Emulsification by Ultra-Sonic Waves

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EMULSIONS have now attained a great importance on account of their surprisingly varied applications in different fields. Consequently various methods have been developed on the production of emulsions conveniently and economically.

Different emulsifying machines, like colloid mills and Homogenizers, are available for large-scale manufacture of emulsions. Various mechanical stirrers have also been designed to produce emulsions by intense agitation.

A study of the physical and biological effects of ultra-sonic waves by Wood and Loomis[1] and of the chemical effects of such high-frequency waves by Richards and Loomis,[2] and the recent production of these waves economically, have led to a wide use of super-sonic waves in the manufacture of emulsions.

It has been shown that ultra-sonic waves readily bring about the formation of emulsions in two liquid systems such as water/oil or water/mercury.

The presence of a gas proved to be of great importance in the formation of an emulsion by ultrasonic waves. It was observed that no emulsion is produced " in vacuo ".

The first explanation of the mechaniism of ultra-sonic waves in emulisfication processes was given by Frendlich[3] and his co-workers. Freundlich assumed a direct dispersing action due mainly to transverse-vibrations of the walls of a capillary U-tube in which the emulsification is allowed to take place. Striations of great regularity are formed in a short time in both branches of the tube. The droplets collect in the nodes while the antinodes remain clear. The distance between two nodes is equal to half a wavelength in the liquid. According to Freundlich, ultra-sonic waves have no specific properties to which emulsification may be attributed, but they do contribute mechanical energy, similar to devices producing shaking or stirring, but only to a greater extent.

An important step in the explanation of the action of ultra-sonic waves in producing emulsions is due to Bondy and Sollner.[4] According to them the emulsifying action of ultra-sonic waves in oil/water systems is due to cavitation. This cavitation arises from the very rapid movement at the surface of the vibration which produces the ultra-sonic waves. This high speed of the vibration cannot be followed by the surrounding liquid because of its (liquid's) own inertia. This results in a discontinuity between the liquid and the vibrator with consequent formation of a cavity. The exact condition of producing a cavity depends on the adhesive force between the liquid and the vibrator, and therefore will vary from system to system. Emulsification occurs when these cavities collapse. Cavitation is favoured by dissolved gases acting as nucleii and the hydrostatic pressure exerted by the gases is essential for the collapse of the cavities. However, high pressure may be unfavourable to emulsification because over-pressure disfavours the formation of nucleii at the interface and therefore the production of cavities.

The cavitation caused by acoustic waves of sufficient energy probably forms during the dilatation stage. In contrast to usual technical emulsification increase of temperature reduces the efficiency of emulsification by ultra-sonic waves, since

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rise of temperature militates against cavitation.

In a later paper, Bondy and Sollner" conclude that cavitation which is so important for water/oil emulsion formation, is of no significance whatsoever in the ultra-sonic dispersion of mercury. The formation of mercurry-water emulsions is due to the bursting of the bubbles of water coated with thin films of mercury. In mercury emulsions, the formation of empty spaces plays no significant part. The presence of gases, such as air, nitrogen, oxygen or hydrogen is found to increase geatly the stability of emulsions prepared ; in the absence of these gases, the emulsious settle out rapidly and the sediment flows together. But emulsification of mercury can take place 'in vacuo', that is, under conditions where no effective collapse of cavities can occur, provided only that substances which favour stable emulsions are present, that is in presence of protective agents like soaps, gelatin, etc. Also emulsification of mercury takes place at quite high pressures (8 atm.) unlike water/oil emulsions. By these two experimental facts the theory of cavitation was shown to be inapplicable to mercury emulsions.

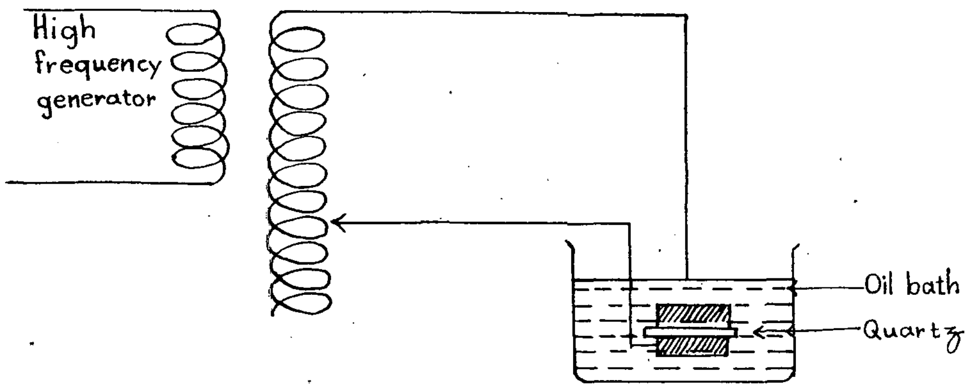
Production of Ultra-Sonic Waves :—

Various machines have been designed for generation of ultra-sonic waves. All mechanical vibrations above 15,000 cycles per second belong to the range of supersonic or ultra-sonic waves.

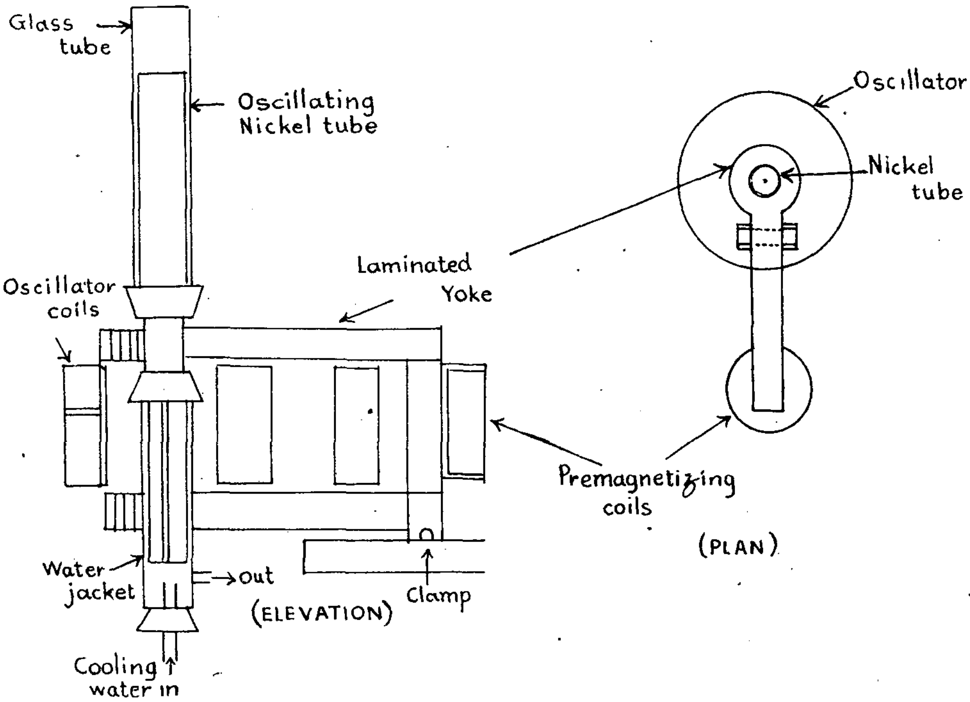
The four main groups of sound generators and their construction and applications are given below.

I. Piezo electric oscillator :—This is a device for transforming high frequency electric oscillation into mechanical oscillation by making use of the Piezo electric effect. This operates at a frequency range of 100, to 1,000 kilo cycles per second. These oscillators were the first used for colloid work and is still used.

The actual source of oscillation is a quartz crystal, which is submerged in an oil bath. The oil is used as a transmitting medium and the reaction vessels are held in it above the quartz. The quartz is oscillated by applying a high electrical field. At a given field strength, the vibrations become much stronger if the natural mechanical frequency of the quartz plate coincides with the frequency of the applied electrical field, that is, if the quartz vibrates in resonance. Under these conditions electrical energy can be efficiently converted into mechanical oscillation. The size of the plate determines the electrical field to the applied to achieve maximum effects through resonance. Circular quartz discs 60 to 80 millimetre in diameter and thickness 7 to 14 millimeter are mostly used producing frequencies from 150 to 300 kilo cycles, per second. A diagrammatic representation of this oscillator is given in Fig. 1. Barium titanate is also sometimes used as the vibrator instead of the quartz plate.



II. *Magnetostrictive Sound Generator:* This produces waves of frequency 5 to 50 kilo cycles per second. The actual source of sound in this is an oscillating nickel tube clamped at the centre with its axis vertical. About the lower half, two coils are wound to provide an oscillatory magnetic field; these are connected in the grid and anode circuits of an oscillating valve. A laminated magnetic circuit is also built up in the form of a yoke, around the lower half of the tube. A glass tube attached to the upper half of the oscillating tube serves as a reaction vessel above the upper (closed) end of the latter. The nickel tube is cooled by a water jacket. The general arrangement of the nickel tube is shown in Fig. 2.



Section through elevation and plan of Magnetostrictive sound generator.

III. *Electro-magnetic vibrator:* This generates sounds at 400 cycles per second, that is, in the range of lower and medium audible sound frequencies and is used in few cases. There are various constructions of these types of vibrators but in all machines the common thing is an oscillating diaphragm vibrated by an high electric field. These vibrators seem to be very promising in treatment of gaseous systems but their effectiveness reported for liquid systems, at least in some cases, is not due to typical sound action.

IV. *Gas-current vibration generator:* This was first constructed by Hartmann[6] and its principle is as follows. If a current of air is allowed to issue from a nozzle at a speed greater than the sound velocity, a periodic structure is formed in the air stream.

Gas-current sound generator:

The Pressure, *P*, varies periodically at different distances from the mouth of the nozzle, *D*, as shown in Fig. 3(a). The regions of rise of pressure are intervals of instability in the jet. They produce sound waves when a hollow body serving as an oscillator is brought into these regions of instability (see Fig. 3(b)). The hollow oscillator is periodically filled with an over pressure or air and in the

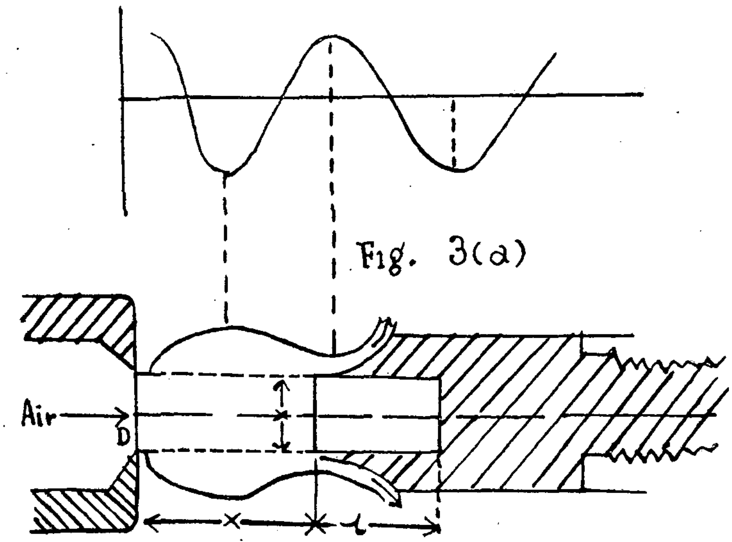


Fig. 3 (b)

intervals this air is forced out again, producing an oscillation. The frequency of these sound waves is determined by the dimensions l and d of the hollow oscillator and its distance x from the nozzle D. The frequencies obtainable from Hartmann's sound generator range from the infra-acoustic range, through the whole acoustic range, up into high ultra-sonic frequencies (500,000 cps.).

On account of its simplicity and the use of inexpensive auxiliary equipment, all that is necessary is a source of compressed air—the gas current vibrator generator seems to be destined to play an increasingly important rôle in colloid work in gaseous systems particularly for industrial purposes.

Uses of Ultra-sonic waves :

" The outstanding merit of the preparation of emulsions by ultra-sonic waves is that relatively stable emulsions can be formed without emulsifying agents and this is probably the only practical way of producing such systems, which may have considerable practical advantages for some purposes ".[7]

Besides emulsification, ultra-sonic waves can be utilized for drilling of brittle metals and cleaning of complex metal parts. Colloidal dispersions of carbon, dyes and Kaolin have been produced. Ultra-sonic waves also kill fish, frogs, larvæ and bacteria.

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