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Mean Time Between Failures (MTBF) for RESON hydrophones TC4032, TC4042

TC4032 on the left and TC4042 on the right.

The following document is about MTBF (mean time between failures) for all RESON hydrophones with and without built-in preamplifiers.

The MTBF analysis is based on RESON COTS models TC4042 and TC4032. TC4042 is a spherical/Omni-directional hydrophone with built in preamplifier. Sensor tip is covered by Nitril Butadiene Rubber (NBR) rubber. Housing is made of sea-bronze.

TC4032 is low noise Sea-State zero hydrophone with Built-in 10dB Preamplifier. The sensor tip of TC4032 is covered by NBR rubber and housing is made of sea-bronze, the same kind as used for TC4042.

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

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

"NON RMA Units" means a unit that hasn't returned to RESON yet.
"Shipment $date_{delivered}$" means the date the actual phone was shipped out to the customer.
"RMA $Units_{delivered}$" is a phone that comes back as a RMA case.
Lifetime of a RMA phone is the RMA_{return} date minus the original shipment date.

Delivery of the first TC4032 phones took place in 1997. Delivery of the first TC4042 in 2000.

Through out the years 5.5% has returned as RMA cases. Some of the RMA's have been for recalibration only, not due to failures or problems. A few of the RMA phones returned flooded by a connector coming loose.

Based on the initial "delivered units versus units returned as RMA" approach TC4032/TC4042 did show a MTBF higher than 57 years and to get that number units from before 2000 were disregarded (including the earlier units the number will become much higher). While "57 years" is not be regarded as an expected life time for a hydrophone, it does indicate robustness and that likelihood of failures is very low.

The above clearly indicate robustness – but can not be used alone as a MTBF figure.

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1. The building blocks of the phones

1.1. NBR rubber window encapsulating the sensor elements on both TC4032 and TC4042

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

The special formulated NBR used by RESON, for all RESON standard COTS hydrophones with vulcanized rubber acoustic window, has got a permeability equal to 1.3 x 10^{-9} g H_2O cm/(cm^2 x Hr x mm Hg). A figure that is very comparable with the figure of Butyl rubber, regarded as one of the best materials concerning permeability. These results were obtained at RESON 2004/2005 during our substituting our previous use of Chloroprene rubber to the new NBR material.

Water permeability of butyl rubber is around 1.2 x 10^{-9} g H_2O cm/(cm^2 x hr x mmHg)
//Handbook of Sonar Transducer Passive Materials, NRL//

The NRB used is first of all resistant to sea and fresh water but is also resistant to oil. It is limited resistant to petrol, limited resistant to most acids and 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 got low permeability and good chemical resistance. The NBR rubber has got 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 RESON are constantly submerged. The following units are used and have been used for many years:

TC4033-1 s/n601010 made in 1997
TC4033-1 s/n4204018 made in 2004
TC4033-1 s/n3306108 made in 2006
TC4034-1 s/n0200023 made in 2000
TC4034-1 s/n4402077 made in 2001

Every second year the phones above are shipped-out to be re-calibrated at NPL. From calibration to calibration, the results have remained very close and uniform.

As with all our hydrophones, the above mentioned TC 4033 and TC 4034 models have got the encapsulation in common with TC4032 and TC4042 phones. The reason we point out our hydrophones used in our calibration facility is that it demonstrates durability, stability, and reliability. These phones are used heavily, daily, and are submerged in water most of the time.

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1.2. 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 lifetime of a hydrophone. 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 rating is shown on the datasheets for the individual phones. Survival depth of TC4032 is 700meter and operational depth is 600meter. Figures for TC4042 are survival 1200meter and operational 1000meter.
The only real threat to piezoelectric ceramics is water, not towards the ceramic it self, but to the silver electrode on the surface for the ceramic that will corrode. The encapsulation is addressing that point.

1.3. The preamplifier

Both TC4042 and TC4032 have got build 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. TC4032 including the preamplifier is from 1997 where the first delivery took place.

The low number of RMA cases does indicate good stability of the preamplifiers.

2. Conclusion

Service/operational life of 10-15 years is realistic for a RESON hydrophone, assuming proper handling and care. Hydrodynamic loads on the phones, rough handling, exposure to UV light, and exposure to some chemicals could shorten service life but in general RESON hydrophones are robust and certainly designed for use in marine environment.

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

Hydrophones with a PUR (Polyurethane) 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. Product data sheets will tell the kind of material used on the particular hydrophone.

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