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(72) Inventeur/Inventor:
SHEHATA, S. RAMSIS, CA

(73) Propriétaire/Owner:
SHEHATA, S. RAMSIS, CA

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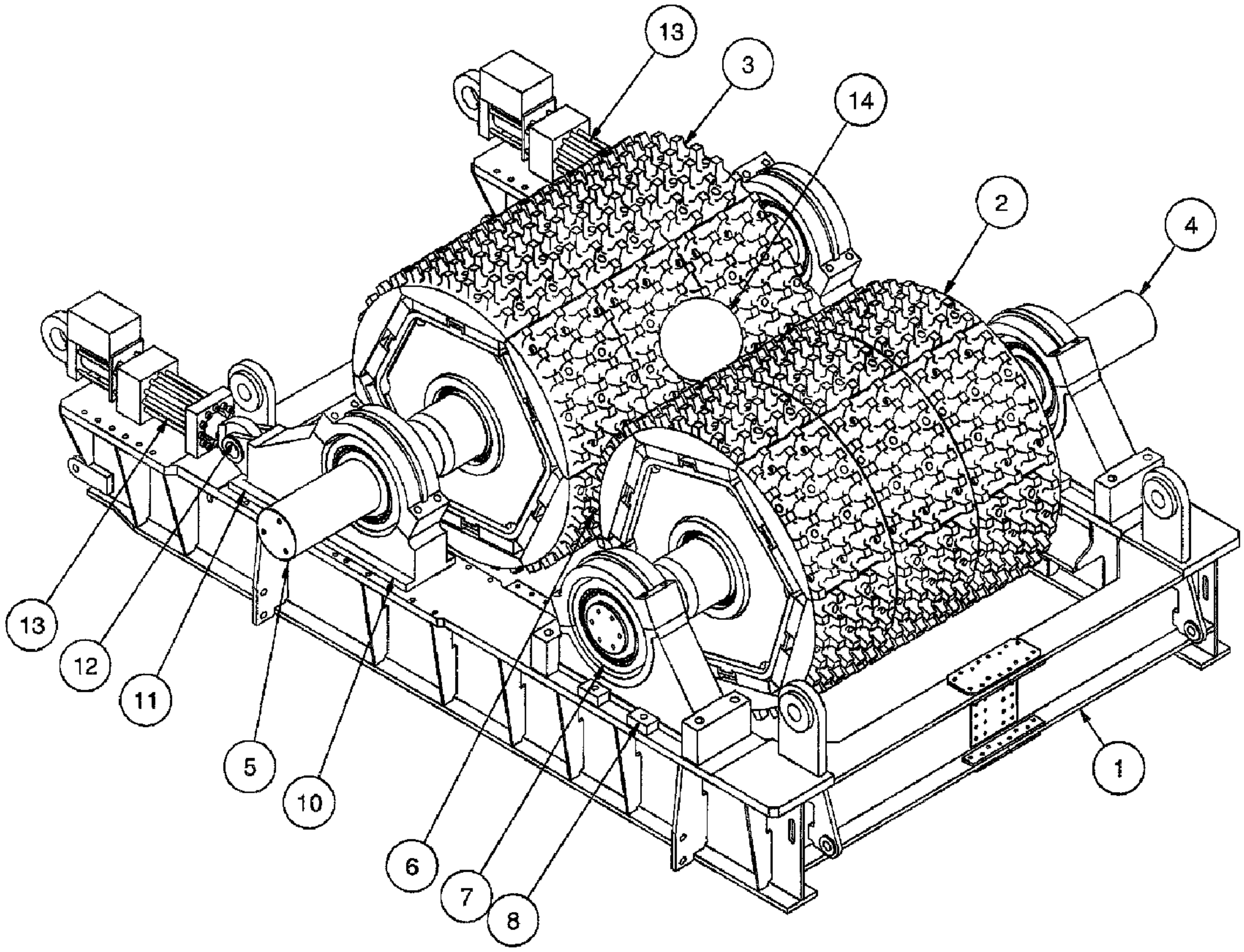

(57) Abrégé/Abstract:
In the field of mining an improved dual-roll crusher design particularly suited to the preparation of a mining ore for a subsequent processing step. The gap of a dual-roll crusher fitted with slide and actuation means can be actively controlled during operation to better suit characteristics of the ore such as variable lump size or other needs such as balancing load between series-wise crushers.

TITLE: VARIABLE GAP CRUSHER

ABSTRACT

In the field of mining an improved dual-roll crusher design particularly suited to the preparation of a mining ore for a subsequent processing step. The gap of a dual-roll crusher fitted with slide and actuation means can be actively controlled during operation to better suit characteristics of the ore such as variable lump size or other needs such as balancing load between series-wise crushers.

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Introduction and Prior Art

In the field of mining the technology of Oil-sand recovery and processing is unique to the deposits found in Northern Alberta, Canada in terms of the evolution of the process and equipment suitable for mining and processing the oil-sand. In the oil-sand mine, equipment used to excavate and transport the run-of-mine (ROM) oil-sand ore is as large in scale as at any world-wide mining operations, typically using electric-hydraulic shovels of up to 62 cubic metre capacity buckets loading into haulage trucks of up to 400 tonnes capacity to transport the ROM oil-sand ore to a centralized oil-sand slurry preparation facility.

Due to the massive scale of the mining equipment and the characteristics of the oil-sand itself, the ore received from the mining operation typically contains a very large range of lump sizes spanning from 3,500 mm and weighing up to 30 tonnes down to sand particles of a few millimeters. The ROM ore typically contains up to 30% moisture, 2% to 18% bitumen and 45% to 55% sand content by weight and also contains amounts of siltstone rock having an unconfined compressive strength of 165 to 221 MPa as a waste component.

The harsh environmental conditions at oil-sand operations encompass an ambient temperature range from +35 degrees Celsius down to -51 degrees Celsius. All mining and slurry preparation equipment is required to function with unhindered effectiveness and productivity under these ambient conditions. Materials handling properties of the ROM ore are highly variable over this temperature range. The oil-sand ore comprises frozen, highly abrasive lumps in winter but exhibits sticky, cohesive behaviour in summer, largely due to the influence of the contained moisture and bitumen components.

A slurry preparation process step is typically required to prepare all ROM ore to be suitable for long-distance transport as a water-based slurry to a remote upgrading facility, at single-stream production rates exceeding 10,000 tonnes per hour of ROM oil-sand. Typical prerequisites for efficient slurry pumping are crushing the oil-sand ore to minus

100 mm followed by the preparation of a homogeneous water slurry, typically with a consistency of about 64% solids by weight at a specific gravity of 1.5.

Current practice for oil-sand slurry preparation in the industry requires the use of multiple series-wise equipment processing steps to accomplish controlled ore feeding, screening and crushing prior to slurry pipelining. Disadvantages of the prior art for oil-sand slurry preparation include a primary constraint of requiring a screening process step and oil-sand re-handling steps to ensure control of the maximum size of lumps. The variable gap crushing innovations disclosed in this specification potentially enable acceptable oil-sand lump size reduction to be achieved and controlled by crushing steps rather than by screening steps.

It is well known in the prior art to use two crushing steps in series to handle a large lump size reduction ratio. In the case of oil-sand the crushers would typically be arranged to reduce lumps from 2,500 mm down to 100 mm (reduction ratio of 25 to 1). Conventional practice would use a primary crushing step of, for example, from 2,500 mm down to 600 mm (ratio 4.2 to 1) by setting the primary crusher roll gap to 600 mm, followed by a secondary crushing step of, for example, 600 mm down to 100 mm (ratio 6 to 1) by setting the secondary crusher roll gap to 100 mm. This is a necessary practice both to balance the crushing work load between the two series-wise crushing machines and to enable the rolls to be able to "grab" the maximum lump size presented to each crushing step. The geometrical concept of an adequate "pinch angle" between the rolls to enable the rolls to "grab" a given maximum lump size is a function both of lump size and gap width between the rolls for given roll diameters.

Also well known in the art is the random nature of particle or lump size distributions arising from the mining process, in which although a very large fraction of the ore will comprise lump sizes smaller than the expected maximum 2,500 mm, larger lump sizes will occur from time to time. A conventional primary crusher used in oil-sand with the roll gap set to 600 mm and roll diameters of 3,000 mm, for example, will be able to "grab" a 2,500 mm lump (reduction ratio 4.2 to 1) with minimal interference occurring to the overall crushing throughput, but if a 3,500 mm or larger lump presented itself in the feed to the crusher (reduction ratio $\geq$ 5.8 to 1) there would likely be some delay and difficulty for the crusher rolls to be able to “grab” the lump, thus causing obstruction of flow and potential spillage of feed requiring a shut-down of the ore crushing operation.

For prior art crushers a possible option to improve the handling of large lump sizes would be to set a large gap width at the primary crusher, thereby achieving a more favourable “nip angle” for large lumps. This solution is highly limited in that it not only throws a much higher percentage of the crushing duty onto the secondary crusher but also negatively impacts the secondary crushing reduction ratio. A second option is to screen the ore stream feeding one of the crushing stages to control the lump size reduction ratio presented to that crushing stage. This known practice requires additional equipment and structure to be added to the crushing plant and results in the unwanted accumulation of reject, oversize ore lumps requiring separate handling. Alternatively it is known to install auxiliary equipment to break the large lumps using mechanical energy or to employ some type of mechanical grapple to remove the lump from the throat of the crusher. Both of these solutions entail the addition of capital-intensive equipment and steel structure and require semi-continuous operator attention and intervention . These are known disadvantages of the prior art and also present serious safety hazards to personnel in the mining industry as well as frequently causing spill and loss of production.

Successfully controlling the maximum lump size in the run-of-mine oil-sand ore preparation process is an essential requirement to facilitate subsequent oil-sand slurry pipeline transportation. The minimum oil-sand slurry pumping velocity is dictated by maximum lump size handled and requires effective control to minimize the operating risk of plugging the final oil-sand slurry delivery pipeline.

Also, it will be appreciated by one skilled in the art that whether or not the crushing service is in oil-sand or in other types of mining ores there is always a strict requirement to control maximum lump size so as to ensure the success of the subsequent processing step.

With Reference to the Figures:

Figure 1 is a simplified isometric view of a dual-roll crusher assembly incorporating preferred embodiments of the invention;

Figure 2 is a simplified elevation view of the dual-roll crusher assembly of Figure 1 showing more clearly the relationship of the crusher rolls and a simulated lump to be crushed.

Figure 3 is a simplified elevation view of the dual-roll crusher assembly of Figure 2 showing an enlarged gap between the crusher rolls.

Figure 4 is a schematic crushing equipment system process flowsheet using two, series-wise crushers in an improved ore preparation plant for the preparation of run-of-mine oil-sand ore for a subsequent processing step.

In Figure 1, a dual-roll crusher assembly is shown mounted on a structural base 1 comprising a fixed roll 2 and a movable roll 3, with projecting shaft 4 on the fixed roll for mounting a drive means (not shown) and projecting shaft 5 on the movable roll for mounting a drive means (not shown), both rolls being held by the structural base 1 in a substantially parallel relationship with each other and in a substantially horizontal plane and having a nominal gap 6 maintained between them. Fixed crusher roll 2 is arranged with bearing means 7 in bearing holder means 8 at each end thereof and movable roll 3 is arranged with bearing means 9 (not shown) in bearing holder means 10 at each end thereof. Bearing holder means 10 is arranged with slide means 11 at its base and coupling means 12 enabling attachment of actuator means 13 which can be motivated to slide the movable pulley assembly to the left or to the right, effectively increasing or decreasing the nominal gap 6 between the rolls. A spherical shape 14 is illustrated above the gap between the crusher rolls 2 and 3 to simulate a lump of run-of-mine ore which can be drawn into the crushing zone above and through the gap by the teeth on the rolls and forced to pass through the gap. The shape 14 can typically be significantly larger in diameter than the nominal gap width between the crusher rolls.

In Figure 2 the crusher assembly mounted on base 1 having fixed roll 2 and movable roll 3 is shown with a simulated run-of-mine ore lump 14 entering the crushing zone between the two rolls. The nip angle 15 is shown to be a geometrical relationship between the lump size, the roll diameter and the gap width between the rolls. In the illustration, teeth on the surface of the rolls are shown as intermeshing in the gap.

In Figure 3 the effect of increasing the gap by movement of movable roll 3 to the left is to allow lump 14 to drop further into the crushing zone, thus enabling the teeth on the rolls to more easily "grab" the lump and force it into the crushing zone and through the gap.

In Figure 4 mine haulage truck 16 dumps run-of-mine ore into receiving hopper 17 from which reclaim conveyor 18 withdraws run-of-mine ore and feeds it via chute 19 to primary crusher 20 to create primary crushed ore. The primary crushed ore passes through chute 21 to conveyor 22 feeding via chute 23 to secondary crusher 24 to create secondary crushed ore. The secondary crushed ore passes through chute 25 to conveyor 26 and chute 27 to subsequent process step 28.

In Figures 1, 2 and 3 the feed hopper side plates controlling feed to the crusher have been omitted for clarity, but it will otherwise be clear that the only possibility of the full stream of ore passing through the crusher is that all lumps first be reduced by the rolls to a size equal to or less than the nominal crusher gap width between the rolls. In fact, the basic presumption of the successful operation of the process flowsheet in Figure 4 is that the full stream of run-of-mine ore will be reduced sufficiently in size after passing through the crushing equipment system illustrated in the flowsheet to be suitable for a subsequent processing step 28.

As explained in conjunction with the Figures the preferred embodiments of the present invention for the dual-roll crusher are the provision of bearing holder slides and actuation means for adjusting the position of the movable roll so as to obtain an operable "variable gap" crusher. For conventional crushers the roll gap can only be changed manually while the crusher is shut-down. Control of the crusher gap width has never been available as an operating parameter in the prior art. The corollary provision of sensing means and logical interpretation means, such as a known industrial programmable logic controller with pre-programmed set-points, enables closed loop crushing control strategies to be implemented based upon measurement of selected characteristics of the oil-sand ore in combination with selected operating parameters of the crushing equipment system itself, thereby to incrementally increase or decrease the crusher roll gap and thereby to control the crushing operation in a beneficial way.

The present invention enables a larger range of lump size reduction ratios to be handled in a given crushing equipment system using less equipment than the prior art. It also enables unique and valuable crushing control strategies such as load sharing between series-mounted crushers. It will be possible to implement anticipatory as well as reactive control of oil-sand crushing based upon specific measurable characteristics of run-of-mine ore and primary crushed ore and secondary crushed ore. A possible associated flow sheet innovation is the elimination of prior art screening and oil-sand re-handling and accumulation of unwanted rejects due to the improved ability to control the maximum lump size.

For example, since the primary and secondary crushers are installed in series and are handling the same stream of oil-sand ore it will be possible to distribute the actual crushing duty load equally between them by measuring the power delivered to each crusher and adjusting the roll gap at one or both of the primary and secondary crushers to balance the power draw, thus enabling control of relative wear rates between the crushers and extending the operating interval between shut-downs for major refurbishment. Balancing the crushing duty between the primary and secondary crushers may also enable increasing the crushing plant oil-sand ore throughput rate or minimizing crushing power consumption as alternate strategies for improving mining profitability. Finally, for crushing run-of-mine oil-sand ores which are highly variable both in composition and in lump size distribution, both seasonally and also between individual mine haulage truck loads, the capability of balancing the crushing loads as a continuous operating function is both unique and valuable for optimizing crushing duty and throughput at each of the primary and secondary crushers and in the process flowsheet itself. No such beneficial capabilities or operating strategies are available in the prior art.

Known means of measuring crusher load include at least sensing means such as measuring power delivery to the crusher rolls or measuring the weight of oil-sand material carried on selected conveyors by means such as belt weigh scales.

Variable gap crushing of the present invention could also be controlled by observation of external factors in the crushing equipment system process flowsheet, enabling the crusher gap to be adjusted in anticipation of receiving a particularly large lump of ore into the throat of the primary crusher. In this case the roll gap could be incrementally increased, thus improving the "nip-angle" of the rolls to enable the large lump to be more easily gripped by the teeth on the rolls and to be forced into the crushing zone above and through the gap. Although oversized large lumps might flow through the primary crusher for several seconds in this instance, system throughput rates could then be temporarily reduced for the time it would take for the secondary crusher to handle the extra crushing duty, without compromising the required control of maximum lump size delivered to a subsequent processing step. No such beneficial capabilities or operating strategies are available in the prior art.

Beneficial crushing control strategies could also be based on observation of lump size in the primary or the secondary crushed ore streams. Any observed increase or decrease in average lump size in the primary crushed ore, possibly due to wear or breakage of primary crusher teeth, could provide a control basis for incrementally closing or opening the primary crusher gap, respectively, both to control crushing system thoughput rate and to control crushing duty at the secondary crusher. Similarly, any observed increase in average lump size in the secondary crushed ore could provide a control basis for an operator alarm or to incrementally reduce the secondary crusher gap so as to ensure meeting the maximum lump size specification for the subsequent process step. No such beneficial capabilities or operating strategies are available in the prior art.

Known means of observing lump size include at least sensing means such as, for example, optical imaging means and level sensing means in feed hoppers or on conveyors in the crushing equipment system.

Although much of the foregoing discussion refers specifically to the mining environment and conditions of Canadian oil-sand ore it will be readily appreciated by one practiced in the art that the improvements described for primary and secondary roll crushers and for crushing equipment system process flowsheets will also be beneficial for other mining plants handling other types of mining ores. Also, it will be understood that the quoting of specific capacity or dimensional data for the crushing equipment system is not intended to exclude the use of other capacities and dimensions, when such use falls within the spirit of the invention.

It will also be clear to one practiced in the art that means to remove tramp metal such as a conventional belt magnet must be provided for the process flowsheet. Although not shown in Figure 4, this tramp metal removal means is understood to be present and would typically be mounted on at least one of the conveyors on the flowsheet.

Claims

What I claim as my invention:

1. In an ore preparation plant means for preparing ore to become suitable for a subsequent processing step, a crushing equipment system means to achieve size reduction of said ore comprising

   an initial receiving hopper means for receiving said ore from haulage truck means and

   a first conveying means for feeding said ore into a primary single-pass crushing means to create primary crushed ore and

   a second conveying means for feeding said primary crushed ore into a secondary single-pass crushing means to create secondary crushed ore and

   a third conveying means for feeding said secondary crushed ore to said subsequent processing step,

   said ore being made suitable for said subsequent processing step by the combined operation of said primary single-pass crushing means and said secondary single-pass crushing means within said crushing equipment system,

   said primary single-pass crushing means and said secondary single-pass crushing means each being independently arranged with a fixed roll and a movable roll, said rolls being held in substantially parallel relationship with each other in a substantially horizontal plane, said rolls being rotated by drive means with a nominal horizontal gap being maintained between said rolls,

   said fixed roll being mounted on bearing means and bearing holder means at each end thereof,

   said movable roll being mounted on bearing means and bearing holder means at each end thereof and said bearing holder means engaging horizontal slide means and being coupled to actuator means to impart linear, horizontal adjustment of the position of said bearing holder means and said movable roll along said horizontal slide means so as to decrease or increase said nominal horizontal gap between said fixed roll and said movable roll in response to an external control signal,

said external control signal being derived from sensing and logical interpretation means which are arranged to monitor, interpret and compare at least one characteristic of said run-of-mine ore or said primary crushed ore or said secondary crushed ore or at least one operating parameter of said crushing equipment system or a combination of ones of said characteristics with ones of said operating parameters with pre-programmed set-points, thereby to control the crushing of said ore.

2. A crushing equipment system means as in Claim 1 in which at least one said operating parameter of said crushing equipment system is a measurement of load at said primary single-pass crushing means or at said secondary single-pass crushing means or at each said primary single-pass crushing means and said secondary single-pass crushing means or is inferred from measurement of load on said first conveying means or said second conveying means or said third conveying means.

3. A crushing equipment system means as in Claim 1 in which at least one said characteristic of said ore or said primary crushed ore or said secondary crushed ore is lump size and measurement of said lump size includes optical imaging sensing means or level sensing means.

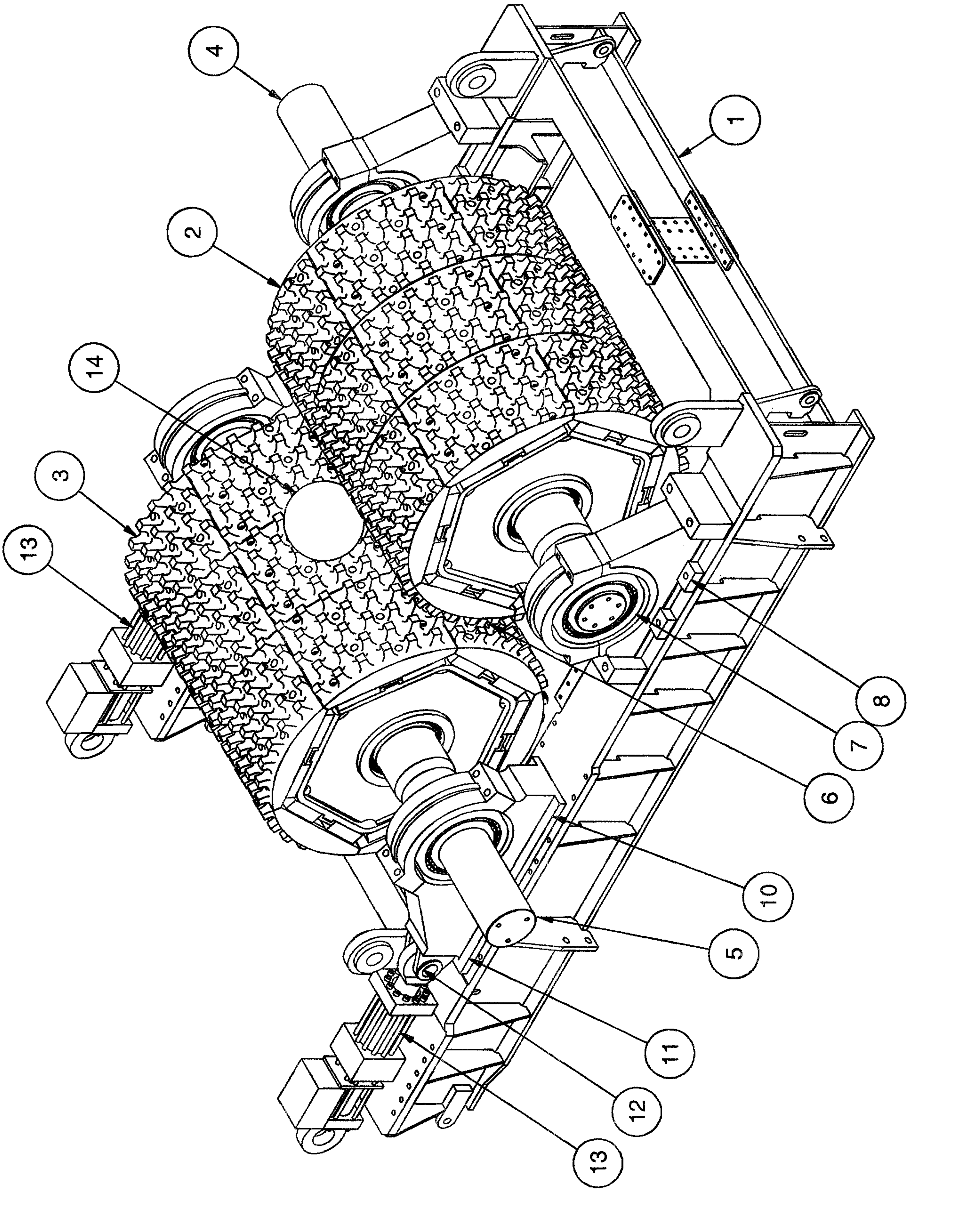
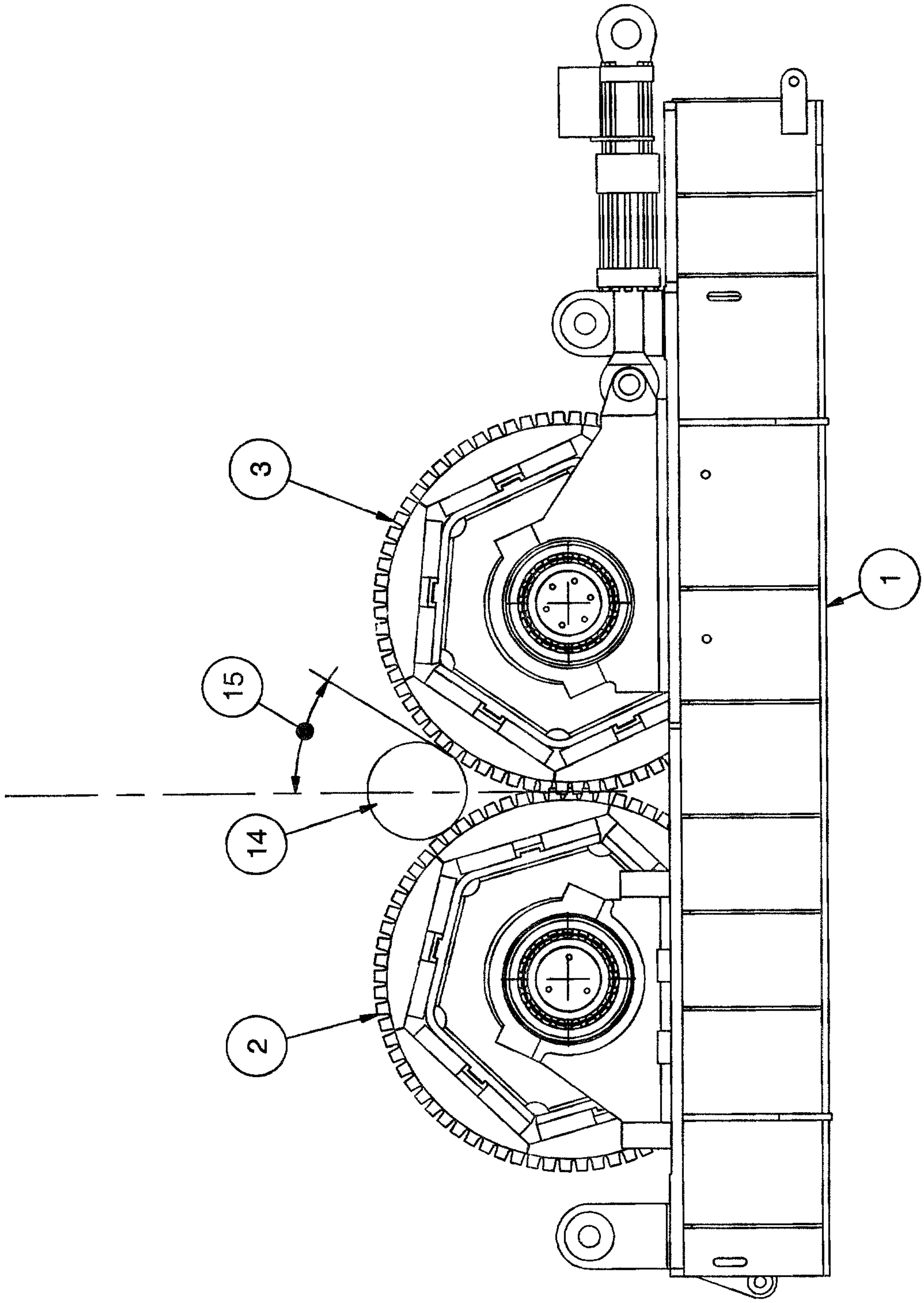


FIGURE 1

FIGURE 2



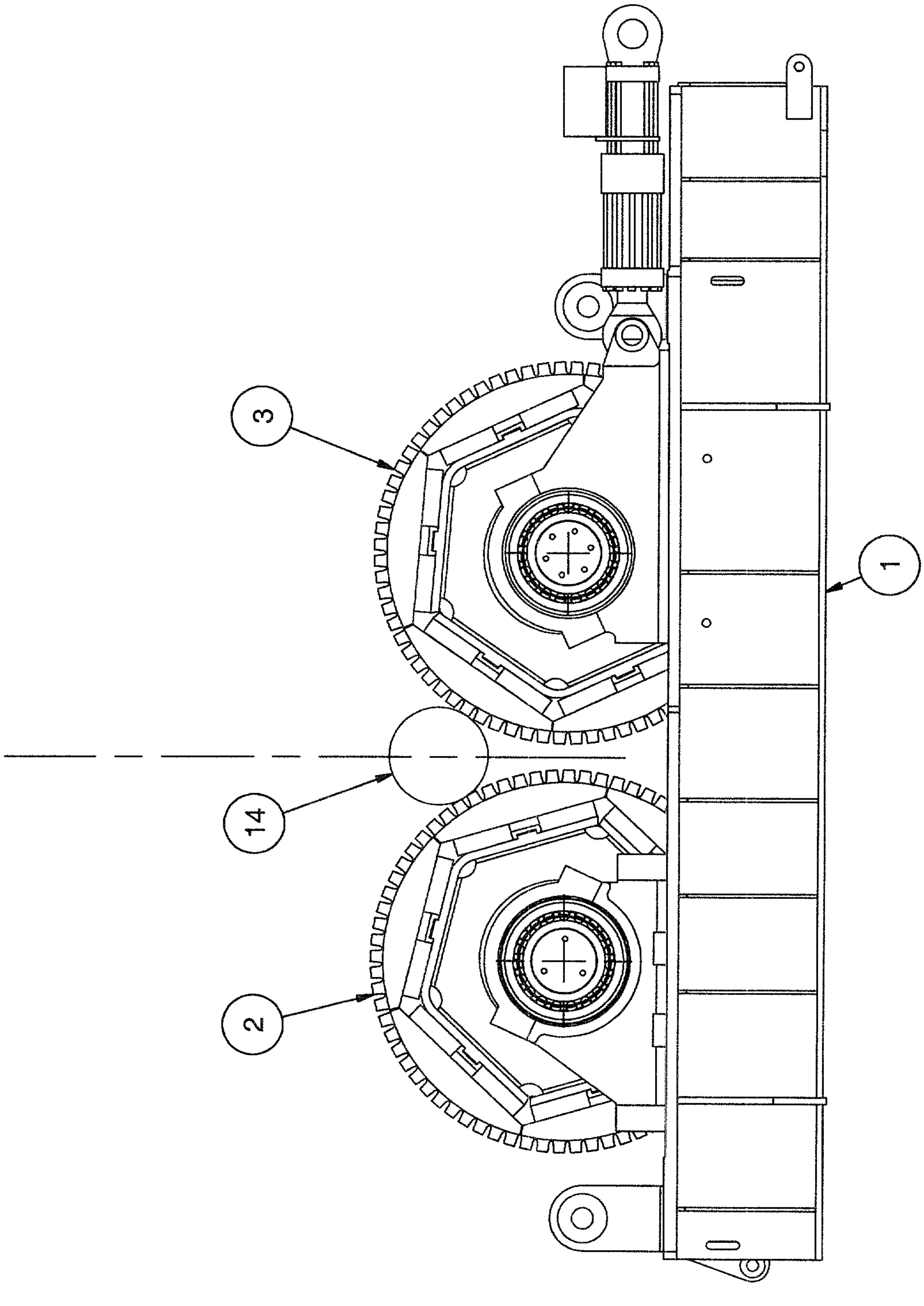
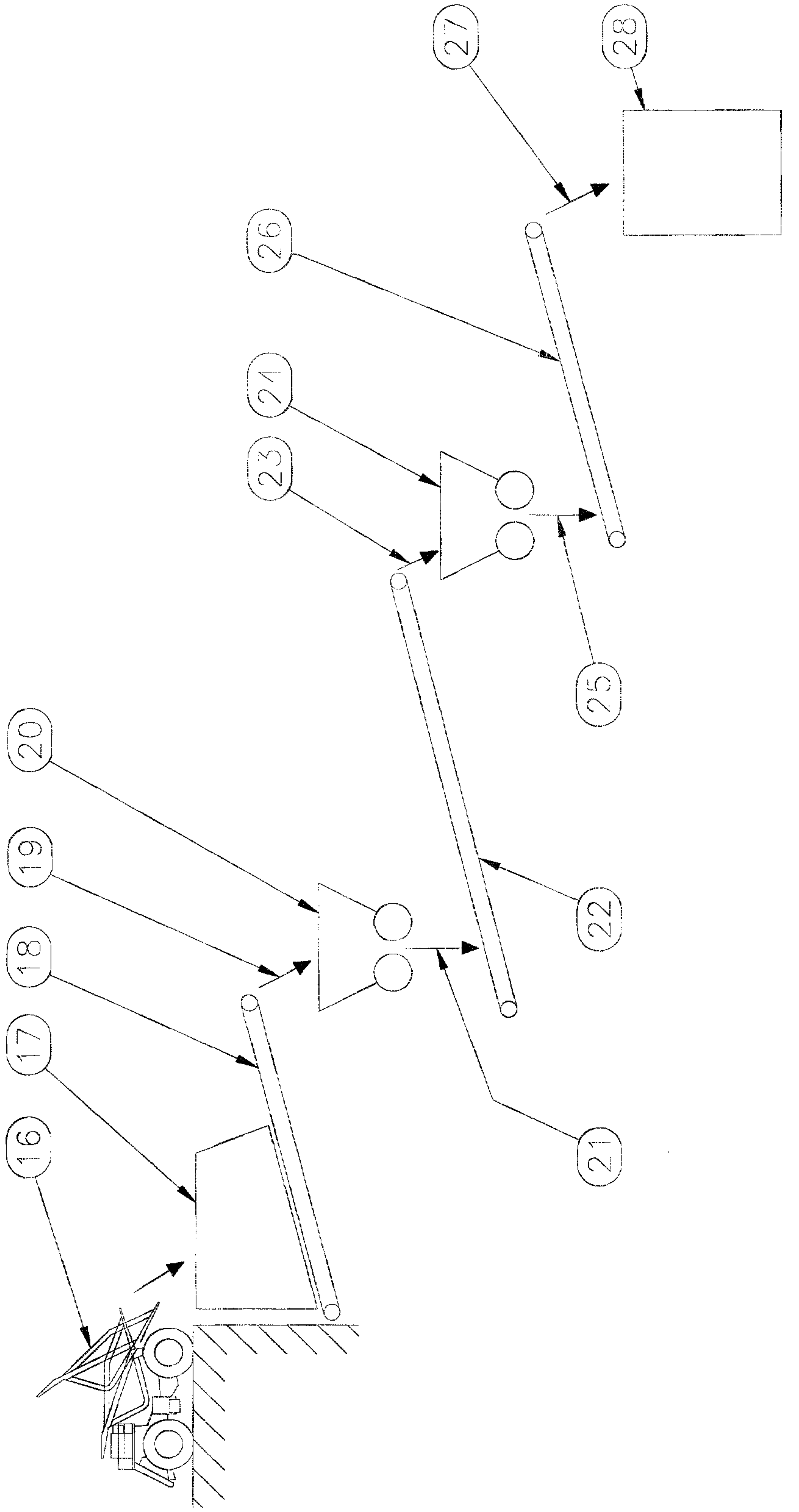
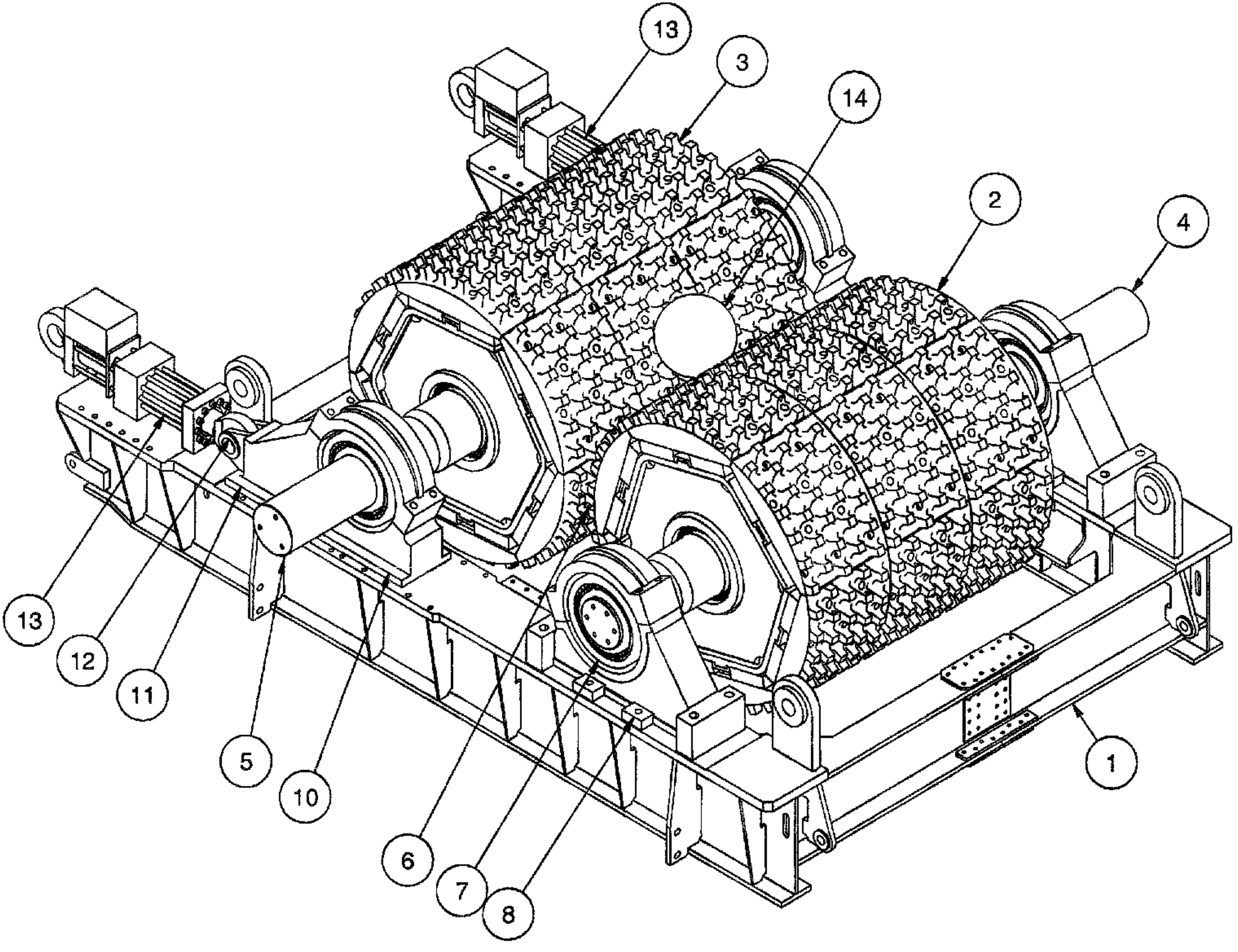


FIGURE 3

FIGURE 4





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