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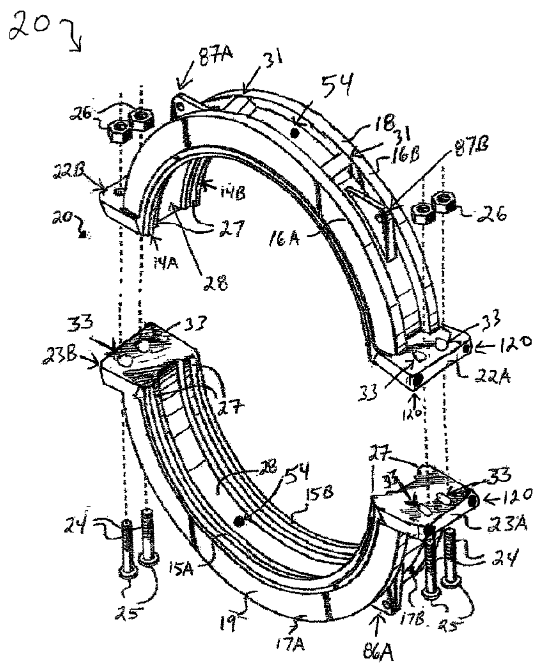


(57) Abrégé/Abstract:
An advanced coupling system that mechanically joins pipe elements together in an end to end configuration. The advanced coupling system interfaces with other coupling makes and models. The advanced coupling system can be fitted with spacers, deflection cones, orifice plates, check valves and protective pipe liners which are positioned between the inside faces of the piping elements with or without stiffening rings. Stiffening rings are fitted with optional access ports to accommodate wires, sensors and probes to monitor pressure, temperature, erosion and corrosion within piping systems. Installation of the protective pipe liners is dramatically improved with the use of an alignment tool and cradle. Installation of the coupling segments is dramatically improved with the use of hinges.

# ADAVANCED COUPLING SYSTEM


## ABSTRACT

An advanced coupling system that mechanically joins pipe elements together in an end to end configuration. The advanced coupling system interfaces with other coupling makes and models. The advanced coupling system can be fitted with spacers, deflection cones, orifice plates, check valves and protective pipe liners which are positioned between the inside faces of the piping elements with or without stiffening rings. Stiffening rings are fitted with optional access ports to accommodate wires, sensors and probes to monitor pressure, temperature, erosion and corrosion within piping systems. Installation of the protective pipe liners is dramatically improved with the use of an alignment tool and cradle. Installation of the coupling segments is dramatically improved with the use of hinges.

## ADVANCED COUPLING SYSTEM

## FIELD OF THE INVENTION

The invention concerns mechanical couplings for joining pipe elements in end-to-end configuration.

## BACKGROUND OF THE INVENTION

Couplings have been used for decades to join pipe elements in end-to-end relation. They differ from flange connections in that they are easier and quicker to install and typically require no welding. Flange connections on the other hand can have up to 28 studs and nuts on a 30" flange which need to be carefully torqued in sequence and to spec. If a flange is over or under tightened it can leak at the joint. Coupling systems eliminate the issues with over or under tightened sealing elements.

The mining sector is a large user of couplings as they typically have extensive piping networks which are low pressure. This makes couplings very attractive as they are easy to install and remove. Piping systems that transport slurries require continuous monitoring to ensure the integrity of the piping system. Couplings make the task of inspection easier and quicker.

Piping systems in the mining industry that transport abrasive slurries are typically rotated a quarter turn after so many hours of operation. This is due to the wear which is mostly concentrated at the 6 o clock position of the piping system. Turning the pipe increases the life expectancy of the piping system and reduces the possibility of a catastrophic failure should the slurry wear completely through the piping system. To save time and resources, mining companies will rotate several pipes at the same time which are joined together.

Coupling systems come in a variety of sizes, shapes and configurations. Coupling systems are typically designed for a single application. Having a variety of shapes and configurations increases the potential applications for couplings. The majority of coupling systems use a circumferential gasket. A gap exists between the faces of the piping elements so gas or liquids can energize the gasket.

## SUMMARY OF THE INVENTION

The advanced coupling system mechanically joins pipe elements together in an end to end configuration. The advanced coupling system consists of coupling segments having a pair of keys projecting radially inwardly toward said pipe elements with or without stiffening rings. A Pair of stiffening ribs projecting radially outwardly away therefrom is added to large coupling systems 20 inches and larger. A minimum of one perpendicular rib exists between the two circumferential ribs on each coupling segment. The stiffening ribs are substantially aligned with said coupling keys and are positioned in spaced apart relation to one another. Each coupling key engages a circumferential key groove on the stiffening ring or cut or rolled grooves on pipe elements. The coupling keys are positioned in spaced apart relation from one another and defining a space there between. The coupling keys are forcibly engaged circumferentially around the pipe elements with or without stiffening rings and the circumferential key grooves on the stiffening rings or pipe elements receive the keys on the coupling segments and said key grooves align perfectly with the keys on said coupling segments. A minimum of one sealing element is fitted and mechanically anchored to a minimum of one face of one stiffening ring. Anchoring points position and hold the standard sealing element in place. A standard circumferential gasket that surrounds the joint can also be used in addition to one or more sealing elements on the face of the stiffening ring. This gasket would only become energized if the sealing elements on the face were to fail.

The advanced coupling system is capable of handling high pressures, temperatures and chemicals due to multiple sealing configurations and sealing element material options. The majority of couplings are only capable of handling low pressures which has limited their use in the market place. The advanced coupling system addresses these issues with multiple sealing configurations and sealing elements. These configurations include optional grooves on the faces as well as well as optional circumferential grooves on the stiffening rings. A minimum of one groove is added on the face or circumferentially. When the optional grooves on the face are used, the standard sealing element on the face is eliminated. These grooves have sides, a bottom and a groove width and can be any size or shape. Each groove side has an orientation angle of $0^0$ to $50^0$ to reference planes. Groove side angles can be identical or different. The circumferential grooves receive sealing elements which are mechanically anchored. The grooves on the face of the stiffening rings receive sealing elements or spacers which are interchangeable and mechanically anchored. A minimum of one anchoring point positions and secures the sealing elements or spacers within the grooves. The spacer completely fills and seals a groove and energizes sealing elements it interfaces with. The sealing elements and spacers can be any shape or size, consisting of a wide range and choice of metallic or non-metallic or a combination of both materials to handle high pressures, temperatures and chemicals in order to handle a wide range of fluids, slurries and gases. These advancements enable the advanced coupling system to be used in high pressure and temperature applications that where once restricted to flanged connections.

The optional groove on the face of the stiffening ring can also receive an alignment ring. The alignment ring reduces misalignment of the two pipe ends which reduces leading edge wear and turbulence. The tapered alignment ring and a sealing element can be joined together. This alignment ring or alignment ring with sealing element is anchored to at least one anchoring point within a groove. The alignment ring or alignment ring and sealing element consist of one solid ring or multiple rings and are metallic or non-metallic or a combination of both.

The coupling stiffening rings consist of metallic, non-metallic or a combination of materials which consist of various hardness, toughness and corrosion resistance to address a wide range of applications. These stiffening rings can be welded, friction welded, bonded, threaded, bolted, cast or forged into piping elements, tanks, vessels, valves, flanges, pumps and shoots. These attachment options provide a significant advancement which significantly reduces installation time and costs. For example: but welded flanges require extensive and highly sophisticated welding processes. The advanced coupling system

provides a variety of options for materials and for attaching stiffening rings and these advancements offer a very high quality and low cost joint system.
A minimum of one optional access port can be added to any location on the stiffening ring to accommodate sensors, monitors, probes, wires, wear indicators and or plugs. These optional access ports can be fitted with permanent sensors, monitors, probes, wires, wear indicators and or plugs or any combination which also provide pressure containment and are locked into the access ports. Locking the sensors, monitors, probes, wires, wear indicators and or plugs in place ensures safety by preventing removal which may release high pressure and high temperature gases and liquids. Plugs can transfer signals and currents from wires or fiber optics from inside the piping element and or access port to the outside while maintaining high pressure containment. The access port can be opened and sensors, monitors and probes installed for monitoring purposes and then removed. The optional access ports extend from the outside diameter of the stiffening ring to the inside diameter of the stiffening ring or pipe or may extend only partially into the stiffening ring. A conductive device or fiber optic device can be embedded into liners or coatings inside the piping system and would run from one access port on one end of the pipe to an access port on the other end of the pipe and acts as a wear indication system. The conductive device or fiber optic device can be imbedded into liners and coatings at different depths and positioned anywhere circumferentially around the inside of the pipe which is lined or coated. The conductive device or fiber optic device can be any shape or size. These advancements enable monitoring of lined or coated piping systems without shutting down the piping system. These advancements eliminate the need to open the piping system to inspect the liner or coating.

The advanced coupling system interfaces with other coupling makes and models while still maintaining high pressure, temperature and corrosion resistance. Coupling systems do not have the standardization that is found within the world of flanges. Flanges, regardless of the manufacturer will interface with one another without any issues. The advanced coupling system solves this issue by offering coupling segments consisting of two keys which are identical or different in size, shape and dimensions having key surfaces of the same or different orientation angles ranging from $0^0$ to $45^0$ relative to said plane in order to connect to any coupling stiffening rings or pipe elements or combination thereof having rolled or cut grooves which are identical or different in size and shape having groove angles ranging from $0^0$ to $45^0$. This advancement enables the connection of any coupling system regardless of make, model or style resulting in a more standardization system which is common with flanged connections.

The advanced coupling system comes with stiffening rings which are mounted on the ends of the pipe elements to be joined face to face. The stiffening rings strengthen the pipe joint as no grooves are cut or rolled into the pipe element which would significantly weaken the joint. These stiffening rings come in standard, narrowed or extended lengths so as to interface with other coupling makes and models and to accommodate the fitment of spacers, deflection cones, orifice plates, check valves and protective pipe liners. These configurations allow for face to face fitment between two advanced coupling stiffening rings, one advanced coupling stiffening ring and a stiffening ring of another make or model, one advanced coupling stiffening ring and a pipe element with no stiffening ring, or the fitment of spacers, deflection cones, orifice plates, protective pipe liners and check valves.

Regardless of configuration, a gap no larger than 3/16 shall exist at any joint with an ideal gap being 1/32 or smaller. Maintaining a small gap at the joints is critical to achieving a high pressure connection. As well, joint gaps create huge issues when abrasive slurries are being transported in piping systems. Gaps create turbulence and leading edge wear on the downstream piping system. The advanced coupling system significantly reduces this issue.

Spacers, deflection cones, orifice plates, protective pipe liners and check valves can be fitted between the advanced coupling stiffening rings, between one advanced coupling stiffening ring and one stiffening ring of a different make or model, or between stiffening rings of different makes and models, between pipe elements with one or no stiffening rings while still maintaining high pressure, temperature and chemical resistance. Spacers, deflection cones, orifice plates, protective pipe liners and check valves can also be fitted between connections while still maintaining high pressure, temperature and chemical resistance. Spacers, deflection cones, orifice plates, protective pipe liners and check valves can be lined or coated to address corrosion and erosion issues. These accessories have been previously restricted to flanged type connections. These advancements reduce the gap between the flexibility and adaptability of flanged connections and coupling connections.

Spacers, deflection cones, orifice plates, protective pipe liners and check valves can be any shape or size, consisting of a wide range and choice of materials to handle high pressures, temperatures and chemicals. Spacers, deflection cones, orifice plates, protective pipe liners and check valves are anchored to a minimum of one stiffening ring or pipe element. Spacers, deflection cones, orifice plates, protective pipe liner rings and check valves come with optional anchoring points on the face to accommodate the installation of a rotation tool and assist with installation and removal. Additional optional circumferential anchoring points are added to the circumferential edge to accommodate rotation without substantial separation of the pipe ends.

Optional grooves can be added to the faces of the spacers, deflection cones, orifice plates, protective pipe liners and check valves which would receive sealing elements or spacers. These sealing elements and spacers are mechanically anchored. These grooves have sides, a bottom and a groove width and can be any size or shape. Each groove side has an orientation angle of $0^0$ to $50^0$ to reference planes. Groove side angles can be identical or different. Spacers, deflection cones, orifice plates, protective pipe liners and check valves can be fitted with one, two or no sealing elements or spacers and consist of non-metallic materials, metallic materials or a combination of both. The sealing elements and spacers are interchangeable.

Spacers, deflection cones and protective pipe liner rings come with optional holes which run from the OD to the ID. These holes are used to accommodate wires, sensors, probes and non-metallic materials. A minimum of one hole is added.

Spacers, deflection cones and protective pipe liners with or without a re-enforced sub-straight ring can be lined or coated with a non-metallic, metallic or combination of both materials. Both liners and coatings can be bonded or mechanically anchored or a combination of both. Metallic coatings can also be bonded by metallurgical means. Wires, sensors and probes can be imbedded into non-metallic liners and materials.

Protective pipe liners consist of a ring with a metallic or non-metallic liner or coating, or a ring and a re-enforced sub-straight ring with a metallic or non-metallic liner or coating. Protective pipe liners are positioned inside the inlet or outlet side of a piping element with or without stiffening rings. Protective pipe liners with no re-enforced sub-straight ring have an OD which is same as ID of the piping element. Protective pipe liners with re-enforced sub-straight rings have smaller OD's than the ID of the piping elements so as to address ovality issues and provide easier installation, rotation and removal as the surface area friction is significantly reduced. Sealing elements are added to the OD of the re-enforced sub-straight ring to provide a snug fit between the protective pipe liner and the ID of the piping element and to seal out contaminants. The sealing element can also be part of the non-metallic liner. The non-metallic liner wraps around the face of the re-enforced sub-straight ring that is placed into the piping element and ultimately has a larger OD than the re-enforced sub-straight ring creating a snug fit between the protective pipe liner and the piping element.

The advanced coupling system includes advancements to improve performance and safety with respect to the installation and removal of coupling segments. Although couplings are easier and quicker to install than traditional flanged connections, this advantage is significantly diminished with large coupling systems. A single coupling segment in a large diameter can weigh over 100 lbs. The advanced coupling system provides an alignment tool, a cradle and hinged coupling segments to address issues with installation, removal and injuries associated with these tasks.

An alignment tool is designed to be used with the advanced coupling system or other coupling systems with or without stiffening rings to improve installation and removal performance and safety. The alignment tool when fitted with a ram can pull pipe ends together or separate pipe ends. This is critical when using a near zero gap coupled connection as it would be very difficult to remove a section of pipe from the piping system without a gap at either end. The alignment tool can also assist with the installation and removal of protective pipe liners. The Alignment tool consists of two separate rings. Each ring is clamped over the two pipe elements. Each ring consists to two halves, a hinge and a connector. The two halves are spread over the pipe ends and the connector locks the two halves tightly over the pipe elements forcibly engaging the alignment ring keys into the key grooves on the stiffening rings or pipe elements. Each alignment ring has a minimum of two attachment points to accommodate all necessary attachments such as hydraulic rams and threated rods. The alignment tool allows for angular articulation enabling the two alignment tool rings to be connected together regardless of the misalignment of the two pipe ends. The alignment tool comes in sizes, models and styles so as to interface with all coupling makes, models and styles.

The stiffening ring has an optional groove on the outside of the ring opposite to the face which is positioned close to the outside diameter of the ring to accommodate the fitment of a cradle. The cradle consists of a threaded shaft or hydraulic ram which extends or contracts the cradle. The cradle holds the two pipe ends together while the coupling segments are being fitted. This device can cradle one of the coupling sections for easier fit up. The cradle can support a coupling segment when the piping system is horizontal, vertical or any angle in between. There is no interference between the cradle and the coupling segments which are being installed and fitted.

Coupling segments are fitted with anchoring points. These anchoring points accommodate hinges or lifting lugs for improved installation and removal performance and safety. The alignment tool, the cradle and the hinged coupling segments provide advancements that significantly improving the performance of installation and removal of coupling segments and accessories, but also significantly improve safety.

The coupling segments consist of metallic, non-metallic or a combination of materials which consist of various hardness, toughness and corrosion resistance to satisfy a wide range of applications. Optionally hardened coupling keys are added to increase strength and rigidity to the joint and to ensure the coupling segments life cycle substantially exceeds the lifecycle of the piping element with or without stiffening rings. The hardened keys offer several different camming surfaces that are identical or different and narrow the keys by as much as 85% on the inside faces of one or both keys at one or both ends of a coupling segment having the same or different lengths of camming surfaces that occupy between 2.5% to 30% of the total arc length of said key. Camming surfaces improve the fitment of the coupling sections when a gap exists between the two pipe element faces buy guiding said keys into said key grooves when said coupling segments are forcibly engaged circumferentially around said pipe elements with or without stiffening rings. Hardened keys are critical for this application.

Camming surfaces come in the following configurations:

The camming surfaces are created with concaved or convexly curved surfaces relative to the surface of the keys

The camming surfaces have an orientation angle between about $2^0$ to about $20^0$ relative to the respective key surfaces on which each camming surface is positioned

The camming surface is formed of a flat surface portion and a concavely curved surface portion. The flat surface portions are substantially parallel to reference plans and offset from the inside key surfaces. The curved surface portions provide a smooth transition between the flat surface portions and the surfaces of the keys.

The camming surface is formed of a flat surface portion and an angularly oriented surface portion. The flat surface portions are substantially parallel to reference plans and offset from the inside key surfaces. The angularly oriented surface portions have an orientation angle relatively to the surfaces of the keys of $2^0$ to about $45^0$ are feasible. The angularly orientated surface portions provide a smooth transition between the flat, offset portions and the surfaces of the keys.

The coupling segments can be fitted with optional access ports. Access ports accommodate sensors, monitors, probes and or plugs. A minimum of one optional access port can be added to a coupling segment and said access port completely or partially penetrates into the coupling segment from the outside diameter of the coupling segment. This advancement allows for monitoring of the piping system.

Stiffening rings without circumferential grooves and optional access ports can be fitted to piping elements. These stiffening rings can be mounted anywhere on piping elements between the two ends of the piping elements with or without stiffening rings attached to the ends. These rings provide additional monitoring capabilities.

## SUMMARY OF THE DRAWINGS

FIG. 1 is a partial cutaway view of the top of the advanced coupling system in end to end configuration with a near zero gap consisting of a coupling segment and two standard length stiffening rings with grooves on the faces. One of the grooves receives a sealing element while the other receives a spacer. Stiffening rings have circumferential key grooves which receive one of the coupling keys. Optional grooves which receive sealing elements are located circumferentially on each of the stiffening rings. The rings are attached to the end of pipe elements;

FIG. 1A is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of two stiffening rings attached to both ends of a pipe element and one stiffening ring with no circumferential grooves position in the middle of the piping element for the purpose of providing additional monitoring;

FIG. 2 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment and two standard length stiffening rings with a standard sealing element fitted and anchored to the face of one of the stiffening rings. An optional access port that extends through the stiffening ring is added to one of the stiffening rings which are fitted with a sensor, monitor or probe;

FIG. 2A is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment and two standard length stiffening rings with a tapered alignment ring with sealing element positioned between the two stiffening ring faces that is anchored to the face of one of the stiffening rings. An optional access port that extends through the stiffening ring and the pipe is added to one of the stiffening rings which are fitted with a sensor, monitor or probe. The pipe elements have a coating or liner attached to the inside diameter;

FIG. 3 is an enlarged scale cut away side view of the top of one stiffening ring which highlights the optional groove on the face which receives a sealing element or a spacer. An anchoring point is also shown. This groove can also be added to the faces of spacers, deflection cones, orifice plates, check valves and protective pipe liners;

FIG. 3A is an enlarged scale cut away side view of the top of one stiffening ring which highlights the optional circumferential groove which receives a sealing element;

FIG. 4 is an enlarged partial cut away view of the stiffening rings with grooves on the faces. One groove is fitted with a sealing element and the other one is fitted with a spacer. Both the sealing element and the spacer are mechanically anchored into the grooves and are interchangeable. Mechanical anchoring is achieved with anchoring points;

FIG. 5 is an enlarged partial cut away view of the top of a pipe element and a standard length stiffening ring that is welded to a piping element with a but weld;

FIG. 5A is an enlarged partial cut away view of the top of a pipe element and a standard length stiffening ring that is friction welded to a pipe element;

FIG. 6 is an enlarged partial cut away view of the top of a pipe element with standard length stiffening rings attached to both ends of the pipe element. The stiffening rings have optional access ports which extend to the inside diameter of the pipe. The access ports are fitted with plugs. The pipe has a non-metallic coating or liner with an embedded conductive device or fiber optic device. The conductive device or fiber optic device acts like a wear indication system.

FIG. 7 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment and one extended length stiffening ring with a groove on the face which receives a sealing element. The second ring is of a different make or model. The rings are attached to the end of pipe elements;

FIG. 8 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and one narrowed length stiffening ring with a groove on the face which receives a sealing element. The second ring is of a different make or model. A spacer is positioned between the face of the narrowed length stiffening ring and the second ring of a different make or model. The spacer must be firm enough to energize the sealing elements. The spacer has a groove on the one face which receives a sealing element. The groove and sealing element are positioned on the face of the spacer that faces the second ring of a different make or model. The spacer is anchored to one of the stiffening rings. The rings are attached to the end of pipe elements;

FIG. 9 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and one narrowed length stiffening ring with a groove on the face which receives a sealing element. The second ring is of a different make or model. A spacer is positioned between the face of the narrowed length stiffening ring and the second ring of a different make or model. The spacer must be firm enough to energize the sealing elements. Both the spacer and the pipe elements are lined with a non-metallic liner or coating. The spacer has a groove on the one face which receives a sealing element. The groove and sealing element are positioned on the face of the spacer that faces the second ring of a different make or model. The spacer is lined or coated and fitted with a conductive device or fiber optic device which acts as wear indicator. A hole accommodates the conductive device or fiber optic device. The spacer is anchored to one of the stiffening rings. The spacer and pipe elements can also be coated with a metallic coating. The stiffening rings are attached to the end of pipe elements;

FIG. 10 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. A spacer is positioned between the faces of the two narrowed length stiffening rings. The coupling segment has an access port in which a probe can be installed for the purpose of measuring thickness. The spacer is anchored to one of the rings. The rings are attached to the end of pipe elements;

FIG. 10A is a partial cutaway view of the top of a spacer with grooves on each face which receive sealing elements. This spacer will be positioned between two rings of a different make or model;

FIG. 11 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. A spacer is positioned between the faces of the two narrowed length stiffening rings. The spacer must be firm enough to energize the sealing elements. The spacer and the piping elements are lined or coated on the inside diameter with a non-metallic liner. However, a metallic coating could also be added to the spacer and piping elements. The coupling segment shows an access port in which a probe can be installed. A hole is added to the spacer to accommodate wires, sensors, probes and non-metallic materials. The spacer is anchored to one of the rings. The rings are attached to the end of pipe elements;

All spacers can also be fitted between flanged connections.

FIG. 12 shows the face of the spacer shown in FIG. 10. Four holes are added circumferentially around the spacer. These holes extend from the outside diameter of the spacer to the inside diameter of the spacer. Holes are added to the spacer to accommodate wires, sensors, probes and non-metallic materials. As well, when these holes are filled with a non-metallic material which continues on into the liner and consists of one solid piece, ultrasonic technology can be used to monitor the thickness of the liner;

FIG. 12A shows the a top view of the spacer with a hole to accommodate wires, sensors, probes and non-metallic materials;

Holes can be added to all spacers to accommodate wires, sensors, probes and non-metallic materials.

FIG. 13 is a partial cutaway view of the top of two pipe elements joined end to end with flanges. A spacer is fitted between the flange faces and lined or coated with a non-metallic material. The two pipe elements are also lined or coated with a non-metallic material. A conductive device or fiber optic device is imbedded into the non-metallic liner or coating. However, the spacer could also be coated or lined with a metallic coating. A hole is added to the spacer to accommodate wires, sensors, probes and non-metallic materials;

FIG. 14 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. A deflection cone is positioned between the faces of the two narrowed length stiffening rings. The coupling segment shows an access port in which an ultrasonic probe can be installed. The deflection cone is anchored to one of the rings. The rings are attached to the end of pipe elements;

FIG. 14A is a partial cutaway view of the top of a deflection cone with grooves on each face which receive sealing elements. This deflection cone will be positioned between two rings of a different make or model;

FIG. 15 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. An orifice plate is positioned between the faces of the two narrowed length stiffening rings. The coupling segment shows an access port in which an ultrasonic probe can be installed. The orifice plate is anchored to one of the rings. The rings are attached to the end of pipe elements;

FIG. 15A is a side cutaway view of an orifice plate with grooves on each face which receive sealing elements. The orifice plate will be positioned between two rings of a different make or model;

FIG. 16 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. A protective pipe liner is positioned between the faces of the two narrowed length stiffening rings and extends into the downstream piping element. The protective pipe liner consists of a ring and a non-metallic liner. The ring must be firm enough to properly energize the sealing elements. The coupling segment shows an access port in which an ultrasonic probe can be installed. The protective pipe line has a conductive device or fiber optic device which acts as a wear indicator imbedded into the non-metallic liner. A hole is added to the ring to accommodate wires, sensors, probes and non-metallic materials. The protective pipe liner is held in place due to a snug fit between the outside diameter of the protective pipe liner that extends into the downstream piping element and the inside diameter of the piping element. The rings are attached to the end of pipes;

FIG. 16A is a partial cutaway view of the top of a protective pipe liner with grooves on each face which receive sealing elements. This protective pipe liner will be positioned between two rings of a different make or model. The protective pipe liner consists of a ring and a non-metallic liner. The ring must be firm enough to properly energize the sealing elements. The protective pipe liner has a conductive device or fiber optic device which acts as a wear indicator imbedded into the non-metallic liner. A hole is added to the ring to accommodate wires, sensors, probes and non-metallic materials. The protective pipe liner is held in place due to a snug fit between the outside diameter of the protective pipe liner that extends into the downstream piping element and the inside diameter of the piping element;

FIG. 17 is a partial cutaway view of the top of a protective pipe liner. The protective pipe liner will be positioned between two narrowed stiffening rings. The protective pipe liner consists of a ring and a re-enforced sub-straight ring which is fitted inside the downstream piping element. The ring must be firm enough to properly energize the sealing elements. The outside diameter of the re-enforced sub-straight ring is slightly smaller than the inside diameter of the pipe element to deal with ovality issues. The ring and re-enforced sub-straight ring are lined with a non-metallic liner. However, a metallic coating can also be applied to the ring and re-enforced sub-straight ring. A conductive device or fiber optic device which acts as a wear indicator is imbedded into the non-metallic liner or coating. Several conductive devices or fiber optic devices which act as a wear indicators can be added to measure several different quadrants of the liner. A minimum of one sealing element is added to the outside of the re-enforced sub-straight ring at the end which is fitted into the piping element. Sealing elements provide a snug fit between the protective pipe liner and the inside diameter of the piping element and also seal out containments. The protective pipe liner can be used with coupling systems and flanged systems;

FIG. 17A is a partial cutaway view of the top of a protective pipe liner with grooves on each face which receive sealing elements. This protective pipe liner will be fitted between two rings of a different make or model. This protective pipe liner consists of a ring and a re-enforced sub-straight ring which is fitted inside the downstream piping element. The ring must be firm enough to properly energize the sealing elements. The outside diameter of the re-enforced sub-straight ring is slightly smaller than the inside diameter of the pipe element to deal with ovality issues. The ring and re-enforced sub-straight ring are lined with a non-metallic liner. However, a metallic coating can also be applied to the ring and re-enforced sub-straight ring. A conductive device or fiber optic device which acts as a wear indicator is imbedded into the non-metallic liner or coating. Several conductive devices or fiber optic devices which act as a wear indicators can be added to measure several different quadrants of the liner. A minimum of one sealing element is added to the outside of the re-enforced sub-straight ring at the end which is fitted into the piping element. Back up rings are used to position the sealing elements. Sealing elements provide a snug fit between the protective pipe liner and the inside diameter of the piping element and also seal out containments. The protective pipe liner can be used with coupling systems and flanged systems;

FIG. 18 is a partial cutaway view of the top of a protective pipe liner. This protective pipe liner will be positioned between two narrowed stiffening rings. This protective pipe liner consists of a ring and a re-enforced sub-straight ring which is fitted inside the downstream piping element. The ring must be firm enough to properly energize the sealing elements. The outside diameter of the re-enforced sub-straight ring is slightly smaller than the inside diameter of the pipe element to deal with ovality issues. The ring and re-enforced sub-straight ring are lined with a non-metallic liner which extends around the edge of the re-enforced sub-straight ring forming a sealing lip. The sealing lip is beveled to assist with the installation of the protective pipe liner. The outside diameter of the sealing lip is greater than that of the re-enforced sub-straight ring so as to create a seal between the protective pipe liner and the inside diameter of the piping element. A conductive device or fiber optic device which acts as a wear indicator is imbedded into the non-metallic liner or coating. Several conductive devices or fiber optic devices which act as a wear indicators can be added to measure several different quadrants of the liner. A metallic coating can also be applied to the ring and re-enforced sub-straight ring. The protective pipe liner can be used with coupling systems and flanged systems;

FIG. 19 shows the face of the ring for the protective pipe liners shown in FIG 17 and FIG. 18. Four holes are added circumferentially around the ring. These holes extend from the outside diameter of the ring to the inside diameter of the ring. Holes are added to the ring to accommodate wires, sensors, probes and non-metallic materials. When these holes are filled with a non-metallic material which continues on into the liner and consists of one solid piece, ultrasonic technology can be used to monitor the thickness of the liner. Optional anchoring holes can be added to the face of the ring. These anchoring points enable the attachment of a rotation tool and can also be used for installation and removal. These holes can be added to spacers, orifice plates, deflection cones, check valves and protective pipe liners. A minimum of four holes are added. Additional circumferential anchoring points can be added to the circumferential edge so as to rotate protective pipe liners, spacers and deflection cones without substantial separation of pipe ends.

FIG. 19A shows the top view of the ring with two holes to accommodate wires, sensors, probes and non-metallic materials as well as circumferential anchoring points;

FIG. 20 shows the rotation tool which is mounted to the face of the ring in FIG. 19. A minimum of four holes are added so anchoring bolts can attach the rotation tool to the ring. The center of the rotation tool has an octagon hole to accommodate a breaker bar so as to rotate the ring and ultimately the protective pipe liner;

FIG. 21 is a partial cutaway view of the top of two pipe elements joined end to end with flanges. This protective pipe liner will be fitted between the flange faces. This protective pipe liner consists of a ring and a re-enforced sub-straight ring which is fitted inside the downstream piping element. The outside diameter of the re-enforced sub-straight ring is slightly smaller than the inside diameter of the pipe element to deal with ovality issues. The ring and re-enforced sub-straight ring are lined with a non-metallic liner. However, a metallic coating can also be applied to the ring and re-enforced sub-straight ring. A minimum of one sealing element is added to the outside of the re-enforced sub-straight ring at the end which is fitted into the piping element. Sealing elements provide a snug fit between the protective pipe liner and the inside diameter of the piping element and also seal out containments. A conductive device or fiber optic device which acts as a wear indicator is imbedded into the non-metallic liner or coating. Several conductive devices or fiber optic devices which act as a wear indicators can be added to measure several different quadrants of the liner;

FIG. 22 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two different keys. One pipe element is fitted with a narrowed stiffening ring which receives one of the keys on the coupling segment. The second pipe element does not have a stiffening ring. The key groove on this second pipe element are cut or rolled into the pipe element. This key groove receives the second key on the coupling segment which has different dimensions. A protective pipe liner is positioned between the stiffening ring and the downstream pipe element. The protective pipe liner has a groove and sealing element on its face that faces the pipe element without the stiffening ring. This configuration also allows for joining pipe of different outside dimensions;

FIG. 23 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment with an access port and two pipe elements without stiffening rings. The key grooves on the two pipe elements are cut or rolled into the pipe elements which receive the two coupling keys. A spacer is positioned between the two pipe elements. The spacer has a groove one each face which receive a sealing element;

FIG. 24 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment and two narrowed length stiffening rings with grooves on the faces which receive sealing elements. A check valve is positioned between the faces of the two narrowed length stiffening rings. The check valve is anchored to one of the stiffening rings;

FIG. 24A is a partial cutaway view of the top of a check valve with grooves on each face which receive sealing elements. The check valve will be positioned between two rings of a different make or model;

FIG. 25 is a cut away side view of two bolt on stiffening rings and the side view of a gate valve. The stiffening rings bolt to the faces of the gate valve allowing the gate valve to be attached to a piping system with the advanced coupling system. Protective pipe liners are fitted to the bolt on stiffening rings and extend into the gate valve to the face of the gate. The stiffening rings can also be cast or forged into the valve body;

FIG. 26 is an exploded view of the coupling sections with stiffening ribs, perpendicular ribs, access ports, anchoring points for hinges and lifting lugs and cammed key surfaces;

FIG. 27 is a side view of the coupling sections which are hinged at one end and being supported by lifting slings. The coupling sections are flared open by the forces exerted on the two sections from the lifting slings. This configuration allows for easy installation of the coupling sections over the pipe elements with or without stiffening rings;

FIG. 28 is a partial sectional view of a coupling segment illustrating the camming of the coupling keys;

FIG. 28A is a view taken from circle 28A in FIG. 28 showing the camming of the coupling keys on an enlarged scale;

FIG. 29 is a partial sectional view of a coupling segment illustrating the camming of the coupling keys;

FIG. 29A is a view taken from circle 29A in FIG. 29 showing the camming of the coupling keys on an enlarged scale;

FIG. 30 is a partial sectional view of a coupling segment illustrating the camming of the coupling keys;

FIG. 30A is a view taken from circle 30A in FIG. 30 showing the camming of the coupling keys on an enlarged scale;

FIG. 31 is a partial sectional view of a coupling segment illustrating the camming of the coupling keys;

FIG. 31A is a view taken from circle 31A in FIG. 31 showing the camming of the coupling keys on an enlarged scale;

FIG. 32 is a partial sectional view of a coupling segment illustrating the camming of the coupling keys:

FIG. 32A is a view taken from circle 32A in FIG. 32 showing the camming of the coupling keys on an enlarged scale.

FIG. 33 is a side view of two pipe elements with stiffening rings attached to the ends. An alignment tool consisting of two separate rings is fitted and clamped over the two stiffening rings. Each alignment tool ring has keys which are received by the circumferential key grooves on the stiffening rings or pipe elements. Each alignment tool ring is fitted with a hinge and a connector. Each alignment ring has a minimum of two attachment points to accommodate the fitment of various devices such as rams and threaded rods. Figure 33 shows the alignment ring fitted with a two way ram. This device allows for angular articulation enabling the two alignment rings to be connected together regardless of the misalignment of the two pipe ends. The two way ram pulls the two pipe ends together or separates the two pipe ends.

FIG. 33A is a front view of one half of the alignment tool showing the hinge, the connector and two attachment points.

FIG. 34 is a side view of two pipes with stiffening rings attached to the ends. A cradle is attached to the two stiffening rings by engaging grooves on the back side of the stiffening rings. A threaded shaft or hydraulic ram extends or contracts the cradle. The cradle can hold the two pipe ends together while the two coupling segments are being fitted. This device can cradle one of the coupling sections for easier fit up. The cradle can support a coupling section when the piping system is horizontal, vertical or any angle in between.

## DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial cutaway view of the top of the advanced coupling system **80** in end to end configuration consisting of a coupling segment **18** and two standard length stiffening rings **3** and **4** attached to two pipe elements **1** and **2**. The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The stiffening rings **3** and **4** are fitted face to face with a near zero gap between them. The stiffening rings **3** and **4** have circumferential key grooves **12** and **13** which receive the coupling keys **14A** and **14B**. The stiffening rings **3** and **4** surround the pipe elements **1** and **2** and serve to add strength to the joint against stresses imposed by bending, pressure and compression due to thermal expansion.

The coupling segment **18** has a pair of keys **14A** and **14B** and a pair of stiffening ribs **16A** and **16B**. The keys **14A** and **14B** extend circumferentially around the coupling segment **18** and project radially inwardly towards the stiffening rings **3** and **4**. The stiffening ribs **16A** and **16B** extend circumferentially around the coupling segment **18** and project radially outwardly away from the stiffening rings **3** and **4.** The keys **14A** and **14B** are in spaced apart relation with a space there between **28.** The ribs **16A** and **16B** are also in spaced apart relation with a space there between **21**; each rib is aligned with a respective key. It is advantageous to align the ribs with the keys to effectively strengthen and stiffen the coupling segments close to where the loads are applied by the pipes to the coupling thereby maintaining maximum key engagement with the circumferential key grooves. Stiffening ribs are utilized on larger diameter couplings, 20 inches in diameter and larger.

Circumferential key grooves **12** and **13** are positioned on the outside diameter of the stiffening rings **3** and **4** which receive keys **14A** and **14B** of the coupling segment **18.** It is advantageous to position the circumferential key grooves **12** and **13** in the rings rather than in the pipe elements **1** and **2** to avoid thinning of the piping and thereby weakening the piping connection. The circumferential key grooves **12** and **13** have a complementary shape to the coupling keys **14A** and **14B**. Engagement of the keys within the grooves prevents thrust loads from separating the pipe elements when they are under pressure. Preferably, the keys and key grooves are sized so that the keys fill the key grooves when the coupling segments are fastened together.

The stiffening rings **3** and **4** have grooves on the faces **10** and **11** which receive a sealing element **5** or spacer **101**. The sealing element **5** and the spacer **101** are interchangeable and are mechanically anchored. A near zero gap exists between the two stiffening rings **3** and **4**. Optional circumferential grooves **55** and **56** can be added to the stiffening rings for additional sealing for extreme high pressure applications. Each circumferential groove receives a sealing element **5**;

FIG. 1A is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of two stiffening rings **3** and **4** attached to both ends of a pipe element **1** and one stiffening ring with no circumferential grooves **32** positioned in the middle of the piping element **1** for the purpose of providing additional monitoring. The stiffening ring with no circumferential grooves **32** is fitted with a minimum of one access port 54 to accommodate wires, sensors, monitors and probes;

FIG. 2 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two standard length stiffening rings **3** and **4** with a standard sealing element **34** fitted and anchored to the face of one of the stiffening rings with the anchoring points **121**. An optional access port **54** that extends through the stiffening ring 3 is added and is fitted with a sensor, monitor or probe **53**;

FIG. 2A is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two standard length stiffening rings **3** and **4** with a tapered alignment ring with sealing element **90** positioned between the two stiffening ring faces that is anchored to the face of one of the stiffening rings with anchoring points **121**. An optional access port 54 that extends through the stiffening ring **3** and the pipe element 1 is added and fitted with a sensor, monitor or probe **53**. The pipe elements **1** and **2** have a coating or liner **60** attached to the inside diameter;

FIG. 3 is an enlarged scale cut away side view of the top of one stiffening ring **4** without circumferential grooves and sealing elements which highlights the groove **10** on the face which receives a sealing element or a spacer. The groove consists of two sides **62,** a width **116** and a bottom **82**. Each side of the groove has an orientation angle **83** and **84** between $1^0$ and $50^0$ relative to an imaginary reference plane **81**. The groove width **116** ranges from .125 inches to 1 inch. The groove depth **82** can range from .125 inches to 1 inch. The sealing element **5** and the spacer **11** are positioned and held in place by anchoring points 118;

FIG. 3A is an enlarged scale cut away side view of the top of one stiffening ring **4** which highlights the optional circumferential groove **55** which receives a sealing element. The groove consists of two sides **62,** a width **116** and a bottom **82**. Each side of the groove has an orientation angle **83** and **84** between $1^0$ and $50^0$ relative to an imaginary reference plane **85**. The groove width **116** ranges from .125 inches to 1 inch. The groove depth **82** can range from .125 inches to 1 inch;

FIG. 4 is an enlarged partial cut away side view of the standard length stiffening rings **3** and **4** with grooves **10** and **11** on the faces. Groove **10** is fitted with a sealing element **5** and groove **11** is fitted with a spacer **101**. Both the sealing element **5** and the spacer **101** are mechanically anchored with anchoring points **79** in the grooves. The sealing element **5** and the spacer **101** and are interchangeable.

FIG. 5 is an enlarged partial cut away view of the top of a pipe element **1** and a standard length stiffening **3** ring that is welded to a piping element **1** with a but weld **119**;

FIG. 5A is an enlarged partial cut away view of the top of a pipe element **1** and a standard length stiffening ring **3** that is friction welded **120** to pipe element **1**;

FIG. 6 is an enlarged partial cut away view of the top of a pipe element **2** with standard length stiffening rings **3** and **4** attached to both ends of the pipe element **2**. The stiffening rings **3** and **4** have optional access ports **54** which extend to the inside diameter of the pipe element **2**. The access ports **54** are fitted with plugs **57**. The pipe has a non-metallic coating or liner **60** with an embedded conductive device or fiber optic device **61**. The conductive device or fiber optic device **61** acts like a wear indication system.

FIG. 7 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and one extended length stiffening ring **6** attached to a pipe element **2** and one stiffening ring of a different make and model **29** attached to pipe element **1**. The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The extended length stiffening ring **6** and stiffening ring of a different make and model **29** are fitted face to face with a near zero gap between them. The extended length stiffening ring **6** has a groove **10** on the inside face. The groove **10** is fitted with a sealing element **5.** The rings are attached to the pipe elements;

FIG. 8 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** which is fitted with an access port **54**. A narrowed stiffening ring **7** is attached to pipe element **2** and one stiffening ring of a different make and model **29** is attached to pipe element **1**. The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The narrowed stiffening ring **7** has a groove **10** on the inside face. The groove **10** is fitted with a sealing element **5**. A spacer **48** with a groove **10** and sealing element **5** is fitted between the narrowed stiffening ring **7** and the stiffening ring of a different make and model **29**. The spacer must be firm enough to energize the sealing elements. The face of the spacer that faces the stiffening ring of a different make and model **29** is fitted with a groove **10** and a sealing element **5**. This configuration creates a near zero gap connection. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe. The spacer is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature;

FIG. 9 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and a narrowed stiffening ring **7** and a ring from a different make or model **29** attached to pipe elements **1** and **2.** The pipe elements **1** and **2** are joined in end to end relation using mechanical coupling segment **18**. The narrowed stiffening ring **7** has a groove **10** on the inside face which is fitted with sealing element **5**. A spacer **48** with a groove **10** and sealing element **5** is fitted between the narrowed stiffening ring **7** and the ring of a different make or model **29**. The spacer must be firm enough to energize the sealing elements **5**. This configuration creates a near zero gap connection. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe or by use of an electronic wear indicator **61**. A hole **99** is added to the spacer **48** to accommodate wires, sensors, probes and non-metallic materials. The spacer **48** and the piping elements **1** and **2** are lined with a non-metallic liner **60**. However, the spacer and the piping elements can also be coated with a metallic material. The spacer is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature;

FIG. 10 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** which are attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The narrowed stiffening rings **7** and **8** having grooves **10** and **11** on the inside face which are fitted with sealing elements **5**. A spacer **43** with no grooves or sealing element or spacers is fitted between the two narrowed stiffening rings **7** and **8**. The spacer must be firm enough to energize the sealing elements **5**. This configuration creates a near zero gap connection. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe **53.** The spacer is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature. If the spacer is non-metallic in nature an electronic wear indicator can be imbedded into the spacer **43**;

FIG. 10A is a partial cutaway view of a spacer **48** with grooves **11** and **10** on both faces and sealing elements **5**. The spacer **48** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings. The spacer **48** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. The advanced coupling system couplings **18** and **19** can be used to connect the two pipe elements in an end to end configuration. Using coupling segments **18** and **19** would enable the addition of an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe or by use of an electronic wear indicator. The spacer is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature and can be used with any coupling system or flanged connections;

FIG. 11 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** which are attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18.** The narrowed stiffening rings **7** and **8** have grooves **10** and **11** on the inside face which are fitted with sealing elements **5**. A spacer **43** with no grooves with sealing elements or spacers is fitted between the two narrowed stiffening rings **7** and **8**. The spacer must be firm enough to energize the sealing elements. The spacer **43** and the piping elements **1** and **2** are lined with a non-metallic material. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe **53.** A hole is added to the spacer **43** to accommodate wires, sensors, probes or non-metallic materials. The spacer **43** is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature;

All spacers can also be fitted between flanged connections.

FIG. 12 shows the face of spacer **43** with no grooves, seals or spacers found in FIG. 11. Holes **99** are added circumferentially around the spacer **43**. These holes extend from the outside diameter of the spacer **43** to the inside diameter of the spacer **43**. Holes **99** are added to the spacer **43** to accommodate sensors, wires, probes and non-metallic materials. When these holes are filled with a non-metallic material which continues on into the liner making one solid piece, ultrasonic technology can be used to monitor the thickness of the liner. These holes **99** can be added to spacers with no grooves or one or more grooves fitted with sealing elements;

FIG. 12A shows the a top view of the spacer **43** with no grooves, seals or spacers with a hole **99** to accommodate sensors, wires, probes and non-metallic materials **60**. A minimum of one hole is added to accommodate sensors, wires, probes and non-metallic materials;

Holes can be added to all spacers to accommodate sensors, wires, probes and non-metallic materials.

FIG. 13 is a partial cutaway view of the top of two pipe elements **1** and **2** joined end to end with flanges **94** and **95**. A spacer **96** is fitted between the flange faces and is lined with a non-metallic liner. The spacer is hard enough to properly energize the sealing gaskets at the flange connections. A stud **97** and two nuts **26** connect the two flanges together and compress the spacer **96** between the two flange faces. One or more holes **99** are added to the spacer to accommodate wires, sensors, probes and non-metallic materials. The two pipe elements **1** and **2** are also lined with a non-metallic liner **60**. A conductive device or fiber optic device **61** is imbedded into the non-metallic liner **60**. However, the spacer **96** and pipe elements **1** and **2** could also be coated with a metallic coating;

FIG. 14 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The narrowed stiffening rings **7** and **8** have grooves **10** and **11** on the inside faces. The grooves **10** and **11** are fitted with sealing elements **5**. A deflection cone **45** is fitted between the narrowed stiffening rings **7** and **8**. This configuration creates a near zero gap connection. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the deflection cone **45** with an ultrasonic probe **53** or by use of an electronic wear indicator. The deflection cone is anchored to one of the stiffening rings. The deflection cone can be metallic or non-metallic in nature;

FIG. 14A is a partial cutaway view of a deflection cone **50** with grooves **11** and **10** on both faces and sealing elements **5**. This deflector cone **50** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings. The deflection cone **50** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. The advanced coupling system couplings **18** and **19** can be used to connect the two pipe elements in an end to end configuration. Using coupling segments **18** and **19** would enable the addition of an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the deflection cone with an ultrasonic probe **53** or by use of an electronic wear indicator. The deflection cone is anchored to one of the stiffening rings. The deflection cone can be metallic or non-metallic in nature and can be used with any coupling system or any flanged connections;

FIG. 15 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. Narrowed stiffening rings **7** and **8** have grooves **10** and **11** on the inside faces. The grooves **10** and **11** are fitted with sealing elements **5**. An orifice plate **47** with no grooves, seals or spacers is fitted between the narrowed stiffening rings **7** and **8** and has a hole in the center **59**. This configuration creates a near zero gap connection. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the orifice plate **47** with an ultrasonic probe **53.** The orifice plate is anchored to one of the stiffening rings. The orifice plate can be metallic or non-metallic in nature;

FIG. 15A is a cutaway view of an orifice plate **52** with grooves **11** and **10** on both faces and sealing elements **5**. This orifice plate **52** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings. The orifice plate **52** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. A hole **59** is located in the center of the orifice plate. The advanced coupling system couplings **18** and **19** can be used to connect the two pipe elements in an end to end configuration. Using coupling segments **18** and **19** would enable the addition of an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer with an ultrasonic probe **53.** The orifice plate is anchored to one of the stiffening rings. The spacer can be metallic or non-metallic in nature and can be used with any coupling system or any flanged connections;

FIG. 16 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. The piping elements **1** and **2** are lined with a non-metallic liner **60**. However, the piping elements **1** and **2** could also be coated with metallic coatings like chromium carbide or other similar erosion and corrosion resistant materials. The narrowed stiffening rings **7** and **8** have grooves **10** and **11** on the inside faces. The grooves **10** and **11** are fitted with sealing elements **5**. A protective pipe liner **44** with no grooves, seals or spacers is fitted between the narrowed stiffening rings **7** and **8**. The protective pipe liner **44** consists of a ring **75** and a non-metallic liner **60**. However, the liner could also be coated with a metallic coating. This configuration creates a near zero gap connection. The coupling segment **18** is fitted with an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the protective pipe liner with an ultrasonic probe **53** or by use of a conductive device or fiber optic device **61**. A hole **99** is added to the protective pipe liner ring **75** to accommodate wires, sensors, probes and non-metallic materials. The protective pipe liner **44** is fitted into the downstream pipe element **1** and compression between the protective pipe liner **44** and the piping element **1** hold the liner in position. The protective pipe liner ring **75** can be metallic or non-metallic in nature;

FIG. 16A is a partial cutaway view of a protective pipe liner **49** with grooves **11** and **10** on both faces and sealing elements **5**. The protective pipe liner **49** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings. The protective pipe liner **49** consists of a ring **105** and a non-metallic liner **60**. The protective pipe liner **49** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. The advanced coupling system couplings

**18** and **19** can be used to connect the two pipe elements in an end to end configuration. Using coupling segments **18** and **19** would enable the addition of an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the protective pipe liner **49** with an ultrasonic probe **53** or by use of a conductive device or fiber optic device **61**. A hole **99** is added to the protective pipe liner ring **105** to accommodate wires, sensors, probes and non-metallic materials. The protective pipe liner **49** is fitted into the downstream pipe element and compression between the protective pipe liner **49** and the piping element hold the liner in position. The protective pipe liner ring **105** can be metallic or non-metallic in nature. The protective pipe liner **49** can be used with any coupling system or flanged connections;

FIG. 17 is a partial cutaway view of the top of a protective pipe liner **110** with no grooves, seals or spacers. The protective pipe liner **110** will be positioned between two narrowed stiffening rings and consists of a ring **104** and a non-metallic liner **60**. The protective pipe liner **110** utilizes a re-enforced sub-straight ring **92** which is fitted inside the piping element and allows for a small clearance between the ID of the piping element and the OD of the re-enforced sub-straight ring **92** to address ovality issues. A non-metallic liner **60** is attached to the re-enforced sub-straight ring **92** and liner ring **104**. However, a metallic coating can also be applied to the re-enforced sub-straight ring **92** and the liner ring **104**. The re-enforced sub-straight ring **92** provides more rigidity of the liner which may be necessary with larger diameter protective pipe liners. A continuity device or fiber optic device **61** can be imbedded into the non-metallic liner **60** to act as a wear indicator. Several continuity devices or fiber optic devices **61** can be added to measure several different quadrants of the liner. A minimum of one sealing element **93** is added to the outside diameter of the re-enforced sub-straight **92** ring at the end which is fitted into the piping element. Sealing elements **93** provide a snug fit between the protective pipe liner **110** and the inside diameter of the piping element and also seal out containments. The protective pipe liner ring **104** can be metallic or non-metallic in nature;

FIG. 17A is a partial cutaway view of the top of a protective pipe liner with grooves **11** and **10** on both faces and sealing elements **5**. The protective pipe liner **111** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings and consists of a ring **109** and a non-metallic liner **60**. The protective pipe liner **111** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. The protective pipe liner **111** utilizes a re-enforced sub-straight ring **92** which is fitted inside the piping element and allows for a small clearance between the ID of the piping element and the OD of the re-enforced sub-straight ring to address ovality issues. A non-metallic liner **60** is attached to the re-enforced stub-straight ring **92** and the liner ring **109**. However, a metallic coating can also be applied to the re-enforced sub-straight ring **92** and the liner ring **109**. The re-enforced sub-straight ring provides more rigidity of the liner which may be necessary with larger diameter protective pipe liners. A continuity device or fiber optic device **61** can be imbedded into the non-metallic liner **60** to act as a wear indicator. Several continuity devices or fiber optic devices can be added to measure several different quadrants of the liner. A minimum of one sealing element **93** is added to the outside diameter of the re-enforced sub-straight ring **92** at the end which is fitted into the piping element. Sealing elements **93** provide a snug fit between the protective pipe liner **111** and the inside diameter of the piping element and also seal out containments. The protective pipe liner ring **109** can be metallic or non-metallic in nature. The protective pipe liner **111** can be used with any coupling system or flanged connections;

FIG. 18 is a partial cutaway view of the top of a protective pipe liner **115** with no grooves, seals or spacers and has a sealing element with a beveled edge **114**. This protective pipe liner **115** will be positioned between two narrowed stiffening rings. This protective pipe liner consists of a ring **104** and a re-enforced sub-straight ring **92** which is fitted inside the downstream piping element. The ring must be firm enough to properly energize the sealing elements. The outside diameter of the re-enforced sub-straight ring **92** is slightly smaller than the inside diameter of the pipe element to deal with ovality issues. The ring and re-enforced sub-straight ring are lined with a non-metallic liner **60** which extends around the edge of the re-enforced sub-straight ring **92** forming a sealing element with a beveled edge **114**. The sealing element is beveled to assist with the installation of the protective pipe liner. The outside dimeter of the sealing element **114** is greater than that of the re-enforced sub-straight ring **92** so as to create a seal between the protective pipe liner **115** and the inside diameter of the piping element. A metallic coating can also be applied to the ring **104** and re-enforced sub-straight ring **92**. A continuity device or fiber optic device **100** can be imbedded into the non-metallic liner **60** to act as a wear indicator. Several continuity devices or fiber optic devices wires **100** can be added to measure several different quadrants of the liner;

FIG. 19 shows the face of the ring **104** for the protective pipe liner **110** shown in FIG 17. and FIG.18. Four holes **99** are added circumferentially around the ring **104**. These holes **99** extend from the outside diameter of the ring **104** to the inside diameter of the ring **104**. Holes **99** are added to the ring **104** to accommodate wires, sensors, probes and non-metallic materials. When these holes **99** are filled with a non-metallic material **60** which continues on into the liner and consists of one solid piece, ultrasonic technology can be used to monitor the thickness of the liner. Optional anchoring holes **102** can be added to the face of the ring **104**. These anchoring points enable the attachment of a rotation tool and can also be used for installation and removal. These holes can be added to spacers, orifice plates, deflection cones, check valves and protective pipe liners. A minimum of four holes are added. Additional circumferential anchoring points **117** can be added to the circumferential edge so as to rotate the protective pipe liners and deflection cones without substantial separation of the pipe ends. The protective pipe liner ring **104** can be metallic or non-metallic in nature and can be used with any coupling systems and flanged systems;

FIG. 19A shows the top view of the ring **104** with two holes **99** to accommodate wires, sensors, probes and non-metallic materials **60** as well as circumferential anchoring points **117**;

Holes **102** are can be added to the face of spacers, deflection cones, orifice plates, check valves and protective pipe liners to provide anchoring points to mount a rotation tool or provide anchoring points to assist with installation or removal.

FIG. 20 shows the rotation tool **106** which is mounted to the face of the ring **104** in FIG. 19. A minimum of four holes **107** are added so anchoring bolts can attach the rotation tool **106** to the ring **104**. The center of the rotation tool has an octagon hole **108** to accommodate a breaker bar so as to rotate the rings and ultimately the protective pipe liners. Erosion is mostly concentrated at the bottom of piping systems so rotation of the liner will extend the life cycle of the liner;

The rotation tool can be attached to all the protective pipe liner rings.

FIG. 21 is a partial cutaway view of the top of two pipe elements **1** and **2** joined end to end with flanges **94** and **95**. A protective pipe liner **98** with no grooves, seals or spacers consisting of a ring **112** and a re-enforcing sub-straight ring **92** is fitted between the flange faces and lined with a non-metallic liner **60**. A stud **97** and two nuts **26** connect the two flanges together and compress the protective pipe liner **98** between the two flange faces. The protective pipe liner and the piping elements are lined with a non-metallic liner **60**. A conductive device or fiber optic device **61** is imbedded into the non-metallic liner and a hole is added to the ring **112** to accommodate wires, sensors, probes and non-metallic materials. A continuity device or fiber optic device **61** can also be imbedded into the non-metallic liner **60** to act as a wear indicator. Several continuity devices or fiber optic devices can be added to measure several different quadrants of the liner. A metallic coating can also be applied to the re-enforced sub-straight ring **92** and the liner ring **112**. The re-enforced sub-straight ring **92** provides more rigidity of the liner which may be necessary with larger diameter protective pipe liners **98**. A minimum of one sealing element 93 is added to the outside of the re-enforced sub-straight ring at the end which is fitted into the piping element. Sealing elements provide a snug fit between the protective pipe liner and the inside diameter of the piping element and also seal out contaminants. The protective pipe liner ring **112** can be metallic or non-metallic in nature. A hole **99** is added to the ring to accommodate wires, sensors, probes and non-metallic materials;

FIG. 22 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **77** with two different keys **14A** and **76B.** Pipe element **1** is fitted with a narrowed stiffening ring **7** which receives one of the keys on the coupling segment **77**. The second pipe element **9** does not have a stiffening ring. The key groove on the second pipe element **9** are cut or rolled into the pipe element **9**. The pair of pipe elements **2** and **9** is joined in end to end relation using mechanical coupling segment **77**. The narrowed stiffening ring **7** has a groove on the face **10** that receives a sealing element **5**. A protective pipe liner **113** consisting of a ring **105** and a non-metallic liner **60** is fitted between the narrowed stiffening ring **7** and the pipe element **9**. The protective pipe liner **113** has a groove **11** on the face towards the pipe element **9** which is fitted with a sealing element **5**. The protective pipe liner ring **105** can be metallic or non-metallic in nature. This configuration also allows for joining pipe of different outside dimensions;

Liners can be bonded or mechanically anchored to all rings and re-enforcing sub-straight rings or a combination of both.

FIG. 23 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **78** with two identical keys **76A** and **76B** of different dimensions. Pipe elements **91** and **9** are not fitted with stiffening rings and instead have cut or rolled key grooves which receive the coupling segment **78** keys **76A** and **76B**. A spacer **48** with grooves **10** and **11** and seals **5** are fitted between the two pipe elements **91** and **9**. The spacer **48** when fitted between two pipe elements without stiffening rings create the seal and provide a near zero gap joint. Coupling segment **78** has an access port **54**. The access port **54** allows for monitoring the erosion and corrosion on the spacer **48** with an ultrasonic probe or by use of a conductive device or fiber optic device. The spacer is anchored to one of the stiffening rings. The spacer **48** can be metallic or non-metallic in nature;

FIG. 24 is a partial cutaway view of the top of the advanced coupling system in end to end configuration consisting of a coupling segment **18** and two narrowed stiffening rings **7** and **8** attached to pipe elements **1** and **2.** The pair of pipe elements **1** and **2** is joined in end to end relation using mechanical coupling segment **18**. Narrowed stiffening rings **7** and **8** have grooves **10** and **11** on the inside faces. The grooves **10** and **11** are fitted with sealing elements **5**. A check valve **46** with no grooves, seals or spacers is fitted between the narrowed stiffening rings **7** and **8**. This configuration creates a near zero gap connection;

FIG. 24A is a cutaway view of a check valve **51** with grooves **11** and **10** on both faces and sealing elements **5**. This check valve **51** is designed to be fitted between stiffening rings of a different make and model or pipe elements having no stiffening rings. The check valve **51** when fitted between stiffening rings of a different make and model create the seal and provide a near zero gap joint. The same is true when fitted between pipe elements with no stiffening rings. The advanced coupling system couplings **18** and **19** can be used to connect the two pipe elements in an end to end configuration. This check valve can be used with any coupling systems and flanged systems;

FIG. 25 is a cut away side view of two bolt-on stiffening rings **64** and **65** and a side view of a gate valve **66**. The stiffening rings **64** and **65** bolt to the faces of the gate valve **66** allowing the gate valve to be attached to a piping system using the advanced coupling system. Protective pipe liners **44** are fitted to the bolt on stiffening rings **64** and **65** and extend into the gate valve to the face of the gate. The stiffening rings can also be cast into the valve body;

FIG. 26 shows a complete coupling **20** consisting of two coupling segments **18** and **19**. As shown in FIG. 26 the camming surfaces **27** face inwardly toward the space **28** between the keys. Each camming surface **27** is defined by a thinning of the keys **14A**, **14B**, **15A** and **15B**. The camming of the keys may thin the keys by as much as 85%. The thinning may be effected in various ways as depicted in FIGS. 28-32. The camming surfaces are located at each end of the coupling segments **18** and **19** and on both keys. The portion occupied by a single camming surface may include between 2.5% and 12.5% of the total arc length of its key.

FIG. 27 shows a complete coupling **20** consisting of two coupling segments **18** and **19,** a hinge **68** and supported by a lifting sling **69**. A hinge **68** is attached to anchoring points **118** on bolt hole pads **22A** and **23A.** Lifting the two coupling segments **18** and **19** from the lifting lugs **86A** and **87B** which are closest to the hinged side will spread the two coupling segments enough that they can be lowered over the pipe elements which are fitted with or without stiffening rings. The coupling segments are placed over the stiffening rings with the camming surfaces engaging the circumferential key grooves on the stiffening rings. The bolts and nuts are tightened until the keys fully engage the circumferential key grooves on the stiffening rings;

FIG. 28 shows each camming surface is defined by a thinning of the key on which it is positioned. The thinning may be effected in various ways as depicted in FIGS. 28-32. As shown in FIGS. 28 and 28A, the camming surfaces are created on the inside faces of the keys **14A** and **14B** by curved surfaces **27A** and **27B** having radii **R1.** Surfaces **27A** and **27B** are concave relative to the surfaces of the keys **14A** and **14B**.

In an alternate configuration, shown in FIGS. 29 and 29A, camming surfaces **27C** and **27D** having convexly curved surfaces having respective radii **R2**;

FIGS. 30 and 30A illustrate coupling **18** wherein each of the keys **14A** and **14B** form a pair of oppositely disposed key surfaces **36** and **37**. The same is true of coupling segment **19**. Key surfaces **36** and **37** are angularly oriented at respective orientation angles **38** and **39** relative to an imaginary reference plane **40** which passes through the coupling segments. Orientation angles **38** and **39** may range between about 0° and about 45° to the plane **40**. The side surfaces of the circumferential key grooves **12** and **13** on the stiffening rings **3** and **4** are matched to the angles on the coupling keys **14A** and **14B**. This range of angles for the side surfaces of the keys and the grooves is necessary to attach to any coupling system. The camming surfaces **27E** and **27F** are substantially flat surfaces which are angularly oriented with respect to the key surface on which they are positioned. The camming surfaces **27E** and **27F** have an orientation angle **58** between about 2° and about 20° relatively to the respective key surfaces **37** on which each camming surface is positioned.

FIGS. 31 and 31A, each camming surface is formed of two surface portions. Camming surface **27G** and **27J** is formed of a flat surface portion **27H** and **27K** and a concavely curved surface portion **27I** and **27L**. The flat surface portions **27H** and **27K** is substantially parallel to the reference planes **40** and offset from the key surfaces **37**. The curved surface portions **27I** and **27L** have respective radii **R3**. The curved surface portions **27I** and **27L** provide a smooth transition between the flat surface portions **27H** and **27K** and the surfaces **37** of the keys **14A** and **14B**.

In FIG. 32 and 32A, each camming surface **27M** and **27N** is formed of two surface portions. Camming surface **27M** and **27N** is formed from a flat surface portion **27O** and **27Q** and an angularly oriented surface portion **27P** and **27R.** The flat surface portions **27O** and **27Q** are substantially parallel to the reference plane **40** and offset from the key surfaces **37**. The angularly oriented surface portions **27P** and **27R** have an orientation angle **63** relatively to surfaces **37** of the keys **14A** and **14B**. Orientation angles between about 2° to about 45° are feasible. The angularly oriented surface portion **27P** and **27R** provide a smooth transition between the flat offset surface portions **27O** and **27Q** and the surfaces of the keys **14A** and **14B.**

One camming surface on a particular key need not be the same length, have the same offset, orientation angle or have the same curvature as its opposite camming surface on the other key. Additionally, the camming surfaces at opposite ends of a segment need not be the same as one another.

FIG. 33 is a side view of two pipe elements **1** and **2** with stiffening rings **3** and **4** attached to the ends. An alignment tool 88 consisting of two separate rings **70** and **71** is fitted and clamped over the two stiffening rings **3** and **4**. Each alignment tool ring has keys **89A** and **89B** which are received by the circumferential key grooves on the stiffening rings or pipe elements. Each alignment tool ring is fitted with a hinge **72** and a connector **73**. Each alignment ring has a minimum of two attachment points **74** to accommodate the fitment of various devices such as rams **67** and threaded rods. Figure 33 shows the alignment rings **70** and **71** fitted with a two way ram 67. This device allows for angular articulation enabling the two alignment rings to be connected together regardless of the misalignment of the two pipe ends. The two way ram pulls the two pipe ends together or separates the two pipe ends.

FIG. 33A is a front view of one half of the alignment tool showing the hinge **72**, the connector **73** and two attachment points **74**.

FIG. 34 is a partial side view of two pipe elements **1** and **2** with stiffening rings **3** and **4** attached to the pipe ends. A cradle **30** is attached to the two stiffening rings **3** and **4** by engaging grooves **41** and **42** on the back side of the stiffening rings **3** and **4**. A hydraulic ram **67** extends or contracts the cradle **30**. A threaded shaft can also be used instead of a ram. The cradle **30** can hold the two pipe ends together while the two coupling segments **18** and **19** are being fitted. This device can cradle one of the coupling sections for easier fit up. The cradle can support a coupling section when the piping system is horizontal, vertical or any angle in between.

## CLAIMS

1. An advanced coupling system that mechanically joins pipe elements together in an end to end configuration which is capable of handling high pressures, temperatures and chemicals due to multiple sealing configurations and seal element materials. The advanced coupling system interfaces with other coupling makes and models while still maintaining high pressure, temperature and chemical resistance. The advanced coupling system can be fitted with spacers, deflection cones, orifice plates, check valves and protective pipe liners which can also be integrated into other coupling makes and models while still maintaining high pressure, temperature and chemical resistance. The spacers, deflection cones, orifice plates, check valves and protective pipe liners can also be fitted between flanged connections. An alignment tool, a cradle and hinged coupling segments provide improved ease of installation and removal of coupling segments. The advanced coupling system comprising: a plurality of segments position able end-to-end around said pipe elements with stiffening rings fitted to the ends of said pipe elements, stiffening rings are offered with several optional sealing element configurations and grooves which receive sealing elements, spacers or a tapered alignment ring, stiffening rings come in standard, narrowed or extended lengths so as to interface with other coupling makes and models and to accommodate the fitment of spacers, deflection cones, orifice plates, check valves and protective pipe liners, coupling segments and stiffening rings can be fitted with optional access ports, coupling segments having a pair of keys projecting radially inwardly toward said pipe elements with or without stiffening rings, a pair of stiffening ribs projecting radially outwardly away therefrom on large coupling systems 20 inches and larger, a minimum of one perpendicular rib exists between the two circumferential ribs on each coupling segment, said ribs are substantially aligned with said coupling keys, said ribs being positioned in spaced apart relation to one another, each said coupling key for engagement with said circumferential key groove of the stiffening ring or cut or rolled grooves on pipe elements, said keys being positioned in spaced apart relation from one another and defining a space there between, coupling keys are forcibly engaged circumferentially around said pipe elements with or without stiffening rings, circumferential key grooves on the stiffening rings or pipe elements receive the keys on the coupling segments and said key grooves align perfectly with the keys on said coupling segments. A minimum of one standard sealing element is fitted and mechanically anchored to a minimum of one face of one stiffening ring. Anchoring points position and hold the sealing element in place. A standard circumferential gasket that surrounds the joint can also be used in addition to one or more sealing elements on the face of the stiffening ring. This gasket would only become energized if the sealing elements on the face were to fail.
2. The advanced coupling system according to claim 1, wherein a coupling segment consisting of two keys which are identical or different in size, shape and dimensions having key surfaces of the same or different orientation angles ranging from $0^0$ to $45^0$ relative to said plane in order to connect to any coupling stiffening rings or pipe elements or combination thereof having rolled or cut grooves which are identical or different in size and shape having groove angles ranging from $0^0$ to $45^0$.

3. The advanced coupling system according to claim 1, wherein the coupling segments consist of metallic, non-metallic or a combination of materials which consist of various hardness, toughness and corrosion resistance to satisfy a wide range of applications.
4. The advanced coupling system according to claim 2, wherein optionally hardened coupling keys are added to increase strength and rigidity to the joint and to ensure the coupling segments life cycle substantially exceeds the lifecycle of the piping element with or without stiffening rings.
5. The advanced coupling system according to claim 4, wherein the coupling segment hardened keys offer several different camming surfaces that are identical or different and narrow the keys by as much as 85% on the inside faces of one or both keys at one or both ends of a coupling segment having the same or different lengths of camming surfaces that occupy between 2.5% to 30% of the total arc length of said key. Camming surfaces improve the fitment of the coupling sections when a gap exists between the two pipe element faces buy guiding said keys into said key grooves when said coupling segments are forcibly engaged circumferentially around said pipe elements with or without stiffening mounting rings.
6. The advanced coupling system according to claim 5, wherein the camming surfaces are created with concaved or convexly curved surfaces relative to the surface of the keys.
7. The advanced coupling system according to claim 5, wherein the camming surfaces have an orientation angle between about $2^0$ to about $20^0$ relative to the respective key surfaces on which each camming surface is positioned.
8. The advanced coupling system according to claim 5, wherein the camming surface is formed of a flat surface portion and a concavely curved surface portion. The flat surface portions are substantially parallel to reference plans and offset from the inside key surfaces. The curved surface portions provide a smooth transition between the flat surface portions and the surfaces of the keys.
9. The advanced coupling system according to claim 5, wherein the camming surface is formed of a flat surface portion and an angularly oriented surface portion. The flat surface portions are substantially parallel to reference plans and offset from the inside key surfaces. The angularly oriented surface portions have an orientation angle relatively to the surfaces of the keys of $2^0$ to about $45^0$ are feasible. The angularly orientated surface portions provide a smooth transition between the flat, offset portions and the surfaces of the keys.
10. The advanced coupling system according to claim 1, wherein a minimum of one optional access port can be added to a coupling segment and said access port completely or partially penetrates into the coupling segment from the outside diameter of the coupling segment.
11. The advanced coupling system according to claim 1, wherein the stiffening ring consisting of a circumferential groove which receives one coupling key having different sizes, shapes and dimensions and orientation angles ranging from $0^0$ to $45^0$ relative to said plane in order to connect to any coupling keys of any make or model.
12. The advanced coupling system according to claim 1, wherein the stiffening rings can be welded, friction welded, bonded, threaded, bolted, cast or forged into piping elements, tanks, vessels, valves, flanges, pumps and shoots.

13. The advanced coupling system according to claim 1, wherein the coupling stiffening rings consist of metallic, non-metallic or a combination of materials which consist of various hardness, toughness and corrosion resistance to satisfy a wide range of applications.
14. The advanced coupling system according to claim 1, wherein a minimum of one optional groove can be added to the face of the stiffening ring and or circumferentially around said stiffening ring. These grooves have sides, a bottom and a groove width and can be any size or shape. Each groove side has an orientation angle of $0^0$ to $50^0$ to reference planes. Groove side angles can be identical or different.
15. The advanced coupling system according to claim 14, wherein the optional circumferential grooves receive sealing elements which are mechanically anchored. The optional grooves on the inside faces receive sealing elements or spacers which are interchangeable and mechanically anchored. The spacer completely fills and seals a groove and energizes sealing elements it interfaces with. The standard sealing element is eliminated when the optional grooves on the face are utilized.
16. The advanced coupling system according to claim 14, wherein the optional grooves on the face receive a tapered alignment ring which significantly improves alignment of the two pipe ends.
17. The advanced coupling system according to claim 16, wherein the tapered alignment ring can be one solid ring or multiple rings consisting of metallic or non-metallic materials or a combination of both.
18. The advanced coupling system according to claim 16, wherein a tapered alignment ring and a sealing element can be joined together.
19. The advanced coupling system according to claim 15, wherein the optional grooves on the face of the stiffening rings have a minimum of one anchoring point to position and secure the sealing elements, spacers or tapered alignment ring within the grooves.
20. The advanced coupling system according to claim 15, wherein the sealing elements and spacers can be any shape or size, consisting of a wide range and choice of metallic or non-metallic or a combination of both materials to handle high pressures, temperatures and chemicals in order to handle a wide range of fluids, slurries and gases.
21. The advanced coupling system according to claim 1, wherein a minimum of one optional access port can be added to any location on the stiffening ring to accommodate sensors, monitors, probes, wires, wear indicators and or plugs.
22. The advanced coupling system according to claim 21, wherein the optional access ports can be fitted with permanent sensors, monitors, probes, wires, wear indicators and or plugs or any combination which also provide pressure containment and are locked into the access ports.
23. The advanced coupling system according to claim 21,wherein plugs can transfer signals and currents from wires or fiber optics from inside the piping element and or access port to the outside while maintaining high pressure containment.
24. The advanced coupling system according to claim 21, wherein an access port can be opened and sensors, monitors and probes are installed for monitoring purposes and then removed.

25. The advanced coupling system according to claim 21, wherein the optional access ports extend from the outside diameter of the stiffening ring to the inside diameter of the stiffening ring or pipe or may extend only partially into the stiffening ring.
26. The advanced coupling system according to claim 21, wherein a minimum of one conductive device or fiber optic device is embedded into liners or coatings inside the piping system and runs from one access port on one end of the pipe to an access port on the other end of the pipe and acts as a wear indication system.
27. The advanced coupling system according to claim 26, wherein the conductive device or fiber optic device can be imbedded into liners and coatings at different depths and positioned anywhere circumferentially around the inside of the pipe which is lined or coated.
28. The advanced coupling system according to claim 26, wherein the conductive device or fiber optic device can be any shape or size.
29. The advanced coupling system according to claim 1, wherein the stiffening ring has an optional groove on the outside of the ring opposite to the face which is positioned close to the outside diameter of the ring to accommodate the fitment of a cradle. The cradle consists of a threaded shaft or hydraulic ram which extends or contracts the cradle. The cradle holds the two pipe ends together while the two coupling segments are being fitted. This device can cradle one of the coupling sections for easier fit up. The cradle can support a coupling segment when the piping system is horizontal, vertical or any angle in between. There is no interference between the cradle and the coupling segments which are being installed and fitted.
30. The advanced coupling system according to claim 1, wherein the stiffening ring comes in standard length, narrowed length and extended length. These configurations allow for face to face fitment between two advanced coupling stiffening rings, one advanced coupling stiffening ring and a stiffening ring of another make or model, one advanced coupling stiffening ring and a pipe element with no stiffening ring, or the fitment of spacers, deflection cones, orifice plates, protective pipe liners and check valves. Regardless of configuration, a gap no larger than 3/16 shall exist at any joint with an ideal gap being 1/32 or smaller.
31. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liners and check valves can be fitted between the advanced coupling stiffening rings, between one advanced coupling stiffening ring and one stiffening ring of a different make or model, or between stiffening rings of different makes and models, between pipe elements with one or no stiffening rings or between flanged connections.
32. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liners and check valves can be any shape or size, consisting of a wide range and choice of materials to handle high pressures, temperatures and chemicals and can be lined or coat to achieve said claims.
33. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liners and check valves are anchored to a minimum of one stiffening ring or pipe element.
34. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liner rings and check valves come with optional anchoring points on the face to accommodate the installation of a rotation tool and assist with installation and removal. Additional optional circumferential anchoring

points are added to the circumferential edge to accommodate rotation without substantial separation of the pipe ends.

35. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liners and check valves can be fitted with one, two or no grooves on the face or faces which receive sealing elements or spacers.
36. The advanced coupling system according to claim 35, wherein these grooves have sides, a bottom and a groove width and can be any size or shape. Each groove side has an orientation angle of $0^0$ to $50^0$ to reference planes. Groove side angles can be identical or different.
37. The advanced coupling system according to claim 1, wherein spacers, deflection cones, orifice plates, protective pipe liners and check valves can be fitted with one, two or no sealing elements or spacers and consist of non-metallic materials, metallic materials or a combination of both. Sealing elements and spacers consist of a wide range and choice of metallic or non-metallic or a combination of both materials to handle high pressures, temperatures and chemicals in order to handle a wide range of fluids, slurries and gases. The sealing elements and spacers are mechanically anchored to said spacers, deflection cones, orifice plates, protective pipe liners and check valves. The sealing elements and spacers are interchangeable.
38. The advanced coupling system according to claim 31, wherein spacers, deflection cones and protective pipe liner rings come with optional holes which run from the OD to the ID. These holes are used to accommodate wires, sensors, probes and non-metallic materials. A minimum of one hole is added.
39. The advanced coupling system according to claim 32, wherein spacers, deflection cones and protective pipe liners with or without a re-enforced sub-straight ring can be lined or coated with a non-metallic, metallic or combination of both materials. Both liners and coatings can be bonded or mechanically anchored or a combination of both. Metallic coatings can also be bonded by metallurgical means. Wires, sensors and probes can be imbedded into non-metallic liners and materials.
40. The advanced coupling system according to claim 39, wherein protective pipe liners consist of a ring with a metallic or non-metallic liner or coating, or a ring and a re-enforced sub-straight ring with a metallic or non-metallic liner or coating. Protective pipe liners are positioned inside the inlet or outlet side of a piping element with or without stiffening rings. Protective pipe liners with no re-enforced sub-straight ring have an OD which is same as ID of the piping element. Protective pipe liners with re-enforced sub-straight rings have smaller OD's than the ID of the piping elements so as to address ovality issues and provide easier installation, rotation and removal as the surface area friction is significantly reduced. Sealing elements are added to the OD of the re-enforced sub-straight ring to provide a snug fit between the protective pipe liner and the ID of the piping element and to seal out contaminants. The sealing element can also be part of the non-metallic liner. The non-metallic liner wraps around the face of the re-enforced sub-straight ring that is placed into the piping element and ultimately has a larger OD than the re-enforced sub-straight ring creating a snug fit between the protective pipe liner and the piping element.
41. The advanced coupling system according to claim 1, wherein an alignment tool is designed to be used with the advanced coupling system or other coupling systems with or without stiffening rings to pull pipe ends together for fitment or to separate

pipe ends. This is a critical necessity when working with a near zero gap coupled connection. The alignment tool improves installation and removal performance and safety. The alignment tool can also assist with the installation and removal of protective pipe liners. The Alignment tool consists of two separate rings. Each ring is clamp over the two pipe elements. Each ring consists to two halves, a hinge and a connector. The two halves are spread over the pipe ends and the connector locks the two halves tightly over the pipe elements forcibly engaging the alignment ring keys into the key grooves on the stiffening rings or pipe elements. Each alignment ring has a minimum of two attachment points to accommodate all necessary attachments such as hydraulic rams and threated rods. The alignment tool allows for angular articulation enabling the two alignment tool rings to be connected together regardless of the misalignment of the two pipe ends. The alignment tool comes in sizes, models and styles so as to interface with all coupling makes, models and styles.

42. The advanced coupling system according to claim 1, wherein coupling segments have anchoring points to accommodate hinges or lifting lugs for improved installation and removal performance and safety.
43. The advanced coupling system according to claim 1, wherein stiffening rings without circumferential grooves and optional access ports can be mounted anywhere between the two pipe ends with or without stiffening rings to provide additional monitoring.

Figure 1

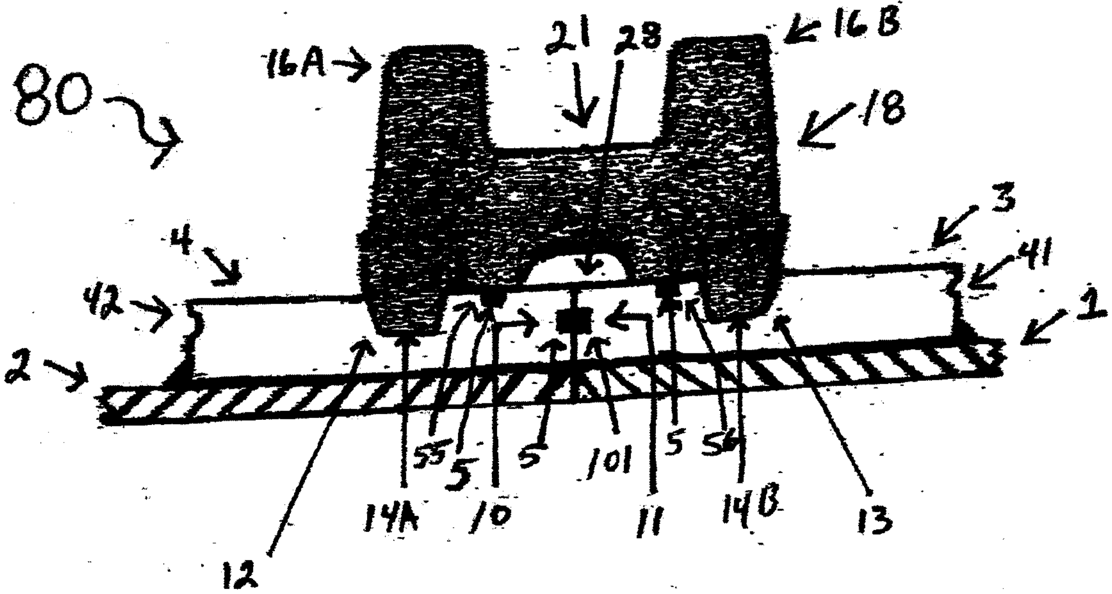



Figure 1A

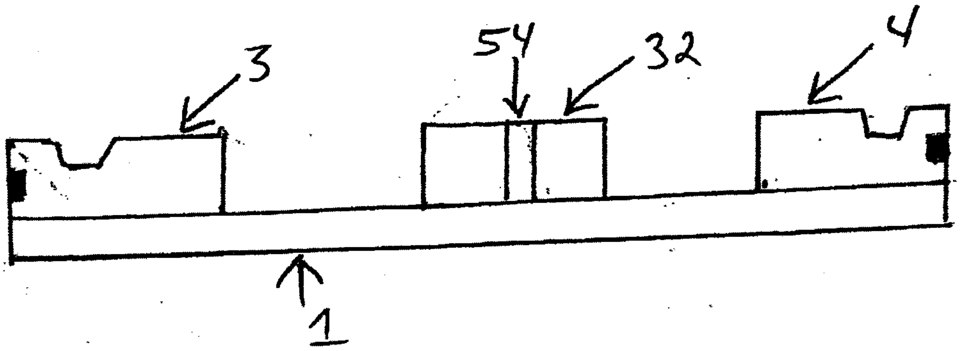


Figure 2

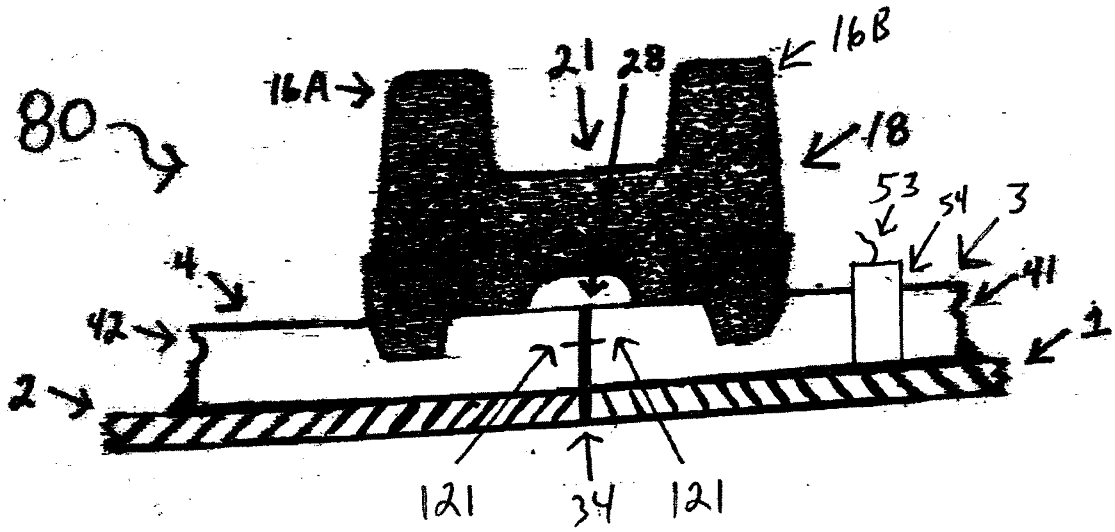



Figure 2A

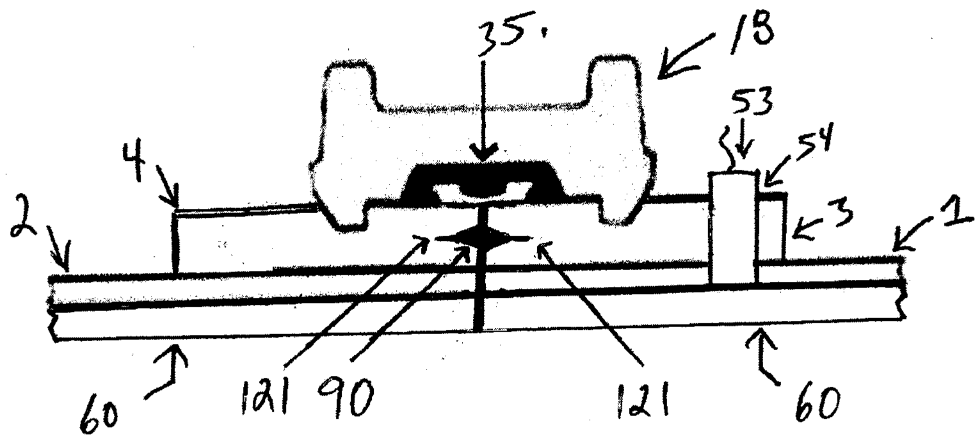


Figure 3

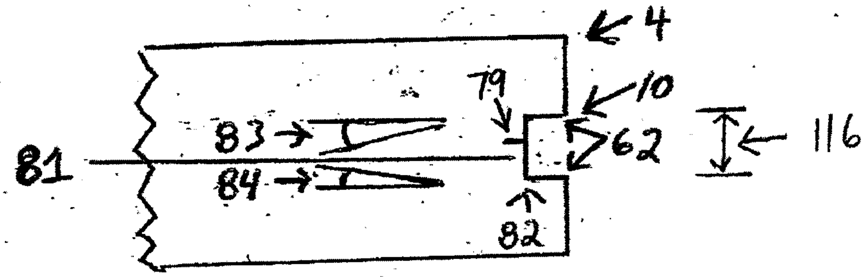
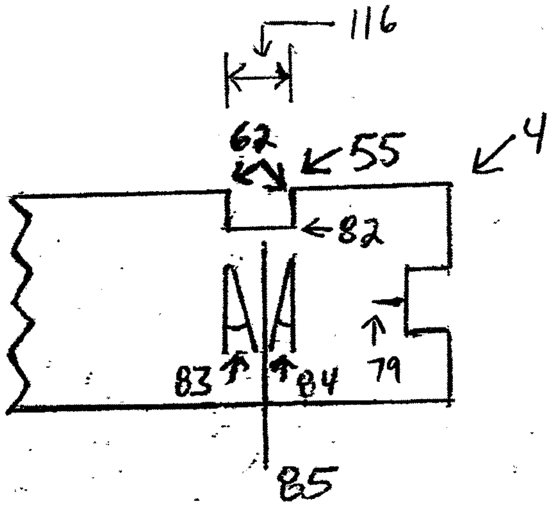
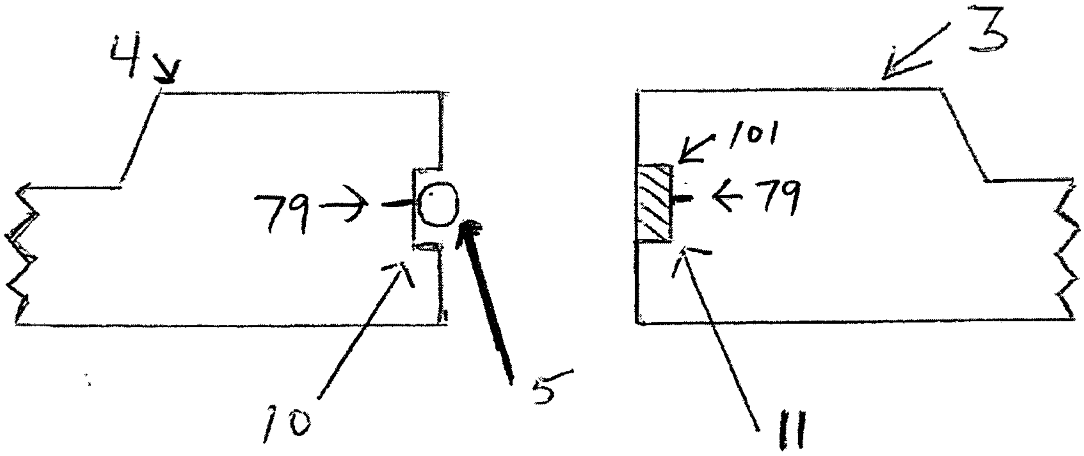



Figure 3A

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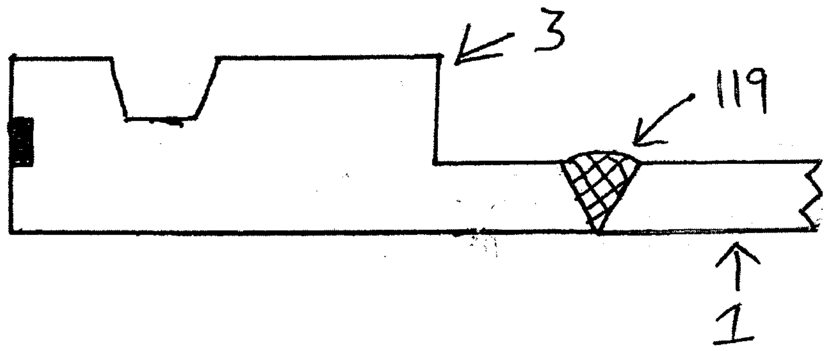
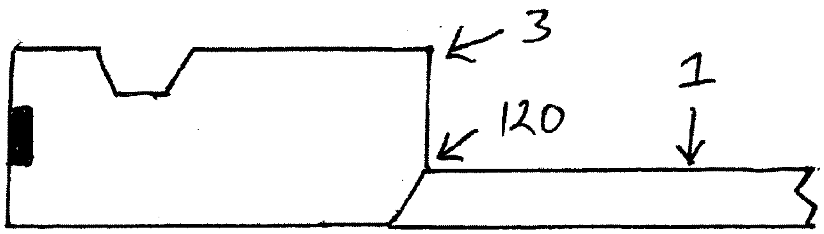
11

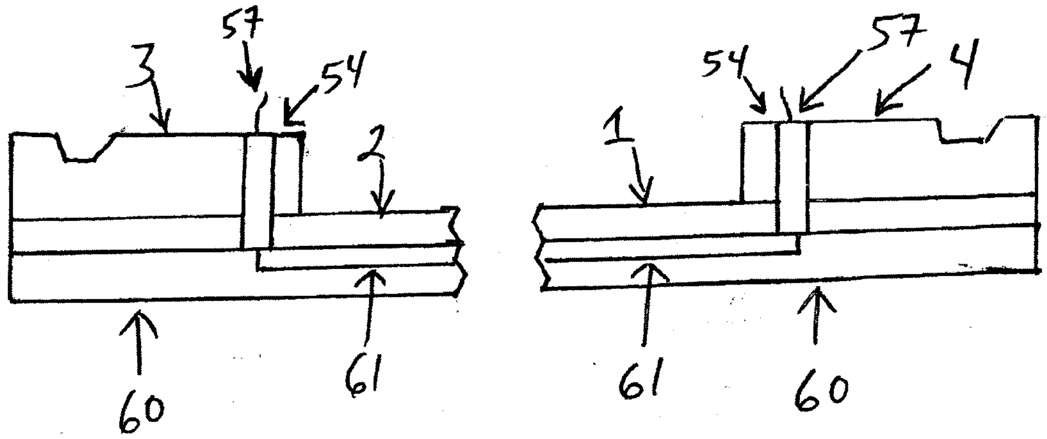
# Figure 5






# Figure 5A

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61
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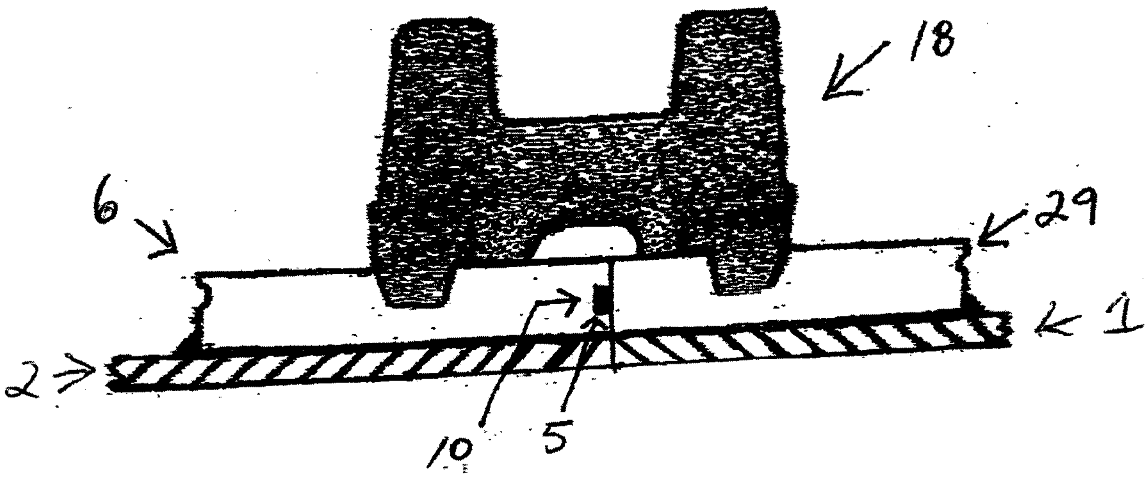
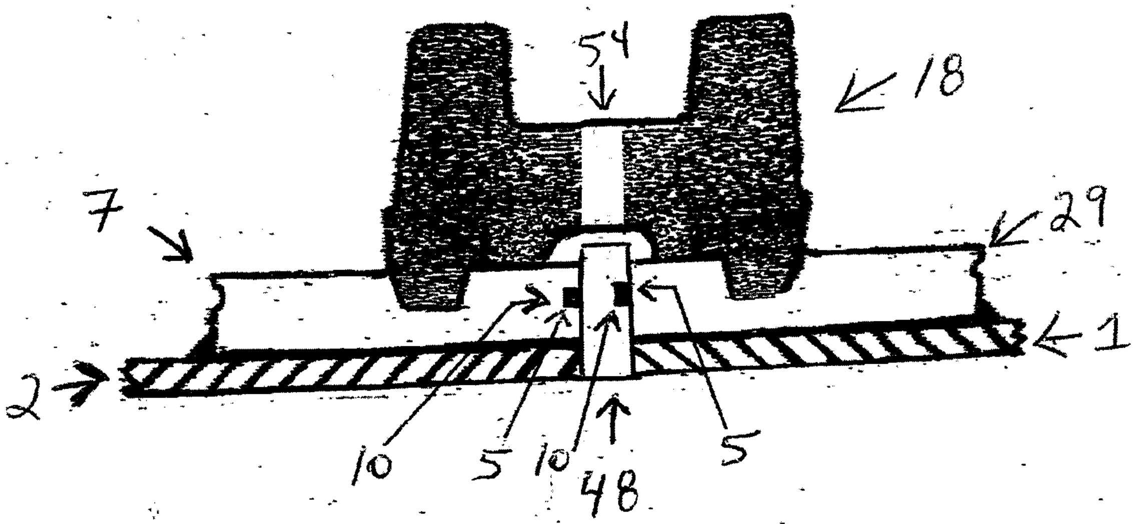
Figure 7 7 of 34

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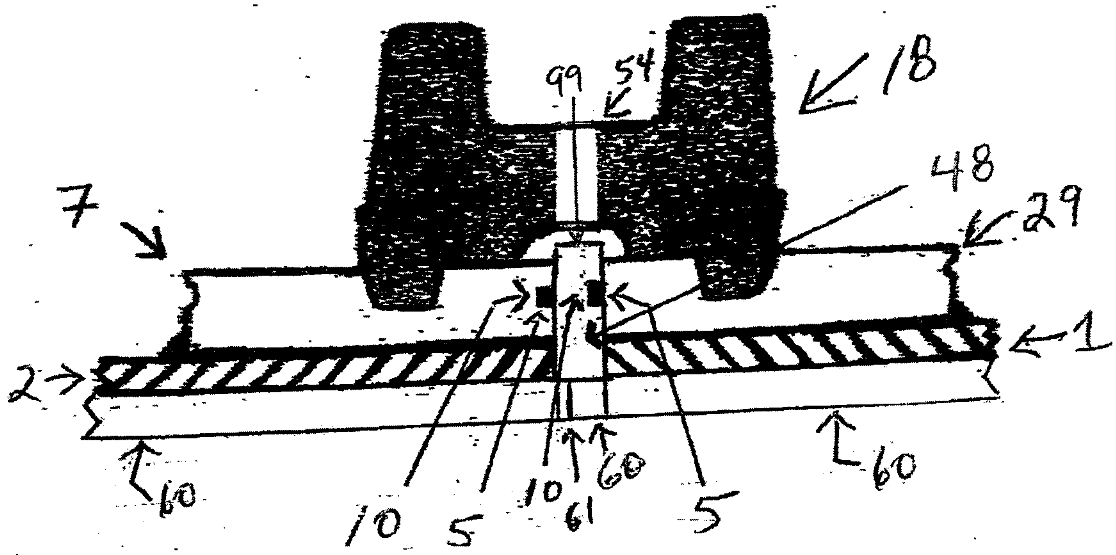
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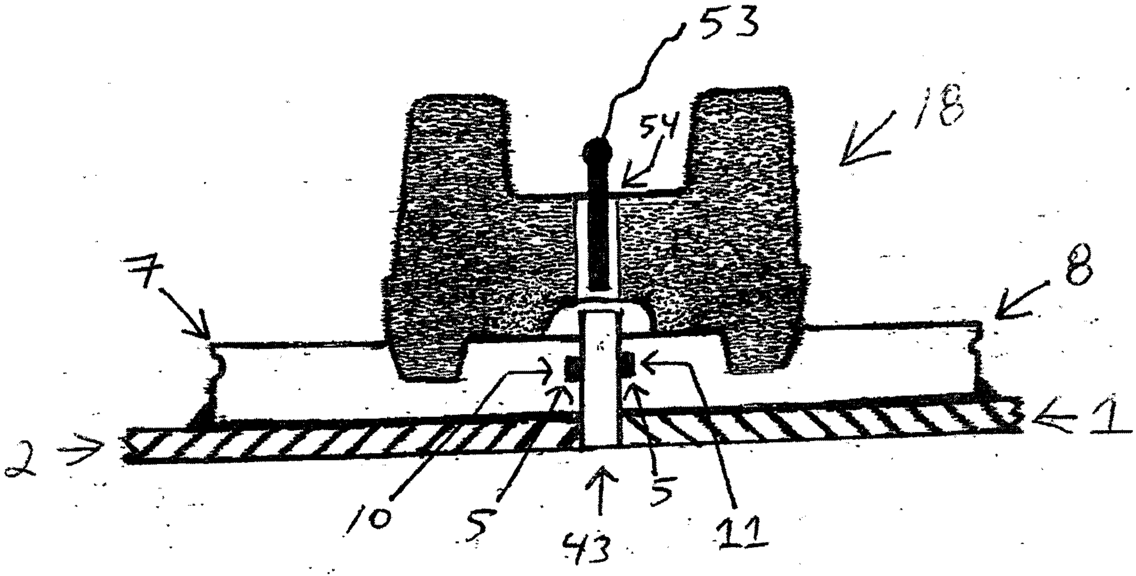
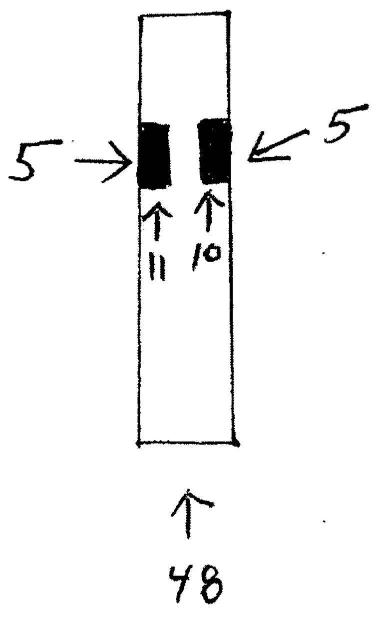
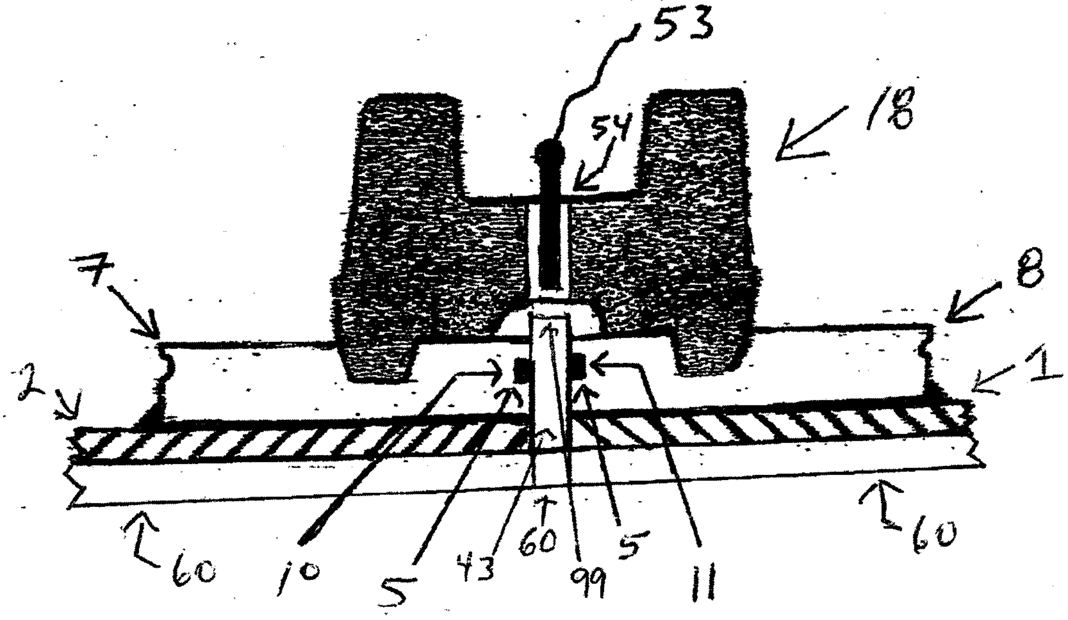
# Figure 10






# Figure 10A

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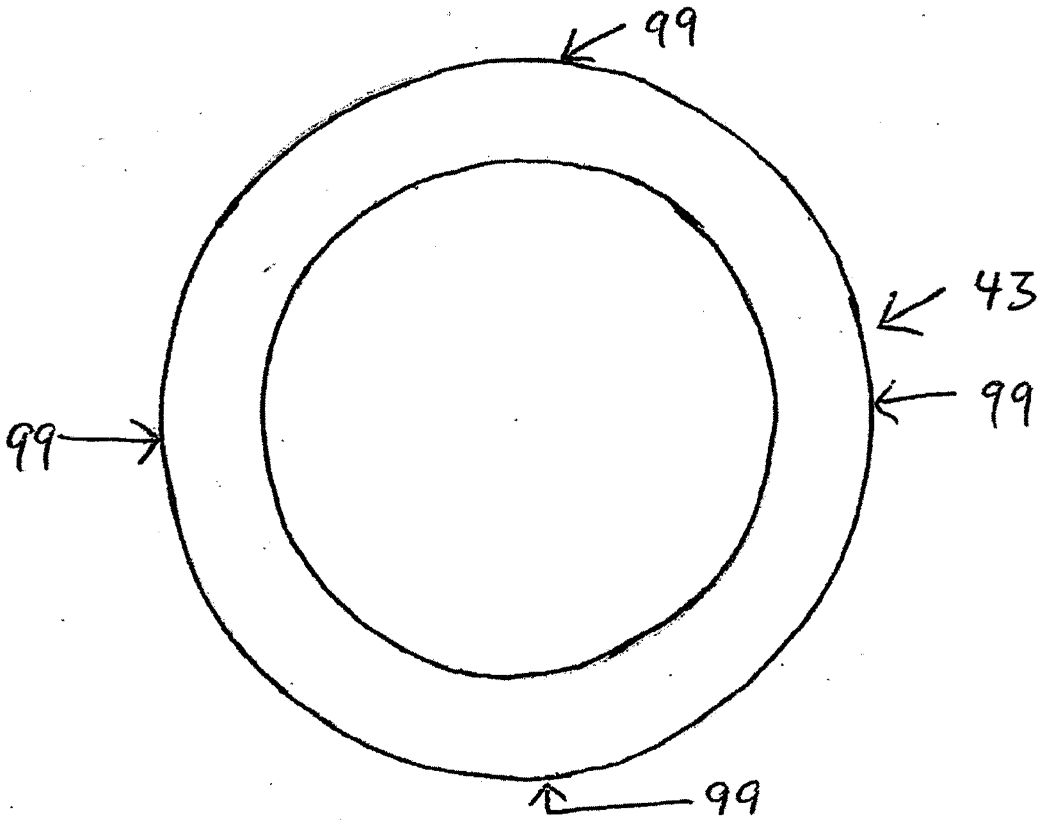
## Figure 12

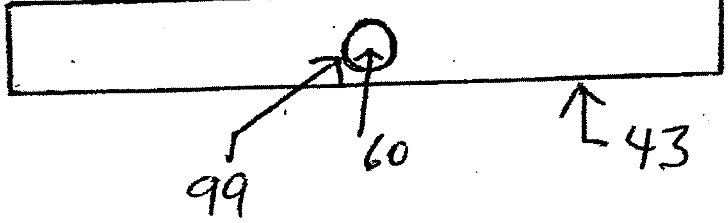


Front View




## Figure 12A

Top View



# Figure 13



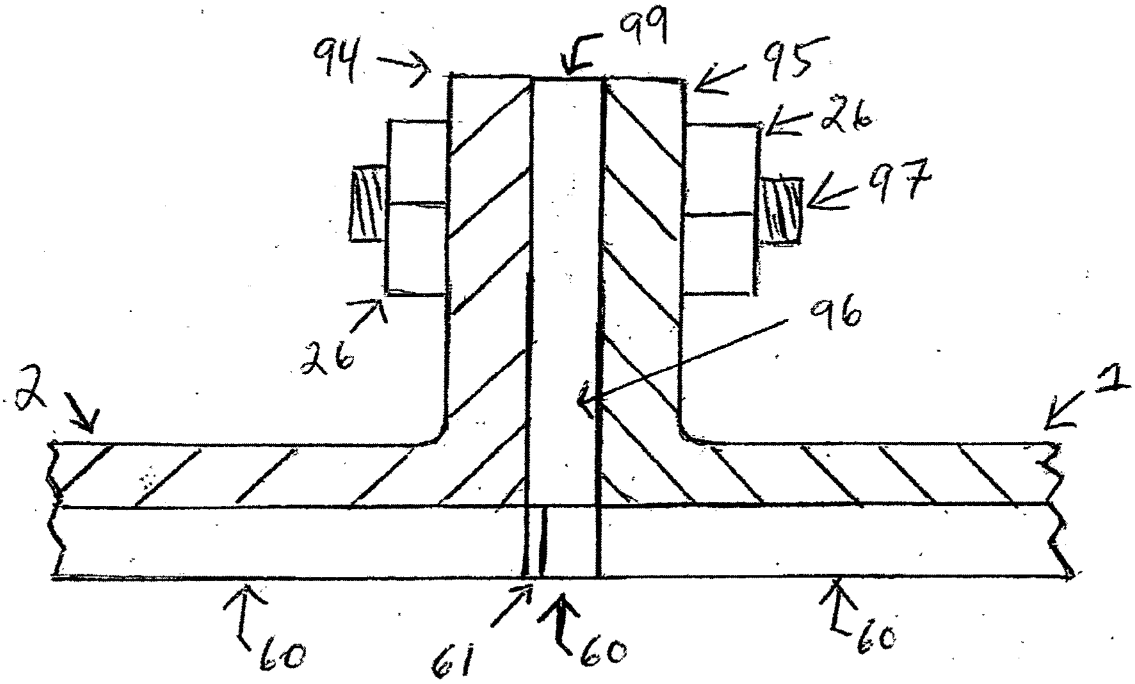


Figure 14

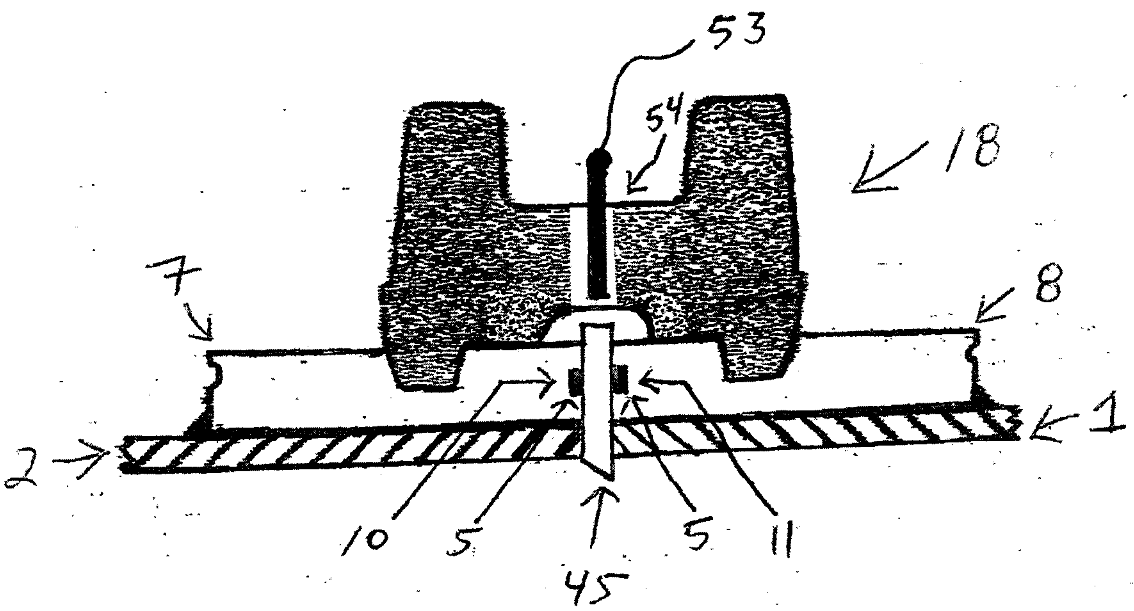



Figure 14A

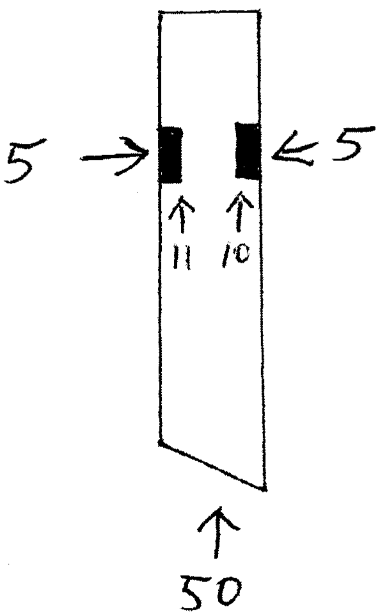


Figure 15

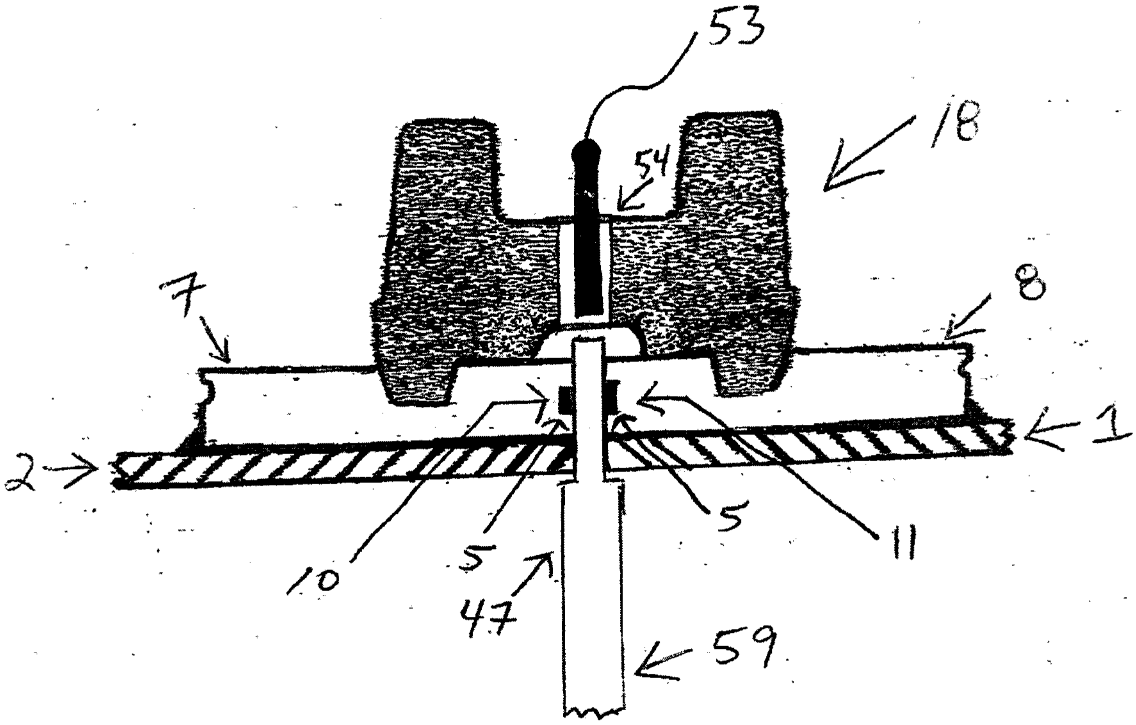



Figure 15A

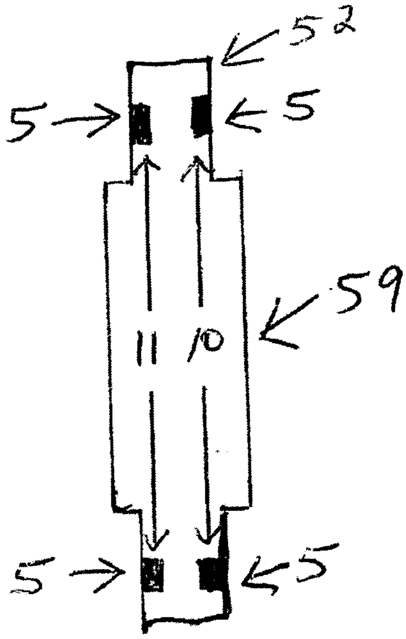


Figure 16

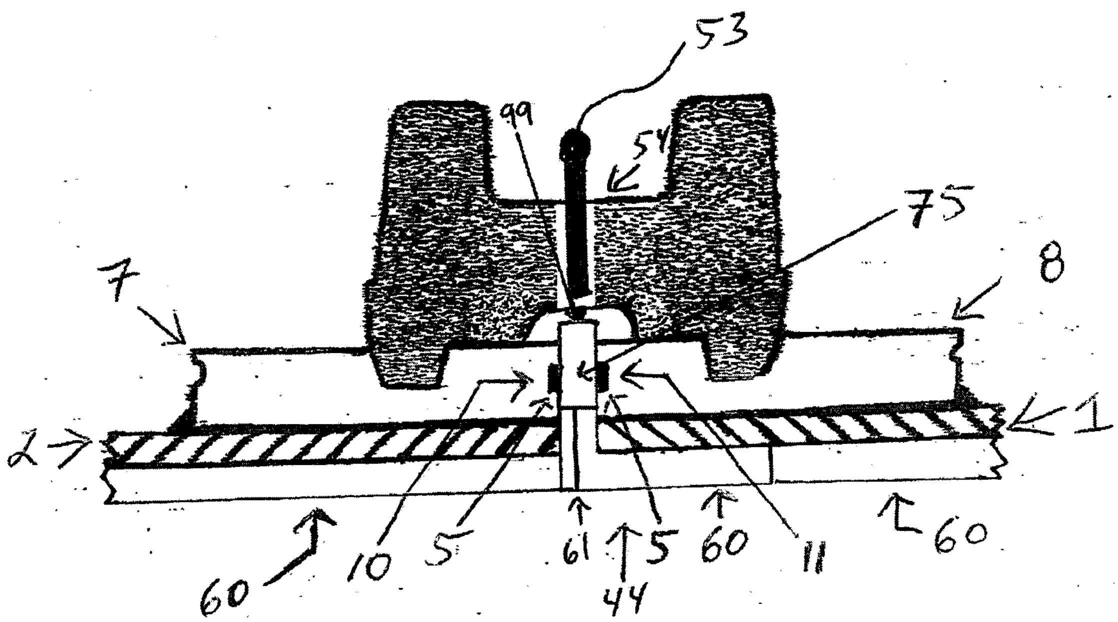



Figure 16A

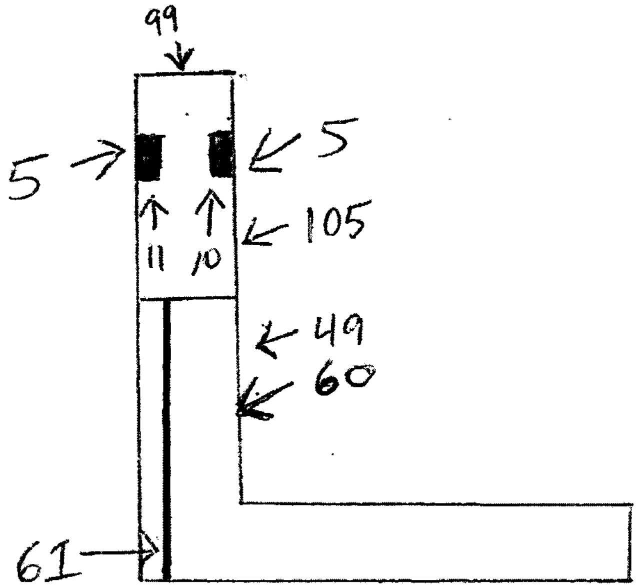


Figure. 17

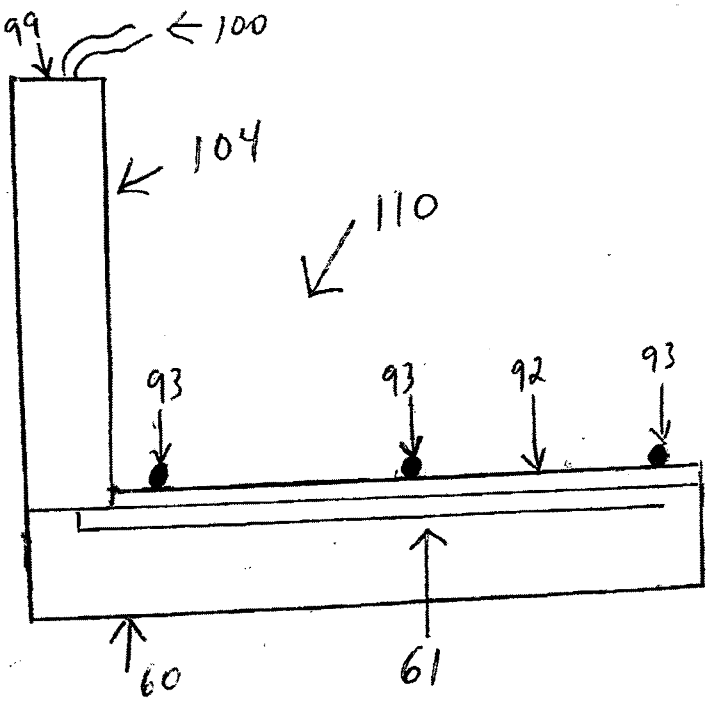
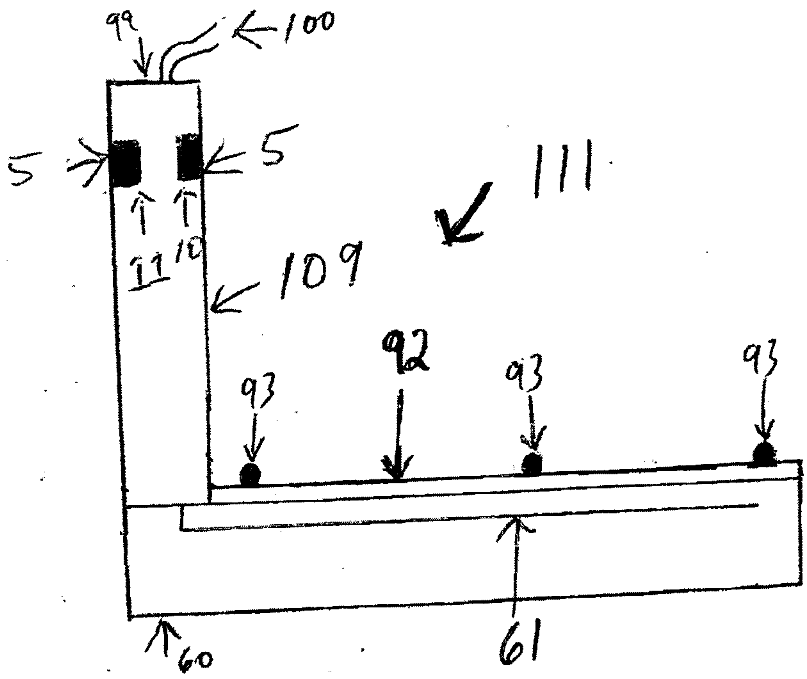



Figure 17A



## Figure 18



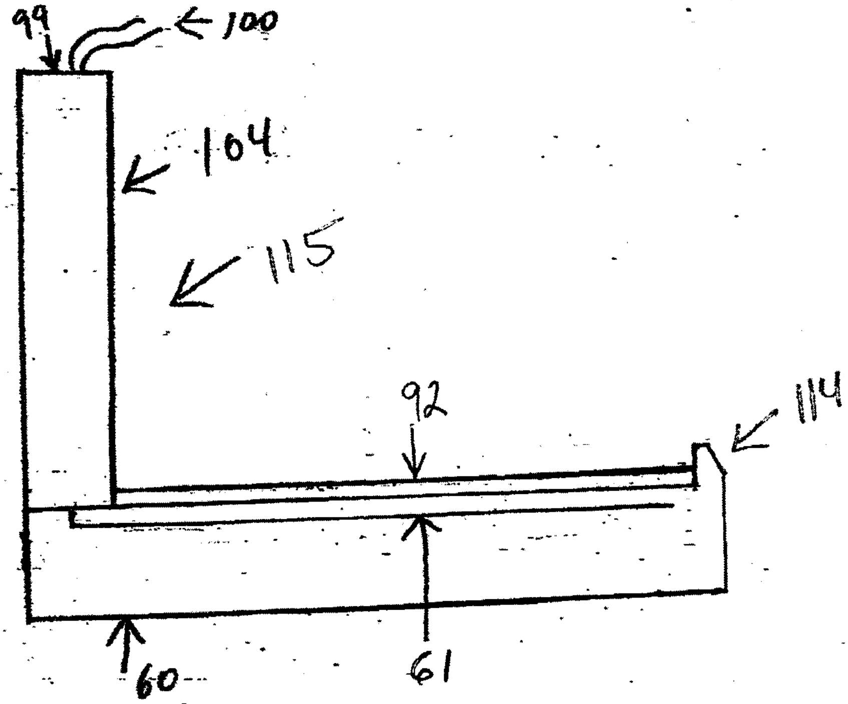


Figure 19

Front view

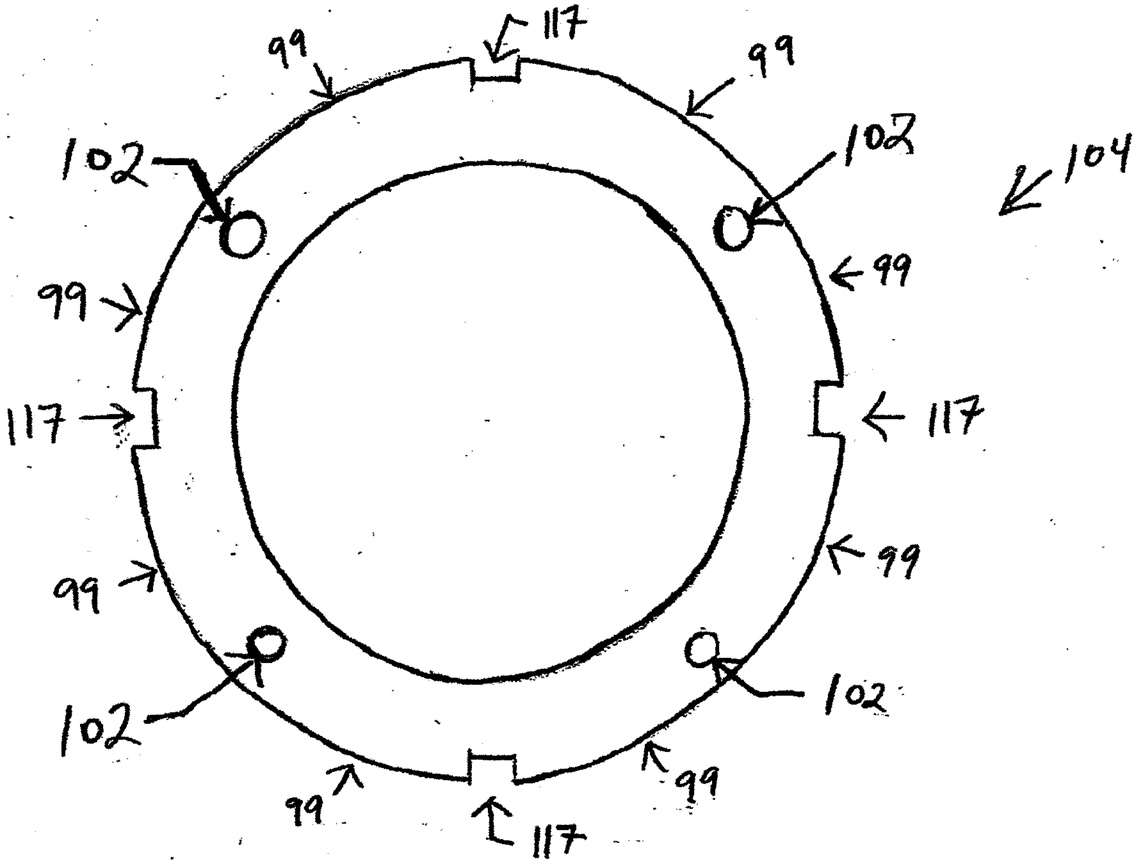



Figure 19A

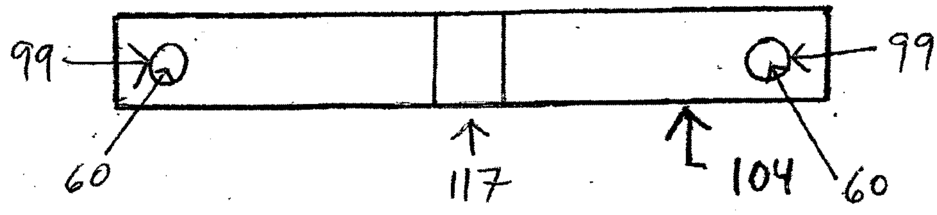


Figure 20 

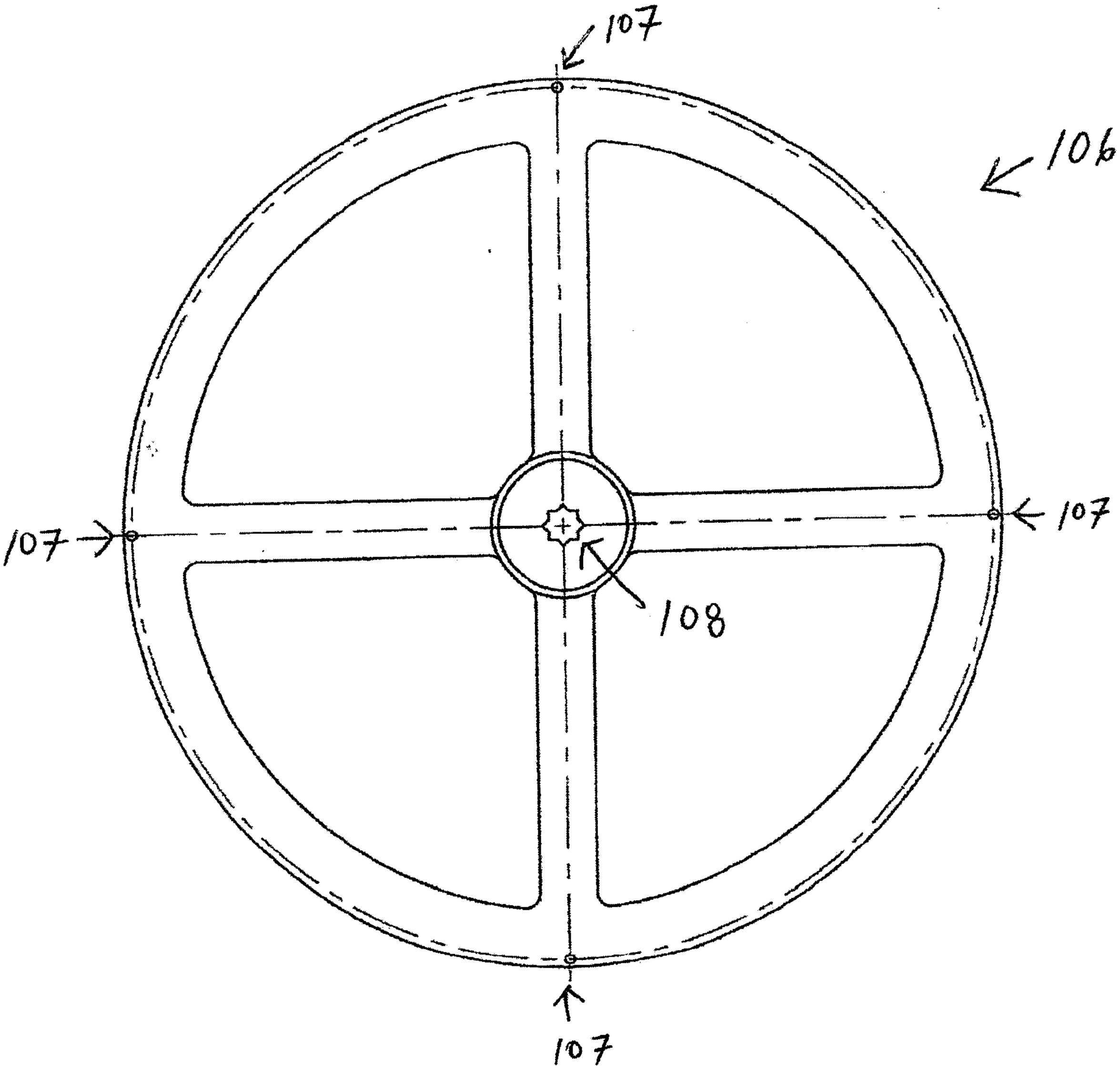
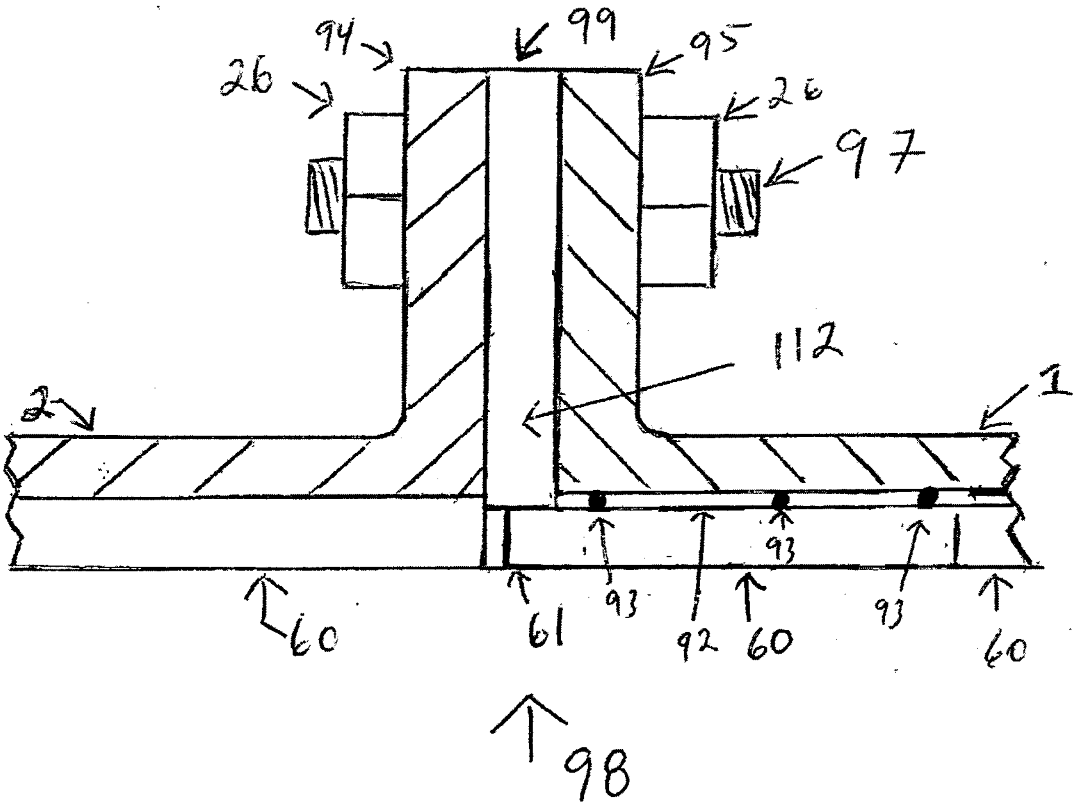
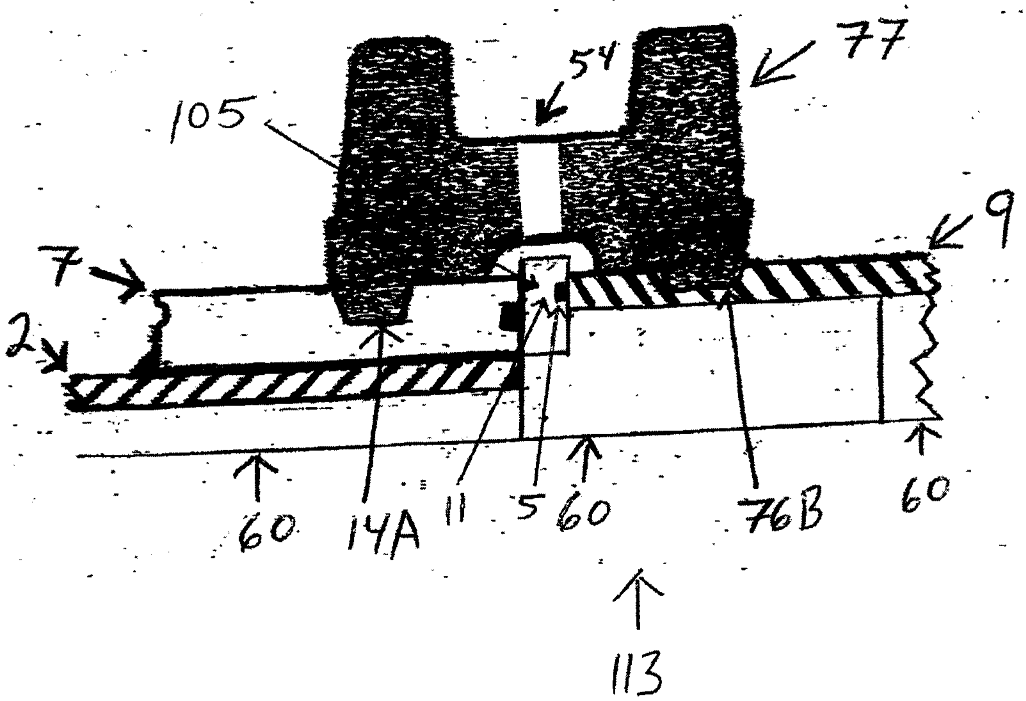


Figure 21 

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# Figure 23



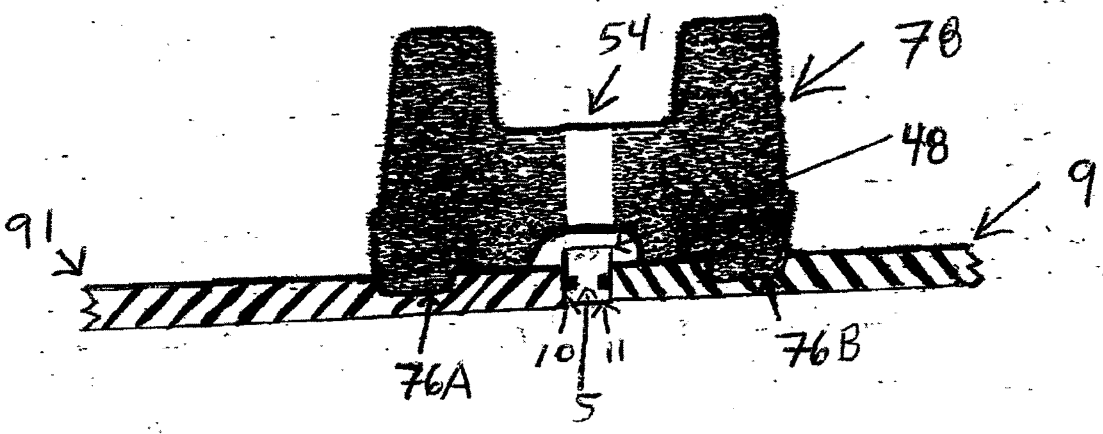


Figure 24 

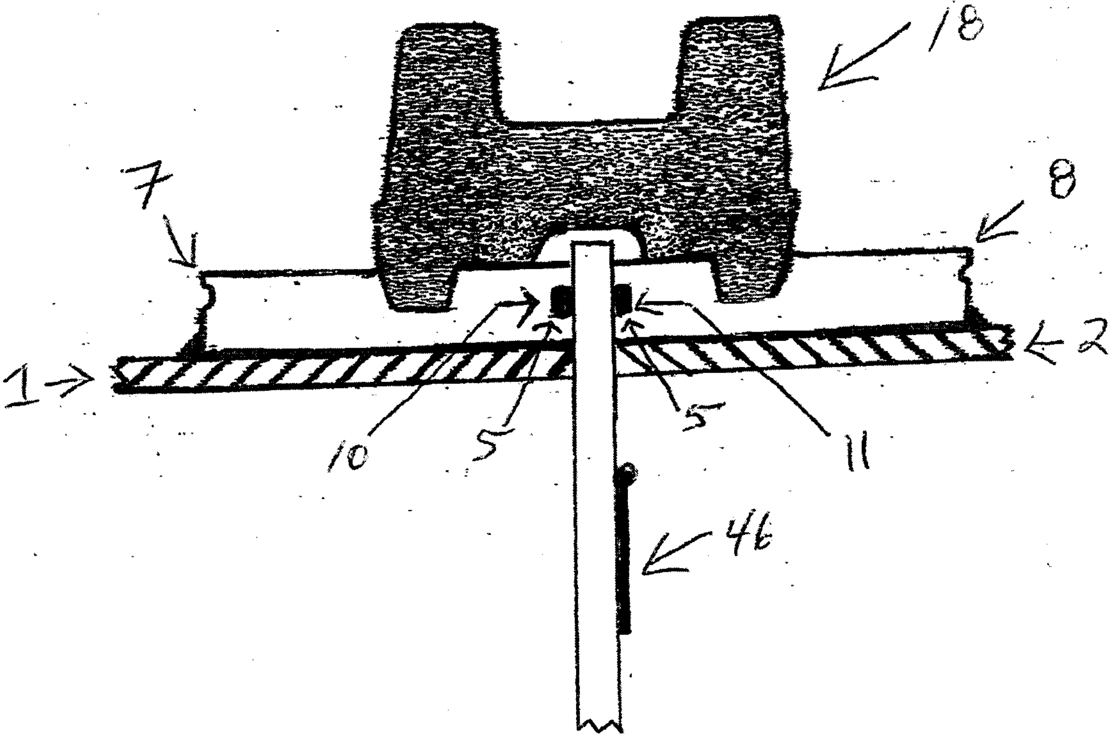
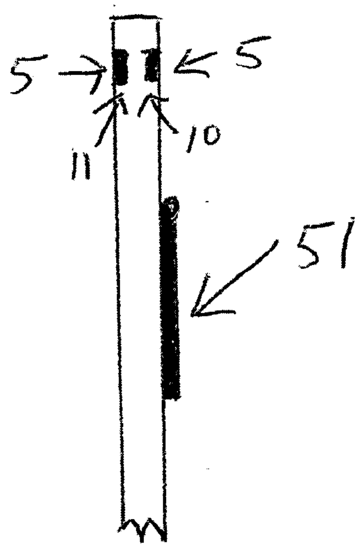
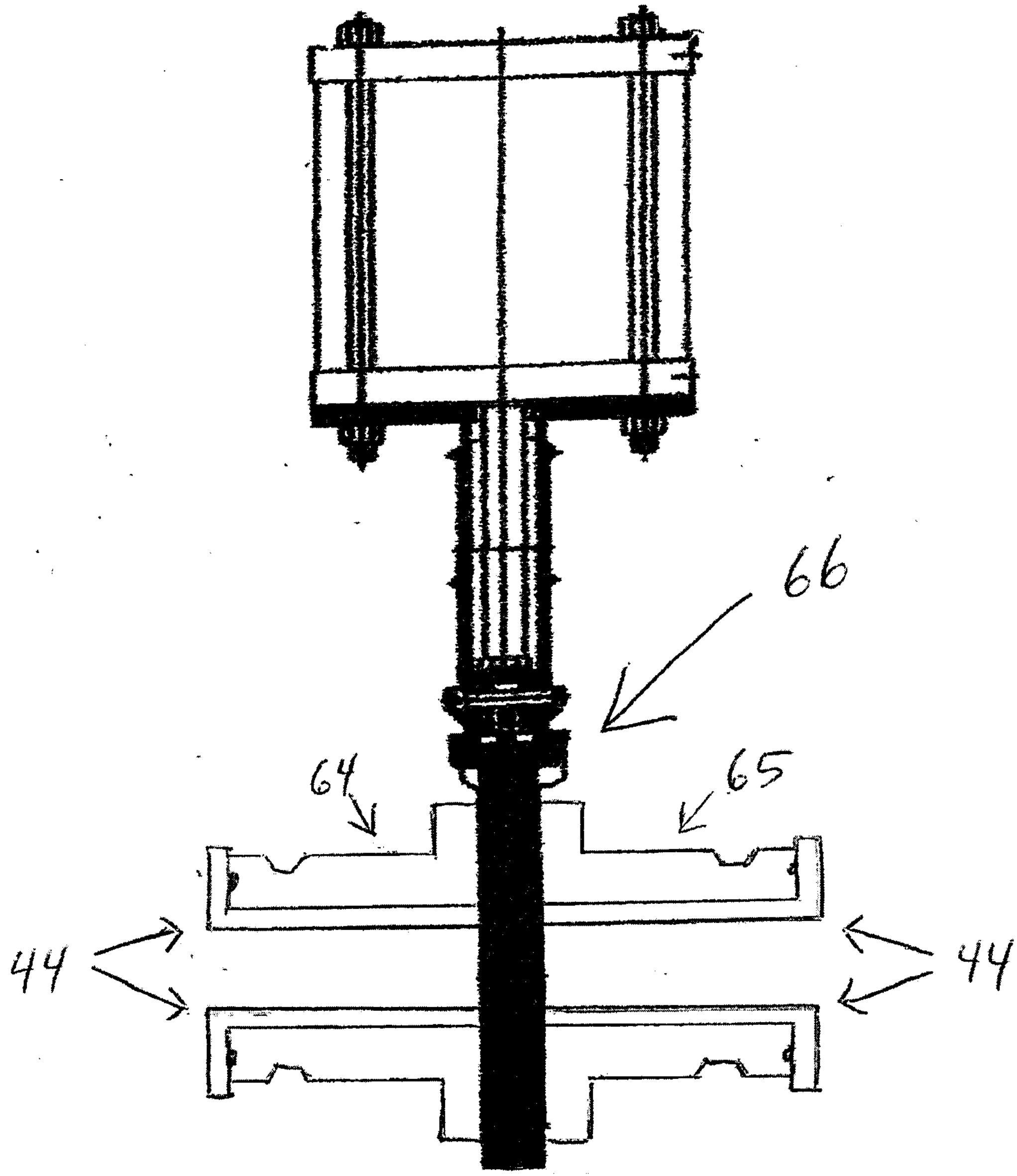



Figure 24A

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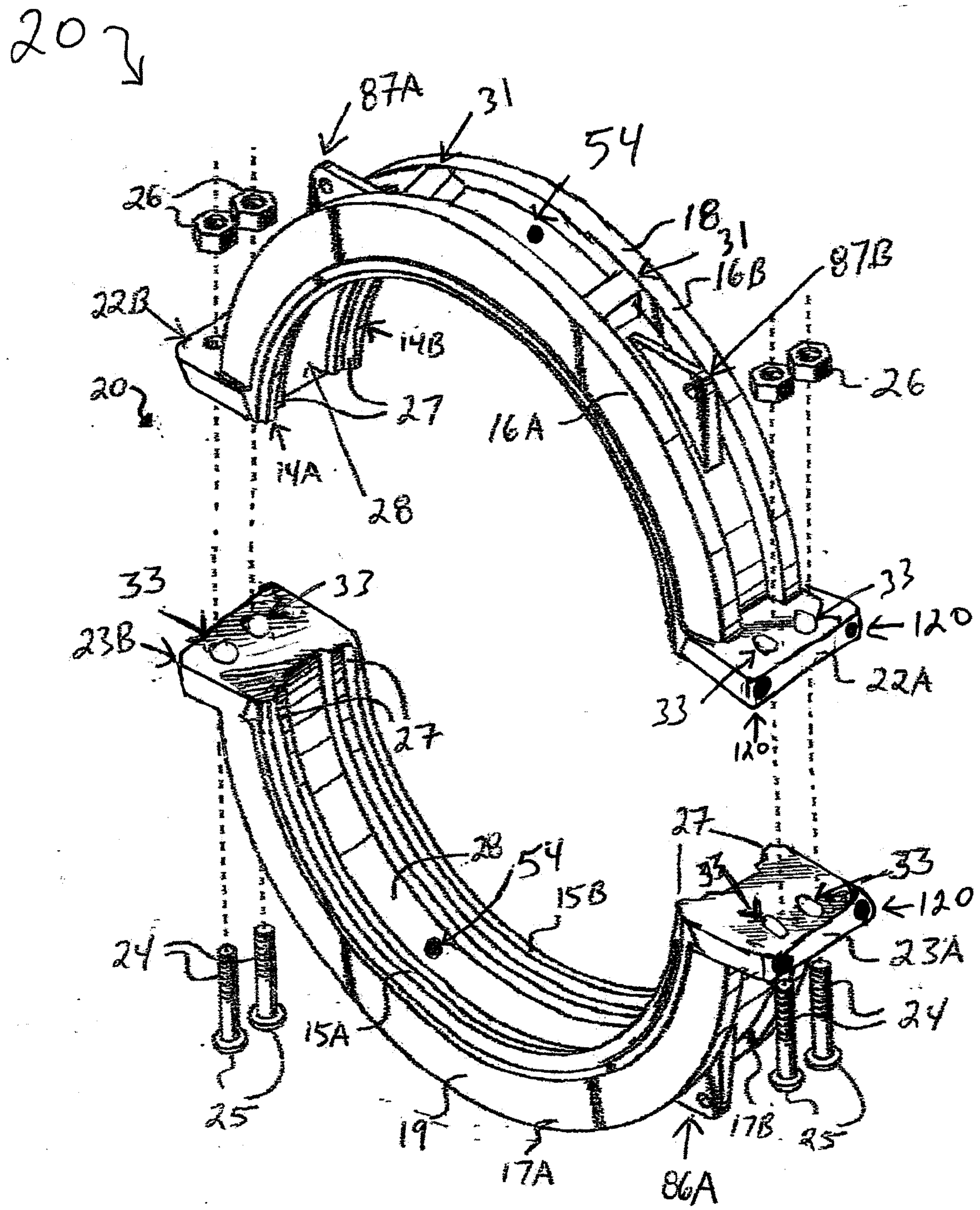
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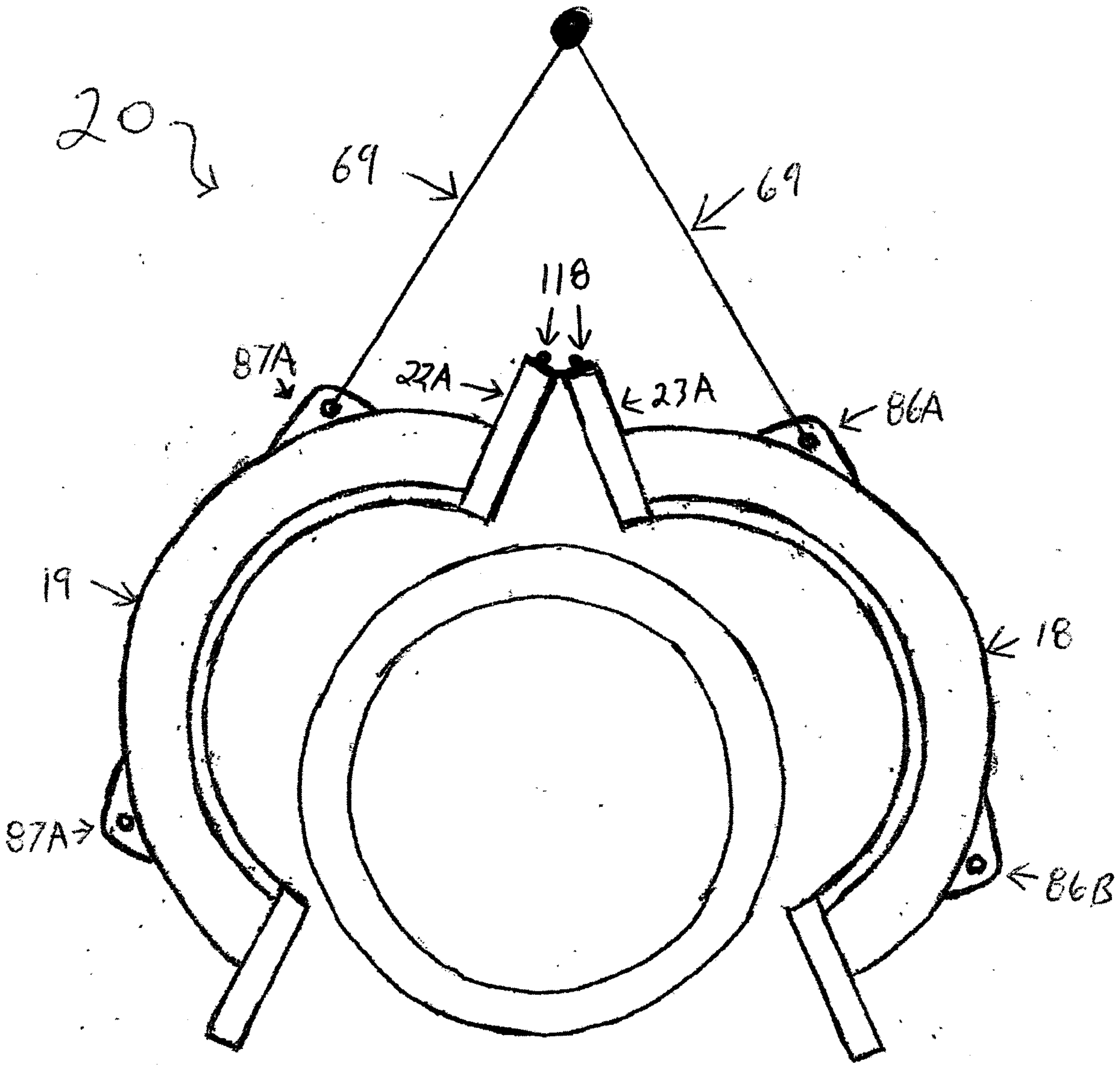
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FIG.

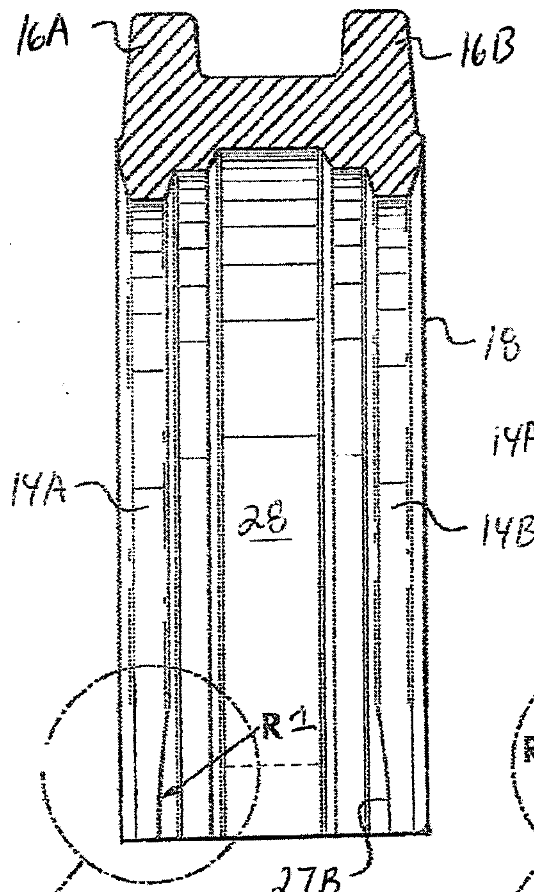
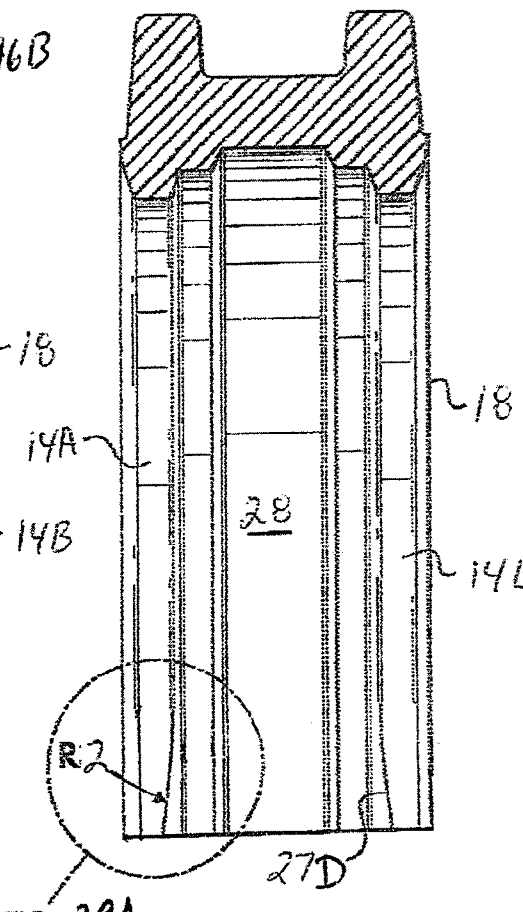



FIG. 29



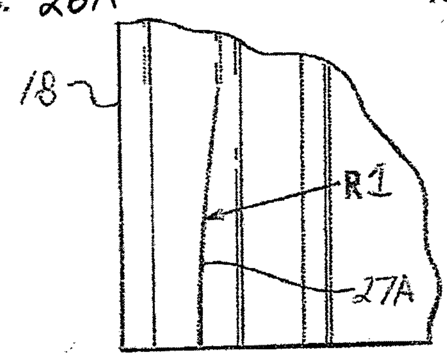




FIG. 28A

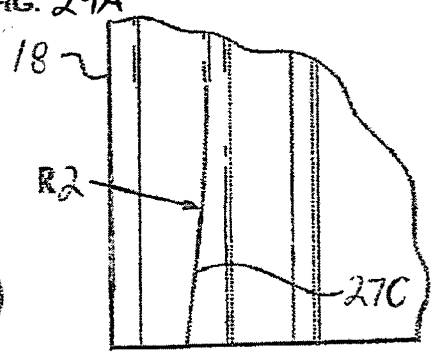



FIG. 29A

FIG. 30

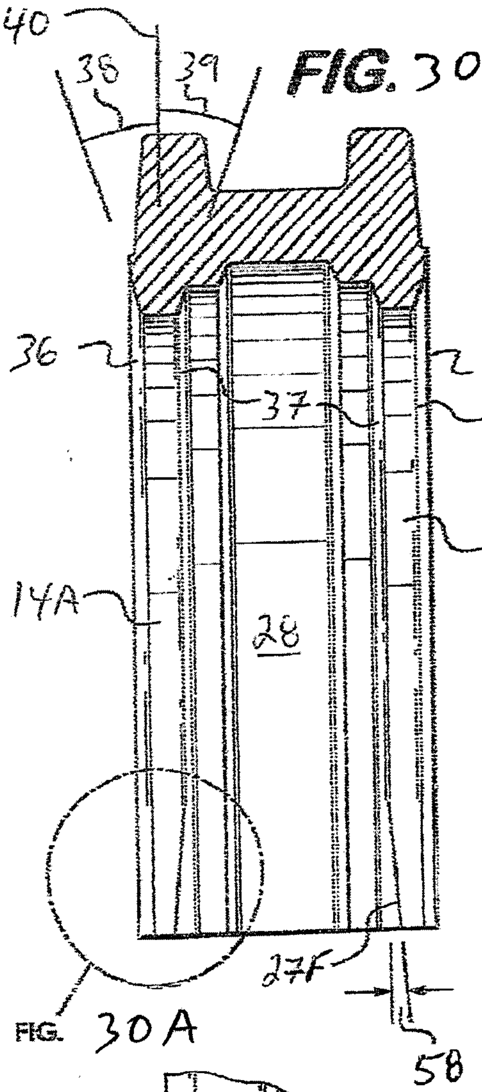
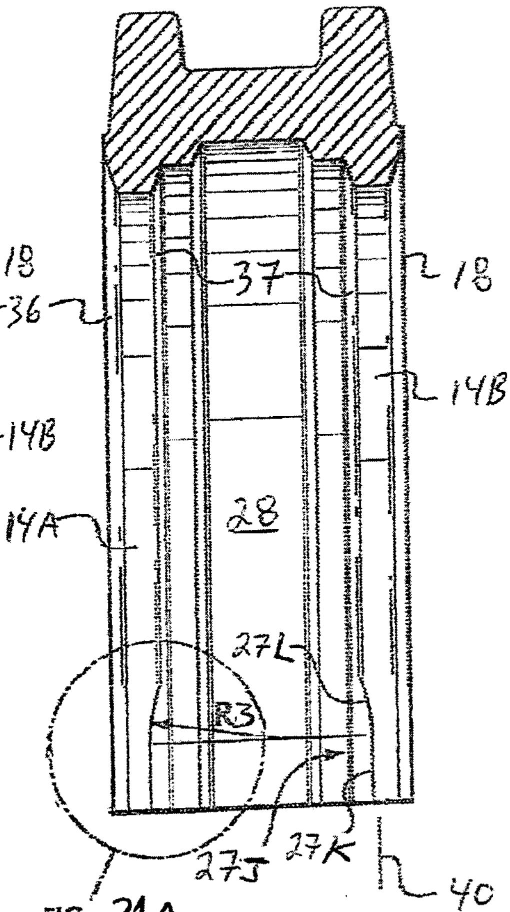



FIG. 31



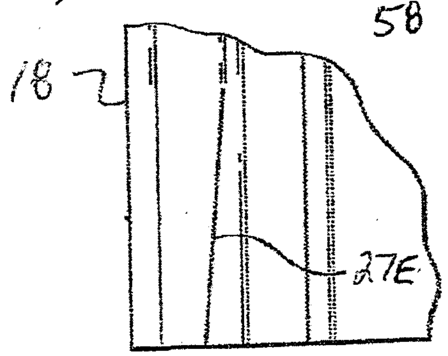




FIG. 30A

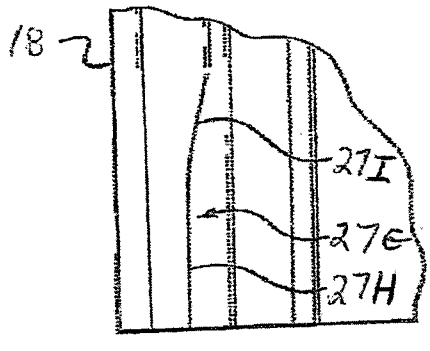



FIG. 31A

FIG.

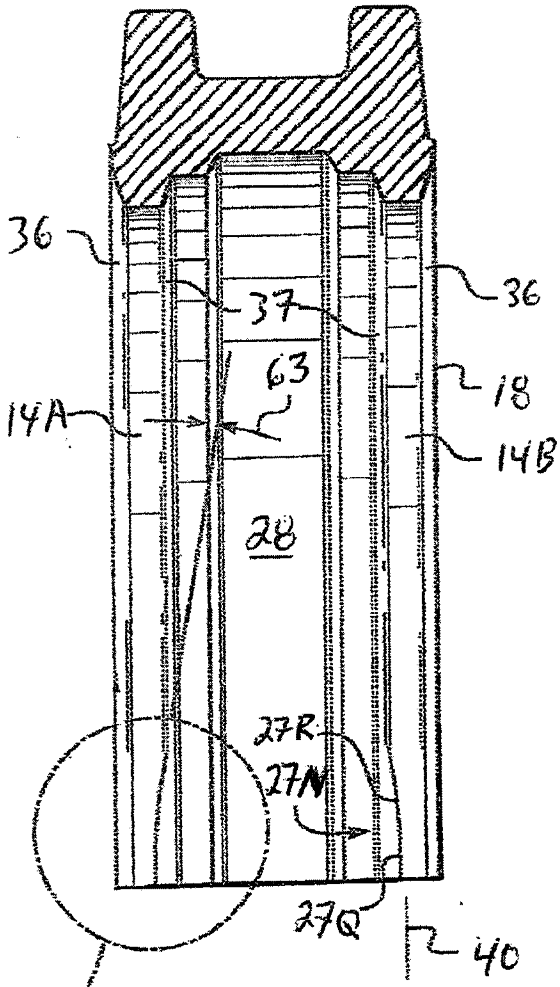



FIG. 32A

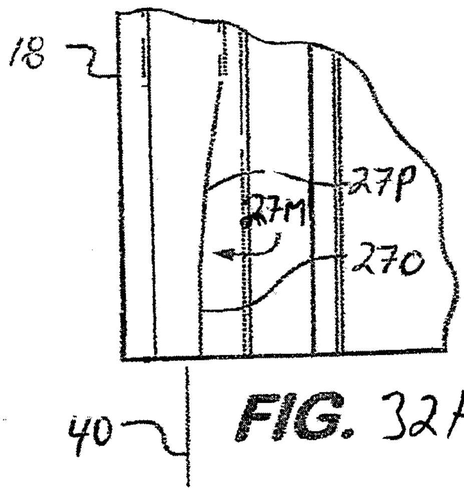
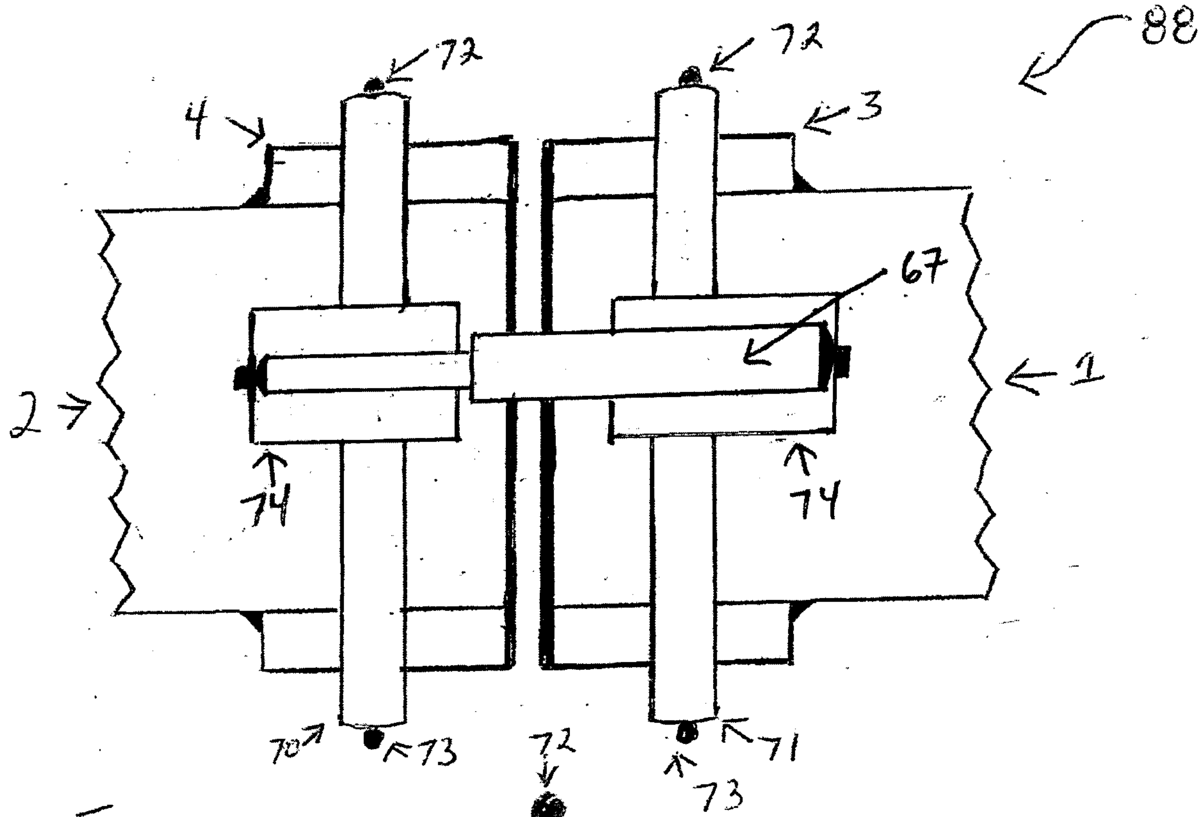
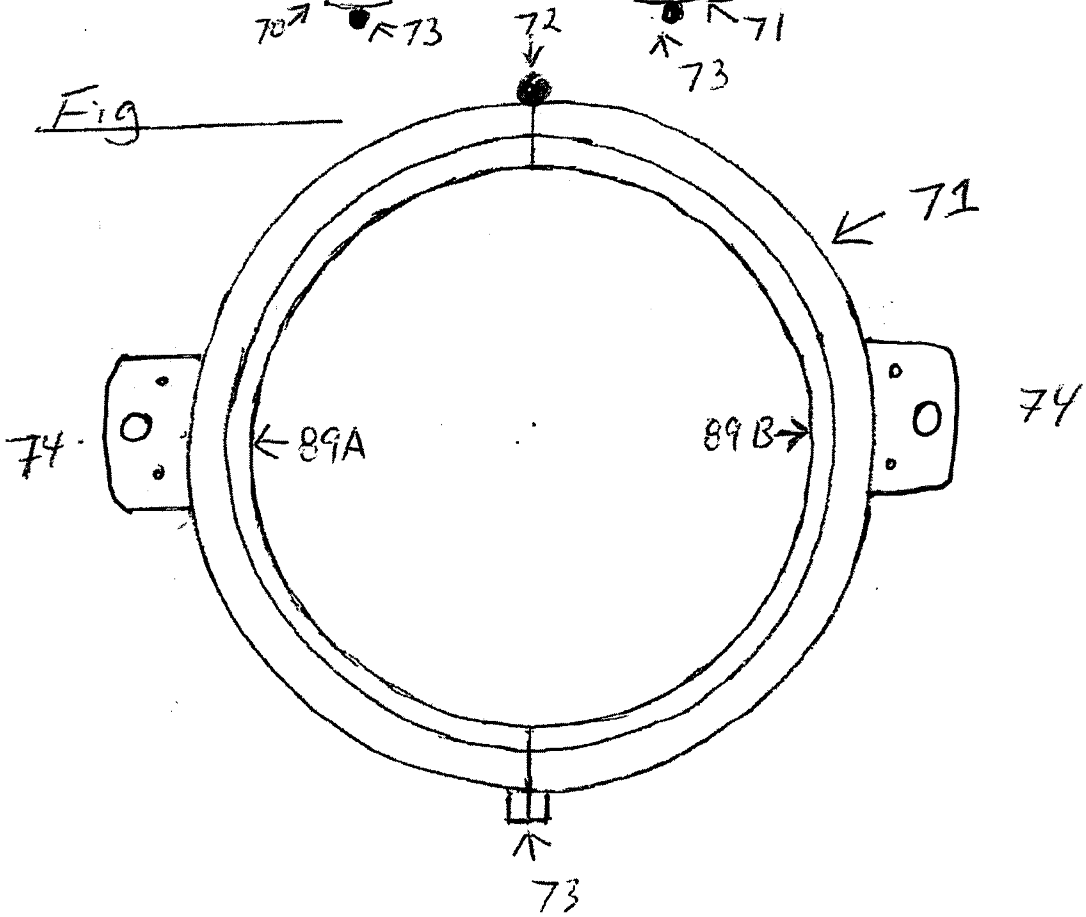
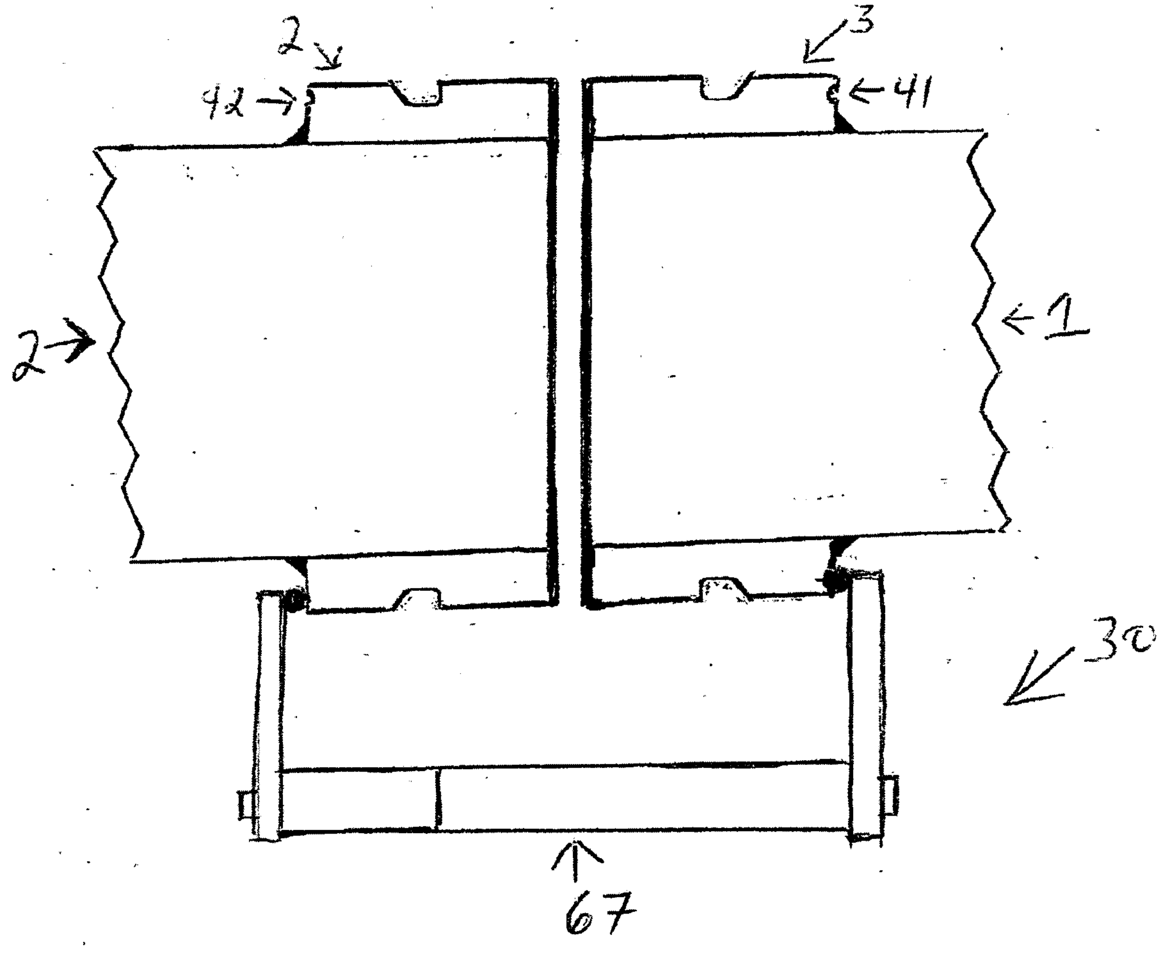



FIG. 32A




Fig

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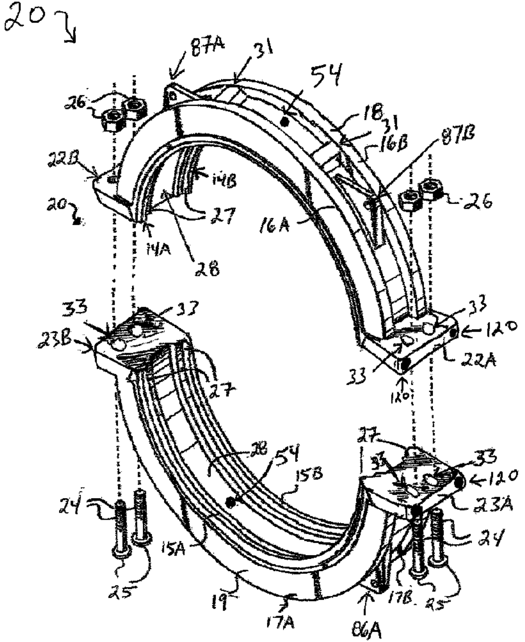

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