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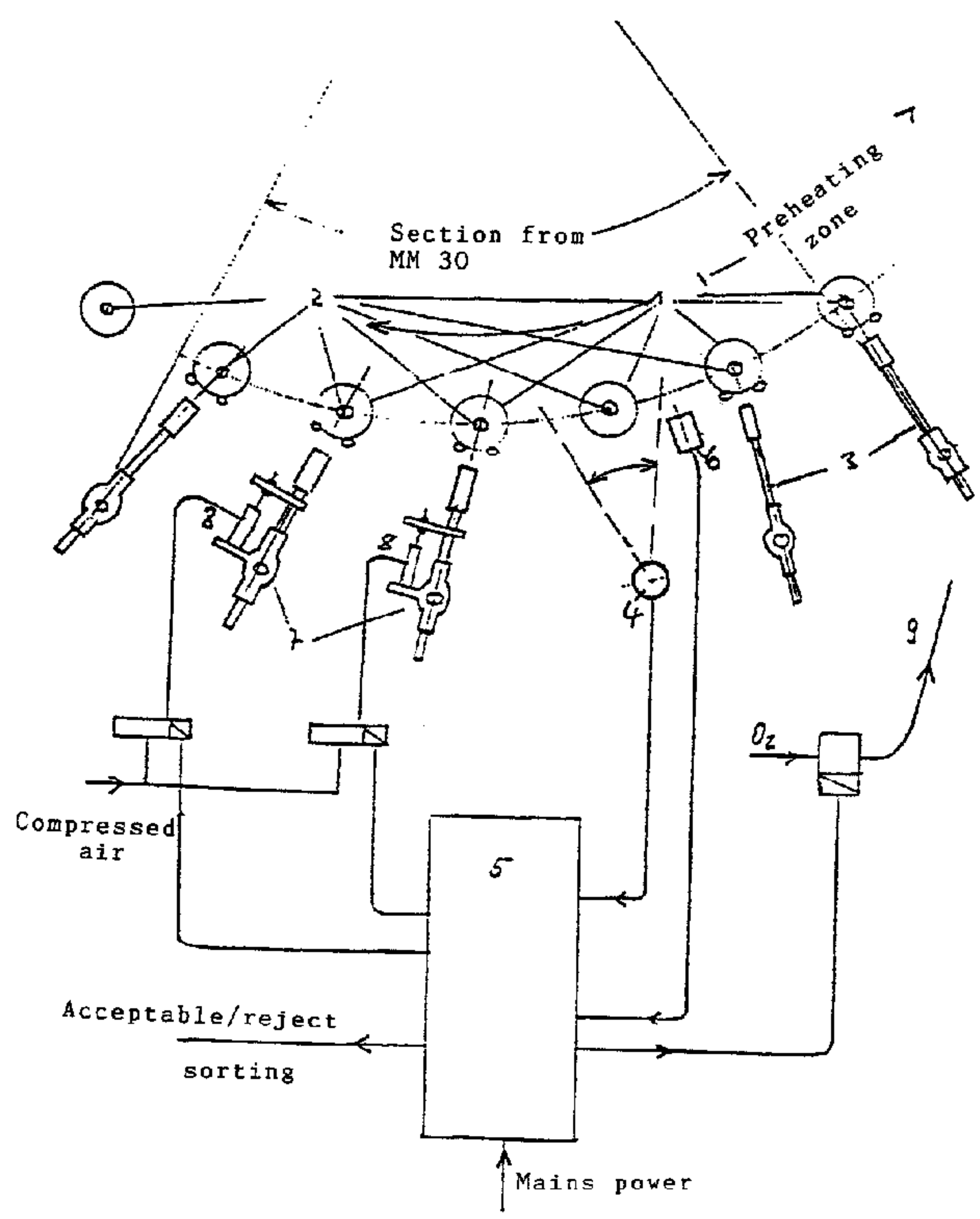
(54) Title: METHOD FOR CONTROLLING THE FREE DEFORMATION OF THERMOPLASTIC MATERIAL



(57) Abrégé/Abstract:
In a method for controlling the free deformation of thermoplastic material in an automated process for the further processing of the material to form articles, in particular in the production of ampoules, small bottles and the like from glass tubes, in which method, to obtain a high dimensional accuracy of the article, a correction action, via the effect of heat on the starting material in the heating phase, is carried out in dependence on a setpoint/actual-value comparison of the deformation, achieved in a predetermined working step, of a workpiece in the deformation region, the measurement of the deformation achieved, the setpoint/actual-value comparison and the correction action are, in order to exclude interference influences in the development of the deformation, carried out in situ on one and the same workpiece during the development of the deformation in the heating phase.

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Abstract

In a method for controlling the free deformation of thermoplastic material in an automated process for the further processing of the material to form articles, in particular in the production of ampoules, small bottles and the like from glass tubes, in which method, to obtain a high dimensional accuracy of the article, a correction action, via the effect of heat on the starting material in the heating phase, is carried out in dependence on a setpoint/actual-value comparison of the deformation, achieved in a predetermined working step, of a workpiece in the deformation region, the measurement of the deformation achieved, the setpoint/actual-value comparison and the correction action are, in order to exclude interference influences in the development of the deformation, carried out in situ on one and the same workpiece during the development of the deformation in the heating phase.

Method for controlling the free deformation of thermoplastic material

The invention relates to a method for controlling the free deformation of thermoplastic material in an automated process for the further processing of the material to form articles, in particular in the production of ampoules, small bottles and the like from glass tubes, in which method, to obtain a high dimensional accuracy of the articles, a correction action, via the effect of heat on the starting material in the heating phase, is carried out in dependence on a setpoint/actual-value comparison of the deformation, achieved in a predetermined working step, of a workpiece in the deformation region.

Methods of the aforementioned kind are of importance in particular in hollow-glass processing. Hollow-glass processing is understood to mean all operations in which a new article is produced from preformed raw glass. In general, this is carried out by deformation under the effect of heat. Glass tubes of all kinds are often the starting product for goods of the hollow-glass processing industry.

In this context, in particular, the ampoules, drinking ampoules, small bottles and tablet tubes produced from glass tubes by means of hollow-glass processing can be mentioned, of which the pharmaceutical industry requires a huge amount for filling with its products. So that they can pass through the high-performance automatic filling equipment of the pharmaceutical industry without problem, they must be precisely and dimensionally accurately produced in precisely operating automatic equipment.

By way of example of such automated processes, ampoule production on the so-called MM 30 (= a 30-station vertical automatic unit from Moderne Mecanique, F-77507 Chelles Cedex) is described below without limiting the generality. Details of this machine are contained, for example, in company literature.

For the production of ampoules from glass tubes on the MM 30, glass tubes are clamped into upper and lower chucks. These clamping points are arranged on a carousel and are fed with glass tubes from above. The zones of the tube to be deformed are heated between the synchronously rotating, aligned chucks to the required processing temperature. The working step follows this. The deformation is carried out by constriction, drawing or compressing, by means of the action of flame or by lowering or raising the lower chuck. The working machine consists of 30 such clamping stations distributed around the circumference of the carousel. The heating of that point of the tube to be worked is carried out via a number of stationary burners which are pivotally mounted and can follow the carousel rotation over a maximum possible zone and act on the glass tube. One ampoule is produced per clamping station and per carousel revolution.

In the art, this process is designated "free deformation", that is to say deformation without a shaping solid body. The magnitude of the deformation depends on the action time of the burners, the calorific value of the gas, the temporal constancy of supplies of gas, oxygen and combustion air, the temperature of the machine and of the surroundings, on draught, on the progressive consumption of the glass tube length and on the geometrical dimensions of the glass tube. These parameters are subject to temporal fluctuations and therefore cause fluctuations in the free shaping.

In the case of ampoule production, the free deformation plays a decisive part, in particular in the spear formation: for spear formation, the starting glass tube is first heated in the spear region until the glass has softened and a constriction forms in the glass tube as a result of the surface tension of the glass. Subsequently the ampoule spear is drawn out in finished form. The spear diameter and the wall thickness in the spear region in this process depend on the diameter and on the wall thickness of the constriction originally present.

To ensure rapid and reliable filling of the ampoules in the high-performance automatic equipment of the pharmaceutical industry mentioned at the outset, high requirements are set for the ampoule spear as regards its dimensional accuracy. Very narrow tolerances have to be maintained in particular by the diameter and centricity of the ampoule spear. For example, it can be said that the spear diameter of a 5-ml ampoule, according to the above-described process may fluctuate by up to ± 0.5 mm. However, the maintenance of tolerances of at most ± 0.2 mm is required by the further-processing companies.

To obtain an improvement in this respect, a method for controlling the spear formation has been developed by Techner Ltd., 33 Great James Street, London, WC1N 3HB, which method is described, for example, in brochures issued by Techner Ltd. to interested parties.

In the case of this method, at the last working station in each case of an ampoule production machine known per se, for example the MM30, the finished spear diameter of the ampoule running through this station is determined and, in dependence on the deviation of the actual value from the setpoint value, a correction action, via the heating in the spear region, is carried out for the subsequent workpieces. The assumption underlying this method is that identical heat effects on the identical tube result in identical spears. The determination of the spear diameter is carried out according to Techner by mechanical sensing by means of two discs which are large enough in diameter to avoid damaging the ampoule spear. The measurement provides a single diameter measurement value per spear.

According to Techner, the heating of the spear region is controlled corresponding to the determined diameter deviation over the co-running time of two individually controlled burners which act on the spear region of the workpiece in the preheating zone. The relationship between the diameter deviation and the co-running time is, according to Techner, determined empirically by experiments.

Since the measurement of the deformation achieved is only carried out in the last station directly before ejection of the finished ampoule, the control resulting from this can however only act on the following workpiece. Likewise, the long dead time has the effect that disturbances occurring in the short term during the heating phase, for example the influencing variables mentioned at the outset on the free deformation, such as draught, short-term changes in the supply of gas, oxygen and combustion air, sudden temperature rises in the surroundings etc., are not detected by the control.

The object of the invention is to develop a method of the type mentioned at the outset such that the dead time is as short as possible and disturbances occurring in the short term in the heating phase can also be compensated for by the control.

This object is achieved with a method with all the features of Patent Claim 1.

The method according to the invention utilizes the measurement of the deformation at a time at which all influencing variables have had a measurable effect and sufficiently large residual deformation still exists. The measurement results make possible the control of the residual deformation. The correction action can therefore be carried out taking into account all influences of the error, with the exception of the error.

Due to the fact that, according to the method according to the invention, both the measurement of the deformation achieved and the setpoint/actual-value comparison and the correction action in the heating phase are carried out in situ during the development of the deformation, the dead time of the control is equal to zero. The method according to the invention thus has the advantage that it makes possible an individual action on the deformation process of each individual workpiece.

The invention is explained in greater detail below without limiting the generality, because of its great importance for this method, with reference to the example of spear production in the ampoule production on the MM30 mentioned at the outset, with the aid of the figures and an exemplary embodiment. This is by no means intended to limit the invention solely to ampoule production, however. The invention as such can, just like the preferred embodiments described below, be readily applied to any methods for further processing of thermoplastic material without the person skilled in the art having to be inventive for this purpose. The procedure, in principle, is the same in all methods and can be taken from the following description of the application of the method to ampoule production. Some examples of further possible applications are specified below.

In the figures:

Figure 1: shows a diagrammatic view of an arrangement for controlling the ampoule spear diameter in the case of ampoule production on an MM30.

Figure 2: shows the characteristic curve which is used in the exemplary embodiment and reproduces the empirically determined relationship between the deviation of the constriction diameter and the co-running time of the individually controlled burners.

Figure 3: shows, as an example of the effectiveness of the method according to the invention, a diagram in which the fluctuations of the spear diameters during ampoule production on an MM30 in uncontrolled and controlled operation are compared with one another.

Figure 1, shows a diagrammatic view of an arrangement which is suitable for carrying out the method according to the invention for ampoule production, in particular for controlling the spear formation on an MM30. Device parts of the MM30 which play no part in carrying out the method according to the invention are for the sake of clarity not shown in the figure.

In the figure, glass tubes (2) clamped in chucks (1) can be seen, which are arranged on a carousel indicated by the "quarter-circular" arrangement of the burners. The heating of those points of the tubes to be worked, in the present example the spear regions, is carried out in the preheating zone via a number of stationary burners (3) (in general 14 in number) which are pivotally mounted and can follow the carousel rotation over a maximum possible zone and act on the glass tube (2).

Following the preheating in the preheating zone, the workpieces/glass tubes (2) are, in the present example, led past an IR camera (4). IR cameras are known per se and are therefore not described further here. The IR camera (4) serves for measuring the deformation of the spear region which has already occurred as far as this station as a result of the preheating. In general, approximately 80% of the spear heating has already been carried out until this point in time, so that the remaining 20% is still available for the correction action.

The measurement of the deformation which has already occurred is carried out in the method according to the invention preferably in a contactless manner, for example by means of optical dimension sensors.

The thermal radiation emitted by the heated starting material is preferably used for contactless measurement, it also having been proven especially favourable to measure the radiation emitted by the workpiece in a spectral range in which the radiation emitted by the burner flames does not interfere. This is possible in a simple manner by interposing a suitable filter. If, in addition, the thermal radiation is measured in a spectral range in which the radiation intensity is independent of the material thickness, a uniformly illuminated image of the deformation region with sharp contours is obtained with the aid of the aforementioned IR camera. The determination of the dimensions of the workpiece in the deformation region is considerably facilitated by this means. A more exact measurement is likewise possible.

In the case of tubular starting material, the free deformation on heating consists in the formation of a constriction in the deformation region as a result of the surface tension of the glass. It is now been found that the diameter and the wall thickness of the originally present constriction determine the diameter and the wall thickness of the finished ampoule spear. The method according to the invention is therefore carried out such that the constriction diameter is set to a predetermined value, the constriction diameter, however, corresponding to an unambiguously assigned spear diameter. In the case of this embodiment of the method, the correction action is thus carried out in dependence on the deviation of the actual constriction diameter from the setpoint diameter on one and the same article.

As can further be seen from the figure, the IR camera (4), which generally executes 50 measurements per second, has an extended field of view. This has the advantage that the deformation region, that is to say in the present case the constriction in the spear region, can be measured over at least one revolution of the workpiece (2) in the rotating chucks (1). This "multiple measurement" permits, in a simple manner, assessment of the ovality and eccentricity of the workpieces (2) in the deformation region. Impermissibly oval or eccentric spears can thereby be separated out in an acceptable/reject sorting, via the control (5) shown as a block in the figure.

In the figure, (6) designates a clock generator. The clock generator (6) transmits the period duration from tube to tube and thus the maximum possible co-running time of the burners. This is smaller than the reset time than the period duration.

The control (5) contains essentially the experimentally determined characteristic curve for the relationship between the deviation of the actual diameter from the setpoint diameter of the constriction and the change resulting from this in the controlled variable. The empirical determination of this characteristic curve has the advantage over possible model calculations that it generally provides more accurate results, since, for example, all machine influences are automatically co-registered. Figure 2 shows a possible characteristic curve. A description of this characteristic curve is given further below.

Corresponding characteristic curves can also be empirically determined in the case of other applications of the method according to the invention.

In the figure, the correction action is carried out via the co-running time of two individually controlled burners (7). A correction action is likewise possible by the sequential switching on/off of a series of burners or by O_2 feed to the individually controllable burners, as a result of which not a change in the flame temperature, for example, but rather a displacement of the hot zone of the flame towards the workpiece is achieved. Furthermore, the correction action may also be carried out by controlled cooling.

A space-saving and elegant method is correction action via the intensity, intensity distribution and/or duration of action of electromagnetic radiation, in particular laser radiation, since by this means measurement and action in ~~a~~ one station may take place. In particular, the use of a CO_2 laser presents itself, since this is a technically tried and tested development and CO_2 lasers are furthermore economical and highly efficient.

Figure 2 shows a characteristic curve which is suitable for the correction action via the two individually controllable burners. It is advantageous in this case to stage the co-running time of the correction burners in integral multiples of the rotation duration of the tube to prevent the formation of oval spears. In the characteristic curve, the co-running time of the correction burners is plotted against the standardized measured constriction diameter. The characteristic curve was obtained by setting both correction actions to 50% and the burners of the preheating zone and the individually controllable burners were adjusted such that the average spear diameters produced correspond to the desired setpoint spear diameter (conventional known setting of the machine). Then it was tested whether in the case of full action of the individually controllable burners the resulting spear diameters are produced 0.4 mm below the setpoint diameter and with minimum action 0.4 mm above the setpoint diameter. In the event of a deviation, preburning and correction burning are improved iteratively.

In the method according to the invention, the measurement, evaluation (= setpoint/actual-value comparison and conversion into control signals) and the control are advantageously computer-aided.

It may be advisable to determine the rate of change of the constriction diameter in cases in which this is particularly high.

Apart from the above-described individual control, it is advantageous to intercept overall influences on the spear-diameter formation by controlling the stationary burner group to maintain the average diameter of the measured constriction in the case of average correction action of the individually controllable burners: a drifting away of the constriction diameter into regions which are no longer accessible to the correction is largely avoided by this means. For the overall action the O_2 feed to the stationary burners (ref. (9) in Fig. 3) is adjusted, for example by means of a three-point step controller. The controlled variable is the fraction of the co-running time which is kept to 50% with a long compensation time.

Furthermore, in the method according to the invention, the results of the setpoint/actual-value comparison can also be additionally used for correction of adjacent shapings.

Ampoules whose measured constriction diameters lie outside the still correctable range are, in the method according to the invention, separated out via the sorting analogously to the ampoules with impermissibly oval or eccentric spears.

The production of a controlled constriction is advantageous not only in the case of the spear formation of ampoules but also, for example, in the base formation in the case of ampoules and small bottles and in the latter case also to provide a uniformly conditioned glass ~~material~~ volume for shoulder and orifice forming. Other continuous processes which make use of the free deformation may also profit from the application of the production of a controlled constriction, with respect to the accuracy of geometrical variables of the final product: for example, processes for re-drawing bars and tubes, in particular micropipettes and capillaries. The data recorded by the IR camera contain information about the work state of the glass which can be additionally used for improving the subsequent working steps: base, constriction, funnel.

Exemplary Embodiment:

According to the above-described method, in an exemplary embodiment 5 ml ampoules were produced from

16.5 mm glass tubes on an MM30 using the control according to the invention of the constriction diameter. For comparison, ampoules were also produced in a conventional manner, that is to say with uncontrolled operation of the MM30. The experimental results can be seen in Fig. 3.

The experimental arrangement of controlled operation corresponded to that shown in Fig. 1. The deformation region was in this arrangement measured by means of an IR camera. In the arrangement used, the forming constriction was on a zone of approximately 100mm in the field of vision of the camera, which makes approximately 50 measurements per second. To suppress the IR light emission of the adjacent flames and because of the emissivity of the glass, by means of an interference filter only radiation from the spectral range between 4.25 μm and 4.30 μm was allowed onto the lead-selenide detector of the camera. The setpoint/actual-value comparison of the measured constriction and the conversion of the constriction measured and obtained with the aid of the characteristic curve shown in Fig. 2 into control signals for the co-running time of the two individually controlled burners, to obtain a predetermined constriction, was carried out in a computer-aided manner.

Taking into account the passing through of the pipe, 100% co-running time means both burners maximum; 50% co-running time means burner A maximum, burner B without action; 0% means both burners without action. Relative co-running paths between 0 and 50% and between 50 and 100% are produced by forcing out by means of compressed-air cylinders (8) from the carrying chuck (1).

In Fig. 3 it can be seen that, in conventional operation of the MM30 (uncontrolled), considerable fluctuations of the spear diameters occur (in the Figure the diameters vary between 6.0 and 7.1 mm) whereas in controlled operation the diameter fluctuations are only slight (in the Figure between 6.4 and 6.8 mm).

This result was obtained by means of starting glass tubes which were investigated in pairs with the smallest permissible wall thickness, medium and highest permissible wall thickness (the exact numerical values for the wall thicknesses are unimportant in this context).

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for controlling free deformation of a thermoplastic material in the production of an article including an ampule and a bottle from a workpiece made of the thermoplastic material including glass, the method comprising the steps of:

freely deforming said workpiece in a deformation region to a predetermined extent by applying heat thereto in a preheating phase so as to allow a residual range of deformation to remain in said deformation region;

measuring, after completing and ending said preheating phase, an intermediate deformation of said deformation region to obtain a measurement of an actual value of the deformation;

comparing said actual value to a desired value of the deformation in said deformation region to provide a variable indicative of the difference between the actual and desired values and therefore indicative of said intermediate deformation; and

applying heat to said deformation region of said workpiece as a function of said variable to continue deforming said deformation region to correct for said difference as the workpiece is further deformed through said residual range and thereafter drawing out said deformation region until the deformation of said deformation region reaches its end value.

2. The method of claim 1, wherein the measurement of said deformation region is made without physical contact.

3. The method of claim 2, wherein the measurement is made with an optical dimension sensor.

4. The method of claim 2, wherein the contactless measurement is carried out via the thermal radiation emitted by the heated material of said deformation region.

5. The method of claim 4, wherein the heat is supplied to said deformation region with a burner supplying a flame emitting heat radiation, and wherein said thermal radiation is measured in a spectral range wherein said heat radiation of said flame does not constitute a disturbance.

6. The method of claim 4, wherein said thermal radiation is measured in a spectral range wherein the intensity of said thermal radiation is independent of the thickness of said material.

7. The method of any one of claims 1 to 6, wherein said workpiece made of thermoplastic material is a tube, and wherein said deformation region is a constriction formed in said tube, said constriction having a diameter adjusted to a pregiven value.

8. The method of claim 7, further comprising the step of determining the rate of change of said diameter while said deformation region is being formed.

9. The method of claim 7 or 8, further comprising the steps of:

empirically determining a characteristic curve defining the time during which said heat is again applied as a function of a standardized measure of said constriction diameter; and

utilizing said characteristic curve to convert said variable into a control signal for again applying said heat to said deformation region to correct for said difference.

10. The method of claim 7, 8 or 9, wherein a plurality of tubular workpieces is processed and each workpiece is rotated through at least one revolution, and wherein each of said workpieces is measured during said revolution to detect and separate out those workpieces having impermissible oval or eccentric constrictions.

11. The method of any one of claims 1 to 10, wherein said comparison is applied to correct shaping adjacent said deformation region.

12. The method of any one of claims 1 to 11, wherein said workpiece is held in a holder which is moved along a predetermined path, wherein the heat is again applied to said deformation region utilizing burners which can engage with said holder to co-run therewith through a predetermined portion of said path, and wherein the corrective action of each of said burners on said deformation region is controlled by adjusting the time for which the burner co-runs with the holder and/or by a sequentially switching-on and switching-off of said burners.

13. The method of claim 12, wherein said corrective action is

controlled by adjusting the supply of oxygen to said burners.

14. The method of claim 12, wherein said corrective action is controlled by the intensity, the intensity distribution and/or duration of electromagnetic radiation.

15. The method of claim 14, wherein said radiation is that of a CO_2 laser.

16. The method of any one of claims 12 to 15, wherein the first application of heat is carried out with burners as the workpiece is passed through a preheat zone, and wherein a corrective action is carried out by adjusting the amount of oxygen supplied to said burners of said preheat zone to thereby maintain the measured diameter during the corrective action of each of the burners which again apply heat to the deformation region after said workpiece passes out of said preheat zone.

17. The method of any one of claims 1 to 16, wherein said difference is corrected by allowing the workpiece to cool down in a controlled manner.

18. The method of any one of claims 1 to 17, wherein the measurement, evaluation and control are all computer supported.

19. A method for controlling free deformation of a thermoplastic material in the production of an article including an ampule and a bottle from a workpiece made of the

thermoplastic material including glass, said workpiece being held in a holder moved along a predetermined path, the method comprising the steps of:

freely deforming said workpiece in a deformation region, being a constriction having a diameter, to a predetermined extent by applying heat thereto in a preheating phase so as to allow a residual range of deformation to remain in said deformation region;

measuring, after completing and ending said preheating phase, an intermediate deformation of said deformation region by scanning said diameter with an infrared camera to obtain a measurement of an actual value of said deformation;

comparing said actual value to a desired value of said deformation in said deformation region to provide a variable indicative of the difference between the actual and desired values and therefore indicative of said intermediate deformation;

applying heat to said deformation region of said workpiece as a function of said variable to continue deforming said deformation region for correcting said difference as the workpiece is further deformed through said residual range and thereafter drawing out said deformation region until said deformation of said deformation region reaches its end value, said heat being applied to said deformation region utilizing burners engaging said holder to co-run therewith through a predetermined portion of said path; and

controlling said deformation in said deformation region by adjusting the time for which said burners co-run with said holder and/or by sequentially switching-on and switching-off of said burners.

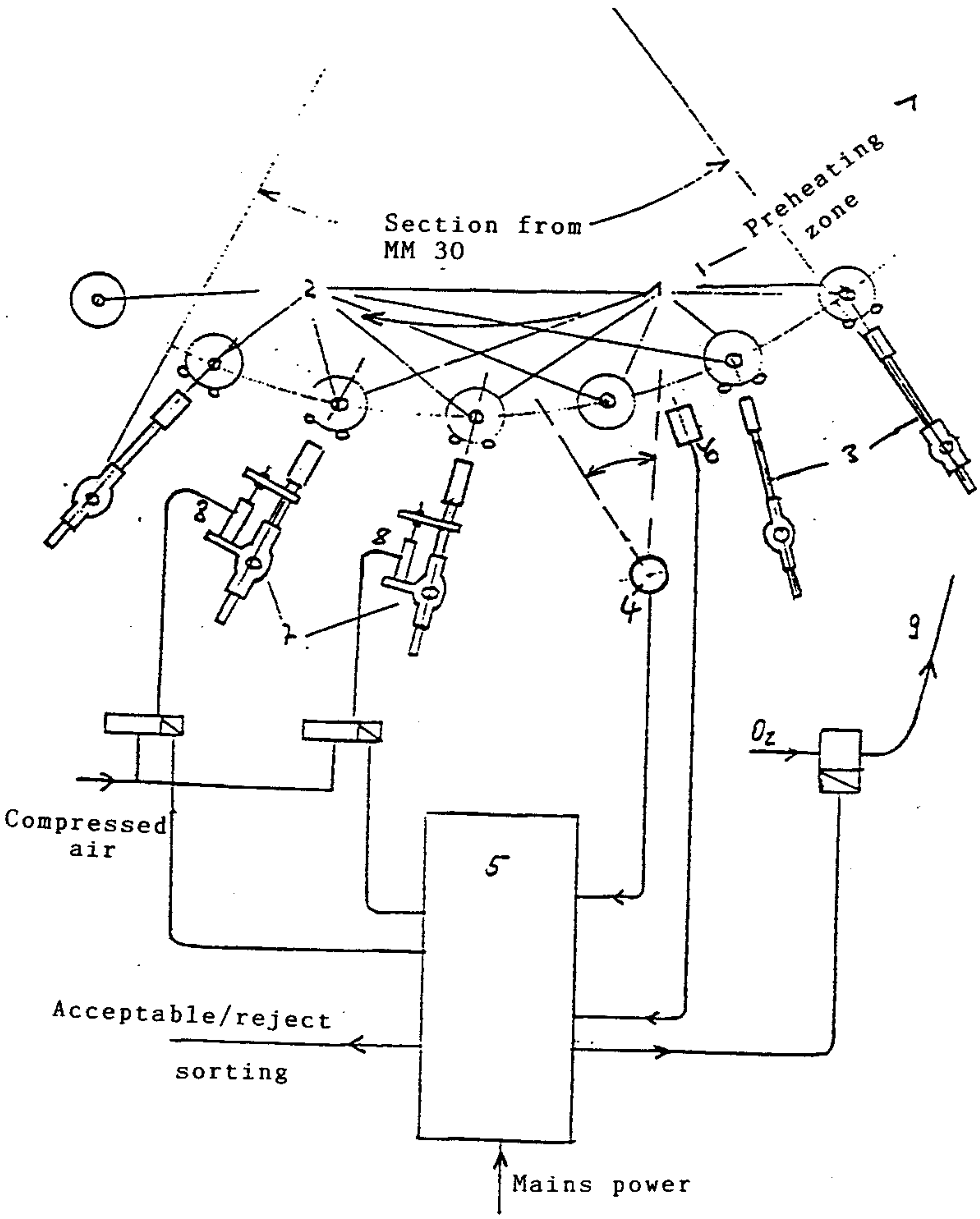

Fig. 1

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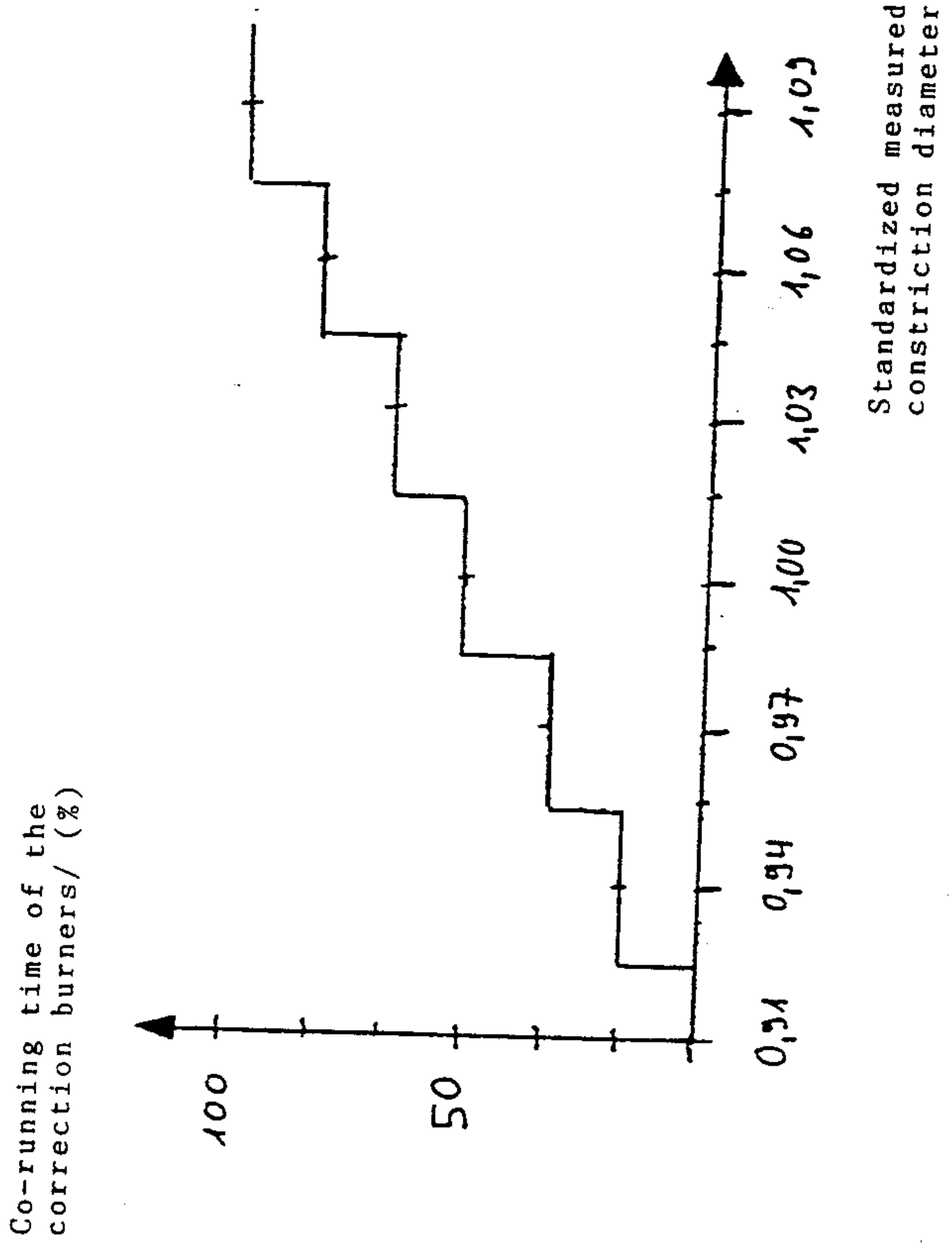

Fig. 2

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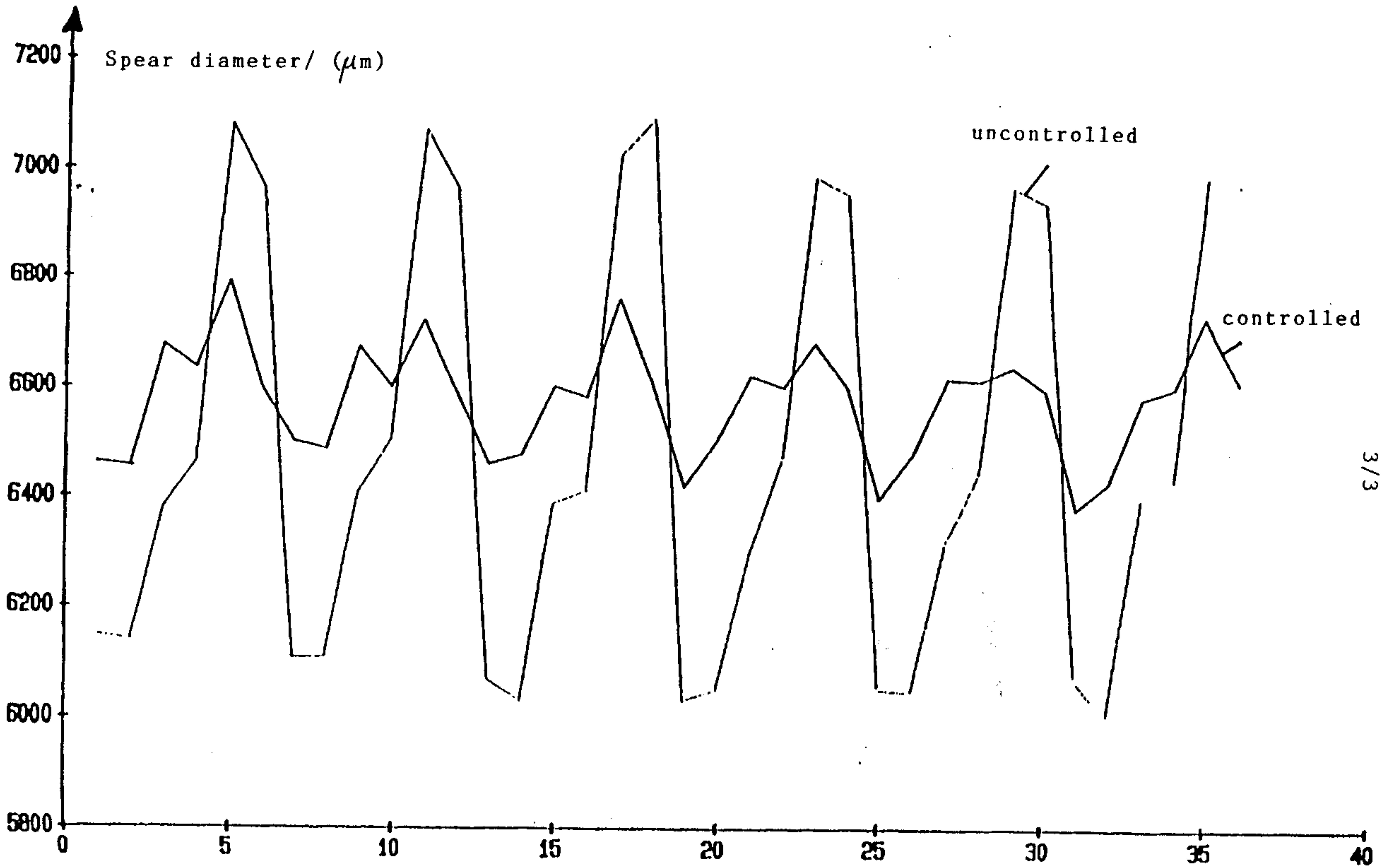

Fig. 3

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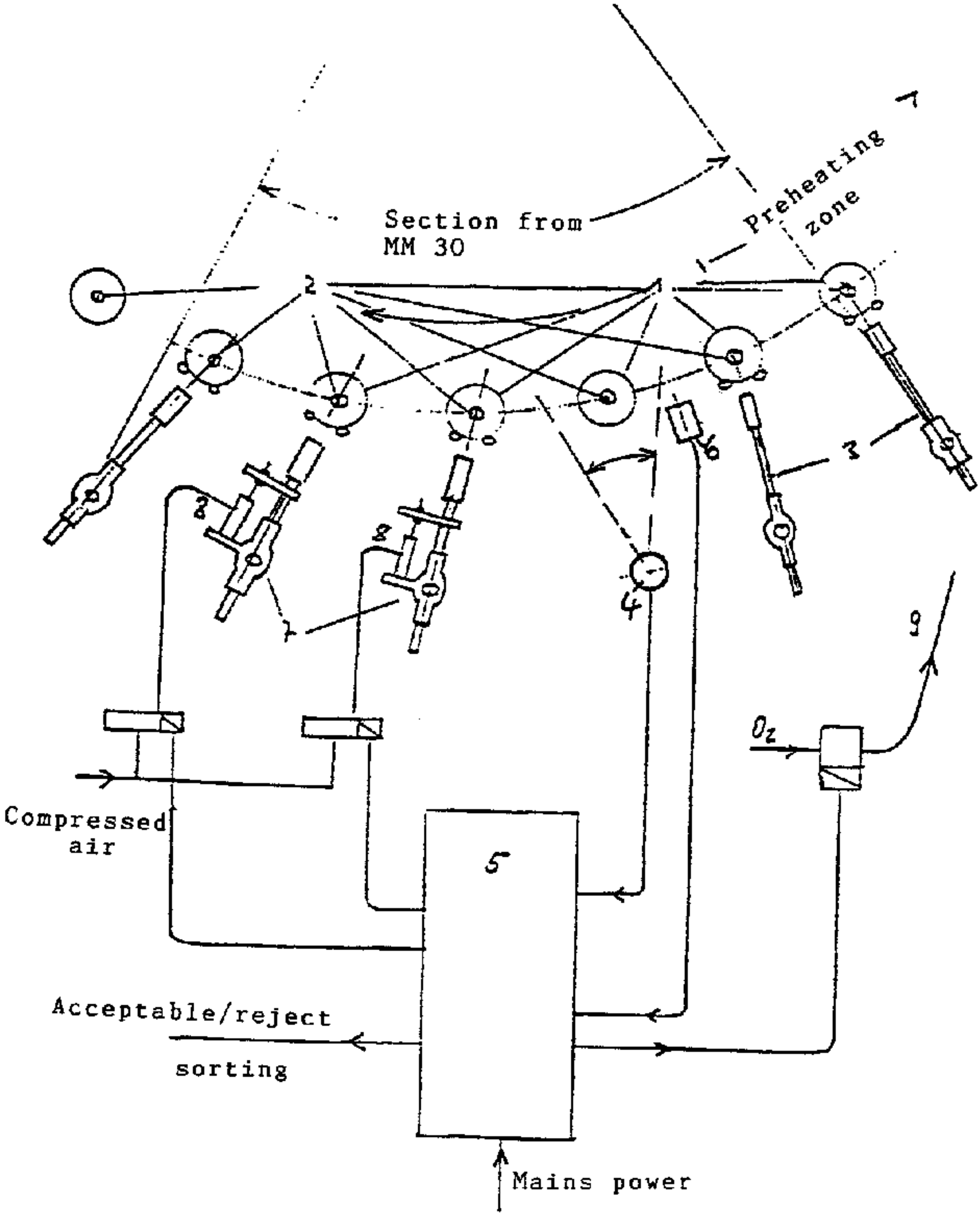

Section from
MM 30
Preheating
zone
7
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1
6
3
8
8
4
7
9
O_2
Compressed
air
5
Acceptable/reject
sorting
Mains power