Application Techniques and Handling of Aqueous Aluminium Brazing Fluxes.

By Michael A. Tompsett
Surface Engineering Process Equipment Ltd, England

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1.1 GENERAL INTRODUCTION – PROCESS PERFORMANCE REQUIREMENTS

In designing an aqueous flux application system, we must firstly start by considering the actual brazing process requirements. Ideally, the component requires a controlled quantity of flux deposited only on the clean metal junctions which are to be brazed, with no flux deposited on open areas and no excess liquid carried over and possibly wasted. This is the perfect situation, which probably cannot be achieved at any cost, and certainly not at a commercially viable cost and production speed. We therefore have to look at compromise solutions which will provide a high yield at acceptable production speeds with a tolerable flux powder consumption.

Two systems have therefore evolved, 1) using a drench spray coverage of the component; 2) fully immersing the component in the flux liquid. The spray method is normally suitable for automobile radiators and various other simple heat exchangers and is highly desirable since it can be carried out continuously; whereas the immersion method is often the only method suitable for components with e.g. turbolators inside of core tubes which need to be brazed, and is less attractive since the dipping process is difficult to carry out effectively in a continuous manner.

Each of these application methods are usually followed by the use of air knives to force the liquid flux into the critical braze areas, while at the same time removing excess liquid. This presents the component to the brazing furnace with an all-over coating of flux, including sufficient in the critical areas to ensure a reliable braze. This aqueous technique is the most commonly used world-wide, and for certain types of component is the only practical method available. It has some disadvantages but these can be largely overcome and this paper will attempt to outline some of the techniques used.

1.2 DESIGN OF AN EFFECTIVE SPRAY APPLICATION CHAMBER

Because flux liquids are a dispersion of an essentially insoluble solid in water, the ability to maintain the solids well dispersed in the water is paramount to the reliable operation of the system., Experience has shown that this is best achieved by holding the flux liquid in a properly equipped separate reservoir tank, and pumping it to the spraying chamber. The separate tank or tanks are then very accessible for adding flux powder and for the regular maintenance which is required, thus the spray application chamber can then have a relatively simple form which also makes operation and maintenance easier. Thus we arrive at a system whereby the flux liquid is pumped from the reservoir tank to the spray chamber, and the excess liquid from the spray application is then returned via a second pump back to the reservoir tank. The flux liquid continues this cycle throughout the production period.

The evolved form of the chamber now usually comprises a stainless steel chamber with vertical sides, glazed side access doors, and a double 'V' form base. which operates as a dry sump. The angles and general shape of the base are critical in order to minimise the settling and build-up of flux powder which would otherwise require substantial maintenance time to keep clear. The geometry of the base must take into account the flow rate and velocity of the excess flux which falls into the base for return to the reservoir tank. Flow rates which are too low will lead to settling of the powder and a subsequent build-up of solids in this area.

Conveyor design also has a significant effect on the performance of the system overall. A typical current form of conveyor would comprise stainless steel cross rods of 10 – 12mm Ø set at a pitch of 50mm to 100mm, driven by hollow link side chains. The rod diameter needs to be as small as possible, consistent with supporting the total component/jig weight, to ensure minimal carry over of flux liquid. The side chains must be located in such a way that flux powder does not build up on the links, which could eventually lead to seizure of the chain. This is no longer a problem with current designs.

A further advantage of using the cross rod design is that locating collars can be placed on the rods to guide and centralise the components, which is particularly important for accurate selective fluxing of e.g. header plates on radiators.

The flux spray chamber is equipped with a number of large glazed doors to enable comprehensive access to the inside for maintenance, as well as providing excellent viewing of the fluxing process. High intensity internal illumination and wash-down of internal window surfaces enhance this facility.

Design of dipping systems is more varied and is more tailored to the component characteristics and the end user's particular performance requirements. A typical installation would comprise an in-line tank fitted with a lift/lower platform onto which the component is loaded from the line conveyor. The component then needs to be tilted at a minimum angle of 15°, and up to 45° in some cases, in order to ensure expelling of air from the core tubes as the component is immersed. Failure to do this can result in air pockets forming inside the tubes, resulting in incomplete internal fluxing, and also a high risk of the component floating off the dipping platform, particularly if the speed of dipping is high. The tilt angle is also very important after dipping to ensure that the excess flux liquid drains out of the tubes. This can often be assisted by well-positioned air blow-out nozzles. Dipping systems, because of their batch processing nature, require carefully planned conveyor systems either side of the dipping unit to ensure no interruption to the continuous brazing process.

1.3 PREPARING AND MAINTAINING FLUX LIQUID

The task of preparing a fluxing liquid can be unpleasant in the absence of any specialised equipment. In its most basic form, preparation will consist of simply scooping flux powder from the supplier's drum and adding it slowly to water in a tank equipped with an electric mixer. This is clearly both time consuming and raises some questions concerning safety, and more automated methods will be dealt with later in this presentation. It is however very important that the correct mixing parameters are observed in order to obtain the best performance and working life from the flux liquid. When process technologists are faced with the need to keep an insoluble solid in suspension, the temptation is always to use aggressive mixer parameters with high shaft speeds and high shear forces. This should not be used in the case of aluminium brazing flux, since after some hours of operation, the flux characteristics change and the flux acquires a 'sticky' property, making it more difficult to re-disperse after settling, and increasing the tendency to blockages in pipes etc. Special low speed, low shear mixers have now been developed which largely overcome this problem, and enable relatively easy re-starts after the system has been shut down e.g. over the weekend.

Reservoir (tote) tank design is also an important factor in determining the ability of the system to maintain the powder in suspension, and to minimise the difficulties of re-starting after a shut down. Tote tanks are now exclusively designed in a cylindrical shape with a domed base, leaving no corners or angles in which powder could settle, and making tank clean-out a relatively simple task. All aqueous fluxing equipment should be fitted with one or more pressure hoses, supplied with demineralised water to assist in the regular cleaning.

Routine maintenance additions of flux powder, if made manually, are generally added directly to the tote tank via a small lidded port fitted with a coarse mesh grid to catch pieces of paper, plastic, gloves etc. which may otherwise accidentally find their way into the flux liquid.

1.4 PUMPING OF FLUX LIQUID

Because of the slurry-like and abrasive characteristics of flux liquids, the choice of suitable pumps tends to be quite limited, and for the majority of fluxing applications, pneumatic twin diaphragm units provide the best combination of performance and cost. The units are self-priming, resulting in considerable flexibility of location on a machine, are very clean and reliable in operation, and require minimal maintenance if operated correctly. Many problems associated with these pumps are caused by stopping the pumps with full-strength flux liquid inside the diaphragm chambers. The powder can then settle to the lower part of the chamber and form a fairly solid mass. When the pump is then re-started, the diaphragm twists, since the lower half cannot move the flux mass, and this can often result in the diaphragm rupturing. PTFE-faced diaphragms are particularly prone to this due to the poor elasticity of this material. It is quite unnecessary to use PTFE since the flux material is not chemically aggressive, which would be the only justification for using such a material. The flux particles are also not highly abrasive, and the most suitable diaphragm material has been generally found to be neoprene or one of its improved derivatives. Using such diaphragm materials in combination with a proper pump shut-down procedure will result in good production reliability and a very long diaphragm life.

Proper pump shut–down is generally achieved in one of two ways; a) by flushing the pump lines through with demineralised water immediately upon shut-down (this can be built into the pumping circuit); or b) using a programmed shut-down of the tote tank, whereby the mixer is switched off at end of production but the pump is left running for a pre-determined period of ½ to 3 hours. During this time the flux powder settles in the tank, such that the liquid passing through the pump becomes increasingly dilute until it contains very little flux, at which point the pump can be stopped, leaving very few solids in the pumping chamber. This method can only work if the pump suction pipe is located at a high level in the tote tank.

Diaphragm pumps, by their very nature, produce a pulsed flow of liquid, which would result in the sprays similarly pulsing and debatably producing uneven flux coating on the component. This is largely overcome by introducing a pulse elimination chamber into the delivery circuit, which comprises very simply of a closed vertical cylinder in which air is trapped. The trapped air provides a pressure buffer and largely smoothes out the pumping pulses, resulting in a very even spray delivery.

The same diaphragm pumps are used to scavenge the base of the spray chamber, returning the excess flux liquid to the tote tank. These units are usually set up to run slightly faster than the delivery pumps, thus ensuring that the chamber bases are always empty. To achieve this, the pumps will draw a certain amount of air with the returned flux, and this air is separated from the liquid in the tote tank using a special separation device, which is important if the liquid is being optically monitored.

Because of the potential that flux liquid has for blocking, all interconnecting hoses used in the system should be of the reinforced flexible type, using rapid disconnect fittings for ease of maintenance.

1.5 SPRAYING OF FLUX LIQUIDS

The core of the coating system is the spraying process, and because of the potential difficulties in spraying slurries or dispersions, demands critical attention to ensure adequate performance. Assuming that we have a smooth and reliable delivery of flux liquid from the pump, we must then use this to coat the component over its whole surface with a minimum amount to ensure good brazing. In the vast majority of applications, this can be achieved using a single overhead spray manifold spraying vertically downwards while the component passes underneath on the conveyor. Some users also opt to use an underside spray just to be sure of total coverage, but this has to be carefully arranged to avoid masking by the conveyor rods, and is generally found to be unnecessary if the overhead spray is properly designed and set up.

Jet nozzle design is of course critically important for proper and reliable performance, and from experience, the type producing the most acceptable reliability is a deflector fan jet made in PVDF polymer. The deflector jet is the least prone to blocking because it is mounted horizontally on the header manifold, and flux liquid tends to drain out of the jet when not in use. PVDF material is used not so much for abrasion resistance, but because flux powder has a very low affinity for it and therefore very little tendency to stick to it and cause blockages.

The jets should ideally be arranged to provide a 'double overlap' pattern at component height, providing a thorough double coverage of all parts of the component, plus still giving complete coverage should any one jet become blocked. To further reduce the risk of nozzle blocking, a filter should be fitted in the pump delivery line to catch any particles which are larger than half the spray jet orifice diameter.

1.6 MINIMISING THE OCCURRENCE OF BLOCKAGES

Several references have already been made to the need for constant vigilance in the system design to avoid or reduce all risks of flux powder settling or blocking. It is relatively easy to design a system that remains free of blockages when operating, but not so easy to design a system that can be re-started successfully after a shut down of several days.

Design features which minimise blocking during operation include attention to the overhead spray manifold, which is normally fed with flux liquid from one end only. To minimise the build-up of solids in what would otherwise be a dead end in the main spray manifold pipe, a pass-through system is used whereby some of the flux liquid passes right through the manifold and out of the far end, from where it is returned to the tote tank. This arrangement keeps the manifold flushed clear of settled solids and also ensures drain out of the manifold each time the pump is stopped. In spite of this precaution, it is common practice to provide two overhead manifolds, one on standby which can be instantly turned on if a problem occurs with the duty manifold.

To ensure reliable start-up after an idle period depends largely on operator training to carry out a series of tasks at the start of the shut-down period. The most important of these is flushing through the pumping system, which modern equipment facilitates by designing in water flushing, requiring only the operation of several valves to achieve. The water flush carries through to the spray chamber and on through the return system back to the tote tank. Attention to this procedure will ensure minimal re-start difficulties.

The internal surfaces of the spray chamber should also be washed down using demineralised water. If this procedure is not carried out, flux solids will settle within individual droplets and form small inverted dome-shaped lumps which do not break up on restart, and are large enough to cause subsequent blockages. (OHP 1).

Reference has already been made to the importance of using minimal shear forces to mix the flux liquid, to delay as long as possible the onset of the 'stickiness' characteristic, which will make settling or blockages more difficult to clear.

1.7 MEASURING AND CONTROLLING FLUX LIQUID CONCENTRATION

Instant, continuous measurement of the concentration of solids in a liquid has always posed many difficulties for the industrial chemist and aluminium brazing flux is no different in this respect. The most common and reliable method of controlling the flux liquid is a gravimetric determination, requiring the taking of a sample of accurately known weight or volume, evaporating off all water, and weighing the residue. This will give a result indicating the total weight of solids (flux + impurities) in a known volume or weight of working liquid. The disadvantages of this method are the long time delay between taking the sample and obtaining a result, and the number of skilled man-hours required to carry out the procedure.

Attempts to develop a sensor which will accurately determine the concentration have until recently centred mainly on the use of optical absorption measurements – i.e. passing a beam of light in the visible spectrum through the liquid and measuring the residual amount of light reaching a sensor, the amount of light absorbed or scattered by the flux particles being assumed to have a relationship to its concentration. This method can work acceptably well with a new solution under certain controlled conditions, but has the following disadvantages in the production environment:-

a) The glass windows of the transmitter and receiver can become coated with flux deposits, leading to inaccurate results;

b) Micro-bubbles introduced into the flux solution during the spraying and scavenging of the spray chamber base (when liquid and air are drawn together through the return hose) will increase light scatter and hence lead to a falsely high reading of concentration. This problem is particularly acute when surfactants (wetting agents) are added to the flux liquid, and can lead to very inaccurate readings. The optical effect of the micro-bubbles is totally disproportionate to the very small influence that they have on the true liquid density;

c) Calibration of the system can drift as the flux liquid ages, due to discoloration from black oxides from the steel jigs, and also due to the changes in particle size range. Both of these factors will affect the optical absorption of the liquid.

d) Frequent re-calibration can be required due to variations in particle size distribution from batch to batch of flux powder;

A change from using visible light to the use of a pulsed infra-red beam has brought some improvements in reliability, but is still far from an acceptable level of accuracy. An entirely different principle of measurement was therefore sought in an attempt to overcome these problems, and the method currently found to be the most promising is the mass flow measuring method known as coriolis.

In this method, the flux liquid is pumped through two parallel metal tubes which are mechanically excited (vibrated) very precisely by electrical coils which input a known level of energy. Sensors located on the tubes then measure the resultant vibration of the tubes, which is affected by the mass flow of flux liquid through the tubes. The mass flow will be proportional to the density of the liquid, and the liquid density has an almost linear relationship to the flux concentration. Thus we have a system which is not misled by micro-bubbles or colour of liquid, nor does any coating on the insides of the measuring tubes have any significant effect on the measurements obtained.

The measuring tubes are best mounted vertically which also ideally suits the application since they will completely drain out during shut-down, and there are no moving parts in contact with the process.

Initial testing has shown the system to be very reliable and unaffected by any of the issues previously mentioned, and provides measurements consistently within ±0.3% without the requirement for frequent re-calibration.

1.8 AIR KNIFE DESIGNS TO CONTROL COATING DENSITY

To produce a production machine which will cater for a very wide variety of component shapes and design characteristics, many aspects of the machine have to be provided with the widest possible range of adjustment. This is particularly true in the design of the air knives used to remove excess flux after spraying or dipping. The velocity of blow-off air at the component surface is the largest single factor in determining the resultant flux coating density, and it had therefore become vitally important to provide as wide a range of velocities as possible. The following variables are therefore included in modern air knife design:-

1) Wide range of adjustment of the knife height above the component. The velocity diminishes very approximately as the inverse square of the distance from the exit nozzle, hence a small change of distance will effect a large change in air velocity:

2) Wide range of adjustment of the width of the air knife exit slot, which will control the velocity in approximately inverse proportion to the slot width;

3) Inverter speed control of the fan motor which will give an almost infinite range of adjustment of air velocity up to the maximum that the system can achieve.

Fan speed is the preferred method of control during production runs since it is very easy to do and the results can be instantly seen.

Another very important aspect of air knife design is the achievement of a constant air flow and velocity along the whole knife length, which can be in excess of 1500mm in some applications. This can only be achieved by using a large volume plenum chamber behind the knife slot, irrespective of how the air is fed into the plenum.

Components for brazing are generally loose assembled and clamped in the jigs prior to the start of the process. A firm clamping force of e.g. radiator fins between core tubes can often be difficult to maintain in production conditions, and rows of fins can often be held very precariously in place. It is therefore important that these are not disturbed by the air knife. If the knife were to be mounted at 90° across the conveyor, each individual row of fins would be hit with the full force of the air knife with potentially catastrophic results. Current design therefore locates the knife at approx 75° across the conveyor, i.e. an offset of 15°, which effectively distributes the force of the air knife over many rows of fins, substantially reducing the risk of them blowing out.

The design of the air knife chamber below the conveyor requires some attention, since in a conventional arrangement, excess flux liquid droplets can be carried back upwards by the force of the air flow, to be dropped back on the component beyond the blow-off zone. This is avoided by the use of special baffle trays which collect and trap virtually all excess flux droplets, channelling it back to the flow return to the tote tank.

The choice of materials of construction of the blow-off fan is very important, and the use of any type of metal unit is inadvisable, due to the affinity that flux liquid has for sticking to metal surfaces. Metal fan impellers and casings will quickly and frequently become coated in flux deposits, and be difficult to clean effectively. Current design specifies fans made only in UPVC or Polypropylene, which will minimise build-up of deposits and be far easier to clean than metal units.

1.9 SPECIAL TREATMENTS FOR CRITICAL COMPONENT AREAS

Certain critical areas of components such as e.g. the header plate areas of automobile radiators, benefit from the selective application of a more concentrated flux solution. Current spray fluxing machine design provides for this by including a second spraying stage for these areas, utilising either needle jets or trailing flexible tubes to direct a higher concentration flux liquid to these areas.

This requires the preparation and operation of a second fluxing liquid operating at a higher concentration, and contained in a second separate tote tank. A smaller capacity twin diaphragm pump circulates the stronger flux liquid to the application jets via similar filters and pulse eliminators to those used for core spraying. The spray nozzles are usually located on adjustable arms which can be positioned manually or automatically according to component size and location of the critical area. The arms can be programmed according to component part number, or can be driven from a component width measuring stage located just before the fluxing machine. The same adjustable arms are also usually fitted with needle jet air blow-off nozzles to remove excess flux and return it to its respective tote tank. The component thus 'fluxed', is then ready for transfer to the dryer.

A very important aspect of running a fluxing machine with two different concentrations of flux is to ensure that the two liquids remain well separated and that cross-contamination does not occur between liquids. Although 100% separation is not economically viable, generally unnecessary, and virtually impossible with a return conveyor system, good levels are attainable with some attention to design detail, and well able to satisfy most production control requirements. Good separation requires substantial 'overspray' sections between processes, coupled with an effective polymer inter-process curtain design. Curtain material must be a hydrophobic polymer that sheds the flux liquid. Flux liquid will tend to adhere to hydrophilic materials, and once dry will cause the material to stiffen and curl, making the curtain ineffective.

Design attention must be paid to ensuring that flux liquid does not run along conveyor support tracks, or transmission chains, which can be a common and major source of cross-contamination.

1.10 EXHAUST VENTILATION AND ENVIRONMENTAL SAFETY

Current data available on the long-term effects of exposure to aluminium brazing flux is not sufficiently conclusive that one can guarantee that there will never be a potential health problem for operators. We therefore design fluxing machines on the assumption that there could be some danger from prolonged exposure to the substance, and incorporate a number of features to minimise any potential risk.

Firstly all spray application chambers are bounded on each side by an exhausted area to ensure that any stray flux droplets are contained within the machine. This is achieved using a relatively conventional UPVC exhaust fan which operates primarily on the entry and exit vestibules of the machine, these being the primary escape routes for any airborne droplets, and is fitted with damper valves in each leg to enable optimum balancing of the system. There are however potential operational problems in using such a system:- a) flux liquid droplets will be drawn into the fan and cause a rapid build-up of deposits on the impeller and casing; b) many of the droplets could be discharged to atmosphere with potential risk to the environment.

Both of these problems are avoided simultaneously by the incorporation of a droplet trap in the system, located just before the entry to the fan. The trap system comprises a number of parallel vanes of approximately sine wave shape, with collecting lips at several strategic points. (OHP 2). Droplets are trapped on the vertical lips, run down into the base of the unit, and are then channelled back to the spray chamber base for recovery.

The design is found to eliminate typically 98% of droplets entering the system, if well maintained. The very nature of a system where air is rushing over wetted areas means that some drying-on and build up of flux deposits will occur, hence the system is designed for easy wash-out and dismantling on a regular basis. All components of the system are manufactured in hydrophobic polymers to ensure ease of cleaning.

The air blow-off chambers are operated on a recirculated air system so that a neutral pressure is maintained in this area. The feed air to the fan is drawn from below special catchment trays which are situated under the top run of the conveyor, directly below the air knives. This ensures a minimal amount of flux droplets are drawn back into the fan, although the fan will require washing out at certain service intervals.

Another standard safety feature incorporated into all fluxing machines is the fitting of safety switches to all the spray chamber access doors, such that if they are opened while the sprays are operating, the pumps will be immediately cut to avoid any risk of operators being sprayed with flux liquid.

2.1 THE SAFE DISCHARGING OF FLUX POWDER DRUMS

Because of the lack of proven data relating to the long term exposure of operatives to aluminium brazing flux, it is considered prudent by many users to take steps to minimise this exposure. This can be addressed at several stages in the procedure of taking the powder from the drums, to getting it mixed with water at the required concentration.

The first and potentially most hazardous stage is to remove the powder from the fibre or metal drums in which it is supplied, and to place it into a storage hopper from which it can be taken by some mechanical means. Several devices are available to do this, all operating on the same general principle, with variations in the degree of automation and mobility. All units require that the operator removes the drum lid and opens out the plastic liner bag, and this can only realistically be carried out manually, which therefore requires the use of safety masks, eye protection, and gloves. The opened drum can then be offered up to the drum handling device and no further exposure to the flux powder occurs. The device is equipped with a special valve plate which is lowered onto the drum forming a dust-tight seal, and clamped in place. The drum is then raised off the ground using either manual or hydraulic power, and then rotated through 180°. The inverted drum is then moved to the storage hopper (if system is mobile), and 'docked' with the special loading plate located on the hopper lid, forming a dust-tight seal. Sliding valves on the drum portion and the hopper portion of the system are then opened to discharge the powder into the hopper. A bag retention device prevents the plastic liner from falling into the hopper. Both slide valves are then closed and the empty drum returned to ground level, from where it is removed from the clamping mechanism and disposed of as necessary.

Units are available to handle drums from 20kg to 200 kg, fibre or metal.

Many manufacturers use one mobile drum handling unit which can serve a number of hoppers located throughout the production area, whereas others use one fixed automatic unit feeding a large central hopper. The automatic units are fitted with electrical vibrators which reduce the risk of compacted powder being left in the bottom of the drums.

The storage hoppers are generally fitted with one or more semi-flexible spiral feed tube conveyors which take powder from the base and distribute it to the tote tanks where it is dosed into the flux liquid. The hoppers are generally constructed with steeply-sloped sides to avoid bridging of the powder when it is taken from the base. This is usually assisted by an electrical vibrator fitted to the hopper side wall which operates whenever the conveyors are taking powder. A low level sensor operating on the capacitive principle indicates an alarm when powder level is low, and also shuts off the spiral conveyors to prevent them being starved of powder, which can lead to mechanical damage.

The spiral tube conveyors are generally made in a polyamide material with a stainless steel spiral screw, with a bore of typically 40mm, and service life can be very long provided installation conditions are followed, particularly with respect to minimum radii of bends. The maximum practical length of the conveyors is approx 9 metres and it is therefore necessary to locate the hopper reasonably adjacent to the tote tanks, and it is always preferable to keep the conveyor length to a minimum. The critical part of the spiral conveyor design is the discharge head located on top of the tote tank. Because of its proximity to water and general damp conditions, there is a strong tendency for the powder to become damp and accumulate in the discharge head, causing clogging to the point where often no powder can get through. This has now been largely overcome by close attention to the design of the discharge head, combined with the use of vibrators and the provision of easy clean-out access. In extreme cases, ventilation fans can be fitted to provide a constant down-flow of relatively dry shop air, which reduces the humidity in the discharge head.

2.2 SAFE AUTOMATIC PREPARATION of WORKING FLUX LIQUIDS

It is possible to prepare and maintain fluxing liquids on a completely automatic basis if required. The system described previously goes a long way towards achieving this, and when linked with the coriolis flux concentration monitor, can provide a virtually fully automatic system requiring minimal operator intervention, other than ensuring the storage hopper if filled with powder.

The preferred method at present is to carry out the preparation and maintenance of the liquid in the tote tank. The tank is fitted with automatic water level control which maintains a constant volume of liquid in the tank, and this volume can be selected by the user within the operational limits of the tank. The coriolis flux concentration monitor then determines when flux powder needs to be added to the tank to bring the concentration within predetermined limits. If the concentration falls below the minimum level selected by the user, the monitor will operate the spiral conveyor to add flux powder until the concentration is again within limits. This is not carried out in one continuous operation, but in a series of short cycles. When powder is introduced into the system, it requires a finite time to become mixed and dispersed homogeneously throughout the working liquid volume. The system therefore doses for a short preset time, waits for a second preset time for mixing to take place, then takes a concentration reading. If the concentration is within limits, no further action is taken, however if the concentration is still below limits, another dosing cycle is initiated. This refinement avoids the very real risk of overshooting the required concentration level.

Although such a system reduces the time demands on operators and process technologists, it would be foolhardy to suggest that the system is 100% reliable and never needs intervention by personnel. Regular routine checks will still need to be carried out to ensure that the system is operating properly.

The system described eliminates as far as is economically practical, the need for operators to come into direct contact with flux powder, and as a secondary benefit, results in a far cleaner working environment in the fluxing area.