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(54) **Titre : ROUE DE MEULAGE LIEE A LA RESINE**
(54) **Title: RESIN BONDED GRINDING WHEEL**

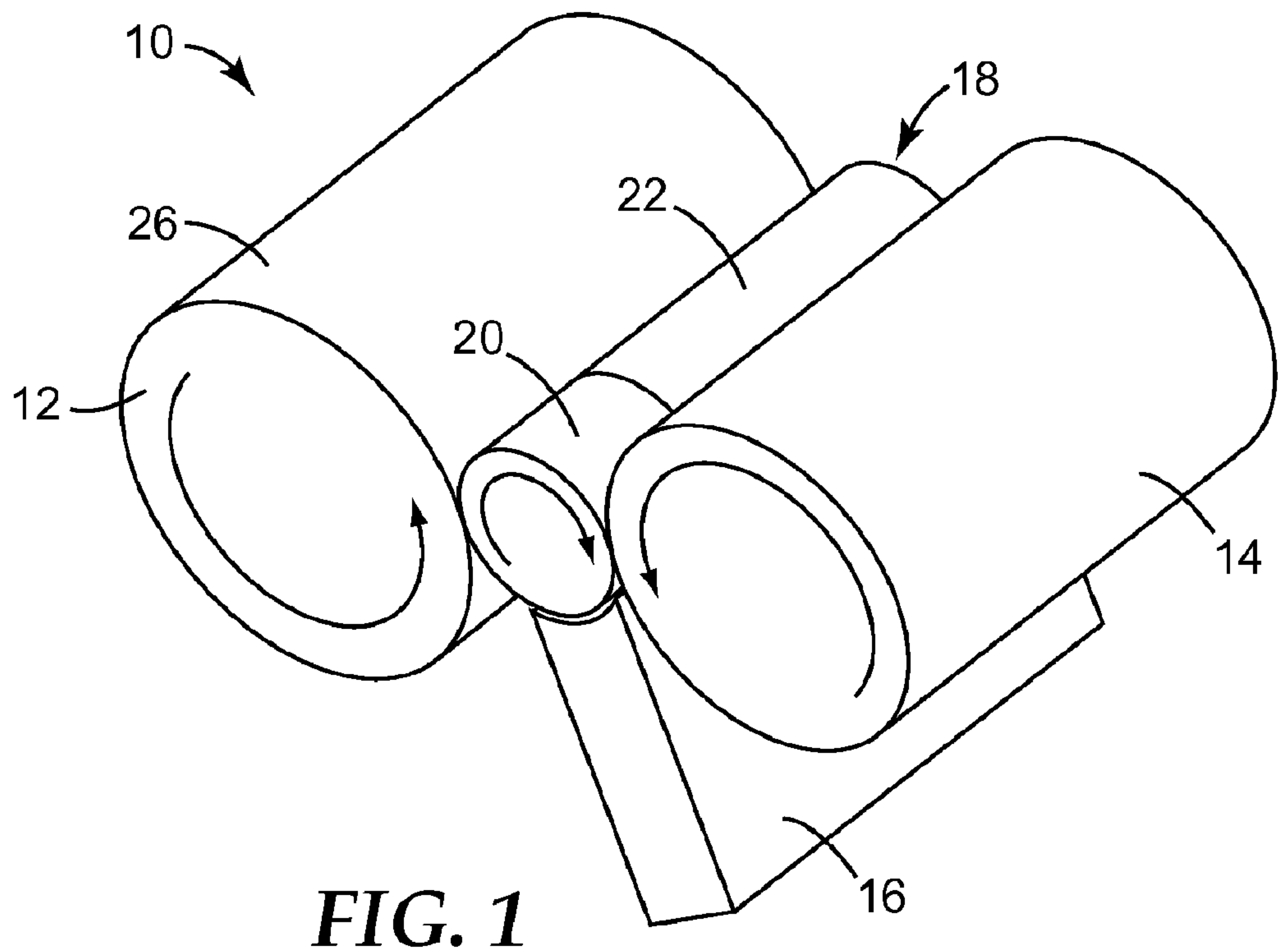

FIG. 1

(57) **Abrégé/Abstract:**
A resin bonded grinding wheel suitable for grinding polycrystalline diamond compacts is disclosed. The resin bonded grinding wheel uses a high concentration of diamonds based on a volume percent along with a mixture of hard and soft filler particles to

(57) **Abrégé(suite)/Abstract(continued):**
effectively grind the polycrystalline diamond compacts while eliminating or reducing the need to continuously dress the outer surface of the resin bonded grinding wheel.

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(54) **Title**: RESIN BONDED GRINDING WHEEL

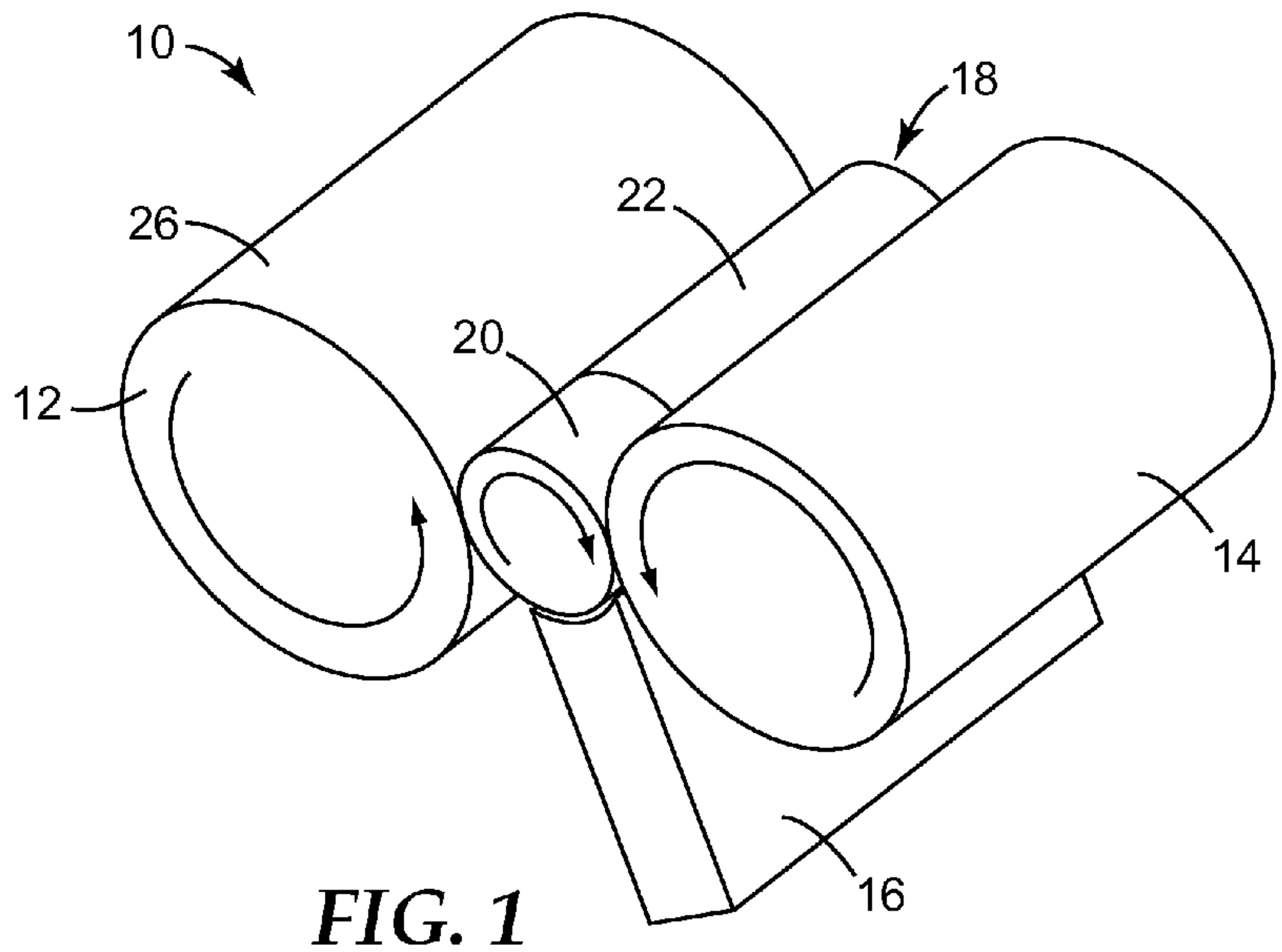

FIG. 1

(57) **Abstract**: A resin bonded grinding wheel suitable for grinding polycrystalline diamond compacts is disclosed. The resin bonded grinding wheel uses a high concentration of diamonds based on a volume percent along with a mixture of hard and soft filler particles to effectively grind the polycrystalline diamond compacts while eliminating or reducing the need to continuously dress the outer surface of the resin bonded grinding wheel.

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RESIN BONDED GRINDING WHEEL

BACKGROUND

Polycrystalline diamond compacts (PDC) include a polycrystalline diamond layer bonded to a tungsten carbide substrate. The polycrystalline diamond layer provides high hardness and abrasion resistance, while the tungsten carbide layer improves the toughness of the composite. PDC's are often employed as the cutting tips for boring bits used to drill into the earth for natural resources.

Resin bond grinding wheels with diamond abrasive particles can be used to grind and finish PDC to its final specified dimensions. PDC is extremely difficult to grind because of the interface of the two dissimilar hardness materials. Because of the extreme hardness of the polycrystalline diamond layer, the diamond abrasive in the resin bonded grinding wheel dulls very quickly. In addition, the tungsten carbide substrate loads the grinding wheel reducing the ability of the abrasive wheel to further grind the polycrystalline diamond layer. As a result, the resin bonded grinding wheel must be constantly dressed with a carborundum stone to reduce or eliminate the tungsten carbide loading of the grinding wheel and to expose fresh diamond cutting points.

SUMMARY

To improve the grinding of PDC with resin bonded grinding wheels, it is desirable to reduce or eliminate the need to constantly dress the resin bonded grinding wheel with a carborundum stone. Reducing or eliminating the need to dress the resin bonded grinding wheel, while still achieving an acceptable cut rate on the polycrystalline diamond layer of PDC, improves the safety and efficiency of the grinding operation. A grinding wheel operator can run more than one grinding machine if the resin bonded grinding wheel does not require constant dressing while finish grinding a PDC.

Hence, in one aspect, the invention resides in a method of grinding comprising: contacting a polycrystalline diamond compact with a grinding wheel; the grinding wheel comprising diamonds, a resin binder, and a mixture of hard filler particles and soft filler particles; and wherein the diamonds comprise a diamond concentration from 175 percent to 225 percent based on volume, the resin binder comprises 30 percent to 40 percent based on volume, a ratio of hard filler particles to soft filler particles in the mixture is from 85:15 to 15:85, and the mixture of hard filler particles and soft filler particles comprises 5 percent to 30 percent based on volume.

In another aspect, the invention resides in an abrasive article comprising: a grinding wheel, the grinding wheel comprising diamonds, a resin binder, and a mixture of hard filler particles and soft filler particles; and wherein the diamonds comprise a diamond concentration from 175 percent to 225 percent based on volume, the resin binder comprises 30 percent to 40 percent based on volume, a ratio of hard filler particles to soft filler particles in the mixture is from 85:15 to 15:85, and the mixture of hard filler particles and soft filler particles comprises 5 percent to 30 percent based on volume.

BRIEF DESCRIPTION OF THE DRAWINGS

Repeated use of reference characters in the specification and drawings is intended to represent the same or analogous features or elements of the disclosure.

FIG. 1 shows a centerless grinding process with a resin bonded grinding wheel operating to grind a PDC to its final diameter.

FIG. 2 shows the grinding results for the inventive resin bonded grinding wheel versus the comparative resin bonded grinding wheel with different dressing frequency.

DEFINITIONS

As used herein, variations of the words "comprise", "have", and "include" are legally equivalent and open-ended. Therefore, additional non-recited elements, functions, steps or limitations may be present in addition to the recited elements, functions, steps, or limitations.

DETAILED DESCRIPTION

Referring to FIG. 1 a centerless grinder 10 is illustrated. The centerless grinder includes a resin bonded grinding wheel 12, a regulating wheel 14, and a support 16 for holding a PDC 18 between the two wheels. The PDC includes a polycrystalline diamond layer 20 bonded to a tungsten carbide substrate 22. The speed at which the PDC will traverse through the grinding interface between the two wheels is controlled by the helix angle α between the axis of the resin bonded grinding wheel 12 and the axis of the regulating wheel 14 in combination with the rotational speed of the regulating wheel. Prior art resin bonded grinding wheels require constant dressing of the outer surface 26 with a carborundum stone to maintain the ability of the resin bonded grinding wheel to grind the polycrystalline diamond layer.

In order to reduce or eliminate dressing of the outer surface while grinding PDC, it is desirable to make the resin bonded grinding wheel behave similar to a vitrified bonded grinding wheel. Such an effect can be achieved by using a very high diamond concentration while including both hard filler particles and soft filler particles to control the breakdown rate of the resin bonded abrasive wheel. Such a resin bonded grinding wheel will ensure the exposure of fresh diamonds particles in the wheel while reducing or eliminating glazing of the outer surface during use. The high concentration diamond portion can be an outer annulus of the grinding wheel, a segmented portion thereof, or the entire grinding wheel.

Suitable diamonds for use in the abrasive wheel include, for example, natural diamond, synthetic diamond, resin bond diamonds, metal bond diamonds, diamond abrasive powder, resin bonded or vitrified bonded diamond agglomerates of the foregoing, and combinations of all of the foregoing. To achieve the necessary hardness of the resin bonded abrasive wheel, the diamond concentration is very high. In particular, the diamond concentration as a volume percent of the total volume of the high concentration diamond portion of the grinding wheel is from 175% to 225% or from 180% to 200%. Diamond concentrations less than175% do not reduce the need for dressing and concentrations greater than 225% become difficult to bond with sufficient integrity. The diamonds may be coated or uncoated with a metal such as nickel or copper. If metal coated diamonds are used, the coating weight percent should be less than 40%, or less than or equal to 30%. Excessive coating amounts reduces the diamond concentration to too low of a level and does not result in reduced dressing of the resin bonded grinding wheel during use. The size of the diamonds, if not agglomerated, should be between 60/80 mesh size to 200/230 mesh size. Ranges above and below these limits do not provide the requisite packing density to achieve the desired diamond concentration.

While resin bond diamonds may be suitable, especially if agglomerated, the diamonds are preferred to be metal bond diamonds. Resin bond diamonds are generally too weak and friable to be used in a resin bonded grinding wheel to grind PDC. Metal bond diamonds are available in strengths from friable (weaker) to less friable (stronger). Such strength rating is qualified by various suppliers using different designations. In order to expose fresh diamonds more effectively, weaker metal bond diamonds are preferred. For example, if using diamonds from ABC Superabrasives, the strength is rated on a scale from ABS 2 (weak) to ABS 9 (strong). When using ABC Superabrasive diamonds, the diamonds are desirably ABS 2 or ABS 3. From Worldwide Superabrasives strength ratings from WSG 200 to WSG 900 are available. Suitable strength diamonds can include WSG 200, WSG300, WSG400, and WSG500. LANDS Superabrasives has strengths designated as LS200, LS230, LS250, LS260, LS270, and LS290. Suitable strength diamonds can include LS200, LS230, and LS240. In general, the bottom 50% of the strength scale for a given supplier's metal bond diamonds are suitable.

Suitable resin binders for use with the diamond abrasive particles include formaldehyde-containing resins, such as phenol formaldehyde, novolac phenolics and especially those with added crosslinking agent (e.g., hexamethylenetetramine), phenoplasts, and aminoplasts; unsaturated polyester resins; vinyl ester resins; alkyd resins, allyl resins; furan resins; epoxies; polyurethanes; cyanate esters; and polyimides. The amount of binder resin used in the resin bonded grinding wheel is from about 30% to about 40% by volume such as approximately 35% by volume of the high concentration diamond portion. In general, the amount of resin should be sufficient to fully wet the surfaces of all the individual particles during manufacturing such that a continuous resin structure, substantially devoid of porosity, is formed with the inorganic components discretely bonded throughout, which comprises the mechanical structure of the grinding wheel.

Suitable filler additives can include reinforcing particles, grinding aids, dessicants, colorants, and lubricants. As mentioned, both hard and soft filler particles are used in addition to the diamonds to reinforce and control the breakdown rate of the grinding wheel. Hard filler particles (excluding diamonds) are those having a Mohs hardness of 7 or greater. Suitable hard filler particles include aluminum oxide, silicon carbide, zirconia, ceramic alpha alumina particles typically derived from boehmite sol gels, or other abrasive particles having the requisite Mohs hardness. Soft filler particles have a Mohs hardness of 5 or less. Suitable soft fillers include petroleum coke, pyrophyllite, cryolite, lime, graphite, refractory grog, ball clay, copper, or talc. The volume ratio of the hard to soft filler particles is from (can be)15:85 to 85:15, or from 30:70 to 70:30, or from 40:60 to 60:40. Suitable hard filler particle sizes include sizes equal to or less than about 30 microns, such as 600, 800, or 1000 ANSI mesh equivalents. Suitable soft filler particles sizes include 100 mesh or finer. The soft particles can have a fine fraction and coarse fraction if desired. The fine fraction can be finer than 280 mesh and the coarse fraction can be from 100 to 180 mesh. If two sizes of soft filler particles are used the volume fraction of the coarse to fine particles can be 50:50 to 70:30. Too large a volume fraction of hard filler particles impedes breakdown leading to heat buildup and glazing of the grinding wheel, and too large a volume fraction of soft filler particles undesirably increase the wear rate of the grinding wheel. The volume percent of a mixture of hard filler particles and soft filler particles used in the resin bonded grinding wheel is from 5% to 30%, or from 8% to 20% of the high concentration diamond portion.

Other fillers can include fibrous and plate-like materials such as carbon or glass whiskers and mica. Grinding aids such as cryolite, potassium tetrafluoroborate (KBF4), polyvinyl chloride, lignosulfonates, and blends thereof. Colorants such as organic or inorganic pigments or dies may be incorporated into the grinding wheel.

EXAMPLES

Objects and advantages of this disclosure are further illustrated by the following non-limiting examples. The particular materials and amounts thereof recited in these examples as well as other conditions and details, should not be construed to unduly limit this disclosure. Unless otherwise noted, all parts, percentages, ratios, etc. in the Examples are by weight.

The following materials were used to prepare the inventive and comparative grinding wheels.

Table 1: Components

Symbol	Description
NP1	Phenolic Resin Powder from Hexion Speciality Chemicals Inc., Augusta, GA as Durite® AD-3237
NP2	Phenolic Resin Powder from Hexion Speciality Chemicals Inc., Augusta, GA as Durite® AD-5575
NP3	Phenolic Resin Powder from Hexion Speciality Chemicals Inc., Augusta, GA as Durite® AD-3235
SC	1000 grit Green Silicon Carbide from Washington Mills Electro Minerals Corp., Niagara Falls, NY as "CGW-3" Green Silicon Carbide, Wheel Grade, Grade 1000
BC	Boron Carbide, Grade 1000 from Electro Abrasives Corporation, Buffalo, NY as Electrobor™ B4C grade 1000
CU	Untreated Copper Powder from ACuPowder International LCC, Union, NJ as Copper Powder EL-100 untreated
MO	Magnesium Oxide from Atlantic Equipment Engineers, Bergenfield, NJ as Magnesium Oxide MG-601
PC1	Calcined Petroleum Coke from Asbury Graphite Mills Inc., Asbury, NJ as Calcined Petroleum Coke (4082)
PC2	Calcined Petroleum Coke from Asbury Graphite Mills Inc., Asbury, NJ as Calcined Petroleum Coke (4372)
CO	Calcium Oxide from Mississippi Lime, Alton, IL as Polycal™ OF325 Calcium Oxide
321	Ceramic abrasive from 3M Company, St. Paul, MN as 321 Cubitron™ JIS800
321B	Ceramic abrasive from 3M Company, St. Paul, MN as 321 Cubitron™ JB800
D1	Metal Bond Synthetic Diamond Powder, 30% Nickel Coated, 100/120 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as MB-100 N30 100/120
D2	Metal Bond Synthetic Diamond Powder, 30% Nickel Coated, 140/170 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as MB-100 N30 140/170
D3	LSMB0 Synthetic Metal Bond Diamond Powder, Uncoated, 200/230 mesh from LANDS Superabrasives Co., New York, NY
D4	LSMB0 Synthetic Metal Bond Diamond Powder, Uncoated, 325/400 mesh from LANDS Superabrasives Co., New York, NY
D5	LS-MA0 Synthetic Metal Bond Diamond Powder, Uncoated, 100/120 mesh from LANDS Superabrasives Co., New York, NY
D6	LS-MA0 Synthetic Metal Bond Diamond Powder, Uncoated, 120/140 mesh from LANDS Superabrasives Co., New York, NY
D7	LS-MA0 Synthetic Metal Bond Diamond Powder, Uncoated, 140/170 mesh from LANDS Superabrasives Co., New York, NY
D8	Resin Bond Synthetic Diamond Powder, Uncoated, 140/170 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as RB-150 140/170
D9	Resin Bond Synthetic Diamond Powder, 50% Copper Coated, 120/140 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as RB-150 C50 120/140
NP4	Resin Powder from Bitrez Ltd., Standish Wigan, Lancashire, United Kingdom as Dialok AR939P Resin Powder

Symbol	Description
CK	Synthetic Cryolite from Washington Mills, Tonawanda, NY as SODIUM HEXAFLUOROALUMINATE, CRYOLITE K
D10	Resin Bond Synthetic Diamond Powder, 30% Nickel Coated, 140/170 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as RB-150 N30 140/170
D11	Resin Bond Synthetic Diamond Powder, 56% Nickel Coated, 100/120 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as RB-150 N56 100/120
G	Graphite/Carbon 4539 Powder from Asbury Graphite Mills Inc., Asbury, NJ
D12	Metal Bond Synthetic Diamond Powder, 30% Nickel Coated, 60/80 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as MB-100 N30 60/80
D13	Metal Bond Synthetic Diamond Powder, 30% Nickel Coated, 80/100 mesh from WorldWide Superabrasives, Ft. Lauderdale, FL as MB-100 N30 80/100
D14	LSMB0 Synthetic Metal Bond Diamond Powder, Uncoated, 60/80 mesh from LANDS Superabrasives Co., New York, NY
D15	LSMB0 Synthetic Metal Bond Diamond Powder, Uncoated, 80/100 mesh from LANDS Superabrasives Co., New York, NY
D16	LSMB0 Synthetic Metal Bond Diamond Powder, Uncoated, 100/120 mesh from LANDS Superabrasives Co., New York, NY
D17	LS-MA0 Synthetic Metal Bond Diamond Powder, Uncoated, 80/100 mesh from LANDS Superabrasives Co., New York, NY
D18	LS00 Synthetic Metal Bond Diamond Powder, Uncoated, 200/230 mesh from LANDS Superabrasive Co., New York, NY

The grinding wheels of Examples 1, 7, 9 to 14 and Comparative Examples 1A to 6A were prepared and tested to evaluate their grinding performance on PDC. Examples 1 and Comparative Example 1A were evaluated under different grinding wheel dressing procedures. The weight percentage compositions of the various grinding wheels are shown in Table 2.

General Procedure for Forming Grinding Wheel Section

Each composition listed in Table 2 was thoroughly mixed for 4 hours in a 1000 ml polyethylene mixing jar and a roller mill stand (2-Bar Tumbler Base, C&M Topline Inc., Goleta CA) set at approximately 180 rpm. The abrasive wheels were direct-pressed onto preformed phenolic cores to yield type 1A1 abrasive wheel sections 8” OD x 1.25” TK x 1.25” ID, with diamond depth x = 0.375. The die cavity in the five-piece, ring-punch double-compaction steel mold was filled with the mixed abrasive composition by rotating the die assembly on a circular table while pouring the abrasive powder mixture into the annular cavity around the core. The powder was then smoothed and leveled with a plastic straightedge tool, and the filled mold was closed with the upper ring punch.

The filled mold was placed in a 200-ton heated-platen hydraulic press with the platen set point temperature set at 350 degrees F. The press platens were closed to bring the ring-punch surfaces flush against the mold shell. A magnetic thermometer was attached to the side of the mold shell and the mold temperature was monitored. When the mold shell reached 350 degree F, the mold was held closed under pressure for 20 minutes.

After 20 minutes at 350 degree F, the mold assembly was removed from the heated-platen press and placed on a water-cooled steel table and allowed to cool to room temperature. The mold shell was stripped from the formed wheel section using a 50-ton hydraulic press and steel spacers. The formed wheel sections were cured in air according the following schedule. One hour ramp to 150 degree F, one hour soak at 150 degree F, 4 hour ramp to 350 degree F, seven hour soak at 350 degree F, followed by 3 hour cool to room temperature.

The wheel sections were surface ground to thickness and then two sections were bonded together using epoxy adhesive. The bonded structure was then trued and dressed using a 40/60 grit SiC grinding wheel on a 3M E228 truing and dressing machine to make the final test grinding wheels

Table 2: Grinding Wheel Compositions

	Percent by Weight												
Component	**Example 1**	**Comp. Example 1A**	**Comp. Example 2A**	**Comp. Example 3A**	**Comp. Example 4A**	**Comp. Example 6A**	**Example 7**	**Example 9**	**Example 10**	**Example 11**	**Example 12**	**Example 13**	**Example 14**
NP1	0	19.5											
NP2	8.4	0			19.4	18.4	16.5		18.2	8.4	8.3	16.2	16.3
NP3	8.4	0								8.4	8.3		
SC	0	10.6	14.6	11.1									
BC	0	1.7											5.0
Cu	0	18.5											
MO	0	1.5											
PC1	3.9	0			4.5	4.3	2.1		3.5	3.9	3.8	3.8	
PC2	3.9	0								3.9	1.9		
CO	0.7	0	0.6	1.1	0.9	0.7	0.6	0.5		0.7	0.7	0.7	0.7
321	12.2	0			14.0	13.3	7.7		11.3	12.2	8.0		
321B											8.0	19.5	11.8
D1	0	34.5			38.8	16.5		21					
D2	0	8.1			9.1								
D3	0	2.8			3.2								
D4	0	2.8			3.2								
D5	23.6	0							25.2	23.5	20.4	20.0	
D6	23.6	0							25.2	23.5	20.4	20.0	20.2
D7	15.3	0								23.5			
D8			11.6										
D9			48.7										
NP4			14.1	12.1				16.1					
CK			10.4		6.9	6.5							5.8
D10				13.5									
D11				55.3									
G				6.9									
D12						16.5		21					
D13						23.8		41.4					
D14							18.8						
D15							33.9						
D16							20.4						
D17									16.6				
D18											20.2	19.8	20.0

Grinding Test

Cylindrical diamond cutter inserts (PDCs), obtained from US Synthetic Corporation, Orem, Utah, were ground using a centerless grinder (Acme Model 47 Centerless Grinder, Acme Manufacturing Company, Auburn Hills, Michigan) using the 8" diameter x 2.5" wide resin bond diamond wheels of Example 1 and Comparative Example A. The PDCs were mounted in a spring-loaded fixture to hold them during the grinding process. The grinding wheel speed was about 4000 SFPM and the regulating wheel speed was about 55 SFPM and the helix angle of the regulating wheel was set to about 3 degrees. This provided a grinding contact time of about 5.5 seconds per load of PDC. A coolant flood of 5% "Shell Metalina Y-850" (Shell Lubricants, Houston, Texas) in water was used. Depending on the size of the PDCs, testing was performed using either 2 PDCs per load or 3 PDCs per load as noted below:

Test Format	PDC Diameter	Diamond Depth per PDC	Carbide Depth per PDC
2 PDCs	Nominal 0.63"	0.085"	0.4365"
3 PDCs	Nominal 0.63"	0.062"	0.257"

Testing was performed with Comparative Example 1A that verified the 2 PDC format gave a similar polycrystalline diamond volume removal rate as the 3 PDC format. The motor load during grinding was controlled to about 2.5 – 3.1 amps over the idle load via in feed control of the regulating wheel. Test grinding wheels were dressed after every pass for the high frequency dressing test. For the low frequency dressing test, each grinding wheel was dressed after every 10th pass. Dressing was accomplished by manually contacting a 220 grit, 1" x 1" x 6" white dressing stick ("3M Dressing Stick 200TH", 3M Company, St. Paul, Minnesota) with the wheel and traversing it across the wheel a total of 6 passes.

Comparative Example 1A is a prior art resin bonded grinding wheel sold by 3M having part number MMMRBDW26435-R. Comparative Examples 2A and 3A utilized non-agglomerated resin bond diamonds, which were too friable and sheared off on the outer surface of the grinding wheels when grinding PDC leading to excessive glazing and poor cut. Comparative Example 4A used the same diamond concentration of

Comparative Example 1A of approximately 125% and a brittle soft filler particles instead of ductile soft filler particles. The need for dressing was reduced, but not significantly. Comparative Example 6A used the same 125% diamond concentration but the fine grade diamonds were replaced with courser grades. No significant performance difference was noted. Example 1 (185%), Example 7 (225%), Example 9 (200%), and Example 10 (200%) used significantly higher diamond concentrations with a mixture of hard and soft filler particles as described above. During test grinding on PDC, the need for dressing was significantly reduced.

Referring now to FIG. 2, the cut rate of the inventive grinding wheel was significantly greater than that of the comparative grinding wheel when dressing was employed every pass (0.0027 cubic inches versus 0.0023 cubic inches), and the inventive wheel had a good level of cut rate when dressing was employed only every 10th pass (0.0013 cubic inches versus 0.0008 cubic inches). The cut rate of the inventive wheel with only every 10th path dressing was approximately 48% of the single pass cut rate versus approximately 35% for the comparative wheel 1A.

Example 1 was evaluated at a customer who produces PDC's using centerless grinding. The centerless grinding application reduced the outside diameter of the PDC's to the final required diameter/tolerance and was conducted under a coolant flood. The existing grinding wheel that was previously used by the customer required frequent or substantially continuous abrasive media dressing to maintain stock removal with the existing diamond abrasive grinding wheel. When the Example 1 grinding wheel was installed on the centerless grinder, the PDC's were processed using the same previous grinding conditions of the prior existing diamond abrasive grinding wheel. No external abrasive dressing media was used on the Example 1 grinding wheel during the centerless grinding of the PDC's. The centerless grinding operations were able to continue to produce PDC's to the required finished size using the existing process parameters while achieving the same production rates without the use of abrasive wheel dressing or conditioning media on the surface of the Example 1 grinding wheel during the production of the PDC's. The total absence of dressing media while grinding PDC's had not been previously possible under the existing process conditions for any prior grinding wheel used. Furthermore, the Example 1 grinding wheels were fully consumed to the core while grinding the PDC's and did not become glazed over or inoperative at any point in the grinding process.

Other modifications and variations to the present disclosure may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present disclosure, which is more particularly set forth in the appended claims. It is understood that aspects of the various embodiments may be interchanged in whole or part or combined with other aspects of the various embodiments. All cited references, patents, or patent applications in the above application for letters patent are herein incorporated by reference in their entirety in a consistent manner. In the event of inconsistencies or contradictions between portions of the incorporated references and this application, the information in the preceding description shall control. The preceding description, given in order to enable one of ordinary skill in the art to practice the claimed disclosure, is not to be construed as limiting the scope of the disclosure, which is defined by the claims and all equivalents thereto.

What is claimed is:

1. A method of grinding comprising:
contacting a polycrystalline diamond compact with a grinding wheel;
the grinding wheel comprising diamonds, a resin binder, and a mixture of hard filler particles and soft filler particles; and
wherein the diamonds comprise a diamond concentration from 175 percent to 225 percent based on volume, the resin binder comprises 30 percent to 40 percent based on volume, a ratio of hard filler particles to soft filler particles in the mixture is from 85:15 to 15:85, and the mixture of hard filler particles and soft filler particles comprises 5 percent to 30 percent based on volume.

2. The method of claim 1 wherein the ratio of hard filler particles to soft filler particles in the mixture is from 70:30 to 30:70.

3. The method of claim 1 wherein the diamonds comprise metal bond diamonds.

4. The method of claim 2 wherein the hard filler particles comprise ceramic alpha alumina and the soft filler particles comprise petroleum coke.

5 An abrasive article comprising:
a grinding wheel, the grinding wheel comprising diamonds, a resin binder, and a mixture of hard filler particles and soft filler particles; and
wherein the diamonds comprise a diamond concentration from 175 percent to 225 percent based on volume, the resin binder comprises 30 percent to 40 percent based on volume, a ratio of hard filler particles to soft filler particles in the mixture is from 85:15 to 15:85, and the mixture of hard filler particles and soft filler particles comprises 5 percent to 30 percent based on volume.

6. The abrasive article of claim 5 wherein the ratio of hard filler particles to soft filler particles in the mixture is from 70:30 to 30:70.

7. The abrasive article of claim 4 wherein the diamonds comprise metal bond diamonds.

8. The abrasive article of claim 5 wherein the hard filler particles comprise ceramic alpha alumina and the soft filler particles comprise petroleum coke.

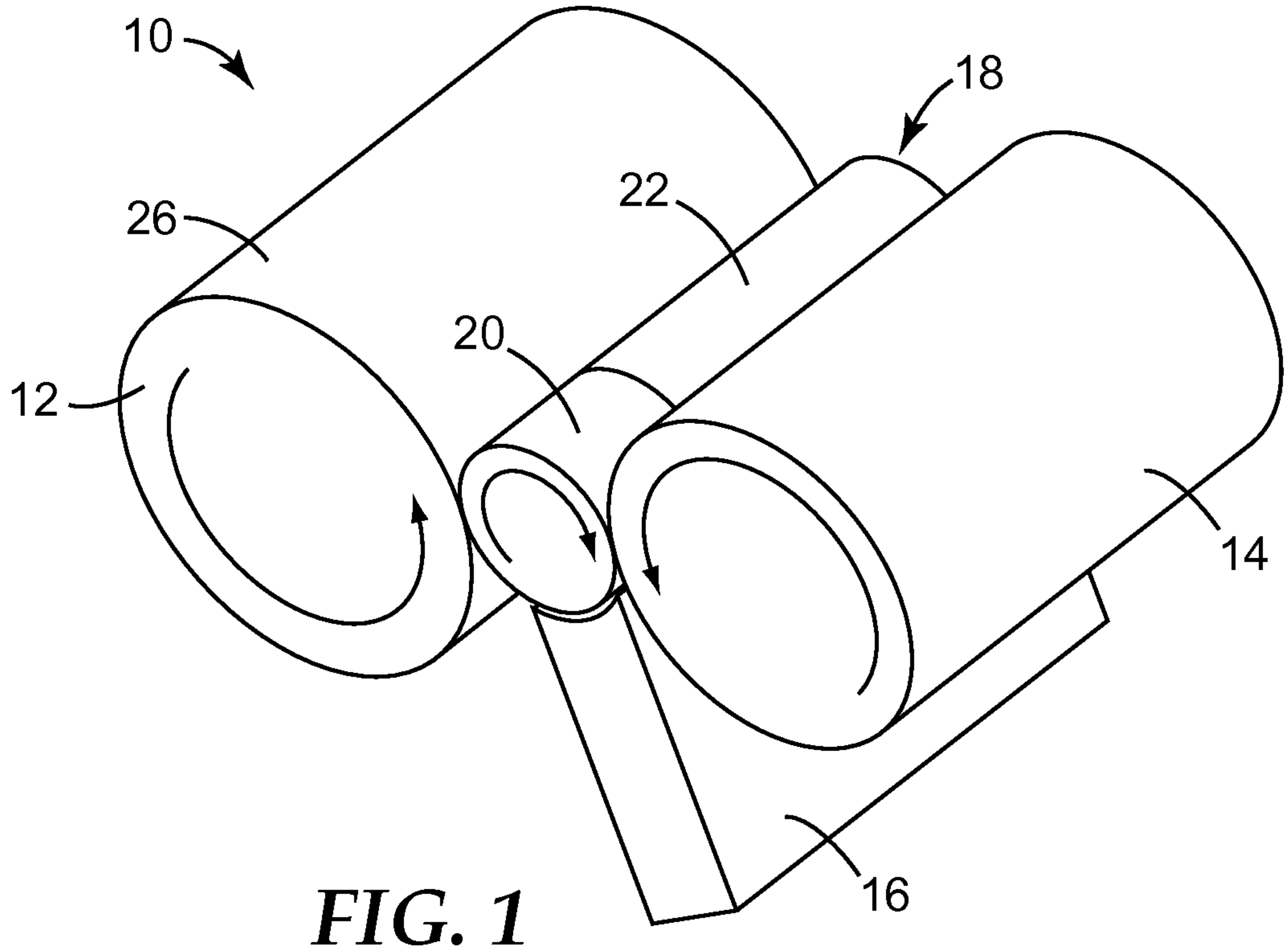
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FIG. 1

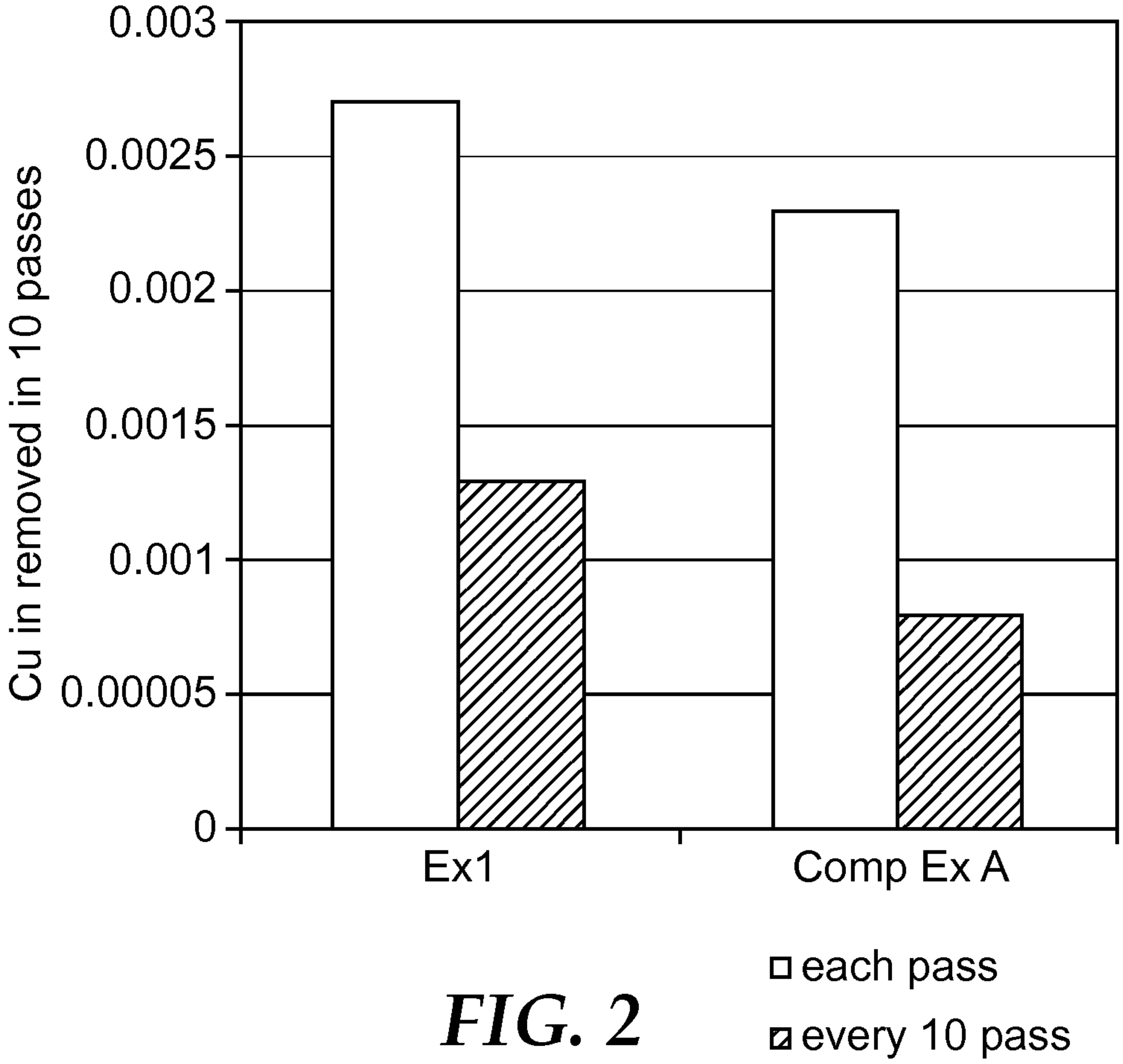
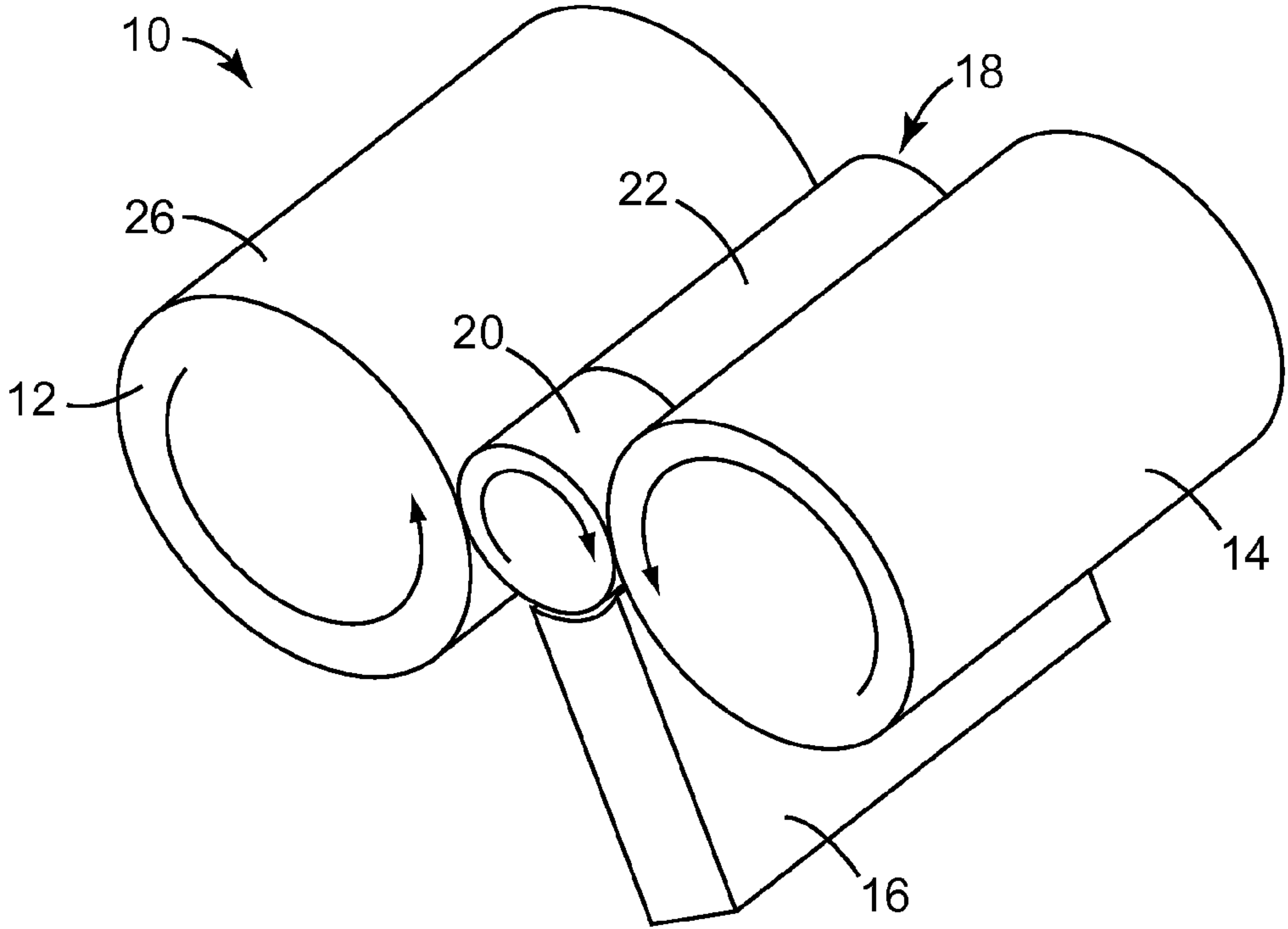

0.003
0.0025
0.002
0.0015
0.001
0.00005
0
Cu in removed in 10 passes
Ex1
Comp Ex A
each pass
every 10 pass

FIG. 2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