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(71) Applicant: **OFFICINE MECCANICHE FERRERO S.p.A.**
Via Privata Trento n. 4
I-17047 Vado Ligure (Sv)(IT)

(72) Inventor: **Ferrero, Francesco**
via Privata Trento N. 4
I-17047 Vado Ligure (SV)(IT)

(74) Representative: **Ferrarotti, Giovanni**
Studio Consulenza Tecnica Dr. Ing. Giovanni Ferrarotti Via Alla Porta Degli Archi 1/7
I-16121 Genova(IT)

(54) **Tubular rotary furnace with combustion air blown-in radially through the lining.**

(57) Tubular rotary furnace specifically designed for equiflow or counterflow combustion or solid, semi-solid and other waste consisting of a cylindrical shell (1) rotating around a slightly inclined (2° - 3°) longitudinal (X-X) axis with respect to the horizontal plane. The furnace lining is consisting of hollow quoin-shaped refractory solid (2) or hollow (3) bricks, of which the latter are creating anular chambers (14, 15, 16) which by means of holes (11) drilled in the shell (1) and valves (12) are communicating with external combustion air inlet pipes; These hollow bricks (3) feature strongly inclined channels (17, 18) through which the air coming from the anular chamber (14,15,16) enters the furnace above and below the fuel bed . A special distributor (20a, 20b) at the head of the furnace permits to blow a proper amount of primary air into the various furnaces zones (S1, S2, S3), only through the refractory bricks covered by the material to be incinerated.

An additional dosis of air may be let into the refractory bricks (3) lining the furnace zone in which combustion gases are collected, thus allowing for proper secondary combustion and total dissociation of the waste gases.

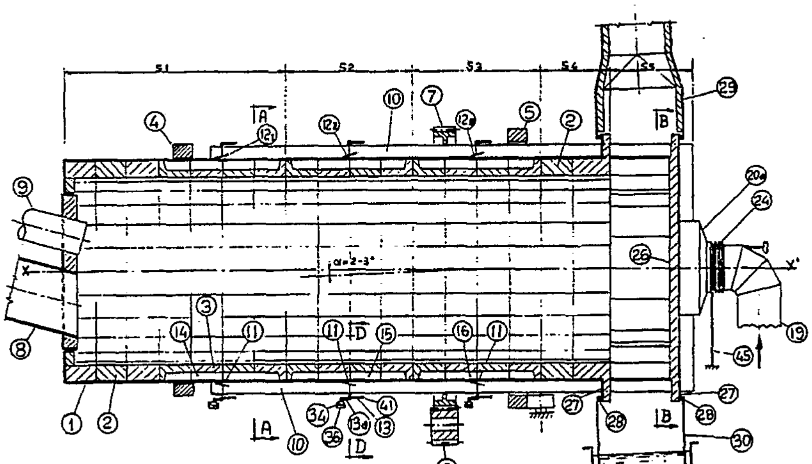

Fig 1

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Rotary furnaces have been extensively used for many years for the combustion and incineration of solid and semi-solid industrial waste and other refuse.

These furnaces can be built for counterflow combustion in which the waste advances in opposite direction to the combustion gas, or in equiflow when the waste advances in the gas flow direction.

Both cases are characterized by the fact that combustion is not achieved in the whole mass of waste located inside the furnace shell but only in the surface area, i.e. in the interface between waste and gases (combustion air and gaseous combustion products).

During rotation, this surface is continuously renewed while the combustible material, heated at the base of the fuel bed, is continuously and slowly collapsing due to the rotary movement of the furnace and is thus slowly disgregating and distilling, usually in reducing conditions. The gas rises to the surface of the waste mass and only then will the gases come in touch with oxygen to complete dissociation and combustion

The parameters disciplining the combustion capacity and efficiency of a furnace, all other conditions such as net heat value and ash content in the fuel being equal, are the furnace diameter (or diameters if the furnace has more than one chamber), length and inclination of the rotation axis, the height of the fuel bed and, in particular, the continuous or intermittent rotation speed, the amount and temperature of the combustion air, the flue gas rate.

On this subject it should be observed that the operation of furnaces characterized by counterflow combustion is usually more difficult.

The waste usually burnt in these furnaces is rather moist waste and has a low heat value is usually burnt. Thus, as combustion progresses, the waste is dried by increasingly hotter gases.

As a rule, combustion must be controlled so that combustion of the the gases is completed when they reach the furnace throat. This is not alwasy easy to achieve.

As the waste advances through the furnace, it is first dessiccated and then distilled; the volatile matter thus released, is not always perfectly burnt since the gases they encounter are already partially burnt. During these combustion stages, the waste mass will be subject either to slightly reducing or to stoichiometric equilibrium conditions, with separation of much small charcoal. The latter will burn causing a strong temperature rise as it approaches the discharging end of the furnace where the gas has a higher oxygen contentg. To ensure complete gas combustion in this portion of the furnace, much excess air will be necessary which may cause temperature peaks and vitreous cinder or slag formation, sprue and damage to the refractory furnace lining.

This is the reason why rotary furnaces with counterflow combustion require the installation of after-burning chambers where gas combustion is completed by the injection of properly preheated secondary air and in high turbulence conditions, to ensure complete oxidation and dissociation of these gases.

On the other hand, rotary furnaces with equiflow combustion have other drawbacks.

First of all, the furnace may have lighting-up problems especially if the material to be burnt has no average constant composition or if there are strong variations in its moisture content; it may also be difficult to maintain combustion in the initial furnace sections. Often, radiation is insufficient for fast ignition, so that an auxiliary gas or mineral oil burner has to be used.

These furnaces are therefore mostly used for burning products having a high heat value, such as for instance plastic shreds, residues from solid urban waste recycling processes, rubber processing waste etc.

Thermal capacity being equal, these furnaces are shorter and have a greater diameter than counterflow furnaces, but they too may cause several operating problems, especially if the products to be burnt are strongly heterogeneous or have a variable moisture content.

Broadly speaking, they are more difficult to operate than fixed hearth furnaces, in which primary combustion air can be regulated within large limits by blowing the air in controlled quantities below the grating, while secondary air is let into the combustion chamber through auxiliary nozzles or along the subsequent gas path.

The furnace, subject matter of this invention intends to provide the advantages of both rotary and fixed hearth furnaces, while eliminating the defects of the former and enhancing the merits of the latter.

In particular, this invention will permit tto blow primary air in prefixed and independent adjustable quantities below the mass of material to be incinerated, in various sections along the longitudinal furnace axis while a controlled amount of secondary air is directly let into the combustion chamber, in the free space above the fuel bed, thus obtaining an optimum combustion which is carefully controlled during all process stages.

It should be stressed that the differentiation between equiflow and countercurrent flow operation of the furnace type subject matter of this invention loses much of its original importance because combustion no longer occurs in the interface between waste and gases only, but also inside the mass since most of the combustion air is directly blown in below the fuel bed, like in hearth (or grid) furnaces where there is virtually no such difference between equiflow and counterflow operation, or if there is any such difference, it will be much less obvious than in conventional rotary furnaces

However, rotary furnaces implemented according to the construction features of this invention may be designed, at the engineers choice, for either equiflow or counterflow operation.

For exemplification purposes, the invention in question is illustrated in the following drawings, in which:

Fig. 1 shows a longitudinal vertical section of the furnace;

Fig. 2 shows a cross section of the furnace according to A-A in Fig.1

Fig. 3 shows a partial internal view of the furnace according to A - A of Fig. 2;

Fig.4 shows a cross section of the furnace according to B-B of Fig. 1;

Fig.5 shows a vertical lengthwise section of the combustion air distributor;

Fig. 6 shows a cross section of the distributor according to C - C of Fig.5.;

Fig.7 shows a magnified cross section of the furnace fitted with valves regulating the combustion air flow at the furnace inlet, according D - D of Fig.1;

Fig.8 shows a top view of the valve control system regulating the combustion air flow rate;

Fig.9 shows a complete cross section of the furnace according to D - D in Fig.1;

Fig. 10 shows the diagram indicating the combustion air flow rate in the various peripheral zones according to section A - A in Fig. 1.

With reference to these figures, the furnace is essentially consisting of a cylindrical shell 1 lined with solid 2 and hollow and/or perforated quoin-shaped bricks 3, rotating around its $x-x'$ axis, which is slightly inclined by 2° - 3° with respect to the horizontal plane, supported by rolling tracks 4 and 5, rotation of the furnace being ensured by a pinion 6 and ring gear 7.

The waste, or more generally speaking, the material to be incinerated is let, through the duct 8, into the hollow space located at one end of the tubular furnace, while the ignition burner is introduced through the duct 9 for the supply of additional secondary air, if required.

The combustion air is blown in through a longitudinal piping system 10, mounted along the peripheral shell plating 1; these pipes are placed in parallel and at equal distance, having their axis parallel to the generating line of the shell, as shown in fig. 1 and 2.

The air enters through holes 11 drilled in the shell 1, and is then conveyed by valves 12 controlled by the device 13 described in detail hereinafter, into distribution chambers 14, 15, 16, obtained in the refractory lining brick 3 of the furnace.

These chambers 14, 15, 16 supply air to the ducts 17 provided with special orifices through which the air enters the furnace below the bed containing the material to be incinerated.

The particular inclination of these ducts 17 (fig.2)having their $t - t'$ axis tangential to a circumference with a slightly smaller inside diameter D than the refractory furnace lining, will prevent ash or waste particles from entering the ducts and from hindering the free combustion air flow.

The air inlet pipes 10, already mentioned above, are rotating together with the cylindrical furnace shell 1; they are extending outside the furnace discharge head thus forming a kind of spider illustrated in fig.6 by C - C.

The primary and secondary combustion air distributor (air scoop) is located in the center of this spider

This air distributor, shown in fig. 5, is essentially consisting of two parts, one of which 20a is external and is rotating with the furnace to which it is connected, whereas the other 20b is fixed and internal, connected by the pipe 19 and the flexible coupling 24 to the main fan of the combustion air previously preheated by a heat-exchanger located outside the furnace and not included in this invention.

The external part 20a, is consisting of a trapezoidal bustle main, divided by means of seven partitions 21 into a series of adjacent chambers C1 .....C24; each externally facing the orifice 10a of one of the air inlet pipes as identified, for completeness sake, by the Roman numerals I thru XXIV.

The inner cylindrical surface of the bustle main consisting of a set of chambers C, is open and is surrounding the fixed inner part 20b of the distributor, essentially formed by a blank cylindrical stub, coaxial to the furnace, anchored to the external fixed furnace structure by means of the anchoring stirrup 45 and supported by the external rotating mechanism 20a with the aid of two supports fitted with bearings 22, and 23 (fig. 5). A ring shaped sliding or labyrinth seal 43 is placed between the fixed internal part 20b and the rotating external mechanism 20a.

The cylindrical surface of the internal mechanism of the rotating distributor 20b has two openings or windows F1 and F2 by which the fixed device of the distributor is communicating with a certain number of chambers C of the rotary distributor and hence with a given and well defined number of inlet pipes 10.

In particular, as shown in the furnace position exemplified in fig. 5 and 6, the window F1 provides for air to be supplied to the pipes 10 ranging from II to X which supply primary combustion air below the waste beds or other combustible material in the furnace, by means of the regulating valves and the distribution chambers 14, 15 and 16. (fig.2)

In turn and in a similar way, window F2 will provide for connecting the air feed to another range of pipes 10, i.e. the pipes number XIV - XV - XVI then feeding the distribution chambers blowing secondary air into the empty furnace zone where combustion and dissociation of the gases is completed.

In a subsequent stage not illustrated in these figures, the furnaces will slowly rotate by an angle, here assumed to be 1/24 of 360°. Since there are twenty-four ducts, duct I will be activated whereas duct X will be desactivated. Likewise, duct XIII will be activated while duct XVI will be desactivated, and so forth as long as the furnace is in operation.

The primary and secondary air flow rate shall both be regulated to ensure correct combustion control in all furnace sections along its longitudinal axis.

For simplification purposes, we have divided the furnace here described into five sections or zones illustrated by S1, S2, S3, S4 and S5 in the figures.

In the practice, there may be a greater number of zones based upon the capacity and waste typology, according to combustion air requirements in the related furnace section.

In the first zone S1, the waste charged into the furnace through the duct 8, will be heated by radiation and by contact with the incandescent refractory lining, until it is dry and is set afflame.

In steady state furnace conditions, the waste will usually self-ignite without need for the auxiliary burner 9, which is activated only to light up the furnace.

The combustion air required in this first zone S1 is relatively modest since the combustion velocity is still limited and will only increase with the temperature.

Then follows zone S2 which we may call the "distillation zone" because of its prevailing reaction.

In this zone, the combustible waste fractions dissociate by thermal cracking. The volatile constituents are released together with combustible gases and production of highly reactive porous carbon. Combustion is very intense and the flame may be longer or shorter according to the rather high combustion air rate required in this zone.

The carbonacious residues are burnt in zone S3, which we may call the "oxidation zone". In the initial part of this zone the temperature reaches its maximum values both in the residue waste mass and in the gases; the air flow rate at the foot shall be adjusted so as to prevent the temperature from rising beyond softening and ash sintering values since the latter shall remain loose and non-coherent. Subsequently, the temperature slowly drops as the combustible carbonacious fractions are depleted. Complete incineration is obtained in S4 called "depletion zone", where no combustion air is blown below the bed, now only consisting of still incandescent inert ashes which will disgregate during the slow rotation of the furnace and may oxidize together with any, not yet completely burnt, carbonacious residues in the interface between solid and gaseous products.

At the end of the zone S4, the gases leave the furnace and enter an after-burning or preheating chamber (which how ever is not indispensable for this furnace type) to be conveyed to suitable steam generators or heat-exchangers where the sensible heat is used to preheat the combustion air. Finaly, the gases reach the neutralizing reactor and flying ash precipitating filters before they are released into the atmosphere.

When reaching the end of S4, the still incandescent residue ashes fall into the quenching basin 25. Fig. 1 clearly shows the discharging zone S5 where the gases as well as any solid residues are discharged. S5 is delimited by the head 26 forming the rear wall of the primary combustion chamber.

To prevent "false air" from entering the furnace, two metal rings 27 are welded onto the furnace shell and are thus rotating together with the furnace. Sliding or labyrinth seals 28 are fitted between these rings 27 and the fixed structures of the flue duct 28 and the ash discharge hopper 30.

Easy discharge of the ashes and any other residual combustion matter is ensured by reducing the distance between the pipes 10 in the zone S5 where these pipes are grouped together and protected by refractory metal quoins 31, as illustrated in fig.4, section B - B.

This is possible because no air was blown in the previous furnace section S4 so that the pipes 10 can be deviated and grouped, for instance, four at a time so as to obtain sufficiently wide passages through which the ashes and other, even bulky, material can be dropped into the water filled quenching basin 25 providing for a perfect hydraulic seal. From this basin, the ashes are removed by a chain scraper and conveyed to a dump.

The above description clearly shows that the primary and secondary air flow has to be regulated and differentiated in the various furnace zones.

This control is provided by a special air regulation system illustrated in fig. 7 and 8. As already explained before, the previously preheated combustion air supplied by a blower located outside the furnace, enters the hollow furnace space through holes drilled in the shell.

From these holes, the air enters the pipes 10 flowing into the distribution chambers 14, 15, 16 (fig.1), to be injected into the furnace through the openings 17 and 18 in the refractory bricks 3.

The combustion air regulation and delivery system illustrated in the figures 7 and 8 is only one of many possible solutions. In this approach, the holes drilled in the shell are also housing the control and delivery valves 12. 12 I refers to the 24 valves letting the air into the first row of distribution chambers 14, while 12 II refers to the group of 24 valves letting the air into the second row of distribution chambers 15 and 12 III indicates the group of twenty-four valves letting the air into the row of distribution chambers 16.

Each valve is consisting of a disk 12 rotating around its z - z′ axis by means of a pin 32, supported with some slack by a bushing 33 secured to the pipes 10. Rotation is caused by the handle 13 which is integral with the pin 32 and the disk 12 . In the furnace illustrated in the enclosed figures, the valve assembly of each distribution chamber 14, 15 or 16 has a double V shaped handle, i.e. forming an auxiliary handle 13a (fig.8) supporting, together with the pin 35, an idler 34 having a diameter K. It should be noted that only one of the twenty-four valves 12 installed in each furnace section S1, S2 or S3 needs to be fitted with the arm 13a and the idler 34.

This idler 34, when rotating together with the furnace, will engage with a wedge shaped guide 36, supported by the pin 37 which in turn engages with the support 38 anchored to the fixed furnace structure. This guide 36 is consisting of two flat and integral components p and p′, converging in the direction of the idler motion until they reach the outlet K′ having a slightly larger diameter than K of the idler 34.

The joint 39 of this guide is connected to the stem of a hydraulic cylinder 40 capable of changing the angular position of the guide 36 within a given angle . Each position of the hydraulic cylinder is associated with a position of the guide 36 and hence, an univocally determined position of the arm 13a of the valve seat 12 regulating the air flow rate in the furnace from an all open to an all closed position.

In the solution shown in fig. 7, corresponding to the D -D section of the furnace zone S2, all valves 12 are interconnected by a set of articulated tie rods 41, so that all twenty-four valves 12 in the furnace zone S2 can be adjusted at the same time by one single servo-controlled hydraulic cylinder 40, one single idler 34 and in one single operation.

Two more servo controls of the same design will permit autonomous regulation of the twenty-four valves 12 in the furnace zones S1 and of those installed in the zone S3. Additional adjustment is provided for secondary air at rotary distributor level. Fig. 5 shows how the secondary air flow rate entering the furnace may be adjusted.

As illustrated in this figure, the window F2 in the fixed internal mechanism 20b of the rotating distributor lets the combustion air, supplied through the duct 19, enter the chambers C14, C15 and C16 of the external rotating distributor component 20a; these chambers are connected to the related pipes 10 through which secondary combustion air enters the furnace section holding no waste but only gases.

The air flow rate can be easily adjusted by acting on the gate valve 42 actuated from outside by a stem and grip 43 or by means of a suitable push-pull cylinder so as to shutter the port of the delivery window F2 as necessary.

The regulation system for the primary and secondary combustion air here described has the advantage of being very simple.

However, in some cases a completely independent adjustment of the valve opening 12 (fig. 7) in the primary air delivery zone may be advisable, by opening this valve 12 for secondary air supply during the rotation of the furnace.

To obtain this independent adjustment, the valves 12 have to be separated by eliminating the tie rods 41 and by fitting each lever 13 with the auxiliary arm 13a and idler 34. while providing them with friction washers fitted between the pin 32 and bushing 33 to prevent accidental spontaneous valve rotation, while two guides 36, 36′, anchored to the fixed furnace structures are each controlled by a suitable hydraulic cylinder so that the first guide 36 will open the valve 12 just enough to supply sufficient primary combustion air, while the second guide 36′ will modify the valve opening according to the actual need for secondary air.

The configuration of the above described distribution system is schematically illustrated in fig. 9 and 10.

Thus, during each rotation of the furnace, each valve in each furnace zone S1, S2 and S3 is adjusted twice: once to control the primary air flow rate below the fuel bed and once to adjust the secondary air flow rate in the upper furnace zone occupied by air and gaseous combustion products.

The system regulating the primary and the secondary combustion air flow may be further sophisticated to achieve independent regulation of each valve in any part of the furnace. For instance, it may be convenient to adjust the opening of each valve based upon the height of the fuel bed for which the valve has to supply combustion air through the related distribution duct.

This can be easily achieved by providing each valve set 12 with as many guides 36, rotating on their pins 36, anchored to the fixed furnace structures 44, as there are desired control and delivery points for each valve during rotation of the furnace.

In this way it will be possible to achieve, for instance, the distribution diagram for primary P and secondary air S in the first furnace zone S1 corresponding to section A -A in fig.2 and plotted for illustrating purpose in fig.11, showing in abscissa the delivery points which in our case are twenty-four, whereas the flow rate or amount of opening of the related valve 12 is reported on the ordinates.

In the exemplified case, eleven primary air and five secondary air regulation points will be required.

No detailed description will be provided here of the supporting structures of the furnace and of the mechanical, hydraulical, pneumatic and other equipment required for rotation and operation of the furnace, since they are not essential for function characterization of this invention.

Claims

1. Tubular rotary furnace, specifically designed for burning fuel of any kind and nature, internally lined with refractory quoin-shaped bricks (2,3), rotating around an X-X axis having a slight inclination with respect to the horizontal plane, consisting: of a charging duct (8) through which the material to be incinerated is introduced, a burner housed in a suitable duct (9) to light up the furnace , which burner (9) may also be used, if necessary, for the supply of secondary air; sealed equipment (29) for evacuation of the waste gases and equipment or seals to discharge the ashes into quenching basins (30), **characterized** by the fact that

- the refractory bricks lining the furnace are partly solid (2) and partly hollow (3), so that the latter are forming anular distribution chambers (14) (15) (16) for the combustion air,
- the holes (11) through which the combustion air flows can be shuttered by means of valves (12) provided with automatic control devices;
- longitudinal and parallel channels or ducts (10) external to the shell (1) are letting air into a corresponding number of holes and valves located on each ring, converging towards the furnace head opposite to the end at which the waste to be incinerated is charged into the furnace, thus forming a "spider" (from C1 to C24);
- a distributor for both primary and secondary combustion air is located in the center of the spider (C1-C24) forming two devices, the innermost one of which is fixed (20b) and connected by a flexible coupling (24) to the air inlet pipe (19), whereas the outermost device (20b), coaxial to the former, is rotating with the furnace , forming a toroidal ring having a trapezoid section, divided by partitions (21) into chambers C connected respectively to the spider and with various inlet pipes or channels (10) for the combustion air;

the internal cylindrical surface of the external toroidal ring or "bustle mains" (20a) forming the spider chambers (C) is open, whereas the external surface of the inner device (20b) has two openings, one of which (F1) permits to blow primary combustion air into the furnace zone below the burning material, whereas the other opening (F2) permits to blow secondary air in the gas filled zone above the material;

- the opening (F2) through which secondary combustion air is supplied is fitted with a shutter (42) for air flow regulation;
- the quoin-shaped hollow bricks (3) have slanting channels (17) and orifices (18) connecting the distribution channels (14, 15, 16) to the internal furnace space,

so as to improve combustion in the rotary furnace by blowing primary combustion air below the fuel mass in the various furnace sections (S1, S2, S3) and secondary combustion air into the gas filled space above the burning waste, while operating the furnace, without distinction either in equiflow or counterflow conditions.

2) Tubular rotary furnace as described in claim 1, **characterized** by the fact that the automatic control system of the valves (12) and holes (11) through which combustion air is blown from the external channels (10) into the distribution chambers (14, 14, 16), is consisting, for exemplification purposes of:

- a rotary disk valve (12) for each hole (11)
- a pivot pin (32) connected to each valve (12) rotating in a support (33) secured onto the rotary furnace;
- a handle (13), one end of which is fastened onto the pivot pin (32), so that valve opening can be controlled at will from partially to totally open or closed.

3) Furnace as described in claim 2, **characterzed** by the fact. that one of the handles (13) operating the valves (12) coinciding with the distribution chambers (14, 15, 16) is double V-shaped, with a further extension (13a) bearing at its free end an idler (34), which during the rotation of the furnace will engage a wedge-shape guide (36) supported by a pin (37) anchored onto the fixed furnace structure and provided with two integral rims (p,p′) converging in the direction of the idler motion (34), leaving a outlet port having a greater diameter than the idler (34) and oscillating on the above pin with an angle ( ) by means of a hydraulic piston (40), whereas all handles (13) are interconnected by rods (41) so that it is possible to actuate all valves (12) of a distribution chamber (14, 15, 16) at

the same time by means of the double handle (13, 13a) of only one valve, the rods (41) and the simple handles (13).

4) Furnace as described in claim 2, **characterized** by a differentiated opening of the the primary and secondary combustion air valves to let the air into the combustion chambers (14, 15, 16), while two wedge-shaped guides (36, 36′) are provided, the lower guide for primary air and the upper guide for secondary air supply, all valves being provided with a double handle (13, 13a) and friction washers fitted between the pin (32) and the support (33) so as to prevent spontaneous rotation of the valves (12), so that these valves can be adjusted in sequence by differentiated opening and supply of the required primary and secondary air flow rate.

5) Furnace as described in claim 2, **characterized** by the fact that there will be as many wedge-shaped guides (36) as there are valves (12) fitted with a double handle (13, 13a) to permit individual flow rate control for each valve;

6) Furnace as described in claim 1, **characterized** by the fact that the channels (17) in the hollow refractory quoins (3) have an inclination opposite to the direction of rotation of the furnace, while their t--t′ axis is tangent to a circumference having a slightly smaller diameter (d) than the concentric I/D (D) of the refractory.

7) Furnace, as described in claim 1, **characterized** by the fact that the internal fixed element (20b) of the distributor is anchored by a stirrup (45) to the fixed furnace structures and is supported by the external rotating element (20a) resting on bearings (22, 23), while an anular seal (44) is fitted between the fixed (20b) and rotating element (20a).

8) Furnace as described in claim 1, **characterized** by the fact that the channels (10) at the discharging end of the furnace are grouped so as to leave space (W) to discharge gases and ashes.

9) Furnace as described in claim 1, **charac terized** by the fact that the channels (10) grouped in the last furnace section (S5) in which gas and ashes are discharged are protected by refractory quoin shaped bricks (31).

10) Operation of the furnace as described in claim 1, **characterized** by the fact that:
- the combustible material is charged through the duct (8) into the first furnace zone (S1) where the material is heated, dried and spontaneously ignited by radiation and contact with the incandescent refractory lining, only a small amount of primary air being blown through the refractory quoins (3) and the anular chamber (14) of this section;
- in the second zone (S2), the material coming from the first zone (S1) is distilled and is burning brightly while being dissociated by thermal cracking during which combustible gases and highly reactive porous carbon are produced. The air volume supplied by the anular chamber (15) in this second zone is very great;
- in the next furnace zone (S3), the material coming from the second zone (S2) is oxidized and causes combustion of the carbonacious residues. In this zone, the temperature of the material and gases reaches its maximum values and the air flow rate must be controlled and adjusted so that the temperature will never exceed the ash softening and sintering value;
- in the next furnace zone (S4), incineration of the material coming from the previous zone (S3) is completed without primary combustion air being blown in;
- in the final furnace zone (S5), the gases are discharged and conveyed for utilization of sensible heat, whereas the still incandescent ashes are dropped into the quenching basins (25).

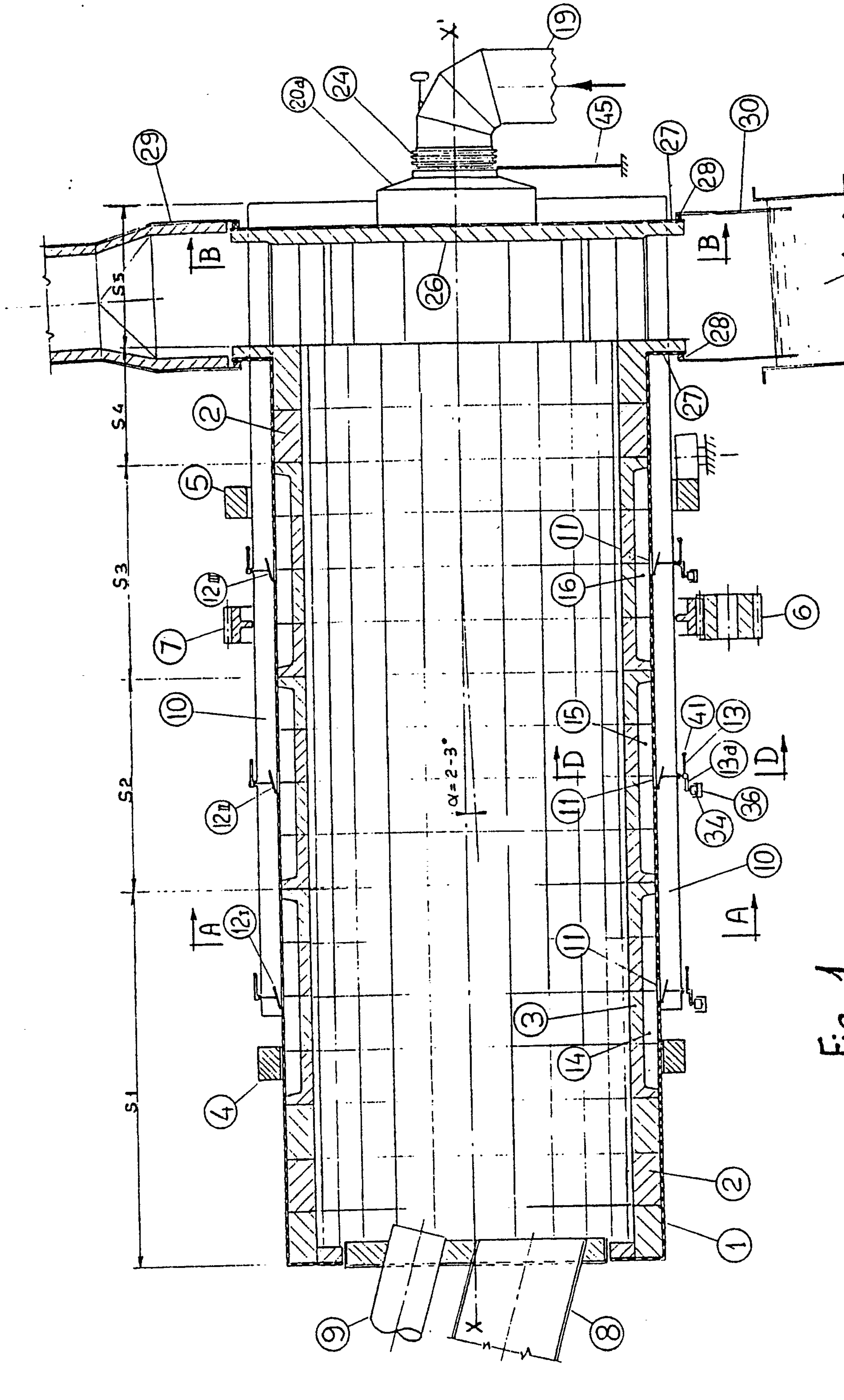
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Fig. 1

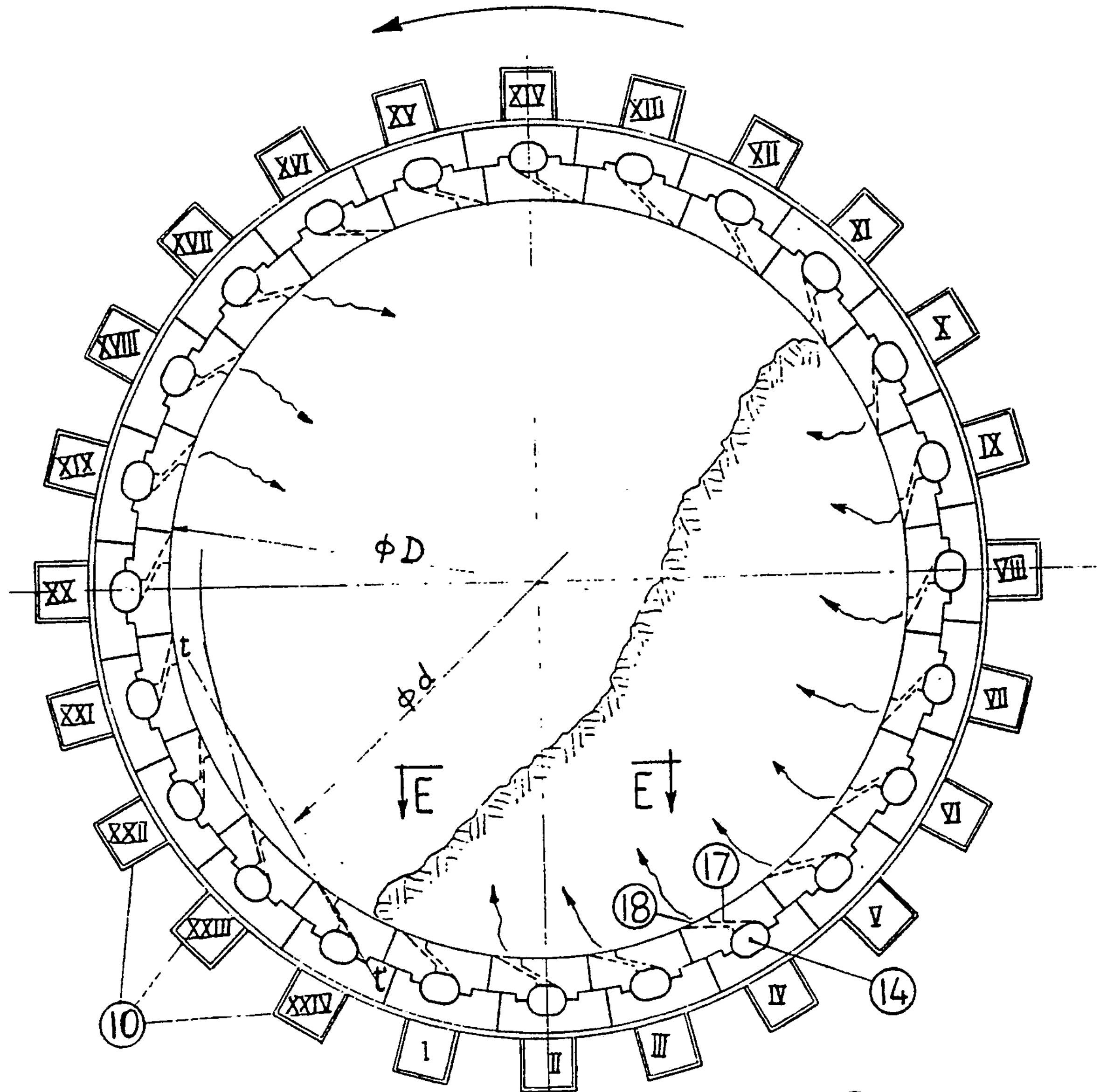
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Fig. 2

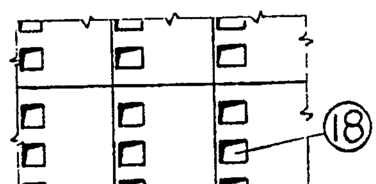
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Fig. 3

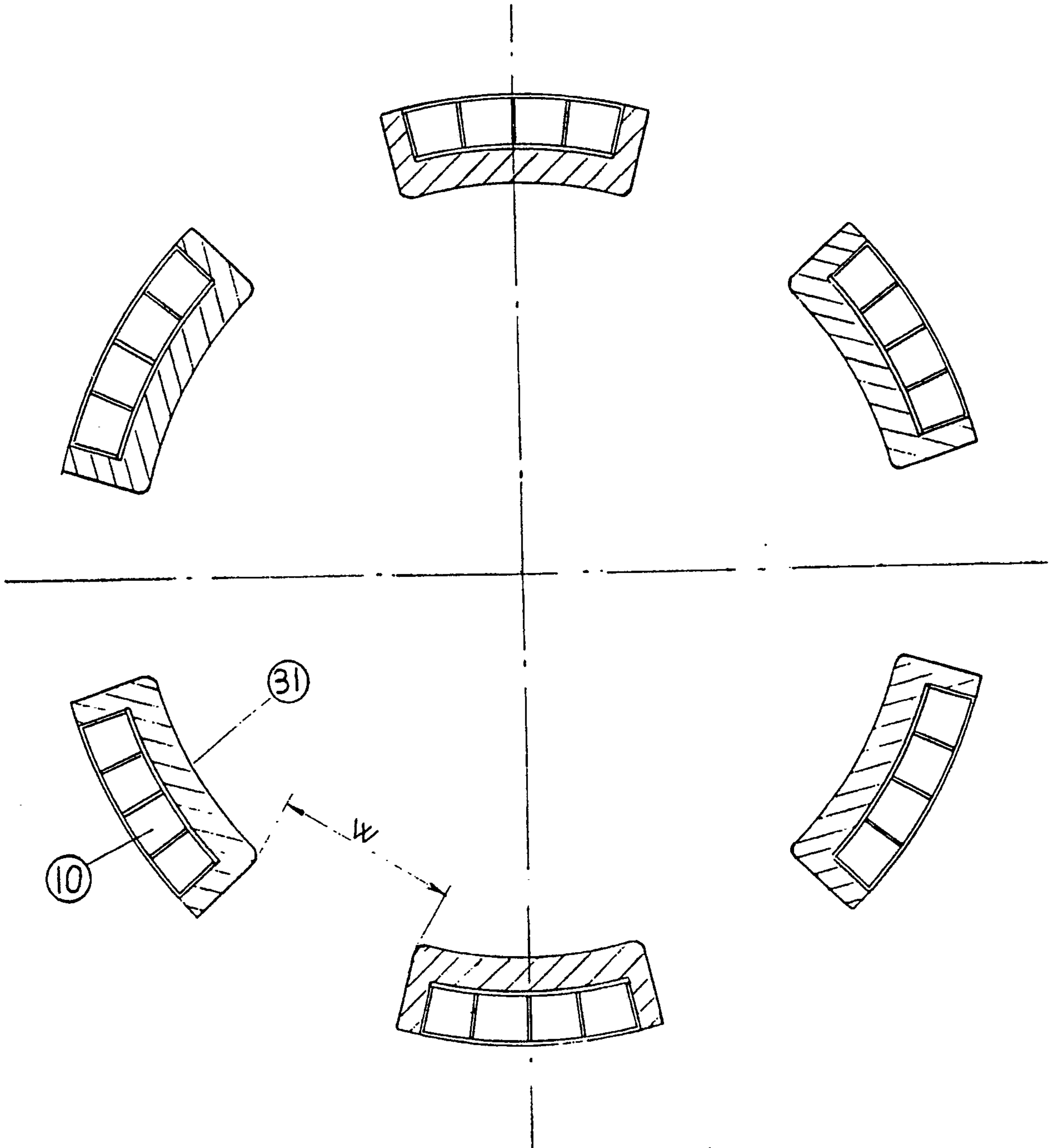

Fig. 4

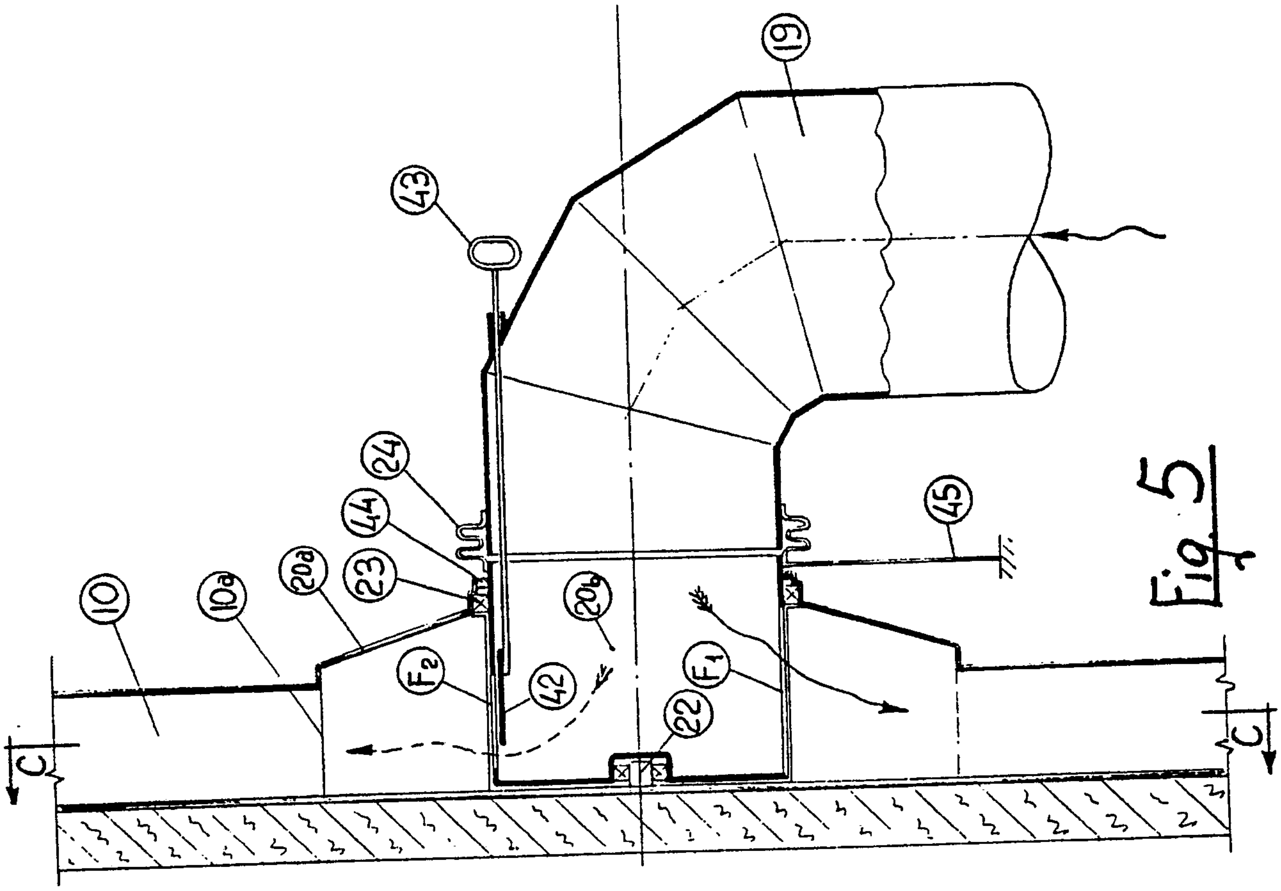
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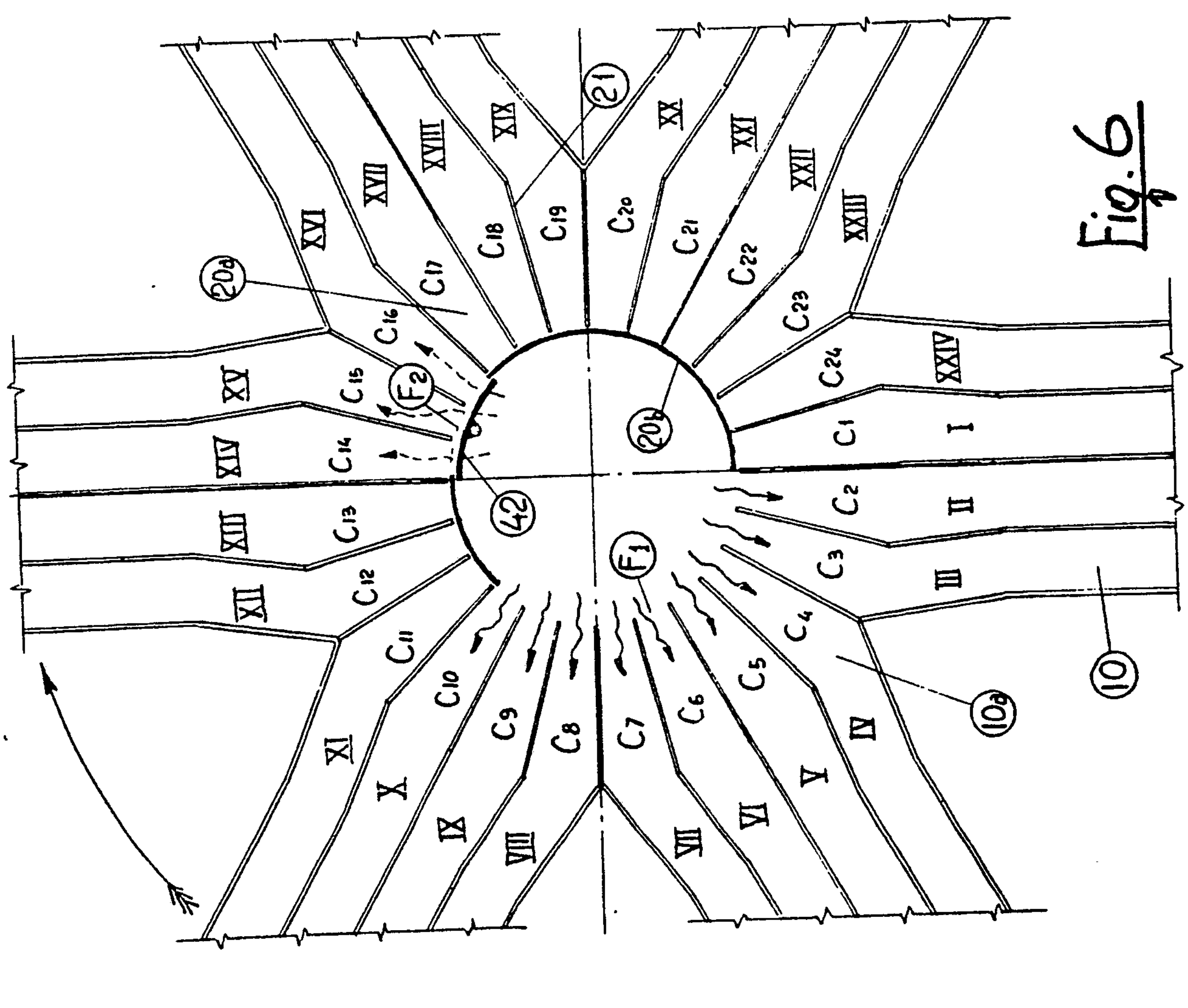
Fig. 5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C14
C15
C16
C17
C18
C19
C20
C21
C22
C23
C24
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
XX
XXI
XXII
XXIII
XXIV

Fig. 6

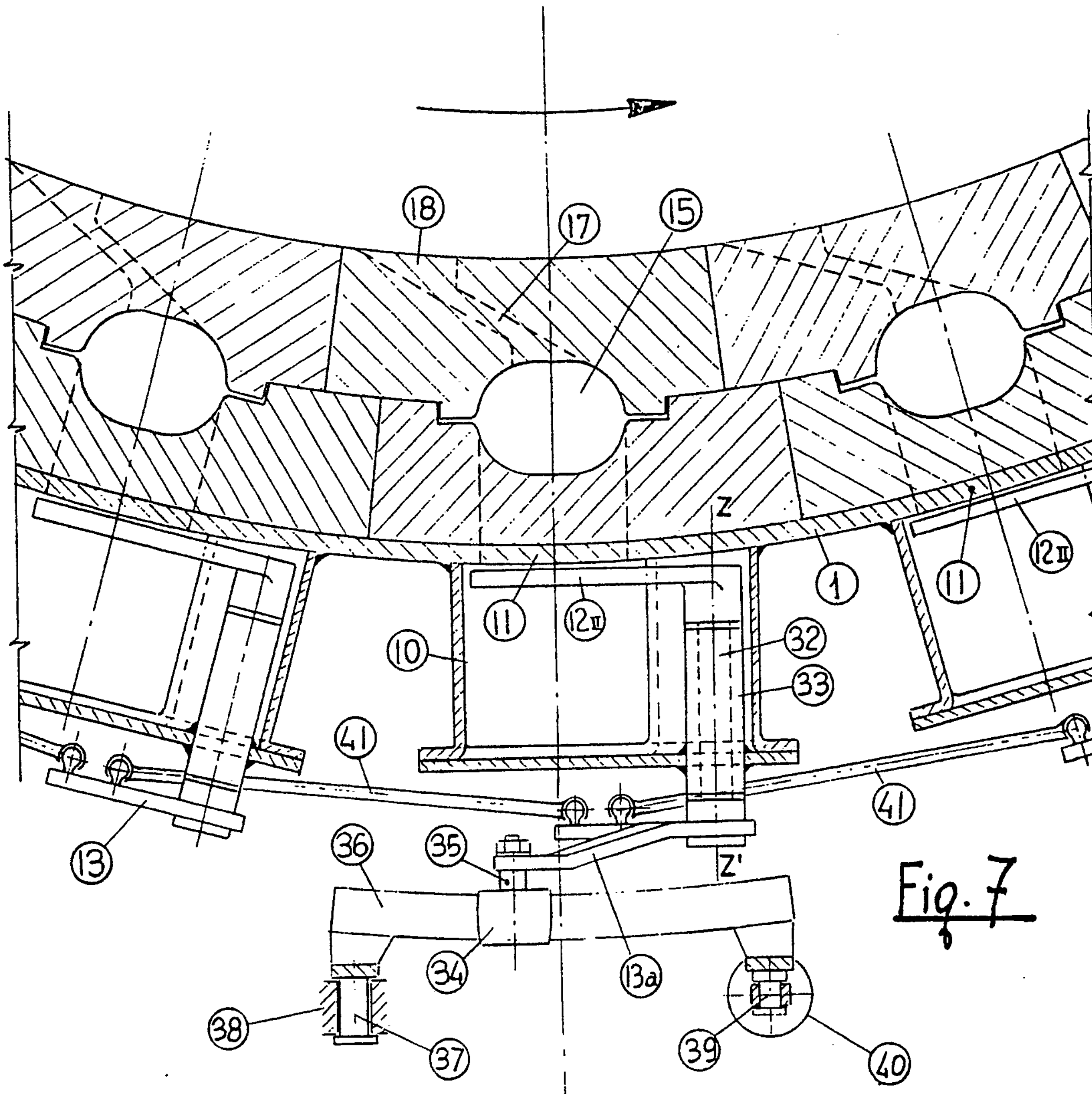
18
17
15
Z
1
11
12II
11
12II
32
10
33
41
41
13
35
36
Z'
34
13a
38
37
39
40

Fig. 7

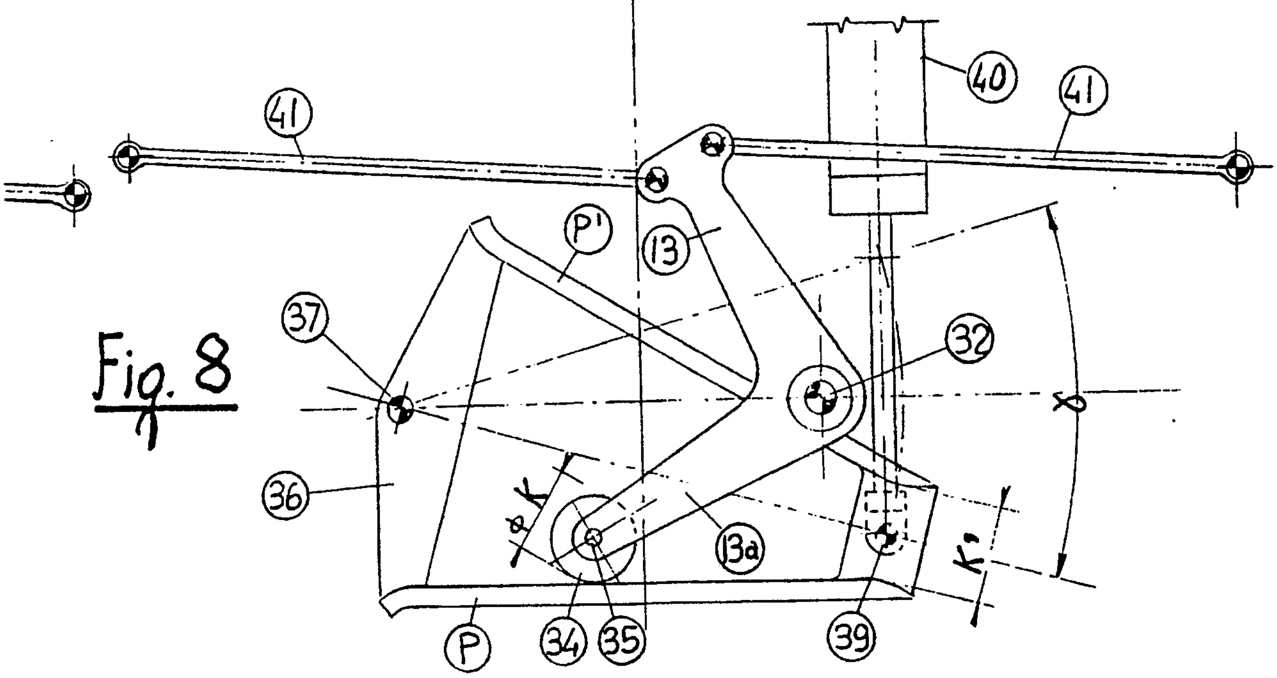
40
41
41
P'
13
37
32
36
K
13a
K'
P
34
35
39

Fig. 8

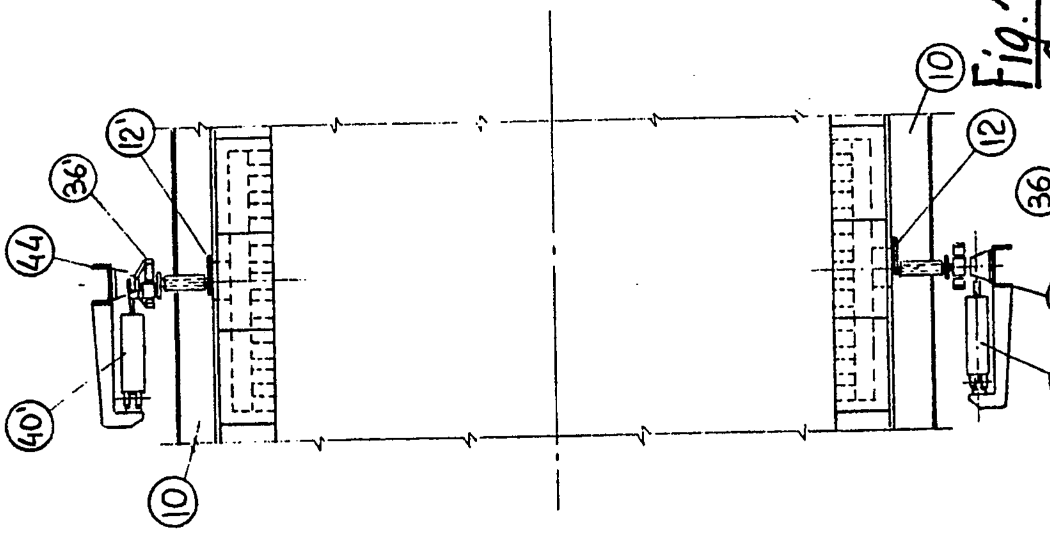

Fig. 10

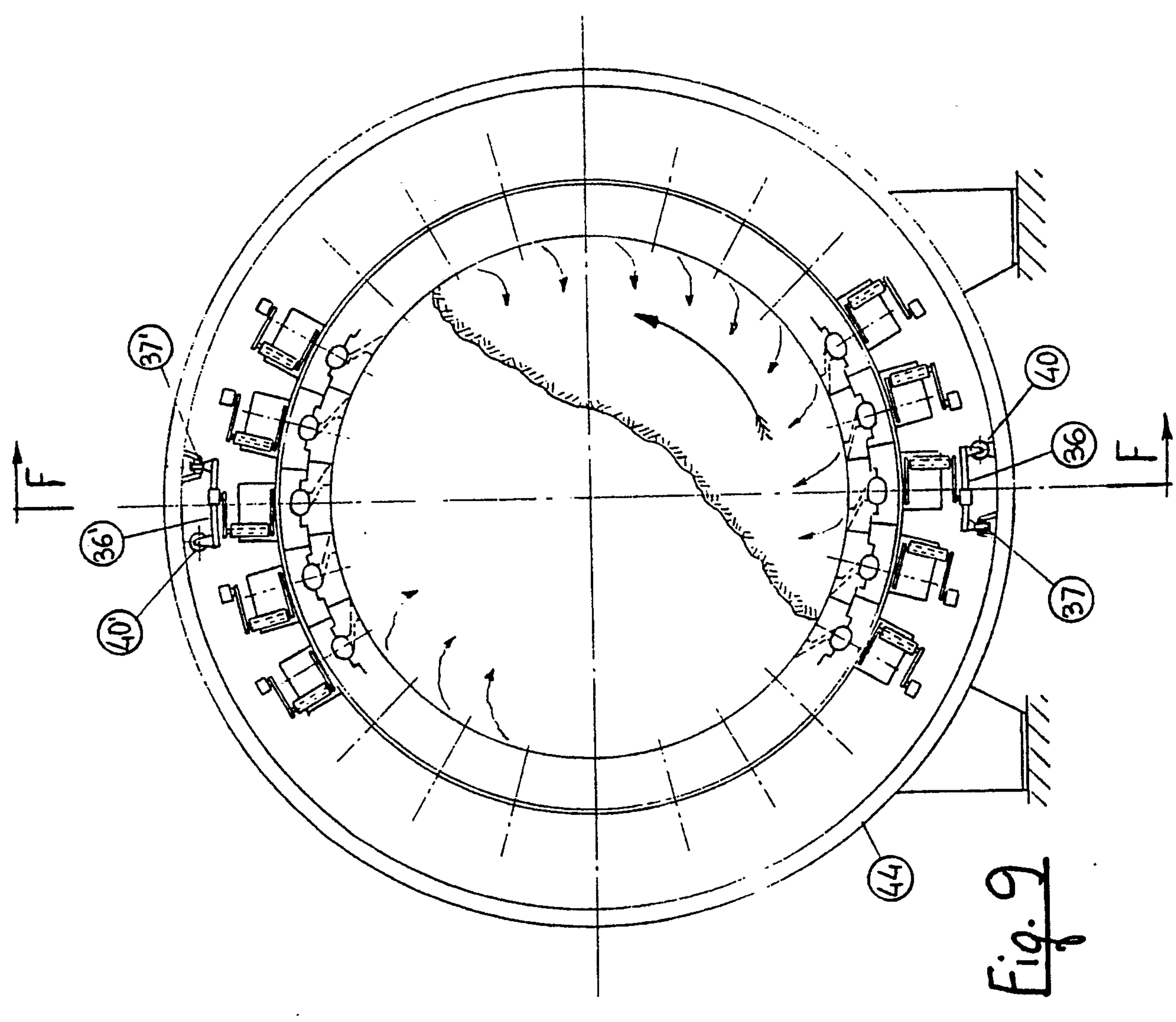

Fig. 9

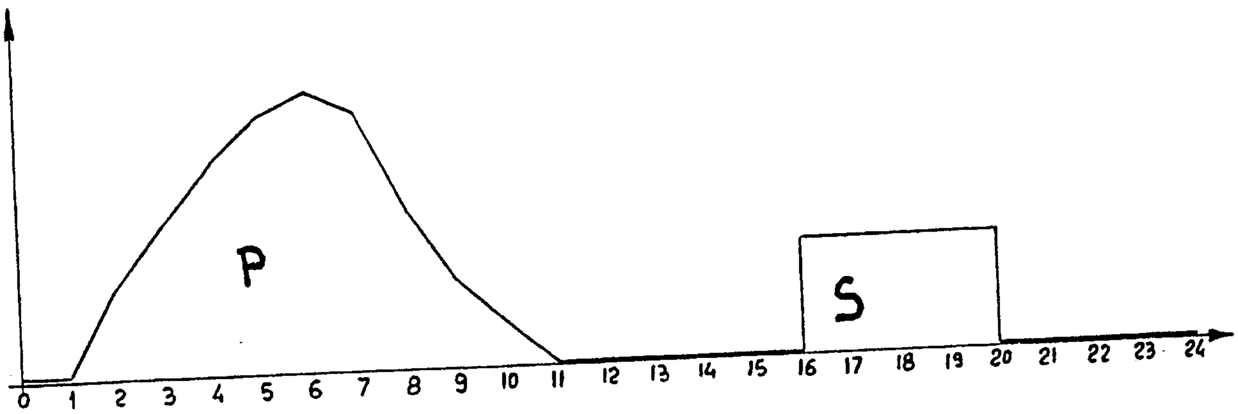

Fig. 11