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TELEDYNE RESON
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TECHNICAL NOTE

MTBF for Teledyne RESON Hydrophones




Figure 1: TC4032 on the left and TC4042 on the right

1. Mean Time Between Failures for Hydrophones TC4032, TC4042

This document is about mean time between failures (MTBF) for all Teledyne RESON hydrophones with or without built-in preamplifiers. The MTBF analysis is based on Teledyne RESON COTS models TC4042 and TC4032.

- The TC4042 is a spherical/omnidirectional hydrophone with built-in preamplifier. The sensor tip is covered by nitrile butadiene rubber (NBR). The housing is made of nickel aluminum bronze.

- The TC4032 is a low-noise sea state-zero hydrophone with built-in 10dB preamplifier. The sensor tip is covered by NBR rubber and the housing is made of nickel aluminum bronze.

The initial approach to find a "real life" based MTBF value was to look at the actual RMA cases for TC4032 and TC4042 and compare the number of hydrophones delivered through the years multiplied by lifetime from delivery of the individual phones with the number of hydrophones coming back as RMA cases. Lifetime of an RMA hydrophone is time from delivered to time/date when the actual RMA hydrophone return to Teledyne RESON for repair/service.

$$MTBF = \frac{\sum NON\ RMA\ Units_{delivered} \cdot (2009 - Shipment\ date_{delivered}) + \sum RMA\ Units_{delivered} \cdot (RMA_{return} - Org\ Shipment\ date_{delivered})}{\sum RMA\ cases}$$

Where:

- "NON RMA Units" means a unit that hasn't returned to Teledyne RESON yet.
- "Shipment $date_{delivered}$" means the date the hydrophone was shipped to the customer.
- "$RMA\ Units_{delivered}$" is a hydrophone that comes back as an RMA case.
- Lifetime of an RMA hydrophone = RMA_{return} date – the Org Shipment $date_{delivered}$.

Delivery of the first TC4032 hydrophones took place in 1997, delivery of the first TC4042 in 2000.

Throughout the years (the period 2000-2009), 5.5% of the delivered hydrophones has returned as RMA cases. Some of the cases were for recalibration only, and not due to failures or problems. A few of the RMA hydrophones returned were flooded due to a connector coming loose.

Based on the initial "delivered units versus units returned as RMA" approach, the TC4032/TC4042 hydrophones showed an MTBF higher than 57 years (units delivered prior to 2000 were disregarded; including these units, the MTBF will likely become much higher). While "57 years" is not be regarded as an expected lifetime for a hydrophone, it does indicate robustness and a very low likelihood of failures.

The above clearly indicates stable longevity, but cannot be used alone as an MTBF figure.

2. Building Blocks of the Hydrophones

2.1. NBR Rubber Window Encapsulating the Sensor Elements on TC4032 and TC4042

Both TC4042 and TC4032 have a uniform encapsulation using an NBR rubber with low permeability combined with good resistance to UV light, ozone, pollutants, and mechanical wear.

The special formulated NBR used for all Teledyne RESON standard COTS hydrophones with vulcanized rubber acoustic window, has a permeability equal to 1.3 x 10^{-9} g H_2O cm/(cm^2 x Hr x mm Hg). This figure is very comparable with the figure of butyl rubber, which is considered one of the best materials with regard to permeability. These results were obtained at Teledyne RESON 2004/2005 during our replacement of chloroprene rubber with the new NBR material (used 2005 onwards).

Water permeability of butyl rubber is around 1.2 x 10^{-9} g H_2O cm/(cm^2 x hr x mmHg)[1]

The NRB used is first of all resistant to sea and freshwater but also resistant to oil. It is limited resistant to petrol and most acids, but will be destroyed by base, strong acids, halogenated hydrocarbons (carbon tetrachloride, trichloroethylene), nitro hydrocarbons (nitrobenzene, aniline), phosphate ester hydraulic fluids, ketones (MEK, acetone), ozone, and automotive brake fluid.

The NBR rubber window used is strong, has low permeability, and good chemical resistance. The NBR rubber has better permeability values than the chloroprene rubber it replaced in 2004/2005. Chloroprene rubber was used on the earlier TC4032 and TC4042 units.

The reference hydrophones used for acoustic calibrations in the calibration tank at Teledyne RESON are constantly submerged. The following units are used and have been used for many years:

- TC4033-1 s/n 601010 made in 1997
- TC4033-1 s/n 4204018 made in 2004
- TC4033-1 s/n 3306108 made in 2006
- TC4034-1 s/n 0200023 made in 2000
- TC4034-1 s/n 4402077 made in 2001

Every second year the hydrophones above are shipped out to be recalibrated at NPL. From calibration to calibration, the results have remained very close and uniform.

As with all Teledyne RESON hydrophones, the above mentioned TC4033 and TC4034 models have the same encapsulation as TC4032 and TC4042. We draw attention to the reference hydrophones used in our calibration facility, as they have demonstrated durability, stability, and reliability. These hydrophones are used extensively, daily, and are submerged in water most of the time.

2.2. The Piezoelectric Ceramic

Piezoelectric ceramics used for the sensor elements age over time. The speed of aging declines rapidly after the first weeks after manufacturing. After that, aging is not an issue for the lifetime of a hydrophone. Teledyne RESON uses aged ceramics in all our hydrophones.

High mechanical stress on piezoelectric ceramics can cause them to break down or degrade. Survival and operational depth ratings are shown in the Product Leaflets for the individual hydrophones.

TC4032:
- Survival depth: 700 meters
- Operational depth: 600 meters

TC4042:
- Survival depth: 1200 meters
- Operational depth: 1000 meters

The only real threat to piezoelectric ceramics is water, not towards the ceramic itself, but to the silver electrode on the surface of the ceramic that will corrode. The encapsulation is addressing that point.

[1] //Handbook of Sonar Transducer Passive Materials, NRL//

2.3. The Preamplifier

Both TC4042 and TC4032 have built-in preamplifiers. The preamplifier for TC4042 is also used as accessory product EC6063 for TC4037 hydrophones. Both the EC6063 preamplifier and the TC4042 hydrophone are from 2000. The TC4032 including the preamplifier is from 1997 where the first delivery took place.

The low number of RMA cases is a strong indication of the good stability of the preamplifiers.

3. Conclusion

A service/operational life of 10-15 years is realistic for a Teledyne RESON hydrophone, provided it has been handled properly. Hydrodynamic loads on the hydrophones, rough handling, exposure to UV light, and exposure to some chemicals could shorten service life, but in general Teledyne RESON hydrophones are robust and certainly designed for use in marine environments.

For MTBF calculations on larger applications where Teledyne RESON hydrophones are used, 7 to 10 years' service life can be expected for the hydrophones with a very low likelihood of failures within that period of time.

Hydrophones with a polyurethane (PUR) front will have a shorter service life due to the higher permeability of PUR. For hydrophones like TC4035 and TC4038, a service life of 3 to 5 years is to be expected. The individual hydrophone Product Leaflets include details on the kinds of material used.

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