Single-blow shockwave generation device

The invention refers to a single-blow shockwave generation device and its implementation process.

Shockwave generation devices are notably used in urological surgery for disintegration of urinary duct stones. Prior Art includes two main types of shockwave generation devices: a first type concerning extra-corporeal shockwave generation devices, and a second type concerning percutaneous shockwave generation devices.

Disintegration devices of the first type use an electrical or piezo-electrical shockwave generator where the shockwave guide is comprised of a pocket containing a fluid, in contact with patient's body cooperating with an ellipsoidal reflector which, firstly, receives a shockwave diffused into a wide space, to focus it through a widely open cone whose apex is located inside the urinary stone to be disintegrated, so that the shockwave is of low amplitude when it crosses through living tissues in order to reduce lesions to said tissues to the minimum possible extent, and of maximum amplitude when concentrated at cone apex.

Disintegration devices of the second type use, for example, specialised endoscopes to match the nature of the intervention to be performed, depending on the size and position of the urinary stone to be evacuated.

When the stone is inside the kidney, the endoscope is introduced percutaneously directly into the kidney. When the stone is in the ureter, it is advisable to introduce the endoscope by natural paths via the bladder and up into the ureter.

The shockwave is transmitted by a waveguide which is a metallic rod of circular cross-section, of a diameter of ten to twenty tenths of a millimetre, tolerating elastic deformation. The shockwave guide features a first end where the shockwave is generated and a second end which is applied against the stone.

Disintegration devices of the first type do not allow high amplitude shockwave production, due to risk of lesions to living tissues crossed through. Consequently, stone disintegration requires multiple shocks which reduce the stone into small fragments which can be evacuated through the urinary ducts.

Prior Art second type disintegration devices, notably that described in European patent EP0317507, use low amplitude shockwave trains whose characteristic feature is also to break the stone to be disintegrated into multiple fragments which can be eliminated by suction, washing, or evacuation through natural paths.

Disintegrated stone fragment elimination through natural paths is very painful, which makes elimination by washing preferable whenever possible, further to an intervention by endoscopy. These stone elimination modes feature a drawback, in that there always remains uneliminated stone debris which can act as a basis for new stone formation. Gas sealing means between moving parts generally include O-rings, for which sealing is obtained by cooperation, either between the higher and lower sealing circles of the O-rings pressed between two flat surfaces or through cooperation between an inner lateral sealing circle and an outer lateral sealing circle of the O-ring pressed between a revolution bore and a revolution cylinder. These sealing means can be classified, for example, into three types of devices: a sealing device of the first type is comprised of an O-ring positioned in a groove machined in a bore and whose sealing is ensured by cooperation between the inner lateral sealing circle and the outer lateral sealing circle. A sealing device of the second type is comprised of an O-ring located in a groove machined in a revolution cylinder. A sealing device of the third type is comprised of an O-ring located in a circular groove undercut in a flat surface.

The object of this invention is a wave generation device, generating a high amplitude wave transmitted either percutaneously or naturally, via an endoscope, permitting controlled fragmentation of the urinary stone in order to break it into a small number of fragments of the necessary and sufficient size to allow their manual extraction by means of tweezers through the endoscope which was implemented in order to visualise, seize and extract them.

The following description of the invention will be better understood by reference to the appended illustrations, in which:

Figure 1A shows a vertical view of a device according to the preferred embodiment of the invention.

Figure 1B shows a schematic cross-section of the device according to the preferred embodiment of the invention, in operating condition.

Figure 1C shows a schematic cross-section of Figure 1A after initiation of an operating cycle.

Figure 1D shows a detail of Figure 1C at the time of shockwave generation.

Figures 2A to 2D each show a detail of Figure 1B, the whole of these figures corresponding to the entirety of Figure 1B.

The invention consists of a single-blow mechanical shockwave generation device (fig. 1A and fig. 1B) including striking means 2 which strike, at high speed, generation means which generate a shockwave 3 which is transferred through shockwave transfer means 4 to an object to be disintegrated, with which said means are put into direct or indirect contact, whereas striking means 2 are put into motion thanks to the expansion of a high pressure gas introduced, prior to each shockwave generation, into accumulation means 5 supplied with high pressure gas, from independent very high pressure gas stores 6, by means of gas expansion means 7 and of supply and sealing means; the gas stored in accumulation means 5 is released by manual operating of control means 8 which, firstly, renders gas-tight, through a sealing means, the intercommunication between independent stores 6 and expansion means 7, on the one hand, and with accumulation means 5, on the other, then secondly, establishes intercommunication between accumulation means 5 and striking means 2; return to initial condition of striking means 2 is ensured by the release of the accumulated energy, by mechanical means, during the shockwave production cycle. Return to initial condition of control means 8 is ensured by the action of high pressure gases which remained at expansion means 7 and by the corresponding supply means.

The gas used can be assimilated to a perfect gas at operating temperature, which is ca. twenty degree Celsius, in an accumulation chamber, making up an accumulation means, and at operating pressure which is a high pressure of ca. fifteen to thirty bar, and chemically compatible with its intended utilisation; for example, the gas can be air or nitrogen from a gas cylinder pressurized at a very high pressure of ca. two hundred bar, making up an independent gas store whose content can vary from half a litre to a few litres; it is connected to the single-blow mechanical shockwave generation device 1 via a flexible hose and through a pressure-relief valve, making up a pressure-relief means, for example, secured to

the gas cylinder and which reduces the very high pressure from two hundred bar to a high pressure of fifteen to thirty bar.

In a preferred embodiment of the invention, the gas used is, for example, carbonic gas commercially available in a single-use gas micro-container 9 (fig. 2A), making up a gas store of a content of ca. two centilitres at a pressure of ca. seventy bar, in which the carbonic gas is liquid, permitting storage of a significant carbonic gas volume in a small store; the description hereinafter can also apply to other gases whereas remaining within the scope of the invention.

The gas micro-container 9 is comprised of a cylindrical body 10 whose outer diameter is ca. eighteen millimetres, and whose rear end 11 is closed by a hemispherical wall and front end 12 is extended by a stepped section, then by a neck 13 comprising a lateral part, essentially cylindrical, closed by a closing capsule 14. The stepped section and neck 13 assembly features a length of ca. thirteen millimetres and the total length of the assembly is ca. eighty millimetres; gas micro-container 9 is directly integrated into single-blow mechanical shockwave generation device 1; it is housed into cradle 15 comprised of two half-cradles; front half-cradle 16 is comprised of a revolution-cylindrical bore, along first symmetry axis 17, of a diameter slightly larger than that of gas micro-container body 9, and features a bottom section fitted with calibrated receptacle 18 which accommodates neck 13 of gas micro-container 9. The lateral part is equipped with a first sealing device of first type 19, with respect to the lateral part of neck 13, whereas the central part of calibrated receptacle 18 features a perforation device 20 which pierces closing capsule 14; rear half-cradle 21 is comprised of holding device 22 for the hemispherical bottom section of gas micro-container 9, centred on the first symmetry axis 17, and capable of sliding, parallel to the latter, thanks to guide stir-up 24 and clamping device 23 which bears upon front half-cradle 16; the guide stir-up features wide lateral openings which allow sliding of front end 12 of gas micro-container 9 into calibrated receptacle 18 of front half-cradle 16, when the rear half-cradle 21 is retracted; it is only necessary to slide holding device 22 which comes against stop upon hemispherical bottom section 11, then to tighten by pushing gas micro-container 9 against perforation device 20 until closing capsule 14 is pierced; perforation

device 20 features a gas transfer means; perforation device 20 is, for example, of the type used on single-use butane gas cylinders, and a gas transfer means is a central cylindrical bore 25 allowing circulation of the gas from micro-container 9. Perforation device 20 is intercommunicated, through a first duct 26, with pressure-relief device 27, integrated with single-blow mechanical shock with generation device 1, making up a gas pressure-relief means 7 (fig. 1A and fig.1B); it is comprised, for example, of a first cylinder revolution chamber 28 (fig. 2A) in the rear section, from which first duct 26 is routed, and whose front section includes a first circular aperture edged by a second sealing device of the first type 29; the first circular aperture extends into a second duct 30 in which, to permit gas passage, valve shank 31 of a gas supply valve slides freely, said valve featuring a valve head 32 located in first chamber 28, and of a diameter significantly smaller than that of first chamber 28, whose lower section features an annular sealing surface which surrounds valve shank 31; the upper part of valve head 32 is pushed back by a first calibrated spring 33 in order to press the annular sealing surface of valve head 32 onto the second sealing device of the first type 29; the free end of valve shank 31 slides through a first bore 34, of a defined depth, acting as a guide, and machined in the head of a first cylindrical piston 35, whose bottom, of first bore 34, acts as a pusher, pushing back valve shank 31; the first piston 35 slides through second revolution-cylindrical chamber 36 which it divides into a first and a second space, of variable volume, sealed from each other by means of a first sealing device of the second type, solid with first piston 35; second duct 30 leads into the rear section 38 of second chamber 36, partly separating the first space of second chamber 36, through a second circular aperture allowing free sliding of valve shank 31 and intercommunicating second chamber 36 with the gas circuit; rear section 38 of second chamber 36 acts as a mechanical stop for the head of first piston 35; the second space, partly separated by front section 39 of second chamber 36, includes a piston stop 40, coaxial with that of second chamber 35, thereby limiting the stroke of first piston 35 and acting as a guide for a second calibrated spring 41.

The assembly comprised by first and second chambers 28 and 36, the gas supply valve, first piston 35, first and second calibrated springs 33 and 41, makes up a

gas pressure-relief means 7 (fig. 1A and fig. 1B) allowing a nominal pressure, defined with a good accuracy comprised between fifteen and thirty bar, to be established in the second gas duct 30 (fig. 2A) which surrounds valve shank 31.

A third duct 42 (fig. 2B), coming out from second duct 30, leads through the lateral wall to a third revolution-cylindrical chamber 43; said third chamber includes a rear section 44 in which a second piston 45 slides; this piston comprises a second gas sealing device of the second type 46, a rear section 47 and a front section 48; the bottom of rear section 44 in third chamber 43 features a circular aperture through which a first cylindrical pusher 49 passes freely, said pusher 49 being solid with rear section 47 of the second piston 45 and preferably oriented coaxially with the second revolution symmetry axis 50 of third chamber 43, which is actuated by manual operating means of control means 8 (fig. 1A and fig. 1B); said manual operating means for first pusher 49 preferably consist of pushing-in second piston 45 into third chamber 43; a manual means is, for example, comprised of a lever 51 hinged around a rotation axis 52, perpendicular and offset with respect to the revolution symmetry axis 50 of third chamber 43, and comprising a symmetry plane which contains revolution symmetry axis 50, and perpendicular to rotation axis 52; the motions of hinged lever 51 are limited by a stop 53; the front section 48 of second piston 45 features a revolution-cylindrical control rod 54, with a captive end on front side 48 of first piston 45 and a free end 55 freely passing through a fourth revolution cylindrical duct 56, and coaxial with the revolution symmetry axis 50 of third chamber 43; the fourth duct 56 leading from the bottom of the front section 57 of third chamber 43 is edged by a coaxial tapered revolution surface which acts as a guide for a third sealing device of the second type 58 which is neutralised, while allowing gas flow into the fourth duct 56; when second piston 45 is, for example, bearing against the bottom of the rear section 44 of third chamber 43, but which, when first pusher 49 is actuated by hinged lever 51, penetrates into fourth duct 56 and ensures gas sealing of the front section 57 of third chamber 43; control rod 54 extends and its free end 55 penetrates into a second bore 59, solid with the body of third chamber 43; the free end 55 of control rod 54, internal to second bore 59, includes a fourth sealing device of the second type 60; the stroke of second piston 45 is limited at rear

position by the mechanical stop of its rear section 47 on the bottom of the rear section 44 of third chamber 43, and is limited in front position by the mechanical stop of free end 55 of control rod 54 on the bottom 61 of second bore 59; in front position of second piston 45, the third sealing device of the second type 58 blanks off the fourth duct 56.

A fifth duct 62 (fig. 2B) includes an inlet aperture leading into the fourth duct 56, downstream of the position of the fourth sealing device of the second type 58, as well as an outlet aperture leading into the rear section of a fourth chamber 64, which is a high pressure gas accumulation means, preferably revolution-cylindrical on a symmetry axis which is merged with that of second stage 59; this fourth chamber includes a discharge valve 65 comprised of a valve body 66, tubular, revolution-cylindrical, coaxial with that of fourth chamber 64, and of a diameter of ca. one third of that of fourth chamber 64, as well as a valve head 67, featuring a flat rear section and a tapered revolution front section 122, of a diameter practically double of that of the valve body on which it connects, as well as a valve body base 68 which slides through a third bore 69, of a diameter the same order of magnitude as that valve body 66, featuring a third sealing device of the first type 70 which cooperates with valve body base 68, whereas third bore 69 is machined in the bottom above front section 71 of the fourth chamber 64, and leading into a fifth chamber 72 which is an expansion chamber; the rear face of valve head 67 is kept pressed against the bottom of rear section 63 of fourth chamber 64 by a first helical spring 73 which bears on the bottom of front section 71 of fourth chamber 64; the rear face of valve head 67, which is circular, features an annular sealing zone next to its edge, which cooperates with a first sealing device of the third type 74, solid with the bottom of rear section 63 of fourth chamber 64; the tubular internal space of valve 66 makes up a sixth duct 75 whose inlet aperture, at the rear face of valve head 67, is flared and essentially tapered; the central section of valve head 67 features a second cylindrical pusher 76, coaxial with second bore 59, comprising a free end 77 and a captive end connected to the rear side of valve head 67 by spacers 78, integrated in the flared aperture of sixth duct 75, and sliding in a fourth revolution bore 79 which interconnects the bottom of rear section 63 of fourth chamber 64 with the bottom

of second bore 59; a fourth sealing device of the first type 80, solid with fourth bore 79, ensures sealing between second bore 59 and sixth duct 75; second pusher 76 features a diameter significantly smaller than that of second bore 59, and a total length which is such that, when valve head 67 cooperates with the first sealing device of the third type 74 to isolate the sixth duct 75 from fourth chamber 64, the free end 77 of second pusher 76 leads into the bottom of second bore 59; when second piston 45 is in front position, the free end 55 of control rod 54 presses against the free end 77 of second pusher 76 and thereby pushes back valve head 67 and separates it from the bottom of rear section 63 of fourth chamber 64, by compressing the first helical spring 73, therefore releasing the opening of sixth duct 75; fourth chamber 64 is intercommunicated through sixth duct 75 with fifth chamber 72; firth chamber 72 is of revolution-cylindrical shape, with a rear section 81, in which sixth duct 75 opens, and a front section 82 from which a fifth revolution-cylindrical bore 83 begins; said fifth bore 83 is preferably coaxial with the symmetry axis of fifth chamber 72. Fifth chamber 72 features a diameter slightly larger than that of valve body base 68, and a significantly smaller length; fifth bore 83 (fig. 2C) leads into a sixth cylindrical rotation chamber 84, which is coaxial with fifth bore 83, of a diameter essentially equal to that of valve body base 68 and a length essentially double of that of fourth chamber 64; fifth bore 83 features a decompression zone 85 of a diameter slightly larger, leading into sixth chamber 84, and of a length essentially equal to one third of the length of fifth bore 83; sixth chamber 84 features a rear section 86 in which fifth bore 83 leads, and from which at least one seventh duct 87 begins, said duct 87 being open to the atmosphere either directly, or via a check valve 88; sixth chamber 84 comprises a front section 89 in whose bottom a seventh revolution-cylindrical chamber leads, coaxial with sixth chamber 90 (fig. 2C and fig. 2D), intercommunicated with sixth chamber 84 via a sixth revolution-cylindrical bore 91, of a diameter significantly larger than that of fifth bore 83, and smaller than that of sixth chamber 90; fifth bore 83 (fig. 2C) acts as guide and drive device for a striking hammer 92, making up a striking means; striking hammer 92 is comprised of hammer body 93, of low thickness, and of a diameter slightly smaller than that of the sixth chamber in which it is located, featuring a rear face directed towards the rear section 86 of

sixth chamber 84, and a front face, directed towards the front section 89 of sixth chamber 84; a third, revolution-cylindrical piston 94, coaxial with fifth bore 83 is solid with the rear face of hammer body 93, and slides through fifth bore 83; third piston 94 features a diameter slightly smaller than that of fifth bore 83, in order to obtain sufficient sealing to permit its propulsion by gases; a revolution-cylindrical striking head 95, coaxial with third piston 94, is secured to the front face of hammer body 93; striking head 95 is of a diameter significantly larger than that of third piston 94, and a length of ca. one quarter of the length of third piston 94; a second helical spring 96 which bears on front section 89 of sixth chamber 84, and on hammer body 93, presses the hammer body onto the bottom of rear section 86 of sixth chamber 84, therefore keeping third piston 94 depressed in fifth bore 83.

Seventh chamber 90 (fig. 2D) includes a rear section 97 intercommunicating with sixth chamber 84 through sixth bore 91, and a front section 98 whose bottom features a seventh revolution-cylindrical bore 99 coaxial with seventh chamber 90, and of a diameter essentially equal to fifth bore 83, thereby allowing seventh chamber 90 to intercommunicate with the rear section 100 of eighth chamber 101; seventh chamber 90 contains a shockwave generating interface device 102 comprised of a revolution-cylindrical interface device body 103, capable of sliding in seventh chamber 90, and comprising a fifth sealing device of the second type 104, which isolates front section 98 from rear section 97 of seventh chamber 90; the interface device body 103 features a rear face directed towards rear section 97 of seventh chamber 90, and a front face directed towards front section 98 of seventh chamber 90; the rear face of interface device body 103 comprises a strike anvil 105, of the same diameter as striking head 95, whose length, when cumulated with that of interface device body 103, is essentially equal to the length of striking head 95 cumulated with that of hammer body 93; the length of sixth bore 91 is determined so that the free end 106 of strike anvil 105 protrudes from the bottom of front section 89 of sixth chamber 84, and that distance 108 (fig. 2C) which separates free end 106 of strike anvil 105 from free end 107 of striking head 95, be of the same order of magnitude as the length of third piston 94 when reduced by a sufficient amount to ensure, in fifth bore 83, a residual guidance effect for third piston 94 at end of travel; the front face of interface device body

103 features a first shockwave transfer device 109, revolution-cylindrical and coaxial with seventh chamber 90, and of a diameter essentially equal to that of third piston 94 and a length essentially equal to that of strike anvil 105; the length of seventh bore 99 must be sufficient to ensure correct guidance of shockwave generation interface device 102; however, it must allow protrusion of first shockwave transfer device 109 in the bottom of rear section 106 of eighth chamber 101; a third helical spring 110 bearing, on the one hand, on the bottom of rear section 97 of seventh chamber 90 and, on the other, on the rear section of interface device body 103, presses the latter onto a first toroidal damping device 111 bearing, on the one hand, on the edge of front section of interface device body 103 and surrounding the first shockwave transfer device 109, and, on the other, on the bottom of front 98 of seventh chamber 90; the front section 112 of eighth chamber 101 comprises an eight bore 113, revolution cylindrical, coaxial with eighth chamber 101, and of a small diameter, of ca. one half of the diameter of third piston 94 which intercommunicates with the outside; eighth chamber 101 contains a shockwave guide head 115 of a second shockwave guide device 114, revolution-cylindrical, of a diameter slightly smaller than that of eighth chamber 101, whose rear face 116 is flat-shaped and whose front face 117 is essentially flat-shaped and comprises, squarely secured at its centre, a shockwave guide rod 118 which passes through eighth bore 113 and which acts as guide for shockwave guide head 115 of the second shockwave guide device 114; when the single-blow mechanical shockwave generation device 1 (fig. 1A and fig. 1B) is in operating condition, the rear section 116 of shockwave guide head 115 is in contact with the free end 119 of the first shockwave transfer device 109 and the front section 117 of the shockwave guide wave 115 comes into bearing contact with a second toroidal damping device 120 which surrounds the base of shockwave guide rod 118, and which rests, on the one hand, on the bottom of front section 112 of eighth chamber 101 and, on the other, on the front face 117 of shockwave guide head 115; the protrusion distance of first shockwave transfer device 109 and the length of eighth chamber 101 are determined, amongst others, to match these requirements; when free end 119 of first shockwave transfer device 109 bears on second shockwave transfer device 114 located in eighth chamber 101, interface

device 102 is slightly pushed towards rear section 97 of seventh chamber 90 and third helical spring 110 is slightly compressed; the length and diameter of shockwave guide rod 118 are generally dictated by the implementation conditions; the maximum efficiency of the shockwave is obtained when the weight of striking hammer 92 (fig. 2C) is equal to the weight of second shockwave transfer device 114; impedance adjustment can be performed, on the one hand, by acting on the diameter of shockwave guide head 115 (fig. 2D) and, on the other, by acting, to the maximum possible extent, on the length of third piston 94, while taking into account the operating requirements.

When the gas pressure in second duct 30 (fig. 1B) is less than nominal, the second calibrated spring 41 pushes back first piston 35 towards the rear section 38 of second chamber 36; valve shank 31 penetrates into first bore 34 of the head of first piston 35, until valve shank 31 abuts on bore bottom and, therefore, supply valve head 32 is pushed back, thereby compressing first calibrated spring 33 and releasing the gas flow from gas micro-container 9; when gas pressure in second duct 30 (fig. 1C) builds up again, first piston 35 is pushed in, thereby compressing second helical spring 41 until, whereas valve head 32 moves back to rest against the second sealing device of the first type 29 under the action of first calibrated spring 33, valve shank 31 will loose contact with the bottom of first bore 34; it should be noted that, as gas expansion is of adiabatic type, the expanded gas is colder than ambient temperature and its reheating causes an increase of its pressure, limited by an additional back motion of first piston 35, thereby compressing second calibrated spring 41 until it possibly comes into contact with piston stop 40. The gas injected into second duct 30 (fig. 1B and fig. 2A) flows into third duct 42 and, from there, into third chamber 43 and pushes back second piston 45 against stop on rear section 44 of third chamber 43, unless second piston is already in contact; the third sealing device of the second type 58 is then located inside third chamber 43, which allows gas flow into fourth duct 56, then into fifth duct 62, to reach fourth chamber 64 which then charges itself with high pressure gas, at a pressure, for example, comprised between fifteen and thirty bar; valve head 67 is now pressed onto the first sealing device of the third type 74, by first helical spring 73, on the one hand, and by high gas pressure, on the other; when

nominal pressure is reached in fourth chamber 64, the shockwave generation device is ready for operation. Shockwave generation begins by operating of hinged lever 51 (fig. 1C and fig. 2B) which pushes in first pusher 49, which, in turn, pushes back second piston 45 into third chamber 43, and control rod 54 moves in translation in third chamber 43 until the third sealing device of the second type 58 penetrates into fourth duct 56 and blanks off this duct so that fourth chamber 64 is isolated from the high pressure gas supply; then, as first pusher 49 continues to be pressed in, the free end 55 of control rod 54 penetrates into second bore 59 until it pushes in the free end 77 of second pusher 76, which, in turn, causes separation of valve head 67 from the first sealing device of the third type 74 and compression of the first helical spring 73; gas then flows into sixth duct 75 and into fifth chamber 72 and violently pushes back third piston 94 (fig. 1C and fig. 2C) which was initially in pressed-in position in fifth bore 83, through the action of second helical spring 96; striking hammer 92 is then driven at high speed into sixth chamber 84, thereby compressing second helical spring 96, and striking head 95 strikes strike anvil 105 (fig. 1D and fig. 2D) of interface device 102, which generates a shockwave which successively propagates itself in interface device body 103, then into first shockwave transfer device 109, and is then transmitted to rear section 116 of shockwave guide head 115 to further propagate itself in shockwave guide rod 118 and to the object to be disintegrated.

At end of travel of third piston 94 in fifth bore 83, decompression zone 85 is gradually uncovered and the gas begins to escape into rear section 86 of sixth chamber 84 and is evacuated to the outside through check valve 88 (if any) and through seventh duct 87: the pressure downstream of the third sealing device of the second type 58 becomes essentially equal to atmospheric pressure; second helical spring 96 then pushes back striking hammer 92 and third piston 94 into fifth bore 83; first helical spring 73 pushes back discharge valve 65 into the bottom of rear section 63 (fig. 1B and fig. 2B) of fourth chamber 64 and restores initial sealing by means of the first sealing device of the third type 74 when second pusher 76 can assume its initial position again by release of the action on hinged lever 51, which permits the displacement of second piston 45 towards the rear sections 44 of third chamber 43, under the effect of high gas pressure in third

chamber 43; the displacement motion of second piston 45 causes the motion of control rod 54 until the third sealing device of the second type 58 escapes from fourth duct 56, which allows gas supply to fourth chamber 64; the pressure drop in third chamber 43 initiates the pressure drop in third and second duct 43 and 30, which initiates the previously described gas supply cycle.

In an improved embodiment of the invention, third chamber 43 (fig. 2B) is interconnected to the outside by a second calibrated discharge valve 121, in order to avoid a possible overpressure associated with gas reheating after expansion, or a leakage at valve head 32 (fig. 1A) and at the first sealing device of the first type 19.

For reference purposes, the single-blow mechanical shockwave generation device 1 intended for disintegration of urinary stones possesses a fourth chamber 64 whose volume is preferably comprised between one and three cubic centimetres, as well as a striking hammer of a weight of ca. ten grams.

In an improved embodiment of the invention, and for applications other than that concerning urinary stone destruction, it is necessary to generate successive shockwave trains; for this purpose, between hinged lever 51 and first pusher 49, a successive shockwave triggering device is inserted; this triggering device is activated by operation of lever 51; this initiates the generation of several successive shockwaves, for example, in a number and at a pace predetermined by successive operations of first pusher 49, without requiring the releasing of hinged lever 51.

CLAIMS

1 – A single-blow mechanical shockwave generation device (1) using striking means (2), driven into motion by gasses, and striking, at high speed, generation means which generate a shockwave (3) which is transmitted, via shockwave transfer means (4), to an object to be disintegrated, with which said shockwave transfer means (4) are in direct or indirect contact, characterised in that striking means (2) are driven into motion thanks to the expansion of a high pressure gas introduced, prior to each shockwave production, into accumulation means (5) supplied in high pressure gas, from independent gas stores (6) under very high pressure, thanks to gas expansion means (7) and supply means (25, 26, 30, 42, 56, 62) and sealing means (19, 37, 46, 60, 70, 74, 80), the gas stored in accumulation means (5) being released by manual operation of control means (8) which, firstly, makes gas-tight, through a sealing means (58), the intercommunication between independent gas stores (6) and gas expansion means (7) on the one hand, and with accumulation means (5), on the other; then, secondly, establishes intercommunication between accumulation means (5) and striking means (2), whereas return to initial condition of the striking means (2) is ensured by the release of energy accumulated, by mechanical energy accumulation means (73, 96), during the shockwave production cycle, whereas return to initial condition of control means (8) is ensured by the high gas pressure which has remained at the expansion means (7) and the corresponding gas supply means (25, 26, 30, 42).

2 – A device as described in claim 1, characterised in that the gas used can be assimilated to a perfect gas at the operating temperature and pressure, and chemically comparable with its intended use, obtained from a pressurized gas cylinder which makes up an independent gas store, which is connected to the single-blow mechanical shockwave generation device (1) via a pipe and which, through a pressure-relief valve making up an expansion means, reduces the gas from very high pressure to operating pressure.

3 – A device as described in claims 1 and 2, characterised in that the gas used is stored in gas micro-container (9), making up an independent gas store (6), which is directly integrated to the single-blow mechanical shockwave generation device

(1), by means of a cradle (15), comprised of two half cradles, namely a front half-cradle (16) featuring a bottom section equipped with a calibrated receptacle (18) comprising a perforation device (20) and a rear half cradle (21) comprised of a holding device 22, sliding the perforation device (20), and intercommunicating via a first duct (26) with an integrated expansion device (27) making up a gas expansion means (7).

4 – A device as described in claims 1 and 3, characterised in that the integrated expansion device is comprised of a first chamber (28) into which the first duct (26) leads, and from which begins a second duct (30), in which a valve shank (31) slides freely, the head (32) of said valve shank being located in the first chamber (28), is pushed back by a first calibrated spring (33), whereas the free end of valve shank (31) is actuated by a first cylindrical piston (35) which acts as pusher for valve shank (31), and whereas first piston (35) slides in a second chamber (36) which acts as guide for a second calibrated spring (41) used as a pusher for piston (35).

5 – A device as described in claims 1 and 4, characterised in that a control means (8) is comprised of a third chamber (43) into which a third duct (42) from second duct (30) leads, and in which a second piston (45) slides, said second piston (45) including a first pusher (49) which allows said piston to be pushed in into third chamber (43), by means of a hinged lever (51), whereas second piston (45) featuring a control rod (54) with an open end (55), and freely passing through fourth duct (56) comprising a third sealing device of the second type (58) which blanks off the fourth duct (56), upstream of a fifth duct (62), leading into fourth duct (56) when second piston (45) is pushed in into third chamber (43), whereas the free end (55) which is engaged into second bore (59) then comes to abut onto the bottom (61) of said bore.

6 – A device as described in claims 1 and 5, characterised in that an accumulation means (5) is comprised of a fourth chamber (64) into which leads the fifth duct (62) including a discharge valve (65) comprised of a tubular valve body (66), making up a sixth duct (75), as well as a hollow valve head (7) and a valve body base (68) which slides in a third bore (69), leading into a fifth chamber (72), whereas valve head (67) maintains sealing thanks to a first helical spring (73)

which makes up a mechanical energy accumulation means, and valve head (67) comprising a second pusher (76) with a free end (77) which slides in a fourth bore (79) and leads into the bottom section of second bore (59), the free end (77) of second pusher (76) being pushed back by the free end (55) of control rod (54) when abutting onto the bottom (61), and the second pusher (76) pushing back the valve head (67) by compressing the first helical spring (73) and releasing the opening of sixth duct (75), thereby intercommunicating fourth chamber (64) with fifth chamber (72).

7 – A device as described claims 1 and 6, characterised in that a striking means is comprised of fifth chamber (72) into which the sixth duct (75) leads, and which intercommunicates with a fifth bore (83) leading into a sixth chamber (84) comprising a decompression zone (85), leading into sixth chamber (84) from which begins at least one seventh duct (87) opening to the atmosphere, either directly or via a check valve (88), whereas the fifth bore (83) acts as guide and drive device for a striking hammer (92) comprised of a hammer body (93), a third piston (94) which slides in fifth bore (83), a striking head (95) with a free end (107), a second helical spring (96) making up a mechanical energy accumulation means, pressing on hammer body (93) in order to maintain third piston (94) pressed in in fifth bore (83).

8 – A device as described in claims 1 and 7, characterised in that a shockwave generation means (3) is comprised of a shockwave generation interface device (102) including an interface device body (103) which slides in a seventh chamber (90) intercommunicated with sixth chamber (84) via a sixth bore (91), whereas the interface device body (103) features a strike anvil (105) passing through sixth bore (91), with a free end (106) located in sixth chamber (84), and a first shockwave transfer device (109) with a free end (119) passing through a seventh bore (99) which interconnects the seventh chamber to an eighth chamber (101), inside which is located the free end (119) of the first shockwave transfer device (109), which is kept in contact with the rear face (116) of a shockwave guide head (115) by a third helical spring (110).

9 – A device as described in claims 1 and 8, characterised in that a shockwave transfer means (4) is comprised of a second shockwave guide device (114),

comprised of the shockwave guide head (115) located in eighth chamber (101), extended by a shockwave guide rod (118) which passes through an eighth bore (113) acting as guide for the shockwave guide head (115) and opening to the outside.

10 – A device as described in claims 1, 4 to 6, characterised in that the gas injected under high pressure through second duct (30) flows into third duct (42), then into third chamber (43) and, pushing back the second piston (45) if it is depressed in the third chamber (43), it releases the third sealing device of the second type (58) from the fourth duct (56), which allows the gas to flow into the fifth duct (62) in order to charge the fourth chamber (64) with high pressure gas, whereas valve head (67) maintains sealing thanks to the pressure exercised by the first helical spring (73), on the one hand, and by the high gas pressure, on the other, until nominal pressure is reached in the fourth chamber (64), the single-blow mechanical shockwave generation device (1) being then ready for operation.

11 – A device as described in claims 1, 5 to 9, characterised in that the generation of a shockwave begins by the operation of hinged lever (51) which presses in the first pusher (49), which pushes back the second piston (45) into the third chamber (43) and the control rod (54) moves in translation in the third chamber (43) until the third sealing device of the second type (58) penetrates into the fourth duct (56) and blanks this duct off, then as the first pusher (49) continues to be pressed in, the free end (55) of control rod (54) penetrates into second bore (59) until pushing in the free end (77) of second pusher (76), thereby causing separation of valve head (67) and compression of first helical spring (73), the gas then flowing into sixth duct (75) to penetrate into fifth chamber (72), thereby violently pushing back the third piston (94), compressing the second helical spring (96), and the striking head (95) then strikes the strike anvil (105) of the interface device (102), which generates a shockwave which successively propagates itself into the interface device body (103), then through the first shockwave transfer device (109), and is transmitted to the shockwave guide head (115) to finally propagate itself through the shockwave guide rod (118) until hitting the object to be disintegrated.

12 – A device as described in claims 7, 10 and 11, characterised in that, at end of travel of the third piston (94), the decompression zone (85) is gradually uncovered

and the gas begins to escape into sixth chamber (84) and is evacuated to the outside by seventh duct (87), whereas the pressure downstream of the third sealing device of the second type (58), blanking off the fourth duct (56), becomes essentially equal to atmospheric pressure and the second helical spring (96) can then push back striking hammer (92), whose third piston (94) penetrates into fifth bore (83).

13 – A device as described in claims 10 to 12, characterised in that as soon as the hinged lever (51) is released, the second piston (45) is pushed back by the high gas pressure residing in the third chamber (43), the second pusher (76) being released, and the discharge valve (65) is released and pushed back by the first helical spring (73) in order to restore initial sealing, the fourth duct (56) being then released, and the high pressure gas can then charge the fourth chamber (64) again, in preparation for the production of another shockwave.

14 – A device as described in one or more of the claims 1 to 13, characterised in that the gas used is carbonic gas stored under very high pressure, at ca. seventy bar, the high pressure in the fourth chamber (64) being to the order of fifteen to thirty bar, the volume of the fourth chamber (64) being to the order of one to three cubic centimetres, and the weight of the striking hammer (92) is to the order of ten grams.