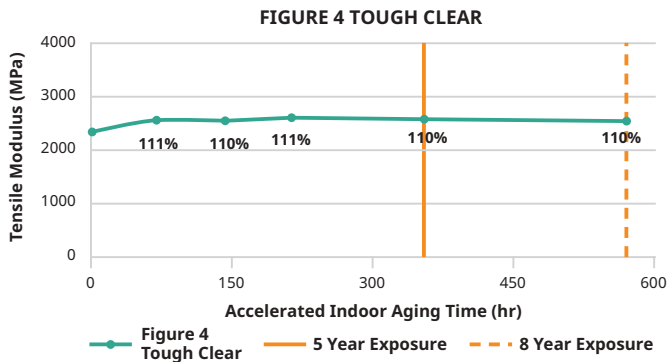
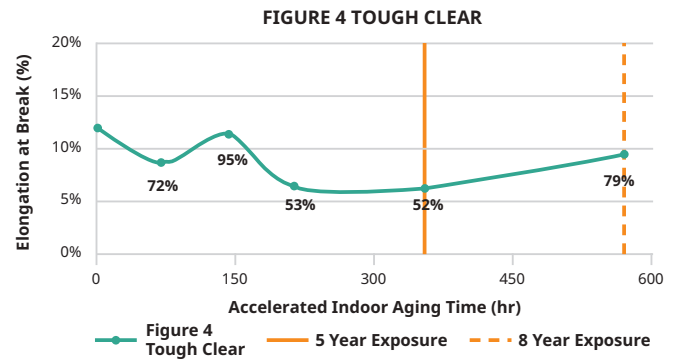
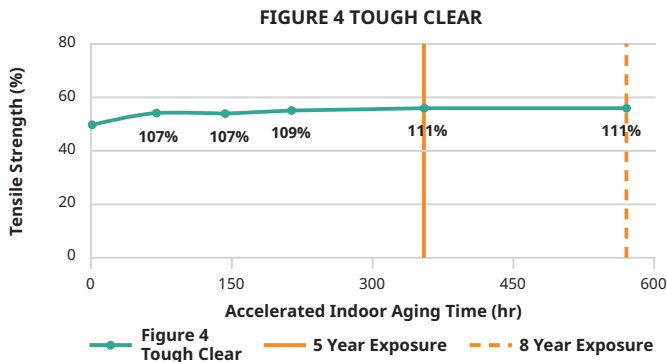


LONG TERM ENVIRONMENTAL STABILITY

Figure 4 Tough Clear is engineered to give long term environmental UV and humidity stability. This means the material is tested for the ability to retain a high percent of the initial mechanical properties over a given period of time. This provides real design conditions to consider for the application or part. **Actual data value is on Y-axis, and data points are % of initial value.**

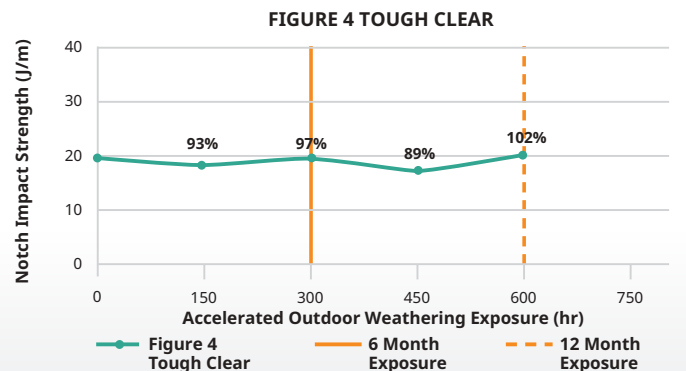
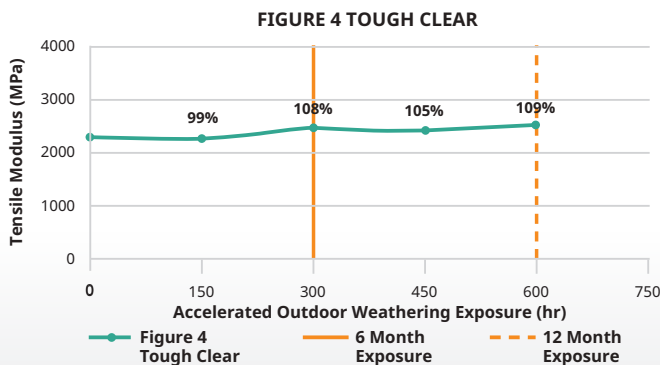
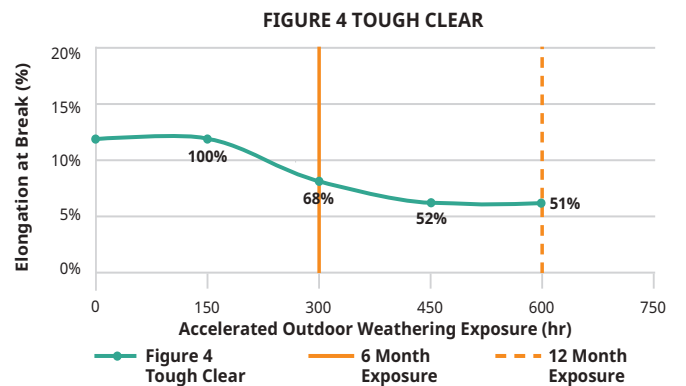
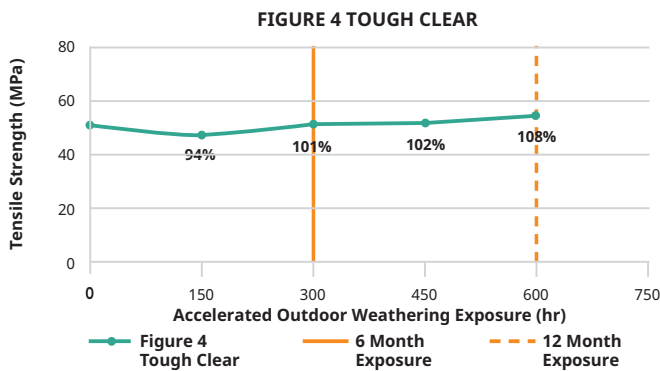
INDOOR STABILITY: Tested per ASTM D4329 standard method.

INDOOR STABILITY



OUTDOOR STABILITY: Tested per ASTM G154 standard method.

OUTDOOR STABILITY



AUTOMOTIVE FLUID COMPATIBILITY

The compatibility of a material with hydrocarbons and cleaning chemicals is critical to part application. Figure 4 Tough Clear parts were tested for sealed and surface contact compatibility per USCAR2 test conditions. The fluids below were tested in two different ways per the specs.

- Immerse for 30 minutes, remove and store for 7 days, then take mechanical property data for comparison.
- Immerse for 7 days, then take mechanical property data for comparison.

Data reflects the measured value of properties over that period of time.

AUTOMOTIVE FLUIDS		
FLUID	SPECIFICATION	TEST TEMP °C
Gasoline	ISO 1817, liquid C	23 ± 5
Diesel Fuel	905 ISO 1817, Oil No. 3 + 10% p-xylene*	23 ± 5
Engine Oil	ISO 1817, Oil No. 2	50 ± 3
Ethanol	85% Ethanol + 15% ISO 1817 liquid C*	23 ± 5
Power Steering Fluid	ISO 1917, Oil No. 3	50 ± 3
Automotive Transmission Fluid	Dexron VI (North American specific material)	50 ± 3
Engine Coolant	50% ethylene glycol + 50% distilled water*	50 ± 3
Brake Fluid	SAE RM66xx (Use latest available fluid for xx)	50 ± 3
Diesel Exhaust Fluid (DEF)	API certified per ISO 22241	23 ± 5

*Solutions are determined as percent by volume

FIGURE 4 TOUGH CLEAR

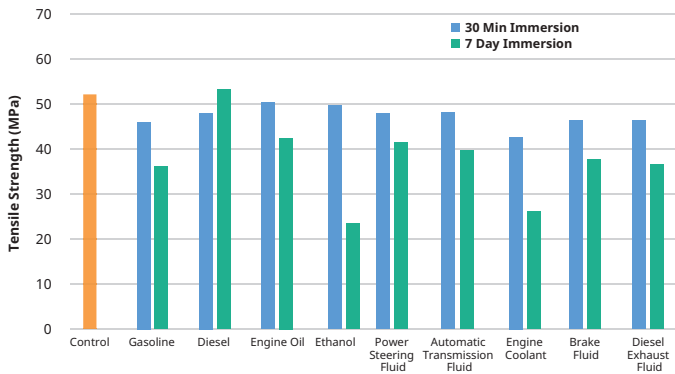


FIGURE 4 TOUGH CLEAR

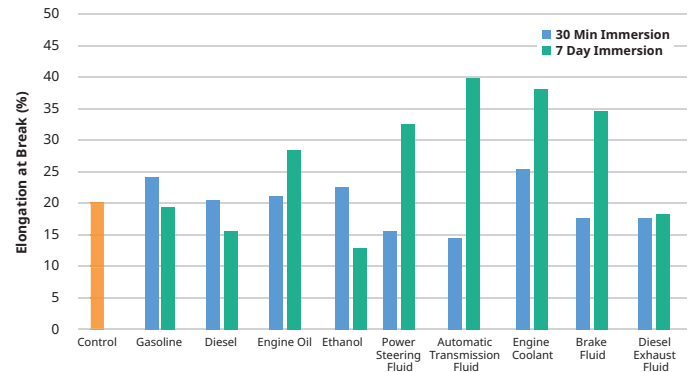


FIGURE 4 TOUGH CLEAR

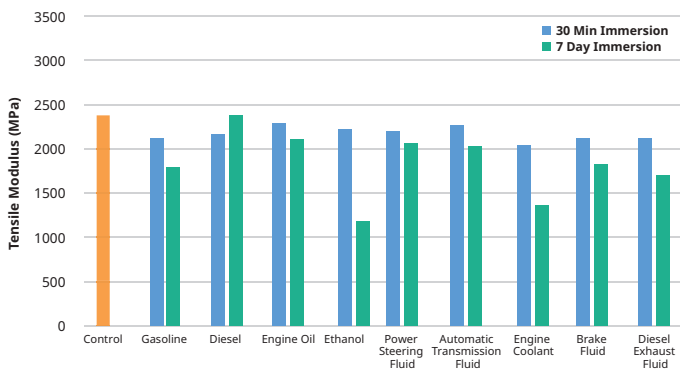
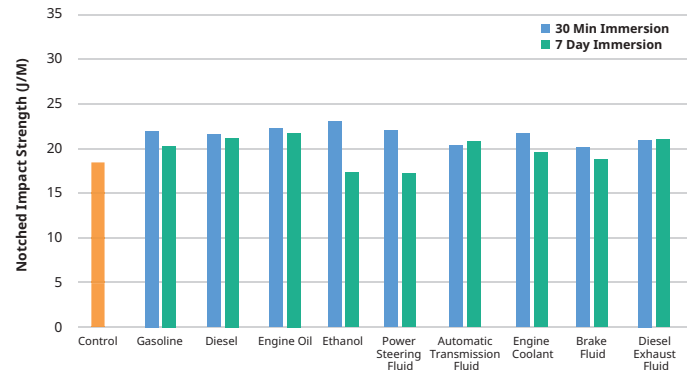


FIGURE 4 TOUGH CLEAR



CHEMICAL COMPATIBILITY

The compatibility of a material with cleaning chemicals is critical to part application. Figure 4 Tough Clear were tested for sealed and surface contact compatibility per ASTM D543 test conditions. The fluids below were tested in two different ways per the specs.

- Immerse for 30-minutes, then take mechanical property data for comparison.
- Immerse for 7-days, then take mechanical property data for comparison.

Data reflects the measured value of properties over that period of time.

*Denotes materials did not go through 7 day soak conditioning.

CHEMICAL COMPATIBILITY
6.3.3 Acetone
6.3.12 Detergent Solution, Heavy Duty
6.3.23 Hydrochloric Acid (10%)
6.3.38 Sodium Carbonate Solution (20%)
6.3.44 Sodium Hypochlorite Solution
6.3.46 Sulfuric Acid (30%)
6.3.42 Sodium Hydroxide Solution (10%)
6.3.15 Distilled Water

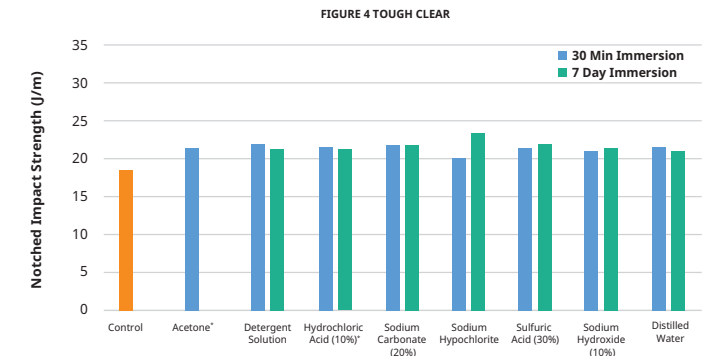
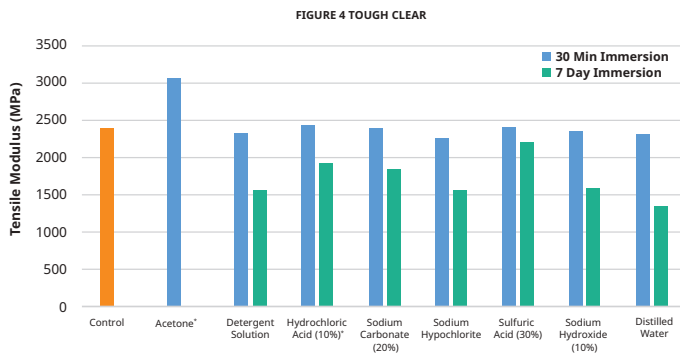
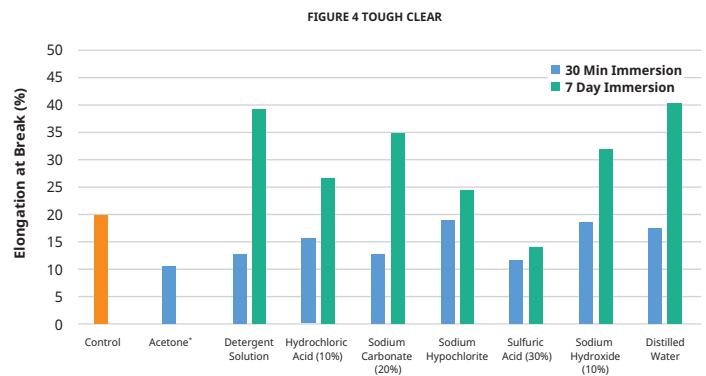
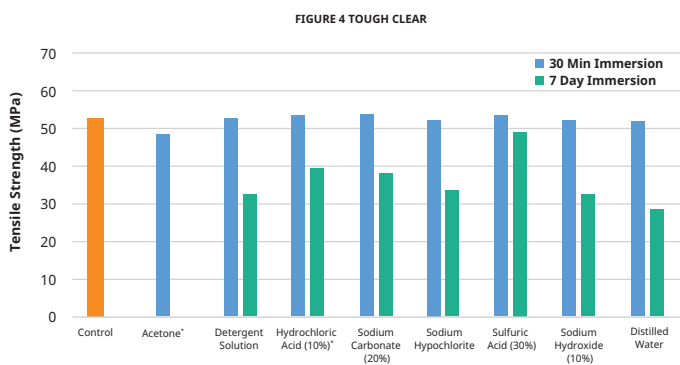


FIGURE 4 TOUGH CLEAR POST PROCESS

CLEANING INSTRUCTIONS

- Fill one plastic or metal container with TPM to a level to cover the parts.
- Place the TPM container inside the sonicator and place parts inside the solution. Sonicate parts for no more than 3 minutes, or at ambient conditions for at least 60 minutes, on the lowest frequency setting.
- Using a spray bottle filled with water, rinse parts thoroughly ensuring that all surfaces have been rinsed with water (over container dedicated to water waste). **DO NOT DISCARD THE WATER/TPM WASTE IN A SINK.**
- Using a spray bottle filled with IPA, rinse parts thoroughly ensuring that all surfaces have been rinsed with IPA (over empty container dedicated to IPA waste).
- Use a soft brush if necessary to remove material from difficult areas. Rinse with a small amount of clean IPA from a spray bottle after brushing.
- If desired, blow the part off with low-pressure compressed air.

DRYING INSTRUCTIONS

- Oven dry at 35 °C for 25 minutes

UV CURE TIME

- 3D Systems LC-3D Print Box UV Post-Curing Unit, Figure 4 UV Cure Unit 350 or PostCure 1050: 60 minutes.

More details can be found in the Figure 4 User Guide available at <http://infocenter.3dsystems.com>

Figure 4 Standalone: <http://infocenter.3dsystems.com/figure4standalone/node/1546>