# TECHNICAL BULLETIN

PROGRESSING CAVITY PUMPS | LS-TB-O10

LIFTING SOLUTIONS

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## BACKGROUND

Elastomer selection and pump rotor sizing for progressing cavity (PC) pumps are critical to successful pump operation in artificial lift operations. An absence of industry standardization regarding elastomers, and their characteristics including fluid swell, necessitates that caution be used in transferring past practices from one PC pump supplier to another. Lifting Solutions (LSI) recommends that applications be reviewed in the context of each suppliers' elastomers, including where appropriate supporting the evaluation through laboratory elastomer fluid compatibility testing. This includes coal seam gas (CSG) applications which are a unique subset of oilfield artificial lift applications.

Historically, PC pump elastomer development has focused on the oil component that had the potential to create swell and mechanical property deterioration resulting in pump performance problems and reduced longevity. This led to nitrile elastomers being most commonly used, including the higher acrylonitrile variations (=>40% ACN) for the medium to lighter oil applications. Because oils are non-polar and water is polar, the measures taken to prevent oil swell were often detrimental in terms of water resistance. Additionally, less attention has been paid to certain ingredients in the elastomer formulations which have undesirable effects with water. Some higher nitrile elastomers also have greater vulnerability in stator-elastomer bonding under warm-to-hot water conditions. As a result of this evolution, legacy PC pump elastomers may not be optimized in their suitability for CSG applications.

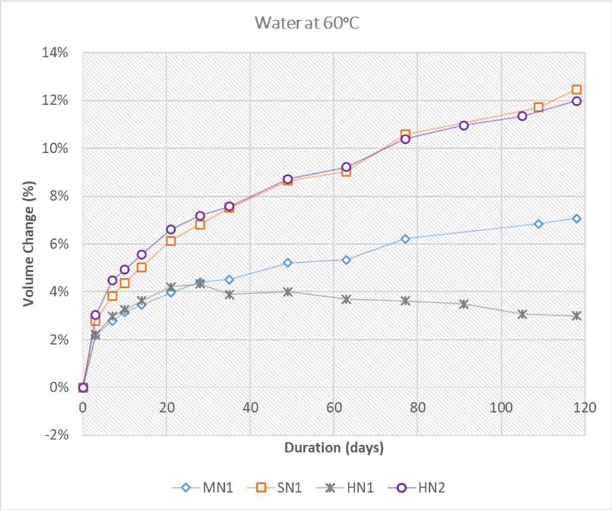
CSG applications are unique in their absence of produced oil unlike most applications where PC pumps are used. Initially, medium nitrile elastomers were successfully used in CSG applications as, at the 15 to 25°C downhole temperatures, they presented low water swell, had better mechanical properties and were lower cost. More recently PC pumps have been deployed in CSG applications with higher temperatures including Australia (50 to 55°C) and India (60 to 70°C). These warmer temperatures present a more challenging pump sizing situation due to a combination of elastomer thermal expansion and water swell tightening the pump fit. Initially there was a tendency to undercompensate for this tightening in the rotor sizing which, when combined with the poor lubricity of the pure water, resulted in high start-up and operating torques and reduced pump longevity. Over time and through experience, sizing was adjusted to looser fits and certain suppliers switched to their high nitrile elastomers. In some instances, these high nitrile elastomers, due to their incompatibility to water applications, exhibited shrinkage rather than swell which, in combination with elevated wear due to solids, led to quick loss of efficiency and much shorter run times. Separately, bonding systems used in some high nitrile elastomers, due to their higher sensitivity to warm water, have led to stator-tube bonding issues. From these past experiences, it is understood that a moderate level of swell is desired for CSG applications: not high enough to lead to high operating torques but enough to counteract the wear that is natural in these applications.

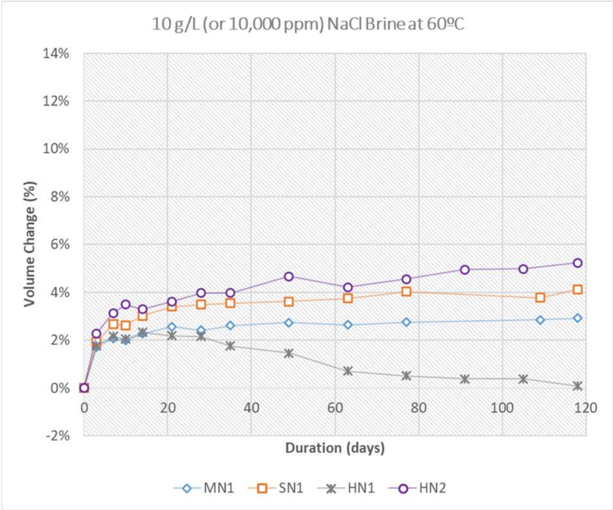
## LIFTING SOLUTIONS ELASTOMERS FOR CSG APPLICATIONS

When developing its PC pump elastomers, Lifting Solutions considered both oil and water applications. This led to careful choices in formulation to attain desired levels of oil and water resistance and avoid the traditional pitfalls in PC pump elastomer development. Additionally, in light of the trend toward higher temperature and higher water cut applications, an emphasis was placed on the elastomer to stator tube bonding which based on past experience can be challenging in warm-to-hot water conditions.

Representative laboratory elastomer fluid compatibility testing is a critical component of elastomer material selection and pump size selection. Considering the liquid component of CSG produced fluids is mainly water with dissolved salts, it offers the ease of synthetically preparing representative fluids for laboratory elastomer compatibility testing. Produced water characteristics of CSG applications can be defined by the quantity (total dissolved salts or TDS) and composition of the dissolved salts. TDS in most CSG applications range from a negligible value up to 20 g/l (or 20,000 mg/l or roughly 20,000 ppm), with 4 g/l to 10 g/l more often encountered. As for chemical composition, predominantly, the waters contain NaCl followed by KCl and NaHCO3 at lower amounts. With this knowledge of produced water properties, LSI conducted several rounds of elastomer compatibility testing with varying amounts and types of dissolved salts to cover the vast majority of scenarios encountered in CSG applications. The test programs also employed various elastomer sample thicknesses, test durations, and temperatures to gain a comprehensive understanding of nature of elastomer swell and the associated mechanisms in water with dissolved salts (i.e., brines). Selected results from these programs and their implications to pump selection and operation are given in this bulletin.

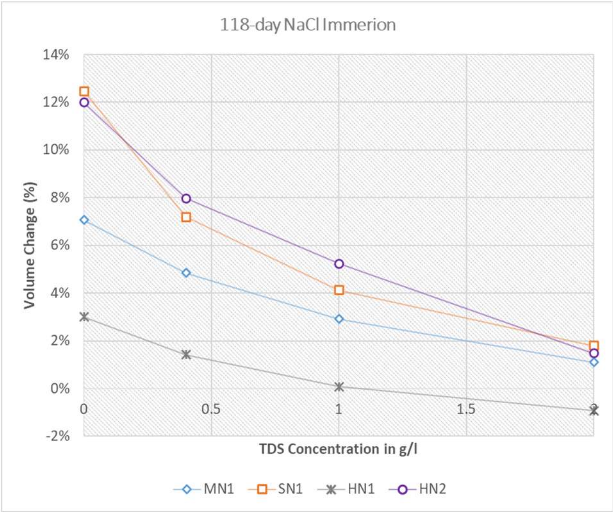
Charts below show the volume swell of a standard ASTM/ISO 15136-1 2mm thick sample of all four commercial LSI elastomers in water (left) and 10 g/l NaCl brine solution (right) from a 60°C/118-day immersion test:

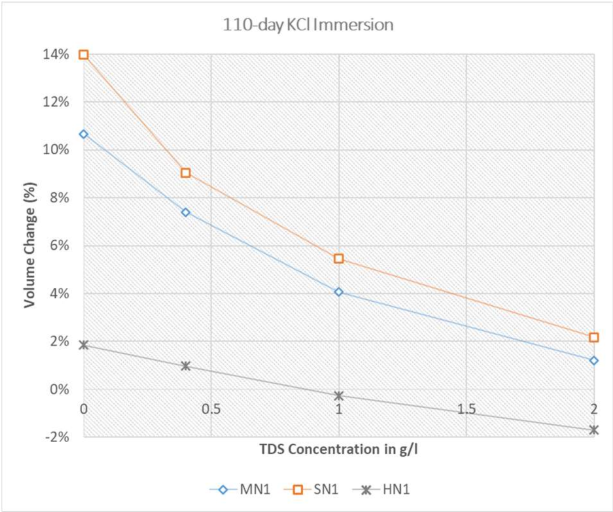



Results above show the significant reduction of swell with the addition of 10 g/l of salt to water. It also shows the relatively quicker stabilization of swell and minimization of difference in swell between elastomers in the presence of dissolved salt. Of the LSI elastomers tested, MN1 elastomer has an intermediate level of swell. LSI HN1 shows low swell and tends to shrink (reduce in volume change) over time. On the other hand, LSI SN1 and HN2 elastomers showed high swell.

In the same swell study, LSI also utilized two other of salt concentrations, 4 and 20 g/l. The entire study was also carried out with KCl to examine the effect of salt composition differences. A summary of the final swell vs salt concentration of the standard 2mm samples after similar immersion durations is shown in the two charts below, with the left showing the results of NaCl study and right the KCl study, both performed at 60°C:



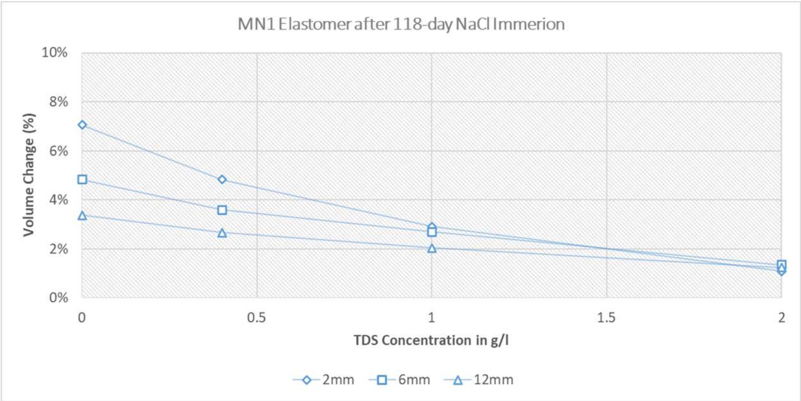




It can be witnessed from charts above that increasing salt concentration has the same effect of suppressing swell in both salts. It appears that the final swell seems to be higher in the KCl study for most of the elastomers, however, the extent of difference is within the normal range of test variability for such long-term test programs conducted at different instances. This was validated by another focused study on salt composition conducted where four different salts (NaCl, KCl, $NaHCO_3$, 30:70 $NaHCO_3$:NaCl) were compared head-to-head. From all these studies, it can be concluded with high confidence that the salt concentration (TDS) has a large effect on the rate and extent of elastomer swell while the effect of salt concentration is minimal.

These studies also encompassed elastomer mechanical property measurements alongside swell measurements. Despite the extended test duration, all elastomers retained reasonable levels of hardness, tensile strength, and elongation at break.

In terms of the comparison between elastomers, MN1 lies in the center of the swell spectrum of all elastomers. As discussed earlier, a moderate level of stator swell is desired for CSG applications to counteract any wear caused by solids production and thereby avoid quicker loss of pump efficiency. This makes the MN1 elastomer the most desired elastomer for most CSG applications from a swell perspective.

It is important to note that results presented until now are of the standard 2mm thick sample, which is far thinner in comparison to PC pump stator elastomer. Therefore, the rate and level of swell in a stator will be significantly lower than what was in witnessed in laboratory testing. To develop better estimates for stator swell, additional thicker samples were also included in all the studies discussed above. The chart below shows the final 118-day swell results of LSI MN1 elastomer at three different sample thickness in water and the three NaCl brine concentrations:

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Results show that swell drastically reduces on samples of higher thickness, which shows the large influence of elastomer thickness. Moreover, in the case of stator elastomer, swell is further reduced by the unidirectional nature of fluid exposure and the constraint imparted to elastomer swell from bonding to stator tube. Predicting downhole stator is therefore a hugely complicated exercise requiring a deep understanding of the influences of many variables on elastomer swell such as duration, salt concentration, elastomer thickness and exposure temperature. However, with LSI's effort to isolate and quantify the impact of variables that impact swell through various test programs, predictions of stator swell with sufficient accuracy is possible for any given set of downhole conditions and fluid characteristics.

Fluid swell is a critical component to pump performance although other aspects are also important to successful pump operation. As part of the elastomer development process, stator bond immersion testing was completed with water exposure for durations from 7 to 28 days over a range of temperatures from 30 to 100°C as per the guidelines in Annex A of ISO 15136-1. LSI MN1, the recommended elastomer from swell perspective, is paired with a robust bond system which retained the as-manufactured 100% rubber (0% bond) failure mode over all test conditions. The push out loads equated to shear stresses of approximately 2500 psi with no deterioration with water exposure after any temperature or time combinations. Similar results were obtained with 30 g/l NaCl brine up to 100°C, confirming the presence of salts doesn't erode bond integrity. Pump durability testing was completed with the LSI MN1 in 85°C water at 500 RPM at 125% of pump rated pressure for 25 million cycles (35 days) as per the ISO 15136-1 V1 requirement. The pump flow rates were maintained within the target range throughout the test period. Post run pump destructive inspection revealed no damage aside from normal wear and tear and minimal loss of bond retention.

## LIFTING SOLUTIONS' CSG ELASTOMER RECOMMENDATION

Lifting Solutions MN1 elastomer offers an excellent balance of swell, bond durability, mechanical and wear properties for CSG applications. Through various laboratory swell test programs simulating CSG environments, it has also been demonstrated that it shows an appropriate level of swell. The test programs helped LSI develop estimates for long-term stator swell for a range of CSG environments with varying TDS values, fluid composition and downhole temperatures. This in turn aids in the development of pump sizing recommendations to achieve optimal short- and long-term performance.

LSI has embarked on a stator-scale long term swell program to further close the information gap and offer even more accurate production of downhole stator swell and its impact on pump torques and efficiency. It is expected that a new or revised tech bulletin with be available soon, offering the most complete and accurate information for optimal product selection for CSG applications.