Magnetic Stirring

The technique of magnetic stirring is an invaluable tool for stirring and mixing in liquid media and is extremely effective over a diverse range of applications including synthetic procedures, drug preparation, chemical analysis, flow control, emulsification, milling, grinding and solid phase extraction (SPE). The process is simple, inexpensive and can be used in open or closed systems, under pressure or vacuum, over a wide range of temperature and with virtually any chemical reagent. No bearings, glands, seals or complex drive mechanisms common to other mixing systems are required.

The basic system has two parts, a **Magnetic Stirrer Bar** placed in a vessel containing a liquid, and a **Magnetic Drive** usually located beneath the liquid container. The Stirrer Bar and Magnetic Drive form a magnetic circuit, the rotation of the drive rotates the stirrer bar and hence stirring or mixing of the liquid. Virtually all drive systems incorporate speed control and may also include automatic reversing. The speed should be increased slowly to eliminate spin-out, tumbling or stalling. Magnetic Stirring is very versatile and almost any combination of Stirrer Bar and Drive will be effective, however, each application is different.

Magnetic Stirrer Bar

The general form of a stirrer bar is a permanent magnet fully encapsulated by a suitable material, typically **PTFE**, to protect the magnet and prevent contamination of the liquid medium.

Magnet Material

The most commonly used magnet material is Alnico V, less common alternatives are the rare earths Samarium-Cobalt (SmCo) and neodymium (NdFeB) and Metal Oxides.

The relative magnetic strengths are: NdFeB > SmCo > Alnico > Metal Oxides

Demagnetisation and Shelf Life

Stirrer bars using an Alnico V (and even more so rare earth magnet cores) are highly resistant to demagnetisation. Within the confines of normal use and storage conditions the shelf life is generally considered to be indefinite.

However, demagnetisation can occur. The principal causes are:

- Contact or close proximity to adverse magnetic fields - from powerful magnets / electrical sources or the effect of a reducing, alternating magnetic field e.g. when removing a stirring bar from a vessel with the drive still rotating.
- Handling - the random movement of magnets in contact with each other e.g. physical shock, especially against iron or steel surfaces.
- Storage – stirrer bars should not be stored in a random mass but in pairs, not on steel or iron surfaces and shall be free from the influence of conflicting magnetic fields and potential mechanical damage.
- Temperature – magnetic stirrers should be stored at ambient temperature. Heating above the magnets Curie Temperature will cause demagnetisation.

Magnet Strength

The fact that certain types of magnet are more powerful than others does not automatically mean that they provide more effective mixing since the magnetic characteristic of the materials may be different. The strength of the magnet can have a significant effect on the stirring process. A powerful magnet may be required to stir large volumes of liquids or viscous solutions but a powerful magnet, especially rare earth magnets, can increase the generation of particulate matter due to the grinding effect of the stirrer bar on the base of the container.

A powerful interaction between the drive and driven magnets may act as a brake on the drive motor and could even prevent rotation. It has been observed that, in these circumstance, raising the vessel (1-3cm) above the drive may enable effective stirring.

Working Temperature

The maximum working temperature for stirrer bars using Alnico or SmCo magnet cores depends on what it is encapsulated with: PTFE 280ºC (300ºC for short periods); Polypropylene 120-130ºC; Glass 400-450ºC.
Note: Neodymium magnets cannot be directly encapsulated with PTFE since the temperature used to process PTFE is in excess of the maximum working temperature, 150ºC.

Encapsulation Materials

PTFE is the preferred and most commonly used material for several reasons:

- Exceptional chemical resistance and insoluble - no contamination of media.
- Working temperature to 280ºC (300ºC for short periods).
- Comprehensive range of stirrer bar shape/size.
- Easily sterilised – Chemical & Thermal but **NOT** using gamma radiation.
- Very high purity.
- PTFE used by COWIE® conforms to FDA and USP Class VI requirements.

Polypropylene is less favoured because of its reduced chemical resistance, especially for hydrocarbons, and lower working temperature, 120-130ºC.
Glass has good chemical resistance and a high maximum working temperature, 400-450ºC, but carries the risk of breakage and an increased possibility of abrasion when stirring in glass containers.
Parylene is used to provide a very thin protective coating which conforms to the shape of the magnet core.

Particle Formation / Shedding in Magnetic Stirring

PTFE is a relatively soft material and, although it has extremely low frictional properties, can generate particles in magnetic stirring due to the wearing action between the stirrer and the container surface. There are several factors which determine the extent of wear and include surface finish, nature of the encapsulation material, type of magnet core, container material, speed of rotation, viscosity of the liquid, temperature and the presence of suspended material.

Stirrer Bar Shape

It is difficult to quantify the most effective shape of stirrer bar, in most cases almost any shape is effective, however some particular shapes are self-evident:
Oval for round bottom containers.
Pivot ring to reduce friction in vessels with curved or uneven bases.
Octahedral provides increased turbulence due to larger surface area.
Triangular to create a pronounced scraping action and strong turbulence at low speeds.

Pre-Use Protocol for Stirrer Bars

Before use stirrer bars should always be cleaned and where necessary, sterilised (Chemical or Thermal but **NOT** gamma radiation).
For demanding applications the cleaning agents should replicate the materials to be subsequently used.
Where the generation of particulate matter must be avoided a preliminary trial under actual conditions is always necessary.

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