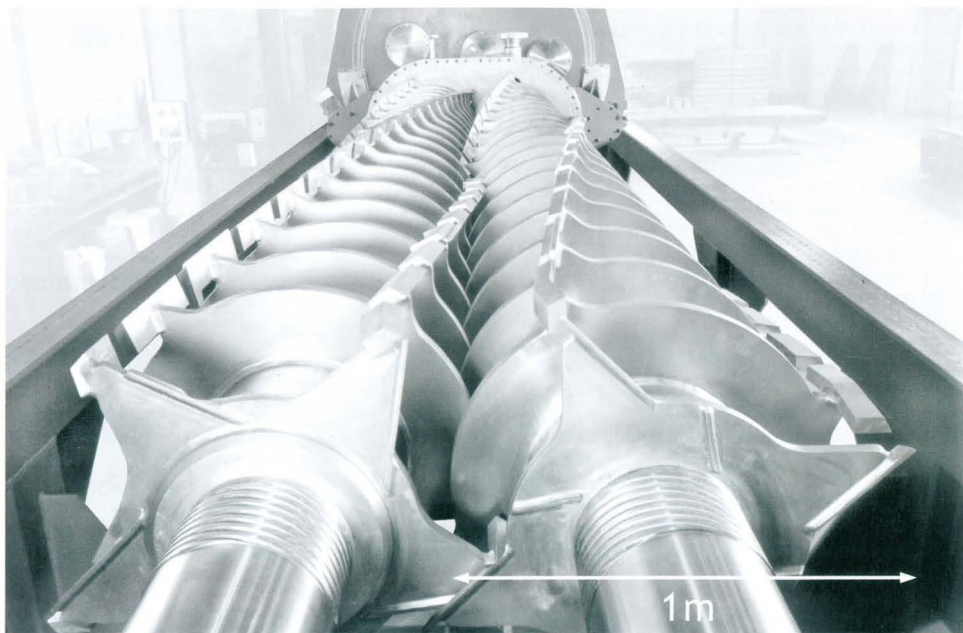


# A clever alternative

The List kneader processor is a unique solution for working in the concentrated phase



Pictures: LIST

**Kneader devolatilizer processing a polymer melt at up to 8 t/h. This customized process incorporates compounding within the devolatilization step.**

Industry is under pressure to develop sustainable processing methods. With this in mind, the List kneader processor provides an alternative to the stirred-tank reactor for the production of polymers, allowing solvents to be eliminated from the reaction step. The kneader processor is also an alternative to the extruder for polymer devolatilization.

ROLAND KUNKEL

● The conventional stirred-tank reactor has long been the standard equipment for polymerization reactions. To allow effective mixing and control of the heat of reaction, however, the stirred tank requires large amounts of solvent to dilute and cool the polymer solution.

Another well-established technology in the polymer industry is the extruder, which is

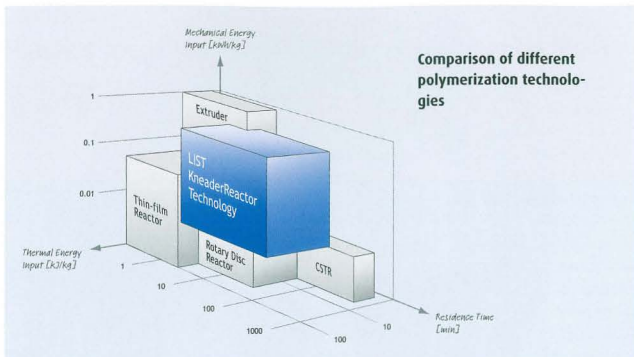
used for operations such as compounding and devolatilization. The basic function of the extruder is forced conveying at high shear rates ( $1000 \text{ s}^{-1}$ ), first melting and then conveying the product, with a simultaneous buildup of pressure. The extruder was developed in the 1960s by Rudolf Erdmenger, and subsequently manufactured by Werner & Pfleiderer as the so called "Zwei Schnecken Kneater" (ZSK).

Heinz List, who founded List AG in 1965, had a different vision: to develop unit opera-

tions working in the concentrated phase. His first reactor was the All Phase Processor—the famous "AP". This twin-shaft kneader reactor is still used in the polyurethane industry to recover toluene di-isocyanate (TDI) from tars.

Unlike an extruder, the shafts and paddles of a kneader reactor do not come into contact with the barrel, instead being supported by bearings at both ends. The ratio of length to diameter is 10–25 times less than that of an extruder. Also unlike an extruder, the kneader

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is characterized by gentle conveying with low shear rates ( $100 \text{ s}^{-1}$ ).

The kneader processor overlaps in function with both the stirred tank and the extruder, yet is very different from both (see table on page 32). Understanding these differences helps us to see how kneaders can best meet the needs of the polymer industry.

#### Kneader as reactor

The table shows that the stirred-tank reactor and the kneader processor are competitors for the reaction step. Both are capable of processing large volumes of polymers with similar residence times (longer than ten minutes). The great advantage of the kneader processor, however, is its ability to improve environmental performance by eliminating solvents from the reaction step. This is especially important for biopolymers such as polylactic acid (PLA).

The kneader processor acts as a series of self-cleaning mixing chambers. The self-cleaning mechanism can be based on the use of either one or two shafts:

- single-shaft with static counter-hooks; or
- two intermeshing shafts.

The number of mixing chambers forms part of the process specification. Reduction in

foaming and the control of free-radical based polymerizations are typical requirements to be addressed by careful specification of the number of mixing chambers.

The kneader reactor is an ideal technology for producing free-radical based copolymers in the concentrated phase. The bulk reaction is controlled by evaporative cooling. A typical example of this application is acrylates, for which there is a world-scale reference plant based on this technology. Another example is reactive block copolymerization, which uses controlled radical polymerization to tailor polymer properties.

Biopolymers can also be processed in a kneader reactor. PLA and polysuccinimide are examples of how solvents can be eliminated from the reaction step during biopolymer manufacture. Monomer conversions above 97 percent are possible.

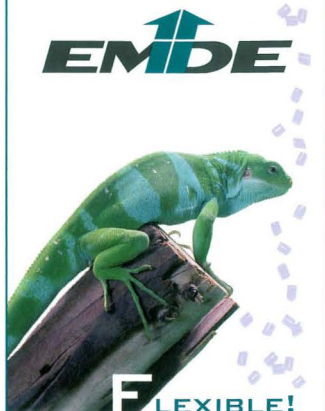
List is currently investigating bulk polymerization of other products in a kneader reactor.

#### Kneader as devolatilizer

When it comes to devolatilization, on the other hand, kneader processors provide serious competition for extruders.

The main issue is the short residence times (two minutes or less) that characterize extruders. To devolatilize the polymer mixture effectively, the extruder needs to renew the polymer surface three times within this short time span. Such intensive surface renewal places stringent requirements on the configuration of the extruder screws.

To ensure good energy transfer and mixing in the short residence times available, the extruder needs to generate the correct pressure profile along its length. This in turn requires very specific configuration of the mixing elements. The result is that for each polymer grade, the extruder needs a particular shaft geometry to create the correct pres-



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