oven must be as high as possible to ensure rapid removal from the ink film.

This simple picture is complicated by the presence of resin in the ink film (see earlier comments on solvent release) and by the fact that the definition refers to a static situation. In a drying oven, the air flow is constantly removing solvent vapour and the equilibrium point is never reached. If it were to be, in a real situation, then further evaporation would be impossible and drying would be retarded. Therefore it is essential that solvent vapours are efficiently removed from the ink/vapour interface.

The other important property is the evaporation rate of the solvent which, although related to the vapour pressure, is a more practical measurement for the ink-maker. Evaporation rate does not have an absolute value for a given solvent but must be compared against a reference standard, frequently n-butyl acetate. Like vapour pressure, evaporation rate is affected by a number of outside influences, for example temperature and pressure, and is very dependant on the molecular attraction between the solvent and the resin and/or other solvents in the case of a solvent mixture. The internal cohesive forces within a simple solvent are also important and explain why evaporation rate cannot be related to boiling point. Water, with very strong polar bonding, and normal propyl acetate both boil at around 100°C but the latter has a much faster evaporation rate.

The advantages of evaporation drying have been adapted to fill the requirements of both flexo and gravure to the virtual exclusion of all other drying methods. Both penetration and chemical action are used but they are nearly always accompanied by evaporation. Some degree of penetration can be expected of solvent based gravure and flexo inks when printed on absorbent paper substrates but, unlike the use of oil based inks on newsprint, the volatile solvent will still need to be removed. In multi-colour work (e.g. gravure publication) the second, third and fourth colours rely less and less on penetration as they are progressively being put down on a less absorbent surface.

	Evaporation Rate (butyl acetate = 1)	Boiling Point (°C)
acetone	7.8	56
ethyl acetate	4.3	77
isopropyl acetate	3.3	88
740P Meths	2.4	75-81
toluol	2.3	111
isopropanol	2.2	82
n-propyl acetate	2.1	102
SBP3	2.0	110-120
n-propanol	0.94	98
cellosolve	0.35	135
water	0.27	100
butyl cellosolve	0.076	171

This table relates evaporation rate to boiling point. Polar compounds will have lower evaporation rates than their boiling points would suggest (cf. water and n-propyl acetate).

There are a limited number of cases where chemical action is used – normally in gravure printing where high gloss and/or exceptionally good resistance properties are required. The inks used are entirely conventional in their initial drying method, relying solely on evaporation to reach a tack-free dry film. The major difference is that the inks are highly reactive and undergo polymerisation, rather like a metal coatings enamel, to form a very tough resistant film. This polymerisation reaction continues after the evaporation drying process has been completed.

There are a number of disadvantages of this method, not least the very reactive nature of the inks. In order to maintain stability before printing, the inks must be supplied in two parts which need to be mixed just prior to the ink being put on the press. Immediately the two parts have been mixed, the reaction begins and the ink must be used as quickly as possible. Any unused ink must be discarded and very thorough cleaning of the press is essential. The use of such inks is inconvenient and costly. The name 'catalytic' inks has been given to these products but in the strict chemical sense this is a misnomer and the term 'two-pack' is far more accurate even though one part may be known as the 'catalyst'. The two parts are designed to react with each other on mixing whereas a 'catalyst' is strictly a substance which only acts to accelerate a chemical reaction and remains unchanged at the end. No such substance exists in these inks.

The one major exception where penetration is the most important drying method is the application of water based inks on paper substrates, notably flexo printing on multiwall sacks and corrugated cases. Modern water flexo inks are based on emulsions which contain a resin which is normally insoluble in water but has been made soluble by the addition of an alkali. This produces a suitable inkmaking vehicle. Being water based, the inks are very stable on the press but, on reaching the substrate, absorption of the water out of the ink film and into the paper is very rapid. The alkali is then partly neutralised by the acidity of the paper whilst some also evaporates leaving a film of water-insoluble resin on the surface – hence explaining the water resistant properties of water based inks. This final stage can take some little while to occur and therefore the overall drying process can be likened to that of quick-setting inks in letterpress or lithography.

The interest in water based inks has spread in recent years to take in many of the less conventional areas such as gravure printing on film and foil. One of the major reasons for this interest is the awareness of environmental protection which prohibits the venting of volatile solvent vapours into the atmosphere. Water is also a very cheap solvent, is readily available and, unlike oil-based products, will not run out in the forseeable future.

The difficulties are clearly substantial – not least the problem of wetting the gravure cylinder with a liquid of very high surface tension such as water. If this can be controlled to give good printability the next problem is to dry the ink once it has reached the stock. With a non-absorbent substrate such as film or foil, penetration drying is clearly of no significance. Evaporation by heat is possible but the high latent heat (i.e. low evaporation rate) of water makes it an extremely difficult solvent to remove. High energy costs make this method prohibitive.

The answer seems to lie, yet again, in the use of electromagnetic radiation, this time from the long wavelength end of the spectrum i.e. radio frequencies. At these wavelengths, the radiation is of relatively low energy compared to both IR and UV but it does have a very marked effect on polar molecules, in particular water. When the polar molecules of water are exposed to an electrical field they will line up along that field. An electric field such as radio frequency radiation is alternating rapidly and this causes the molecules to oscillate and generate heat.

This internal heat provides sufficient energy for the solvent molecules to evaporate in the normal way. The important differences between radio frequency and conventional heating (such as infra-red or hot air) are that the former causes heating throughout the mass and there is no thermal delay when the energy source is turned on or off. Also, only polar molecules will respond to radio-frequency energy and the dangers of scorching of the substrate are geatly reduced.

Despite its many advantages, radio-frequency is costly to install and operate, and the frequencies that are used fall within the band of radio transmissions and, in the UK, their use is controlled by the communications authorities.

UV curing is also being examined for both inks and varnishes and although no significant advantages in drying speed are likely, the problems of venting of solvents are eliminated. Furthermore, the feedstock