

SOLDER LEVELLERThe Field of the Invention

The present invention relates to a solder leveller.

5 The Background of the Invention

A solder leveller is apparatus for tinning exposed metal - normally copper - on printed circuit boards, and similar elements - particularly for supporting electronic components - hereinafter referred to simply as "boards",
10 with solder preparatory to connection of components thereto. Generally a solder leveller comprises a bath of molten solder into which a board is lowered vertically for tinning with solder and means for levelling solder deposited on the board as it is withdrawn from the bath. Such a leveller is
15 the subject of British Patent No. 2151528 and equivalent U.S. Patent No. 4,599,966, both in the name of the present applicant.

Such conventional solder levellers operate on a one-at-a-time basis, inserting boards into a deep, narrow solder
20 bath one-at-a-time from above. This is an essentially slow process, although the speed of withdrawal from the solder is relatively high in terms of speed of travel of boards along conveyors through pre- and post- treatment stages, up-and down-stream of the leveller. A feature of a vertical acting
25 solder leveller is that the lower part of the board remains in the solder for longer than the upper part. This can result in formation of a thicker copper/tin intermetallic compound layer on the lower part to which it can be difficult to satisfactorily solder components. Such a thicker layer
30 can cause a board to "age" more rapidly, aggravating solderability problems.

Intermetallic compounds can be both of the Cu_6Sn_5 type and of the Cu_3Sn type. The latter is particularly problematic and more prone to formation where the board experiences

longer dwell times in hotter solder.

Equipment for continuous soldering treatment is known in various forms, in particular for soldering components to pre-tinned boards. "Drag soldering" involves the dragging
5 of a board with its components across the surface of a bath of molten solder, see for instance U.S. Patent Specification No. 4,284,225 (EMP Ag). "Wave Soldering" involves passing a board across the top of a wave created in a bath of molten solder, see for instance British Patent Specification No.
10 2,117,690A. (Zevatron GmbH).

Both drag and wave soldering have been adapted for continuous tinning. U.S. Patent Specification No. 4,277,518 (Gyrex Corp.) describes the use of a continuous conveyor forced down into molten solder by a fixed upper bed to drag
15 a board through the solder. The board tends to float up against the conveyor which causes frictional engagement of the board with the conveyor. The speed of forward operation is limited by potential slippage between the board and the conveyor.

20 U.S. Patent Specification No. 4,465,014 (Siemens Ag) describes movement of a board through a solder wave so that solder wells on to the top surface of the board. Speed of operation is limited by time available for heat transfer from the solder to the board.

25 The object of the present invention is to provide an improved solder leveller capable of operating fast enough for effective operation of the levelling means and yet able to heat the board quickly in a compact solder bath with a short dwell time in the bath to minimize the formation of an
30 intermetallic compound layer.

Another object of the invention is to provide a solder leveller including means by which a board is rapidly heated to the temperature at which exposed copper on the board is wetted by solder.

35 Another object of the invention is to provide a solder

leveller operating substantially horizontally to provide even treatment of the entire board and in which the board is moved fast enough for successful air knife levelling.

The Invention

According to one aspect of the invention there is provided a solder leveller having a bath for containing molten solder with a free surface and means for levelling solder deposited on a board (B) as it leaves the bath, the solder leveller comprising:

curved-path defining rollers arranged across the bath to define a curved portion of a board path through the solder leveller;

at least two of the curved-path defining rollers comprising a pair of superimposed board-gripping rollers having a nip therebetween beneath the free surface of the molten solder at which the board (B) is gripped for drive;

the upper one of the said pair(s) of board-gripping rollers being in use less than half immersed beneath the free surface of the molten solder;

means for rotational drive of at least one of the said pair(s) of the board-gripping rollers;

the board path having:

an upstream portion above the free surface of the molten solder leading to,

the curved, board-heating and tinning portion below the surface of the solder, including the nips of the or each said pair of board-gripping rollers at which the board is gripped and leading to,

a down-stream portion above the free surface of the solder to the levelling means.

According to another aspect of the invention there is provided a solder leveller comprising:

a bath for molten solder,

air knives at a down-stream end of the bath,
three pairs of board-gripping rollers arranged across the
bath to define a curved board path portion below a free surface
of the solder in the bath,

5 one pair of guide rollers up-stream of the board-gripping
rollers for guiding a printed circuit board (B) into the nip of
an up-stream one of the board-gripping rollers,

two beams one extending along one side of the bath and the
other along the other side for supporting the rollers,

10 lower bearings fixed to the beams for journalling the lower
rollers

upper bearings movable up and down on the beams for
journalling the upper bearings,

a drive motor for rotationally driving the upper rollers in
15 synchronism.

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In being gripped, the board has heat transferred to it by conduction from the rollers. It passes through the nips of the successive pairs of rollers. There are preferably three. As soon as it is heated to the melting point of solder, the copper contact pads etc. on the board are wetted by the solder and the board is thus tinned.

Because, in passing through the bath, the board is substantially horizontal - whilst first having a slight inclination in one direction and then having a slight inclination in the other direction - and because of the action of the board-gripping rollers in moving solder towards and away from the board, any air pockets in through-plated board holes are positively displaced allowing the plating of these holes to be tinned.

Having been passed around the path's curve, the board emerges from the solder at a speed suitable for levelling of the solder in the levelling means, preferably so called air knives.

The pairs of board-gripping rollers may be biased together in a variety of manners. Since most materials are buoyant in molten solder, the upper of each pair of these rollers may be journalled in a translationally fixed manner, whilst the lower roller is so journalled as to be free to float up against the upper roller. Alternatively, the lower roller may be fixed and the upper roller biased downwards, either by spring force and/or by its own weight.

The board-gripping rollers may be journalled in bearings attached to or guided on side walls of the solder bath. However, in the preferred embodiment a pair of separate roller support beams is provided extending longitudinally of the bath. Preferably the lower rollers are journalled in graphite bearing blocks held on the beams, whilst the upper rollers are journalled in graphite bearings able to move vertically on the beam, though biased down by their weight and bias springs onto the lower rollers.

Each upper roller may be constrained to move vertically and not horizontally by engagement of its bearings with the beams. However, in the preferred embodiment, the central upper roller alone is so constrained, whilst the upper
5 rollers adjacent up- and down-stream along the board path are linked to the central roller by links interconnecting adjacent upper rollers' bearings.

Firm gripping of a board by the board-gripping rollers is important not only to drive the board along the board
10 path, but also for heat transfer by conduction from the rollers to the board. Accordingly, in the preferred embodiment, board-gripping rollers have a large diameter and hence thermal capacity. Further guide rollers where provided will normally be of smaller diameter. In the preferred embodi-
15 ment, guide rollers are provided both in pairs to grip the board though less strongly than the main rollers and as a single guide roller. The guide rollers direct the board in and out of the bath along the desired board path.

The board path is curved during that part of the board
20 path of passing below the surface of the solder. Despite printed circuit boards being rigid at room temperature, curvature of them to pass along the board path is feasible because at the temperature of molten solder the boards become relatively flexible and because the radius of curva-
25 ture of the path is comparatively large. Either of the upper or lower board-gripping rollers can be driven.

However, in the preferred embodiment, the axes of the upper rollers are arranged above the surface of the solder, and it is convenient to drive the upper rollers directly - with the
30 lower rollers being driven by frictional contact between the pairs of rollers.

Solder circulation is important in a solder bath, since solder is a poor conductor of heat, as compared with most metals. Whilst a solder pump could be provided, it is
35 anticipated that rotation of the totally immersed lower

rollers may provide adequate circulation. However, further circulation is preferably provided for by means of at least one of the lower rollers having an impeller for moving solder axially through the roller.

- 5 To help understanding of the invention, a specific embodiment thereof will be described by way of example with reference to the accompanying drawings.

The Drawings

- 10 Figure 1 is a side view of a solder leveller according to the invention;

Figure 2 is a central cross-sectional side view to a larger scale on the line II-II in Figure 3,

- 15 Figure 3 is cross-sectional plan view on the line III-III in Figure 2 from which certain components have been omitted for the sake of clarity;

Figure 4 is a cross-sectional end view on the line IV-IV in Figure 3.

The Preferred Embodiment

- 20 Referring to the drawings, Figure 1 shows a leveller of the invention having a solder bath 1 mounted on a frame-work 2 having wheels 3 engaged on rails 4 extending transversely of the solder bath. Solder levelling air knives 5 are mounted on the bath at its downstream end. An upstream conveyor 6 is arranged for transporting boards to be tinned
25 to the bath and a downstream 7 conveyor is arranged for transporting away tinned boards. The conveyors 6, 7 are arranged at angles α, β - both typically 13° - of entry and exit of the boards to and from the bath 1. The conveyors 6, 7 are driven from a motor 44 - described below - in synchronism with board-gripping rollers - also described below.
30 Upstream of the feed-in conveyor 6 are arranged, but not illustrated, pre-treatment stations including cleaning, flux and preheating stations; whilst downstream of the feed-out conveyor 7, again not illustrated, are post-treatment stations
35 including cooling and washing stations. These pre- and

post-treatment stations feed boards at typical speeds of 1.5 to 7.5 m/min.

Also shown in Figure 1 is the upper, cover portion 8 of a cast, rollersupport beam described in more detail below and non-heating portions 9 of heating elements extending in the solder bath.

Referring now to the other Figures, the solder bath 1 has three pairs of upper and lower board-gripping rollers 10_u , 10_l ; 11_u , 11_l ; 12_u , 12_l , extending transversely of it. The rollers can be of metal which is not normally wetted by solder for instance stainless steel, nickel or titanium. However, it is preferably of wettable - though solder insoluble - metal for instance mild steel to provide even solder contact with the board. These rollers are journaled via end shafts 14 in upper and lower graphite bearings 13_u , 13_l carried on roller support beams 15, extending along the bath 1, one on one side of the rollers and the other on the other side. The lower bearings 13_l are of rectangular cross-section and are held captive in downwardly open complementary seats 16 by straps 17 to translationally fix the lower rollers. It should be noted that although the straps 17 support the weight of the lower rollers when the solder bath is empty, when it is full of molten solder the lower rollers 10_l , 11_l , 12_l , tend to float so that they are located directly by engagement of the bearings 13_l in their seats 16.

The upper graphite bearings 13_u each comprise a pair of flanged annular bushes 18 accommodated within a stainless steel, cylindrical sleeve 19. The sleeves 19 of the central, upper roller 11_u are located in vertically-extending, vertically extending bearing horns 20 in the beams 15. The horns are of such height that the upper roller 11_u can drop onto the lower roller 11_l or be lifted slightly from it by the thickness of a typical board B. A pair of links 21, having eyes 22 engaging around the sleeves 19 for the roller

11_u, extend respectively up- and down-stream of the bath to the rollers 10_u, 12_u, where further eyes 23 at the other ends of the links 21 engage around the sleeves 19 for these rollers 10_u, 12_u. The beam 15 and its upper cover portion 8 have a cavity 24 at each bearing 13_u with inwardly-directed side faces 25 laterally captivating the links 21 - and further links 26, 27 to be described - via their eyes 22, 23. Thus the centre links 21 are able to swing and move up and down with the upper rollers 10_u, 11_u, 12_u, whilst the centre distances of the rollers are kept constant as they move to allow the board B to pass between the pairs of rollers.

The horns 20' at the sleeves 19 for the rollers 10_u, 12_u are relieved to allow for slight movement of these rollers axially of the bath as the links 21 fore-shorten.

The upper rollers 10_u, 11_u, 12_u are urged towards the lower rollers 10_l, 11_l, 12_l by springs 28 acting on the eyes 22, 23 and housed in bores 29 in the upper beam portion 8. Each spring 28 is pre-loaded by an adjustable eccentric 30 accommodated on the beam and a pin 31 passing through the spring, whereby the degree of bias of each upper roller towards its lower roller can be adjusted to suit the thickness of the board B.

The beams 15 are secured to the solder bath 1 at weirs 32, 33 described below, thus they locate the rollers laterally of the bath by contact of thrust spacers 34 with the inner, opposed faces 35 of the beams and the ends of the rollers. The bearings 13_u, comprised of the bushes 18, are located on the upper rollers' shafts 14 by thrust collars 36 secured to the shafts.

On the upstream side of the board-gripping rollers 10_u, 10_l, 11_u, 11_l, 12_u, 12_l, a lower idling guide roller 37 is provided, journaled in the same manner as the lower gripping rollers. Upstream of this is a pair of guide rollers 38_u, 38_l journaled in the same manner as the main board-gripping

rollers. Links 26 extending from the rollers 10_u have eyes 39 adjacent to eyes 23 and an enlarged eye 40 at the roller 38_u performing the function of the sleeve 19 in accommodating graphite bushes 18'. Similarly on the down-stream side a pair of guide 41_u; 41_l is provided in like manner to the rollers 38_u; 38_l, with the upper roller 41_u linked to the roller 12_u by links 27. Thus all the upper rollers can be removed for service as one linked together unit.

To one side of the bath, the upper rollers' shafts 14 are extended and carry sprockets 42. Those on the shafts of the rollers 10_u, 11_u, 12_u are double and those on the shafts of the rollers 28_u, 41_u are single. Respective drive chains 43 extend between each adjacent pair of sprockets 42, drivingly linking the adjacent rollers, whereby all the upper rollers are ganged together. A motor 44 drives the rollers via a dog clutch 45. Except for the idler roller 37, the lower rollers 38_l, 10_l, 11_l, 12_l, 41_l are all frictionally driven by their upper rollers due to the upper rollers being biased down onto the lower rollers. To guard against snatch of a board B and consequent damage to it, as it enters the first pair of rollers 38_u, 38_l and is accelerated by them, a torque limiting clutch 46 is provided between the upper rollers' sprocket 42 and its shaft 14. The dog clutch 45 is provided to enable the bath to be disconnected from the motor 44 and withdrawn on its rails 4 for service.

The bath 1 is constructed of mild steel plate and supported on a chassis 47 itself supported on the framework 2. Along each side of the bath, channels 48 are provided inboard of which sides 49 extend up and drop down into a sump 50 centrally of the bath. Solder heating elements 51 are arranged across the bath in the sump 50 and have non-heating portions 9 in which their resistance wire is not coiled - looping over the sides 49 and out through the bottom of the channels 48.

At each end of the bath the liquid height control weirs

32, 33 are provided. Upstream of the upstream weir 32 a further small sump 52 is provided. In use, solder 53 is added as required to keep the free surface 54 of the solder just below the level of the weirs. Anti-oxidation oil 55 is
5 pumped from the further sump 52 onto the solder 53 to flow back over the weir 32 and keep the solder covered.

In use of the solder leveller, the sump is filled with solder 53 which is kept molten by the heating elements 51. During idling, the motor 44 keeps the rollers turning at
10 slow speed typically 5rpm, this circulates the solder, partially by the solder being dragged around by the board-gripping rollers' peripheries and partly by the lower rollers being hollow and fitted with impellers 56 for moving the solder in one direction 57 through the roller 11₁ and back
15 in the other direction 58 in the rollers 10₁, 12₁. During operation the motor speed is varied between a board-gripping roller speed matching the pre- and post-treatment station speeds and a processing speed. When a board is detected as
20 approaching down the feed-in conveyor 6 the motor is accelerated to provide a processing roller peripheral speed of the region of 50 m/min, given by roller rotation at 125 rpm for 125mm diameter rollers. The board B on reaching the rollers 38, the lower of which runs in the oil 55, is accelerated and fed through the free surface 54 of the solder along an
25 upstream portion 59 of a board path through the leveller. It is guided by the roller 37 and passes into the nip of the rollers 10. In passing along a curved portion 60 of the path through the nips of the three pairs of board-gripping rollers 10_u, 10₁; 11_u, 11₁; 12_u, 12₁, it is heated from an
30 initial temperature in the region 50-150°C to just above the eutectic point of the solder i.e. 183°C, by contact with the solder and more importantly, contact with the rollers which conduct heat to the board. The temperature of the solder is controlled in the region 220-260°C; although the lower end
35 of the range is preferred to inhibit the formation of inter-

metallic compounds. In this respect it can be noted that parts of the board remain in the solder for equal lengths of time. On reaching the eutectic temperature the board's contact pads wet and are tinned. The board is fed out from the solder on a downstream path portion 61 and through the air knives 5 at the roller speed for effective levelling. As soon as the board clears the air knives, the rollers, together with the up- and down-stream conveyors, are returned to the speed of the pre- and post-treatment stations to await the next board.

Typical dimensions of the solder leveller are as follows:-

	Board-Gripping roller diameter	125 mm
	Board-Gripping roller length	650 mm
15	Bath length between weirs	600 mm
	Radius of curve path	800 mm
	Guide roller diameter	50 mm.

The invention is not intended to be restricted to the details of the above described embodiment. The leveller described is appropriate for processing boards which are up to 610mm wide and of indefinite length over 290mm. For other size of boards, the bath dimensions and the board-gripping roller number and dimensions may vary. The specified operating speeds and temperatures may vary. The overriding requirement is of course that the boards have been heated to the eutectic point and been wetted by the solder on emerging from the solder. The air knives may be constructed to be rigid with the bath or may be separate and spaced from the bath along the downstream portion of the board path.



CLAIMS

1. A solder leveller having a bath for containing molten solder with a free surface and means for levelling solder
5 deposited on a board (B) as it leaves the bath, the solder leveller comprising:
 - curved-path defining rollers arranged across the bath to define a curved portion of a board path through the solder leveller;
 - 10 at least two of the curved-path defining rollers comprising a pair of superimposed board-gripping rollers having a nip therebetween beneath the free surface of the molten solder at which the board (B) is gripped for drive;
 - the upper one of the said pair(s) of board-gripping rollers
15 being in use less than half immersed beneath the free surface of the molten solder;
 - means for rotational drive of at least one of the said pair(s) of the board-gripping rollers;
 - the board path having:
 - 20 an upstream portion above the free surface of the molten solder leading to,
 - the curved, board-heating and tinning portion below the surface of the solder, including the nips of the or each said pair of board-gripping rollers at which the board is
25 gripped and leading to,
 - a down-stream portion above the free surface of the solder to the levelling means.
2. A solder leveller as claimed in claim 1, wherein the two rollers of the said pair(s) of board gripping rollers are of
30 substantially the same diameter.
3. A solder leveller as claimed in claim 1 or claim 2, including means for providing a layer of solder-oxidation-inhibiting oil over the molten solder in the bath, the said means including a sump from which the oil is pumped onto the
35 molten solder and a weir over which the oil flows back to the



- sump to regulate depth of the oil over the molten solder.
4. A solder leveller as claimed in claim 1, claim 2 or claim 3, wherein the said board-gripping rollers are metallic.
 5. A solder leveller as claimed in claim 1, claim 2, claim 3 or claim 4, including guide rollers provided singly and/or in pairs within and/or without the solder bath.
 6. A solder leveller as claimed in claim 5, including at least one pair of guide rollers on the upstream portion of the board path.
 - 10 7. A solder leveller as claimed in claim 5 or claim 6, either as appendant to claim 2, wherein the oil sump is upstream of the solder bath, and one of the guide rollers runs in the oil sump.
 8. A solder leveller as claimed in any one of claims 1 to 7, 15 wherein a plurality of pairs of the board-gripping rollers is provided, the solder leveller including respective bearings fixed with respect to the bath for one of each pair of board-gripping rollers and respective bearings translationally movable with respect to the bath for the other of each pair of 20 board-gripping rollers.
 9. A solder leveller as claimed in claim 8, wherein the bearings are of graphite.
 10. A solder leveller as claimed in claim 8 or claim 9, wherein the lower ones of the pairs of board-gripping rollers have the 25 fixed bearings and the upper ones of the pairs of board-gripping rollers have the movable bearings, and the solder leveller includes means for urging the translationally movable bearings towards the fixed bearings, whereby the board-gripping rollers in each pair are biased together.
 - 30 11. A solder leveller as claimed in claim 10, wherein the urging means comprise a respective spring acting at one end thereof on each translationally movable bearing.
 12. A solder leveller as claimed in claim 11, including adjustment means acting on the other end of each spring, 35 whereby the degree of bias of the or each upper board-gripping



roller towards the respective lower board-gripping roller is adjustable to suit the thickness of the board (B) to be passed along the curved portion of the board path.

13. A solder leveller as claimed in any one of claims 8 to 12,
5 including a respective roller support beam at each end of the board-gripping rollers on which both the fixed and the translationally movable bearings at the respective ends of the board-gripping rollers are located, the beams extending longitudinally of and being fixed with respect to the bath.
- 10 14. A solder leveller as claimed in claim 13, including respective inter-bearing links linking adjacent pairs of movable upper board-gripping-roller bearings at each end of the upper board-gripping rollers, whereby the separation of adjacent upper rollers along the curved portion of the board
15 path is determined.
15. A solder leveller as claimed in claim 14, wherein one, preferably a central one, of the upper board-gripping rollers is constrained against horizontal movement by engagement of its bearings with the beams.
- 20 16. A solder leveller as claimed in claim 14 or claim 15, including drive sprockets carried on each upper board-gripping roller and drive chains extending between the drive sprockets of adjacent rollers for ganged together rotational drive of the upper board-gripping rollers and drive of the board (B) through
25 the solder.
17. A solder leveller as claimed in any preceding claim, including a drive motor and a drive connection from the motor to the upper board-gripping roller(s).
18. A solder leveller as claimed in claim 17, including a
30 support framework for the solder bath, support rails extending transversely of the board path, wheels journaled on the framework and running on the support rails for lateral withdrawal of the solder bath, and a dog clutch incorporated in the drive connection, whereby the rollers are drivingly
35 disconnected from the motor on withdrawal of the solder bath.



19. A solder leveller as claimed in any preceding claim, including at least three pairs of board-gripping rollers and two pairs of guide rollers, one up-stream of the board-gripping rollers and one down-stream thereof.
- 5 20. A solder leveller as claimed in claim 19, as appendant to any one of claims 14 to 16, wherein the guide rollers are journaled and driven in like manner to the board-gripping rollers.
- 10 21. A solder leveller as claimed in claim 20 as appendant to claim 16, including a torque limiting clutch between the driven up-stream guide roller and its drive sprocket.
22. A solder leveller as claimed in any preceding claim, wherein at least one of the lower board-gripping rollers is hollow, open at both ends and provided with an impeller for
- 15 circulating molten solder therethrough.
23. A solder leveller as claimed in claim 3 or any one of claims 4 to 22 as appendant to claim 3, wherein the solder bath includes a second weir for controlling the height of the free surface of the solder-oxidation-inhibiting oil above the free
- 20 surface of the molten solder in the bath.
24. A solder leveller as claimed in claim 23, as appendant to claim 12, wherein one of the weirs is at the up-stream end of the bath, the other of the weirs is at the down-stream end and the roller support beams are located on the two weirs.
- 25 25. A solder leveller as claimed in any preceding claim, including electric solder heat elements extending in the bath across its bottom.
26. A solder leveller comprising:
- 30 a bath for molten solder,
- air knives at a down-stream end of the bath,
- three pairs of board-gripping rollers arranged across the bath to define a curved board path portion below a free surface of the solder in the bath,
- one pair of guide rollers up-stream of the board-gripping
- 35 rollers for guiding a printed circuit board (B) into the nip of



an up-stream one of the board-gripping rollers,

two beams one extending along one side of the bath and the other along the other side for supporting the rollers,

lower bearings fixed to the beams for journalling the lower
5 rollers

upper bearings movable up and down on the beams for journalling the upper bearings,

a drive motor for rotationally driving the upper rollers in synchronism.

10 27. A solder leveller as claimed in claim 26, including springs acting on the upper bearings for urging the upper rollers into board-gripping contact with the lower rollers.

28. A solder leveller as claimed in claim 26 or claim 27, including another pair of guide rollers down-stream of the
15 board-gripping rollers for guiding the board (B) through the air knives.

29. A solder leveller as claimed in claim 26, claim 27 or claim 28, including:

an oil sump up-stream of the solder bath, the lower one of
20 the up-stream pair of guide rollers running in the oil sump, and

a pair of weirs for controlling the height of the free surface of solder-oxidation-inhibiting oil above the free surface of the molten solder in the bath, the nip of the
25 board-gripping rollers being below the level of the weirs.

30. A solder leveller as claimed in any one of claims 26 to 29, including:

support rails extending transversely of the board path;

a support framework for the solder bath;

30 wheels journaled on the framework and running on the support rails for lateral withdrawal of the solder bath;

a drive motor for the board-gripping rollers fixed with respect to the support rails; and

a drive connection including a dog clutch between the drive
35 motor and the board-gripping rollers, whereby the



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board-gripping rollers are drivingly disconnected from the motor on withdrawal of the solder bath.

31. A solder leveller as claimed in any one of claims 26 to 30, including a drive connection including a torque limiting clutch
5 between the up-stream pair of guide rollers and the board-gripping rollers.

32. A solder leveller substantially as hereinbefore described with reference to the accompanying drawings.

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