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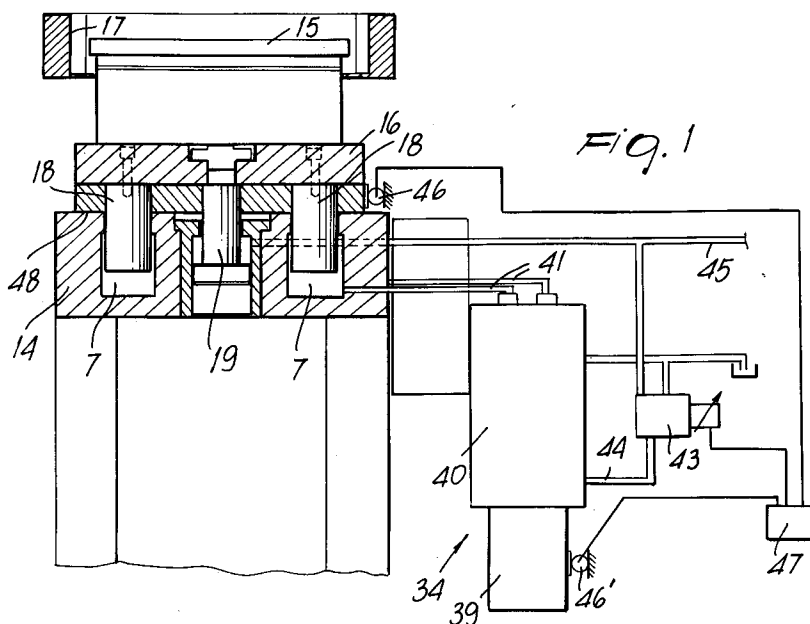
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I-20121 Milano (IT)(54) **Process for the dry pressing of a granular or powdery material and associated device and apparatus.**

(57) The present invention relates to a process for the dry pressing of a granular or powdery material, to a device suitable to be used to perform pressing and to a pressing apparatus which comprises the device. The process according to the invention comprises a step during which the depth of the mold is changed and the upper surface of the material contained in the mold is leveled simultaneously. The

device comprises a base, a body for supporting the lower mold and a plurality of hydraulic cylinders and pistons which are supplied by a flow divider element. The invention allows to obtain any profile of distribution of the material in the mold, in the direction of the leveling means, so as to compensate inadequacies in distribution.

*Fig. 1***EP 0 547 305 A2**

The present invention relates to a process for the dry pressing of a granular or powdery material, to a device suitable to be used to perform pressing and to a pressing apparatus which comprises the device.

More in particular, a pressing apparatus suitable to perform said process comprises: a main structure for containing a pressing force, which generally has a ring-like shape; loading means to load said material into a lower mold; leveling means for leveling an upper surface of said material loaded in a lower mold; vertical movement means for lifting or lowering a bottom of said lower mold. The loading means and the leveling means are preferably formed by a single body, generally termed truck or tray, which comprises a grid which can slide for loading and a front end which performs the leveling during backward motion.

More in particular, the present invention relates to an extraction device which comprises hydraulic pistons for vertical movement which are arranged so as to change a depth of a lower mold, and thus raise a molded part, up to the level of the upper edge of the lower mold so that the molded parts can be extracted from the mold and moved to the level of a substantially horizontal surface, also termed mold template plane, on which said upper edge is arranged. The truck can move along the template plane between a position arranged below a hopper for feeding the material to be pressed and a position which lies above the mold to be filled. During the advancement of the truck, the finished part is furthermore unloaded by making it slide on the template plane.

The bottom of the lower mold is supported by a moving body which is arranged above a base. Said moving body can be lifted vertically by means of first pistons so as to directly raise or lower the bottom of the mold for loading and extraction.

During pressing, the lower face of the moving body rests directly on the base in order to discharge thereon the pressing force.

After the extraction of the finished part from the mold, during the loading of the material to be pressed, said moving body does not descend until it rests on the base, but arranges itself at a specific height which determines the volume of the mold which can be loaded with material and then leveled at the top. Then the moving body descends until it rests on the base, which directly bears all the pressing force; the upper molds then descend and pressing occurs. The height at which the moving body stops for loading thus determines the vertical thickness of the finished part.

The upper molds are supported by a movable ram which is actuated for example by a hydraulic piston which can provide the pressing thrust.

Still more particularly, said pressing apparatus is suitable for the dry pressing of ceramic materials to be subsequently baked in kilns which operate continuously at high temperature. Said kilns, which are generally of the type with rollers, require a rather long startup time before they reach their normal operating conditions, and therefore cannot be shut down easily in all those cases in which an interruption in production occurs, typically if the size of the molds and/or the type of production must be changed. In this case it is in fact necessary to test and adapt the molds and/or the type of loading and/or the extent of the descent of the molds during loading, etc., with high precision in order to reduce the chances of rejects once production resumes. These tests can require as much as a couple of days. It is in fact necessary to check in practice the results of the loading of the material to be pressed, of the unloading of the pressed material and of the molding operation. These three aspects affect one another and depend considerably both on the type of production and on the size of the molds. In practice, adjustment and optimization of the many process variables are very complicated.

The above is briefly the main field of industrial use of the invention, but said field does not constitute a limitation to its scope, since the process, the device and the apparatus according to the invention, in particular as hereinafter described and claimed, can be advantageously used in any other equivalent field, as claimed in the accompanying claims.

Italian patent application No. MI 91 A 002420 in the name of the same Applicant discloses a pressing apparatus which comprises means for loading the material to be pressed in a lower mold. Said loading means are actuated by a rack and are supported directly by the body of the press. Other types of actuation of the loading means are known, for example from Italian patent No. 719423 and from Italian patent No. 717878. In these cases, too, the loading means are supported directly by the pressing apparatus. Italian utility model patent No. 0216666 furthermore describes loading means which can move vertically so that they can move together with the template of the mold, if the bottom of the lower mold is fixed and the template is instead movable; said patent furthermore describes means for feeding the loading means which are formed by a hopper equipped with a shutter which is suitable to release a fixed and preset amount of powder.

Pressing apparatuses are furthermore known which comprise a base which can directly support the loading means, such as for example the one described in patent application PCT No. WO 89/11969 in the name of the same Applicant.

It is furthermore known, for example from Italian patents No. 677031, No. 687318, No. 968676 and No. 968677, to use a moving body with a flat lower face in order to support the movement of the bottom of the molds. The vertical movement pistons are arranged below the base and raise the moving body by means of rods which pass through the base. Machines have also been marketed wherein the cylindrical seats of the pistons for the vertical movement of the moving body with flat lower face are defined in the body of the base.

Said known devices, however, entail some problems; in particular, every time it is necessary to change the size of the molds and/or the type of production, it is necessary to halt the entire production line, including the kilns, for all the time required to perform the above described tests. The position of the moving body during the loading of the material to be pressed is furthermore preset and can be modified only with difficulty. Therefore it is not easy to intervene on the volume of material loaded into the lower mold before pressing.

Patent Abstracts of Japan vol 7 No 183 (M-235) and Japanese patent application No 58 084 700 teach the use of a loading apparatus which can be removed together with the lower mold. However after the remotion it is impossible to carry out the full range of tests required because the change-ment of the depth of the lower mold is associated with means which cannot be removed. Also the whole arrangement can be only substantially weak, so that it can be reliably used only for molding small pieces.

US patent 4 222 726 teaches the use of a bottom of the lower mold which can be removed. However the removed part can only be adjusted by means of shims and does not participate to the movement which changes the depth of the lower mold. So it is completely useless for the purpose of carrying out tests on the removed part.

Italian patent No. 1220351 describes mechanical means with gears combined with hydraulic pistons for varying the inclination of the moving body and of the bottom of the mold so that before the loading and leveling step the bottom of the mold is inclined in order to compensate the greater compression of the powder inside the mold in the terminal region of the leveling action. The adjustment of this system, however, in practice is very complicated and difficult to repeat; furthermore, only one type of adjustment is possible, according to a profile which is linear along the entire length of the mold.

German patent No 1 255 554 and German patent No 528 100 and German utility model 8 803 036 disclose a process in which the movement of the leveling means and the movement of the means for changing the depth of the mold are

simultaneous. However this process can be used only for the molding of very small pieces (such as 250 cm²) since the means disclosed for changing the depth of the mold cannot be used with large pieces or for the simultaneous pressing of many small pieces because it is impossible to achieve a precise coplanarity; in fact according to the actual industrial precision requirements it is important to achieve a vertical precision of at least 0.1mm. Also the mechanical response time of this system is low, while according to the actual industrial speed requirements it is important to obtain a point-to-point change of the depth of the lower mold in about 0.1 sec. Furthermore it is extremely difficult to adapt the system to a change of production, such as a different size of molds. For these reasons even if this teaching is very old it was never really adopted for large scale production.

Plastics Engineering, vol XXXVI, No 2, February 1980, pages 40-44, Manchester, New Hampshire, US, discloses the use of a flow divider to compensate the off-center load on the upper mold during pressing, but does not disclose anything about the need of a control and the kind of control for the change of the depth of the lower mold before pressing.

According to a first aspect, the aim of the present invention is to overcome the problems described above by providing a process for pressing a granular or powdery material with a pressing apparatus which comprises leveling means for leveling an upper surface of said material loaded in a lower mold, and vertical movement means for changing a depth of said lower mold, said process comprising:

- a) a vertical movement of said vertical movement means controlled by means of an adjustment of a liquid flow delivered to said vertical movement means by means of a first proportional valve; said first proportional valve being adjusted according to a signal emitted by a first position detector which is arranged so as to be able to detect said depth of said lower mold;
- b) a leveling movement of said leveling means;
- c) step a) and step b) being carried out at least in part simultaneously; so that certain preset regions of said lower mold are loaded with an amount of material which is more or less than the physical dimensions of said lower mold as they are when said leveling begins.

This process allows to adjust non-uniformities in loading according to any type of profile in a direction parallel to the direction of the motion of the leveling means, allowing to compensate even highly localized defects by loading too much or too little material exactly in the regions which require it. It is furthermore easily repeatable, since it is based on a type of adjustment which can be easily auto-

mated. Point-by-point control of the position, of the bottom of the mold is thus easily allowed, and thus the adjustment of the distribution profile required for the material can be very precise and reliable. The movement of the vertical movement means, which perform also the extraction of the molded piece from the mold, can be easily controlled with a closed-loop control circuit both during ascent and during descent, so as to have in both cases perfect control over position, speed and acceleration. This is particularly useful for creating fast acceleration and deceleration ramps which do not entail damage to the fragile freshly-pressed material and not yet fired. In this manner, the amount of granular material loaded into the mold can be changed simply by means of the control software according to the results obtained, without requiring manual mechanical interventions.

According to a second aspect, the present invention has the purpose of overcoming the above described problems by providing a device suitable to be used with a pressing apparatus, comprising: vertical movement means for changing a depth of a lower mold before pressing for adjusting the amount of material charged in said lower mould; a plurality of hydraulic first cylinders and first pistons for actuating said vertical movement means; a flow divider element which can distribute the same flow to each one of said first cylinders.

In this manner it is possible to provide a device and an apparatus which allow to change the depth of the lower mold in a very simple and reliable way, even when the molds are very large, such as for pressing tiles of 10000 cm² or even larger. Also the template plane and the bottom of the mold can be maintained parallel even during the motion for changing the depth of the lower mold. So the process according to the invention can be performed with a smooth execution which surprisingly can be extremely precise.

According to a third aspect, the invention has the purpose of overcoming the above described problems by providing a device suitable to be used with a pressing apparatus, comprising: loading means for loading a material to be pressed; vertical movement means for changing a depth of a lower mold, so as to adjust the amount of material charged in said lower mold; a plurality of hydraulic first cylinders and first pistons for actuating said vertical movement means; supporting means which are mounted on said vertical movement means and are suitable to bear the weight of said loading means; and conveyance means which are defined on said vertical movement means and are suitable to allow the removal of said vertical movement means from a main structure of said pressing apparatus, so that said removal automatically entails a removal of said loading means, of said plurality of

hydraulic first cylinders and first pistons and of said lower mold.

It is thus possible to drastically reduce the time required to change the size of the molds and/or the type of production. Furthermore, in difficult cases it is possible to perform all the necessary tests on a dedicated press which is not connected to a production line, allowing to separately prepare the new molds on another base, with another loading means and another extraction device, so as to be able to solve without hurry any problem related to the new molds without interrupting production.

Preferably, the device comprises vertical adjustment means for adjusting the alignment between the level of said loading means and the level of said mold. More preferably, said vertical adjustment means comprise two parallel eccentric bodies which are directly supported by said base; a frame for supporting said loading means rests on said eccentric bodies. It is thus possible to easily adjust the alignment between the loading means and the level of the template of the molds, furthermore ensuring that the plane of the loading means and the plane of the molds are perfectly parallel to one another. It is furthermore thus possible to install or remove the frame of the loading means on or from the base with a very rapid operation which does not entail the tightening of bolts etc..

Preferably, the rotation of said two eccentric bodies is adjusted by a single adjustment shaft which is arranged perpendicular to said two eccentric bodies and allows to adjust the vertical position of the loading means with a very simple operation while keeping the loading means always perfectly horizontal.

Preferably, the conveyance means are formed by two horizontal recesses and in particular by two holes defined in said base. Conveyance of the base and of the loading means, which are supported in a cantilevered manner, is thus particularly easy.

According to another aspect, the present invention relates to a loading, unloading and extraction assembly which comprises loading means for loading the material to be pressed and for unloading the pressed material, and a device according to what has been described above.

According to another aspect, the present invention relates to a pressing apparatus which comprises a main structure for containing the pressing force, loading means for loading the material to be pressed and for unloading the pressed material; and a device according to what has been described above. For the description of the pressing apparatus suitable to comprise a device according to the invention, reference is made to the pressing apparatus described in the patent application PCT No. WO 89/11969 which integrates and is consid-

ered part of the present specification.

Further characteristics and advantages of the invention will become apparent from the following description of a preferred but not exclusive embodiment, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a schematic sectional front view of the device according to the invention;

Figure 2 is a partially sectional side view of the device, of the unit and of the apparatus according to the invention;

Figure 3 is a front view of a detail of the device of Figure 2;

Figure 4 is a side view of a detail of the device of Figure 2;

Figure 5 is an enlarged partially sectional view of a detail of the device of Figure 1;

Figure 6 is a top sectional view, taken along the plane VI-VI of Figure 5;

Figure 7 is a front enlarged-scale view of a detail of the device of Figure 1;

Figure 8 is a plan view of the device of Figure 1;

Figures 9 to 13 are schematic sectional side views of the detail of the lower mold and illustrate the process according to the invention;

Figure 14 is a Schematic view of the connections of the electronic circuit according to the invention;

Figure 15 is a front sectional view of a second embodiment of the flow divider of fig 5; and

Figures 16 and 17 are front, sectional, enlarged scale views of a detail of figure 15.

With reference to Figures 1 to 17, the pressing apparatus comprises a main structure 10 which generally has a ring-like shape and hydraulic actuation means to perform pressing by means of the descent of the upper mold 9. The hydraulic actuation means and the relevant hydraulic circuit are described in detail in patent application PCT no. 89/11969. The loading means are formed by the grid 11, which is loaded by means of the hopper 12, and can unload the pressed material by means of the thrust of the end 13, making it slide on the plane of the template 26. The leveling means are defined by the knife 8 of the grid 11.

The vertical movement means are formed by the cooperation of the base 14 and the moving body 16. The base 14 has a considerable thickness in order to withstand the pressing force, and supports the thrust on the lower mold with the interposition of a moving body 16 which is formed by the plate 16, which is arranged above the base 14. In particular, the side walls 17 of the lower mold are directly supported by the base 14, whereas the bottom 15 is supported by the base 14 by means of the plate 16. Said moving body 16 is raised and lowered by means of the first pistons 18 or 19. In particular, the pistons 18 and 19 are assigned

respectively to lifting and lowering. The cylindrical seats 7 both for the piston 19 and for the first pistons 18 are defined in the body of the base 14. In particular, for each seat 7 there is a bush, in particular the bush 20 for the piston 19 and the bush 21 for each of the first pistons 18. Each bush has a hole 22 which is fed by a hollow expansion 23 defined in the body of the base 14 around the bush in order to feed the seat 7 of the piston 18. During working of the press only the moving body moves while the base 14 operates as a stable support of the moving body 16.

Even if the above embodiment is preferred, according to different embodiments of the invention (not represented in the drawings), it is possible to arrange the seats of the first cylinders in the moving body instead of in the base. The loading means 11 are supported by means of two supporting bodies 24 which are mounted directly on the base 14. The two supporting bodies 24 act as vertical adjustment means in order to adjust the alignment between the level of the powder-carrying plate 25 and the level of the plane of the mold 26. The two supporting bodies 24 are eccentric and are supported directly by the base 14, by means of the element 27 which is inserted directly and rigidly in the body of the base 14. Each one of the two bodies 24 comprises two coupled eccentric disks 28.

The conveyance means for removing the base 14 comprise two horizontal holes 42 defined on the vertical movement means and particularly on the base 14, so that any lifting machine can be used for lifting and removing the base 14, the moving body 16, loading means 11, first cylinders 7, first pistons 18 and lower mold 15, 17.

The frame 29 for supporting the loading means 11 is simply rested on the eccentric bodies 28 by means of the free rollers 30, whose axis is rigidly associated with the frame 29. In this manner, the frame 29 can be separated from the press 10 simply by lifting it. The height of the frame 29 is adjusted by rotating the bodies 24. In order that the rotation is synchronized on both sides of the loading means, there is a single adjustment shaft 31 which is arranged perpendicular to the two bodies 24. More particularly, said shaft 31 is coupled to a pair of gears 32 and 33 for each one of the bodies 24. The adjustment of shaft 31 can align the level of the loading means 11 with the level of the plane of the template.

This embodiment is preferred because in this manner there is the further advantage that higher speeds can be achieved, since the plane of the template of the mold remains motionless and the truck does not have to be subjected to vertical movements during leveling.

Even if the above embodiment is preferred, according to different embodiments of the invention (not represented in the drawings), it is possible to support the side walls of the lower mold and the loading means by the moving body and support the bottom of the lower mold by the base. However in this last case the weight supported by the first pistons is about ten times heavier.

The term "flow divider element" designates an element which is capable of receiving a single liquid flow in input and of dividing said flow into a plurality of mutually identical output flows. A flow divider element is generally schematically indicated by a plurality of non-motorized positive-displacement pumps whose axes are all interconnected mechanically so that all the pumps necessarily rotate at the same rate. A flow divider of this type is marketed for example by Vivoil Oleodinamica S.r.l. in Bologna.

The flow divider element 34 shown in Figure 8 can distribute the same flow to each one of the seats of the first piston 18, so it that can actuate the vertical movement means. Particularly the moving body 16 can be gradually moved vertically and it can be parallel to itself by means of gradual passages of flow through the flow divider 34.

According to a second preferred embodiment, the flow divider element 34 is formed by a separate hollow second piston 36, 36' for each pair of first cylinder 7 and first piston 18. The second pistons are mutually connected by means of the flange 37, 37', and each one is contained in a separate second cylinder 38, 38'. The cylinders 38, 38' are mechanically connected to one another according for example to three embodiments.

According to one embodiment, with particular reference to figures 5 and 6, the cylinders 38 are all obtained from a single part 39. Said single part 39 is shaped like a large piston which can slide into an actuation cylinder 40 arranged outside the group of second cylinders 38. The cylinder 40, is rigidly associated with the flange 37.

According to another more preferred embodiment, with particular reference to figure 15, the cylinders 38' are connected with an actuation double effect cylinder 40' arranged inside the group of second cylinders 38'. The piston 39' is rigidly associated with the flange 37'.

The cavities 58 of the pistons 36, 36' are connected to the first cylinders 7 by means of the tubes 41, 41'.

In both cases the second cylinders are moved by the actuation cylinder with respect to the second pistons which remain still. However, even if the above two embodiments are preferred, according to a third embodiment of the invention (not represented in the drawings), it is possible to move the second pistons, maintaining the second cylinders

still. In this case, tubes 41, 41' are connected directly with the second cylinders.

Preferably the ratio of the length of the stroke of the second pistons 36, 36' with respect to the corresponding length of the stroke of the first pistons 18, 18' is in the range of from 1.1 to 8, preferably of 1.5 to 5 and more preferably of 2.5 to 3.5. In this manner it is possible to obtain the following additional advantages: the diameters of the cylinders can be smaller, so it is possible to use smaller and faster proportional valves; smaller diameters give rise to small oil leakages; it is possible to obtain a better precision and resolution if the encoder is arranged to detect the relative movement of the second cylinders 38, 38' with respect to the second pistons 36, 36'; the second cylinders 38, 38' can be arranged closer to each other, so the moment on the group of second cylinders is substantially reduced even if there are strong load differences on the first pistons 18; with lower moments involved the operation of the flow divider is easier and more reliable.

With particular reference to figures 15-17, the correction means 59 can set a certain flow increase for the flow 41' which is directed to one of the first cylinders 7 with respect to the flow 60 which is directed to another first cylinder 7.

The distribution of the amount of material charged in said lower mould can be adjusted, by the correction means, in a direction perpendicular to the direction of the movement of the leveling means. The distribution of the material can be adjusted, by the correction means, also in a direction parallel to the direction of the movement of the leveling means. However in both cases, with the simple use of the correction means, such distribution can be adjusted only according to a linear profile. According to the claimed process on the contrary, it is possible to control such distribution according to any profile in a direction parallel to the movement of the leveling means.

Particularly the correction means 59 comprise adjustable means 61 to adjust the filling of one of said second cylinders 38' with respect to the filling of another second cylinder 38'. The adjustable means 61 are formed by a movable element 62 which is movable between an engagement and a release position, so as to engage or release one or more pairs of a second piston 36' and a second cylinder 38'. The engagement position causes a changement of the penetration of the engaged pair and so a preset increase of passage of oil. The movable element 62 is normally in the release position under the action of springs 63 and can be moved to the engagement position by a passage of oil through valve 64 at every pressing cycle, so that during the leveling of the surface of the material in the mold, the movable element 62 is in the

engagement position. Figure 16 and figure 17 show respectively the engagement and the release position of the movable element 62.

A position detector formed by a potentiometer or preferably an encoder 46 is mechanically connected to the moving body 16. Alternatively and preferably a potentiometer or an encoder 46', 46'' is connected between the second pistons 36, 36' and the second cylinders 38, 38', so as to detect their relative movement. In both cases the rotation of the encoder 46, 46', 46'' is in linear proportion to the lifting or lowering of the moving body 16, so as to detect the depth of the lower mold 15, 17. This last arrangement has the advantage of facilitating the removal of the base without requiring the disconnection of the electric line which connects the encoder. The encoder can furthermore be arranged in a more protected position.

The first proportional valve 43 is connected to the supply 44, 65 of the flow divider element 34 and is supplied with pressurized liquid by means of the line 45. The first proportional valve 43 can be for example a D661 servovalve having a linear motor with permanent magnet manufactured by Moog inc.

Preferably the first proportional valve 43 has a response time of less than 140 milliseconds, more preferably less than 90 milliseconds, still more preferably less than 50 milliseconds, for passing from completely closed to completely open conditions.

Preferably the first proportional valve 43 has a frequency higher than 2 Hz, more preferably higher than 5 Hz, still more preferably higher than 8 Hz, with an attenuation of 3 DB.

The movement of the leveling means 8 and of the loading means 11 is controlled by an adjustment of actuation means formed by hydraulic motor 68. Hydraulic motor 68 engages gears 69, 70, 71, 72 and moves the second position detector 49 and the racks 73. The racks 73 are in fixed relationship with the leveling means 8 and the loading means 11. The hydraulic motor 68 is controlled by means of an adjustment of a liquid flow delivered by a second proportional valve 66. This valve is supplied with pressurized oil delivered for example from a hydraulic accumulator 67 and actuated according to a signal emitted by the position detector 49 formed by a potentiometer or an encoder. The encoder 49 can detect the rotation of the shaft 74 and so can detect the position of the leveling means 8.

The second proportional valve 66 can be for example a D633 servovalve having a linear motor with permanent magnet manufactured by Moog Inc.

Preferably the second proportional valve 66 has a response time of less than 90 milliseconds,

more preferably less than 45 milliseconds, still more preferably less than 25 milliseconds, for passing from completely closed to completely open conditions.

Preferably the second proportional valve 66 has a frequency response higher than 5 Hz, more preferably higher than 10 Hz, still more preferably higher than 20 Hz, with an attenuation of 3 DB.

With particular reference to figure 14, the first proportional valve 43 and the second proportional valve 66 are adjusted by means of control means 47 which are connected respectively with the first encoder 46 and the second encoder 49. The electronic circuit of the control means 47 is formed by the BUS 75 which connects dedicated microprocessors 79, 76, 77, 78. Microprocessors 76, 77 and 78 are respectively dedicated to the control respectively of the vertical movement means 14, 16, of the leveling means 8 and of the ram connected with the upper mold 9. Each microprocessor 76, 77 and 78 is for example formed by a LM628 precision motion controller manufactured by National Semiconductor Corporation.

Preferably each microprocessor 76, 77, 78 operates with a sampling interval smaller than 5000 microsec, more preferably smaller than 2000 microsec and still more preferably smaller than 400 microsec.

Microprocessor 79 is connected with a keyboard and display 80 and can store the profiles of position, velocity and acceleration for microprocessors 76, 77 and 78.

Particularly microprocessor 79 comprises a first stored profile for microprocessor 76 to control the first proportional valve 43 and a second stored profile for microprocessor 77 to control the second proportional valve 66. Microprocessor 79 processes independently the second stored profile, while the first profile is processed in consequence of the execution of the second profile.

More particularly when encoder 49 communicates to microprocessor 79 that certain programmed steps of the second profile have been reached, an interrupt stops the execution of the second profile so that a certain step of the first profile can be executed by means of the action on proportional valve 43. When encoder 46 communicates to microprocessor 79 that such certain step of the first profile has been executed, the independent execution of the second profile can begin again.

Microprocessor 77 is endowed with a digital Proportional Integral Derivative filter, also called PID filter, which compensates the control loop of the movement of the proportional valve 66 which controls the hydraulic motor of the leveling means. Microprocessor 76 is endowed with a distinct PID filter which compensates the control loop of the

piston proportional valve of the vertical movement means. In operation the electronic circuit and particularly each microprocessor 76 and 77 subtracts the actual position (feedback position) from the desired position (profile generator position), and the resulting position error is processed by the PID filter to drive the actuator to the desired position. The actuator is held at the desired position by applying a restoring force to the actuator that is proportional to the position error, plus the integral of the error, plus the derivative of the error. Each microprocessor 76 and 77 comprises a 32 bit position feedback processor.

With particular reference to the pressing of granular or powdery materials and in particular of ceramic tiles, and considering figures 9 to 13 in particular, the pressing process is described by the following non-limitative example.

EXAMPLE

When a new pressing cycle begins, the moving body 16 moves upwards so that the depth of the lower mold decreases, until the bottom 15 of the lower mold reaches the plane 26 of the template. The loading means 11 with the powder 48 to be loaded in the mold are caused to advance until they are above the lower mold; the proportional valve 43 is opened in order to discharge the liquid contained in the cylindrical seats 21 of the first pistons 18; due to the pressure which acts on the piston 19, the moving body 16 and the bottom of the mold 15 descend, so the depth of the lower mold is increased. The encoder 46 detects the position of the moving body 16, and this measurement is analyzed by the storage and comparison element 47 in order to compare it with a first stored loading position. When said position is reached, the proportional valve 43 is closed; this step is illustrated by Figure 9.

The leveling means 8 are then moved backward, in the direction of the arrow 50, by actuating a second proportional valve which controls a hydraulic motor which is dedicated to the movement of loading means 11 and of leveling means 8. The second position detector 39 detects the position actually reached by the leveling means 8, their speed and their acceleration. The storage and comparison element 47 compares the data detected by the detector 49 with the stored data, so as to be able to perform the necessary corrections by acting on the second proportional valve. Simultaneously, the bottom 15 of the mold is progressively lowered, in the direction of the arrow 51, keeping this movement always under closed-loop control. The point-by-point inclination of the leveling in the inclined region 53 depends on the ratio between the vertical movement speed of the bot-

tom 15 and the horizontal movement speed of the leveling means 8. This step is illustrated by Figure 10.

The movement of the bottom 15 is then stopped with the complete closure of the proportional valve 43, while the leveling means continue to move in the direction of the arrow 52. This step is illustrated by Figure 11.

The opening of the proportional valve 43 causes the upward movement of the bottom 15, while the leveling means continue to move in the direction of the arrow 54. The point-by-point inclination of the leveling in the inclined region 56 depends on the ratio between the vertical movement speed of the bottom 15 and the horizontal movement speed of the leveling means 8. This step is illustrated by Figure 12.

Preferably the leveling movement is controlled by proportional valve 66, so that the combined actuation of proportional valves 43 and 66 performs the process.

Once leveling has ended, the proportional valve 43 is opened again in order to discharge the remaining liquid which is still contained in the seats 21, until a lower face 48 of the moving body 16 rests on the base 14. The lower mold is thus ready for pressing. This step is illustrated by Figure 13.

Pressing is performed with the descent of the upper mold 9. The proportional valve 43 is then opened in order to fill with liquid the seats 21 of the first pistons 18. The extent of the opening of the proportional valve 43 is adjusted according to the position detected by the encoder, and in particular in the first part of the path the opening is increased progressively and during the last part of the path the opening is decreased progressively until complete closure occurs at the point at which the encoder 46 detects a position which is identical to the one stored for unloading, that is to say at the point at which the bottom 15 of the lower mold reaches the level 26 of the plane of the template. The loading means 11 are then caused to advance in order to unload the pressed part by means of the edge 13.

The particular profile obtained with leveling before pressing, as illustrated in particular by Figure 13, has been chosen merely by way of example in order to show that it is possible to obtain any type of profile simply by acting on the ratio between the vertical speed of the bottom 15 and the horizontal speed of the leveling means 8.

Furthermore, in this example constant accelerations have been kept both for the bottom 15 and for the leveling means 8, and therefore straight profile segments 53, 56 and 57 have been obtained; however, it is sufficient to adequately vary the accelerations in order to obtain curved and blended profiles.

The preferred ranges of numerical parameters above described for the first proportional valve, the second proportional valve and the electronic circuit can be important to improve the reliability of the process, particularly if a high speed is required and if control point-by-point of velocity and acceleration is required.

The invention is susceptible to numerous modifications and variations, all of which are within the scope of the inventive concepts identified in the claims, so that the mechanical details may be replaced with other equivalent ones.

Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the scope of each element identified by way of example by such reference signs.

Claims

1. Process for pressing a granular or powdery material (48) with a pressing apparatus which comprises leveling means (8) for leveling an upper surface (53, 56, 57) of said material loaded in a lower mold, and vertical movement means (14, 16) for changing a depth of said lower mold (15, 17), said process comprising:
 - a) a vertical movement of said vertical movement means (14, 16) controlled by means of an adjustment of a liquid flow delivered to said vertical movement means (14, 16) by means of a first proportional valve (43); said first proportional valve being adjusted according to a signal emitted by a first position detector (46) which is arranged so as to be able to detect said depth of said lower mold (15, 17);
 - b) a leveling movement of said leveling means (8);
 - c) step a) and step b) being carried out at least in part simultaneously; so that certain preset regions of said lower mold are loaded with an amount of material which is more or less than the physical dimensions of said lower mold as they are when said leveling begins.
2. Process according to claim 1 in which said leveling movement is controlled by means of an adjustment of a actuation means which actuates said leveling means (8); said actuation means being adjusted according to a signal emitted by a second position detector (49) which is arranged so as to be able to detect the position of said leveling means (8).
3. Process according to claim 2 in which said actuation means comprise an hydraulic motor (68) controlled by means of an adjustment of a liquid flow delivered to said hydraulic motor by means of a second proportional valve (66).
4. Process according to at least one of claims 1-3, in which said vertical movement means (14, 16) are actuated by a hydraulic first piston (18).
5. Process according to at least one of the preceding claims, comprising the following steps:
 - a) reducing said depth of said lower mold by means of said vertical movement means (14, 16);
 - b) advancement of loading means (11) until they are located above said lower mold (15, 17);
 - c) increasing said depth of said lower mold (15, 17) by means of said vertical movement means (14, 16);
 - d) leveling of said upper surface of said material loaded into said lower mold (15, 17), and simultaneously actuating a vertical movement of said vertical movement means (14, 16);
 - e) pressing by descent of an upper mold (9).
6. Process according to at least one of the preceding claims, comprising the combined actuation of said first and second proportional valves (43, 66).
7. Process according to at least one of the preceding claims in which said first proportional valve (43) has a response time of less than 140 milliseconds, preferably less than 90 milliseconds, more preferably less than 50 milliseconds, for passing from completely closed to completely open conditions.
8. Process according to at least one of the preceding claims in which said second proportional valve (66) has a response time of less than 90 milliseconds, preferably less than 45 milliseconds, more preferably less than 25 milliseconds, for passing from completely closed to completely open conditions.
9. Process according to at least one of the preceding claims in which said first proportional valve (43) has a frequency higher than 2 Hz, preferably higher than 5 Hz, more preferably higher than 8 Hz, with an attenuation of 3 DB.

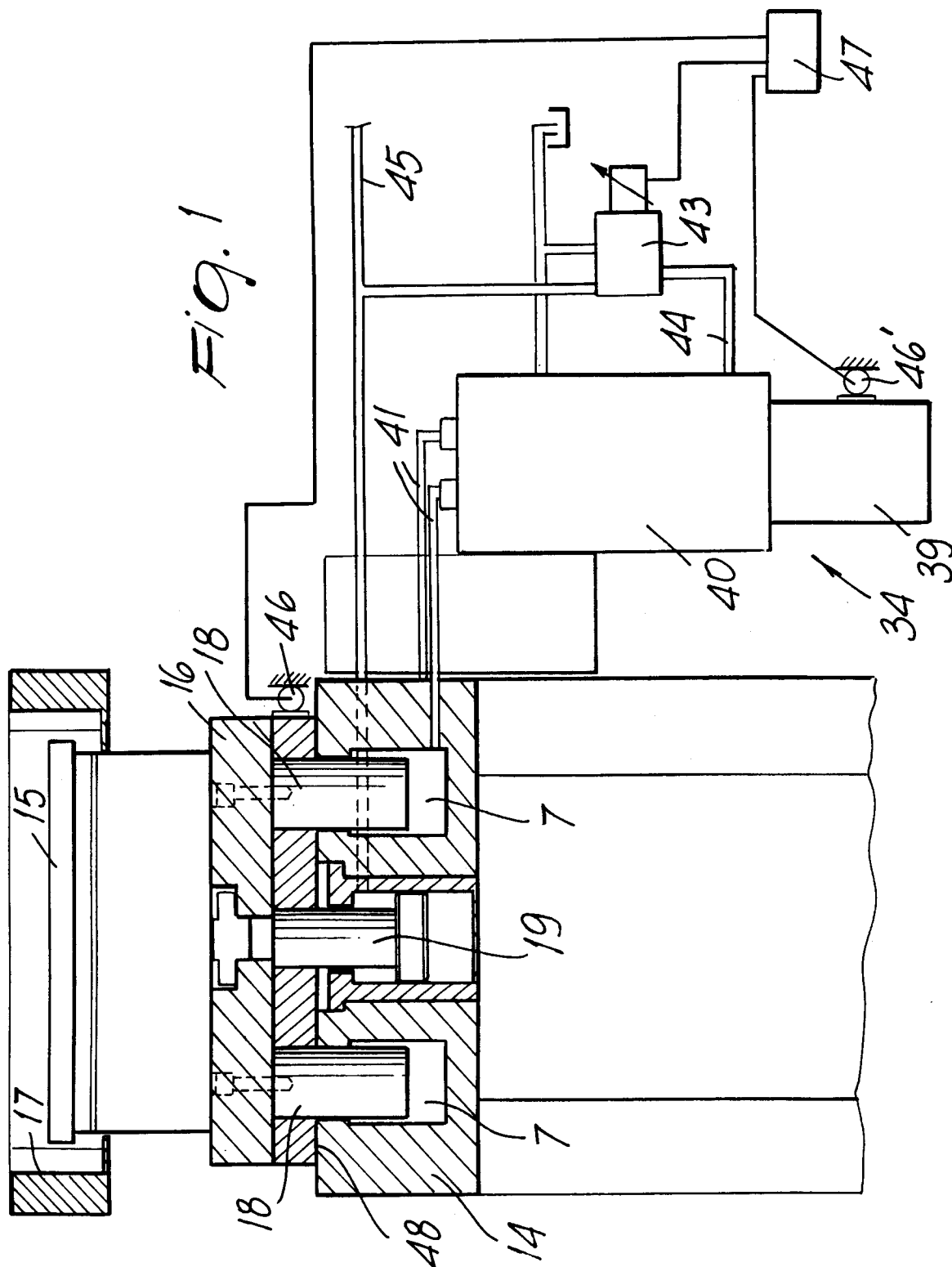
10. Process according to at least one of the preceding claims in which said second proportional valve (66) has a frequency response higher than 5 Hz, preferably higher than 10 Hz, more preferably higher than 20 Hz, with an attenuation of 3 DB. 5
11. Process according to at least one of the preceding claims in which said first proportional valve (43) and/or said second proportional valve (66) is adjusted by means of control means (47) connected respectively with said first position detector (46) and/or said second position detector (49); said control means (47) comprising an electronic circuit. 10 15
12. Process according to claim 11 in which said electronic circuit (47) operates with a sampling interval smaller than 5000 microsec, preferably smaller than 2000 microsec and more preferably smaller than 400 microsec. 20
13. Process according to claim 11 in which said electronic circuit (47) operates with a digital proportional integral derivative (PID) filter to compensate the control loop. 25
14. Process according to at least one of the preceding claims in which said electronic circuit (47) comprises a first stored profile of position, and/or velocity and/or acceleration actuated by said first proportional valve (43) and a second stored profile of position, and/or velocity and/or acceleration actuated by said second proportional valve (66); said second profile being processed independently; said first profile being processed in consequence of the execution of said second profile. 30 35
15. Process according to at least one of the preceding claims in which said position detector (46, 49) is an encoder. 40
16. Device suitable to be used with a pressing apparatus, comprising: vertical movement means (14, 16) for changing a depth of a lower mold (15, 17) before pressing for adjusting the amount of material charged in said lower mould; a plurality of hydraulic first cylinders (7) and first pistons (18) for actuating said vertical movement means (14, 16); a flow divider element (34) which can distribute the same flow to each one of said first cylinders (7). 45 50
17. Device suitable to be used with a pressing apparatus, comprising: loading means (11) for loading a material to be pressed; vertical movement means (14, 16) for changing a depth of a lower mold (15, 17), so as to adjust the amount of material charged in said lower mold (15, 17); a plurality of hydraulic first cylinders (7) and first pistons (18) for actuating said vertical movement means (14, 16) and are suitable to bear the weight of said loading means (11); and conveyance means (42) which are defined on said vertical movement means (14) and are suitable to allow the removal of said vertical movement means (14, 16) from a main structure (10) of said pressing apparatus, so that said removal automatically entails a removal of said loading means (11), of said plurality of hydraulic first cylinders (7) and first pistons (18) and of said lower mold (15, 17). 55
18. Device according to claim 17, comprising vertical adjustment means (24) for adjusting the alignment between a level of said loading means (11) and a level (26) of said mold.
19. Device according to claim 18, wherein said vertical adjustment means (24) comprise two parallel eccentric bodies (28) which are directly supported by said base (16); a frame (29) for supporting said loading means (11) resting on said eccentric bodies (28).
20. Device according to claim 19, wherein the rotation of said two eccentric bodies (29) is adjusted by a single adjustment shaft (31) which is arranged perpendicular to said two eccentric bodies (29).
21. Device according to at least one of the preceding claims in which said vertical movement means (14, 16) comprise: a base (14) for withstanding a pressing force discharged onto said lower mold (15); and a moving body (16) which engages said base (14) by means of said first cylinders (7) and first pistons (18) and which can change said depth of said lower mold (15, 17).
22. Device according to claim 21 in which said first cylinders (7) are arranged inside said base (14).
23. Device according to at least one of the preceding claims in which said conveyance means are formed by two horizontal recesses (42) defined in said base (14).
24. Device according to at least one of the preceding claims in which said moving body (16) can be gradually moved vertically and it can be

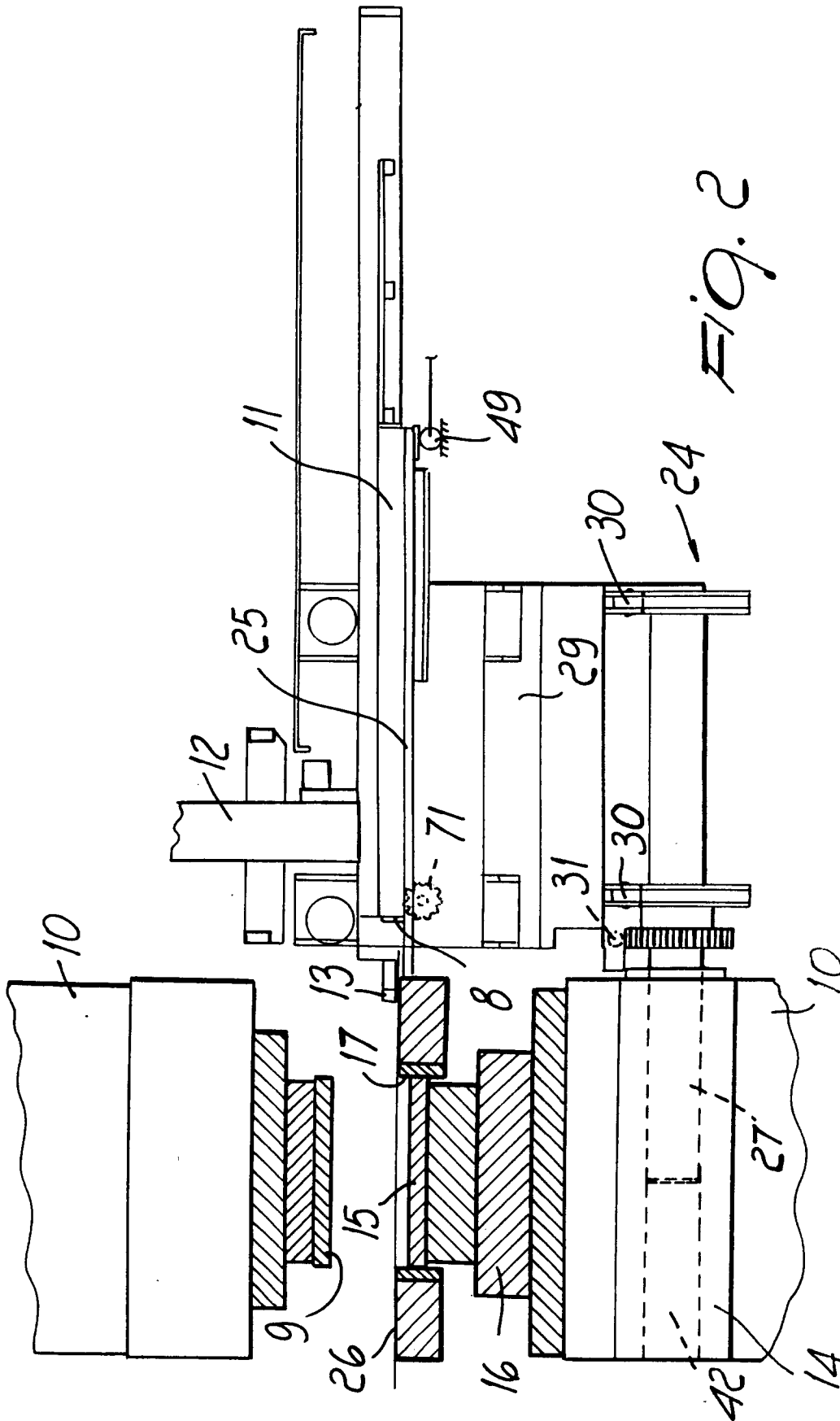
parallel to itself by means of gradual passages of flow through said flow divider element (34).

25. Device according to at least one of the preceding claims in which said moving body (16) supports a bottom (15) of said lower mold. 5
26. Device according to at least one of the preceding claims in which a flow divider element (34) comprises a separate hydraulic second piston (36, 36') for each one of said first pistons (18); said second pistons being mechanically connected to one another and each one being contained within a separate second cylinder (38, 38'); said second cylinders being mechanically connected to one another. 10 15
27. Device according to claim 26, in which the movement of said second pistons (36, 36') with respect to said second cylinders (38, 38') is actuated by an actuation cylinder (40, 40'). 20
28. Device according to claim 26 or 27 in which said second pistons (36, 36') comprise hollow cavities (58, 58'), so that said first cylinders (7) are supplied by means of said cavities (58, 58'). 25
29. Device according to at least one of the preceding claims comprising correction means (59) for setting a certain flow increase for the flow directed to one of said first cylinders (7) with respect to the flow directed to another first cylinder (7); so as to adjust the distribution of material charged in said lower mould; 30 35
30. Device according to claim 29 in which said correction means (59) comprise adjustable means (61) to adjust the filling of one of said second cylinders (38) with respect to the filling of another second cylinder (38). 40
31. Device according to claim 30 in which said adjustable means (61) comprise a movable element (62) which is movable between an engagement and a release position, so as to engage or release one or more pairs of a second piston (36') and a second cylinder (38'); said engagement position causing a change of the penetration of the engaged pair. 45 50
32. Device according to at least one of the preceding claims in which the ratio of the stroke of said second pistons (36, 36') with respect to the corresponding stroke of said first pistons (18, 18') is in the range of from 1.1 to 8, preferably of 1.5 to 5 and more preferably of 55

2.5 to 3.5.

33. Device according to at least one of the preceding claims, comprising a position detector (46) which is coupled with said moving body (16) so that the rotation of said position detector (46) is in linear proportion to the lifting and lowering of said moving body (16).
34. Device according to at least one of the preceding claims, comprising a position detector (46) which is mechanically connected between said second pistons (36, 36') and said second cylinders (38, 38'), so as to detect their relative movement.
35. Device according to at least one of the preceding claims, comprising a proportional valve (43) which is connected to a supply of said flow divider element (34).
36. Loading, unloading and extraction assembly, comprising loading means (11) for loading the material to be pressed and for unloading the pressed material, and a device according to at least one of the preceding claims.
37. Pressing apparatus, comprising: a main structure (10) for containing the pressing force; loading means (11) for loading the material to be pressed and for unloading the pressed material; and a device according to one or more of the preceding claims.
38. Every new characteristic or new combination of characteristics described or illustrated herein.





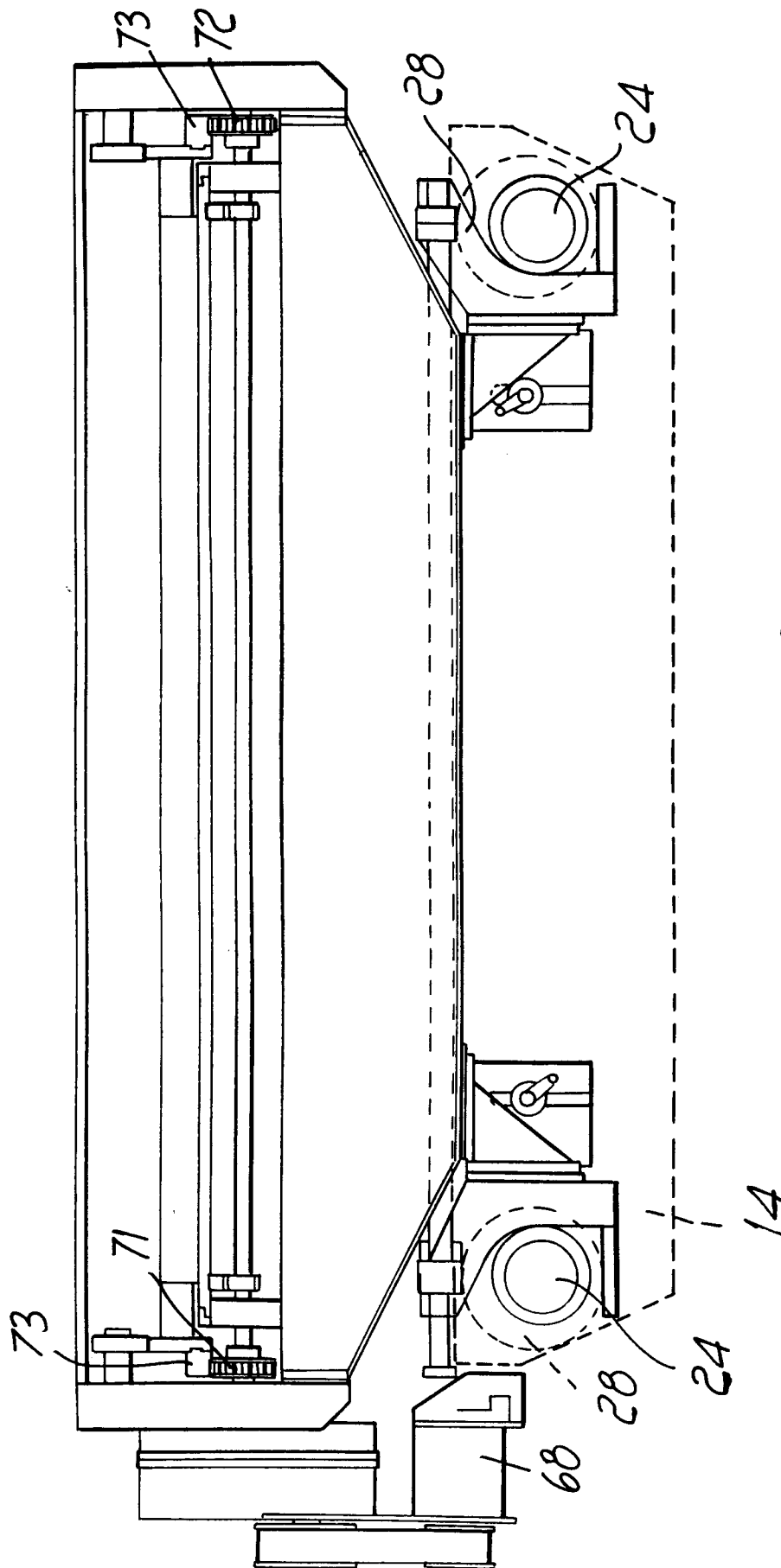


Fig. 3

