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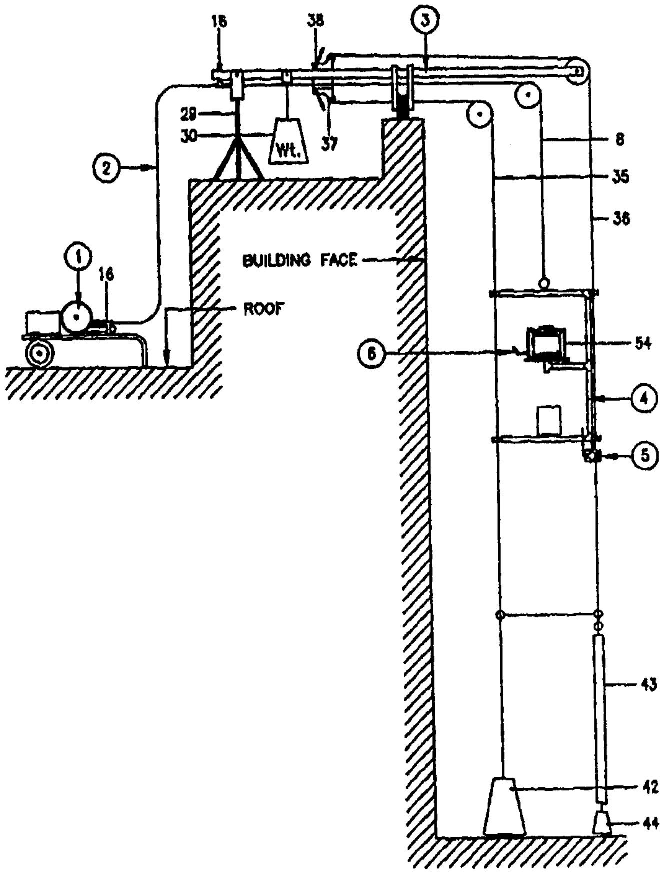
(54) Title: APPARATUS AND METHODS FOR REMOTE INSPECTION OF STRUCTURE FACADES

(57) Abstract

A remote inspection drone (4) having an imaging device (6) for recording images of traversed regions of a building façade. A position indicating device for indicating the position of the inspection drone (4) relative to one or more predetermined reference points, and recording the respective indicated positions for each of the recorded images of the façade.



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APPARATUS AND METHODS FOR REMOTE INSPECTION OF STRUCTURE FACADES

Field of the Invention

The present invention pertains to apparatus and methods for the systematic inspection of the facades of large and tall structures utilizing a remote imaging device.

Background of the Invention

Previously, structural inspection was done by erecting swing stages, which are platforms on which men or women stand. The inspectors would either merely visually note defective regions and record their general location, or take photos of various regions. Such swing stages are undesirable in that they require persons to be perched at high locations. Even under the best weather and other conditions, ascending several hundred feet in the air on a cable is an uncomfortable and distracting position in which to attempt an engineering analysis. Hence, the collected information was incomplete and consisted of a few notes and still photos. Also, there was lacking any consistency from one inspection to the next. These inspection methods were relatively quite expensive and labor intensive. In fact, the high cost of the prior art building facade inspections was so great that, in practice, typically an inspection would only be undertaken of approximately 15-25% of the actual structure's surface, and this limited data was then required to be extrapolated to arrive at a rough estimate of the work and expense required for the entire building facade.

Unmanned equipment currently in use is undesirably heavy in construction, and requires a crew to relocate the equipment. The tension system for the guide wires which guide the imaging device are too large and cumbersome to move sufficiently quickly. Hence, current structures and systems lack flexibility, which prevents their use on irregular shaped structures and where adjacent areas are congested or limited in space. Also, due to the heavy weight of the equipment and its attachments, current systems may cause damage to the building facades during inspection. Additionally, the delivery, storage, erection and disassembly of previous structures and systems required a large assembly area and caused traffic disruption in congested areas.

The existing problem is that only two methods of façade inspection are currently available.

1. Long distance telescopic inspection where the building is viewed from a distance with binoculars in an effort to locate defects and evaluate the overall condition of the façade. Dramatic failures of buildings inspected in this manner have triggered proposed legislation that may outlaw this method as acceptable for ordinance compliance.
2. The second alternative is to erect swing stages and traverse the building. This system requires two experienced riggers and one engineer to spend long days in the air under extremely adverse conditions. The swing stage method has been the only viable inspection method to date.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, an apparatus for remote inspection of building facades is provided. An inspection drone is used for traversing the building facade, with the inspection drone having an imaging device, such as a camcorder or the like, for recording images of the traversed regions of the facade. A support structure is provided which is lightweight and flexible, for supporting and guiding the inspection drone in a selective path along the building facade, such as successive vertical paths. A position indicating device is provided for indicating the position of the inspection drone relative to one or more predetermined reference points, and for recording the respective indicated positions for each of the recorded images of the facade. The plurality of scanned images may be assembled so that a plurality of separate images of the building facade may be combined to create a single composite image.

In accordance with another aspect of the present invention, an apparatus is provided having a support structure for the apparatus which has a pressure assembly for biasing the inspection drone against the building facade, to al low for inspection of angled surfaces.

In accordance with a further aspect of the present invention, a method for remote inspection of a building facade is provided. An imaging device is used, and a plurality of selective regions of the building facade are imaged with the imaging device and recorded. A position indicating device is used for indicating the position of the imaging device relative to one or more reference points. The location of the imaging device as it traverses the building facade is recorded along with the plurality of respective images taken.

KK. The entire drone assembly with camcorder weighs 10 pounds. This is 1/100th the weight of the prior art.

LL. Survey inspectors conclude with 95% to 100% of façade surfaces being recorded as archival data. This is a 10- to 20-times increase in archival data when compared to the prior art.

MM. Archival data of 95% to 100% of façade surfaces can be provided to professionals for second opinions without re-surveying the façade from a scaffold.

NN. Due to the economical cost of the data acquisition, it is possible to perform affordable guarantee inspections to protect the investment associated with major repairs.

OO. The equipment can survey approximately 20,000 square feet of wall surface during each 8 hours of operation. This is a four-fold increase from prior art.

23. Due to the heavy weight of the equipment and its attachments, damage was caused to the building's surface and ornamentation.
24. The heavy equipment required large diameter cables that caused damage to the façade.
25. The delivery, storage, erection and disassembly of previous equipment required a large assembly area and caused traffic disruption in congested areas.
26. Previous equipment was in a constant state of assembly and disassembly that created an on-going hazard to public safety.
27. Due to hazardous working conditions, employers pay a premium of 20% of each dollar paid an employee to workmen's compensation insurance.
28. It takes one crew-day (usually a 3-man crew) to assemble a power scaffold to make it functional.
29. It takes one crew-day (usually a 3-man crew) to disassemble a power scaffold and remove it from a site.
30. Counter balance weights placed on the roof to support the scaffold require special cushioning devices to protect fragile roof membranes from damage.
31. It takes approximately 2 hours of an 8-hour day to mobilize equipment, allow workers to take breaks and de-mobilize equipment. The actual productive time for survey work is 6 hours of a normal 8-hour day.
32. Scaffolds are normally operated during daylight hours. Rarely are scaffolds operated by a second or third work shift.
33. A fully loaded scaffold (men and equipment) weighs 1,000 pounds.

34. Scaffold inspectors conclude with 3% to 5% of actual wall surfaces being recorded as archival data. Due to the limited quantity of data collected, comparing data from different survey inspections is restricted.
35. Procuring second opinions regarding the condition assessment of a façade requires a re-inspection of the façade. Due to the excessive cost of repeating a scaffold inspection, second opinions are generally unfeasible.
36. Due to the excessive cost of scaffold inspections, re-examination of facades to determine if repairs which are under guarantee are performing rarely occurs. Typically, contractors' defective work is not known until guarantees have expired.
37. A scaffold inspector will cover approximately 5,000 square feet of wall surface in a typical 8-hour work shift.

Advantages and Solutions Which Have Advanced the State of the Art.

1. Engineers and riggers no longer at risk of equipment failure and accident.
2. Heavy equipment no longer above public areas.
3. Heavy equipment no longer contacts the building, damaging the façade.
4. It is economically impractical to survey more than 25% of a building using a swing stage. A drone can survey nearly 100% of the building for the same cost.
5. A drone records all of the building's surface defects.
6. A drone indexes the location of all surface defects.
7. All past and future surveys are also indexed on the same benchmarks.
8. Drone data is archival and can cover the entire life of the structure.
9. A drone guidance system is accurate enough to provide overlay comparison.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This preferred embodiment of our invention is a description of a lightweight, portable and flexible assemblage of mechanical, electronic and optical modules which comprises a system for inspecting the façade of large and tall structures.

Referring to the drawing, Fig. 1, this figure illustrates the overall system layout of one preferred embodiment of this device.

Power Head Module

Drawing Fig. 2 is a detailed layout of a power head module **1**. This module contains an electric motor **10** with reversible speed control and gear reduction. Motor 10 is controlled by a hand-held remote power head control station **11** which is attached to the motor controls by a multi-strand electric cord. The electrical power for motor 10 is supplied by battery, generator or line voltage (not shown). Mounted on the gear reduction unit is a cable reel **13** which is capable of storing large quantities of cable. Mounted on cable reel **13** is a cable guide **14** which positions the cable in an orderly fashion on cable reel **13**. This cable is drone-positioning cable **8**. Aligned with cable reel **13** is a mounting point **15** for an umbilical terminator fitting **16** to be attached. A power head transporter **9** is a wheeled chassis for transporting the power head module components, and supplies hard points to mount components and accessories.

Drawing Fig. 1 is a general layout of the most preferred embodiment of our invention. This embodiment consists of five major modules, power head **1**, umbilical **2**, parapet boom **3**, inspection drone **4** and drone location transmitter **5** and visual module **6**.

These modules are highly mobile and, with the available accessories, can adapt to almost any structural configuration.

Drawing Fig. 2 is a detailed layout of our power head module **1**. This module is a motorized cable reel that is controlled by an operator from a position near the power head **1**. This operator will normally be at the uppermost level and can safely supervise the complete system. The operator has a hardwire remote control station **11**, which has instant response and is not susceptible to outside interference. Control station **11** has a stop, start, reverse and a motor speed control. This controller **11** operates motor **10** that, through a gear reduction, turns cable reel **13**. Cable reel **13** has a cable guide **14**, which organizes the cable on the reel **13**. The systematic organization of the cable allows the use of cables more than 1,000 feet in length.

These components are attached to a lightweight wheeled power head transporter **9**. This transporter **9** acts as a chassis with hard points to mount accessories. Hard point, umbilical terminal mount **15** is critical in that it is the attachment point that connects power head **1** to umbilical **2**.

The cable which is controlled by power head **1** is called drone positioning cable **8**. Drone positioning cable **8** passes through the guidance of several modules and eventually is attached to inspection drone **4** (Fig. 1 and Fig. 8). The primary job of cable **8** is to support the weight of inspection drone **4** (Fig. 1). When the equipment operator reels in cable **8** then drone **4** is lifted higher and when cable **8** is paid out then drone **4** is lowered.

This preferred embodiment of our invention is a description of a lightweight, portable and flexible assemblage of mechanical, electronic and optical modules which comprises a system for inspecting the façade of large and tall structures.

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Umbilical System

1.) The umbilical system is a mechanical connection between the power head and the parapet boom.

2.) The power head generates motion in the form of a cable which is reeled in or paid out. This motion is transmitted to the parapet boom by the guidance and incompressability of the umbilical's cable sheath.

3.) The motion of the power head cable is guided by the parapet boom to the inspection drone.

4.) The inspection drone is supported by the power head cable and is locatd at any desired elevation along its wire guides by the action of the power head.

5.) The design of the umbilical system is unique in that the actual components are familiar to many applications, but the actual operational applications are new. Note the following:

A.) Normally a spiral-wound cable sheath is used when power is transmitted by rotating the central cable, as in a rotary flex shaft.

The second most common use is when the cable is moved only a very limited distance and is used as a flexible control rod, as in a carburetor control or a bicycle brake.

In this application the central cable can transmit motion, both in free fall and under tension, over an unlimited length of cable without rotary friction or adjustment limitations.

B.) The spiral-wound cable, which acts as if it were a rigid tube, is susceptible to contamination and must be protected with a pliable cover. In this case the pliable cover acts as a storage reservoir for oil. When the sheath is flexed by tension, the oil enters and lubricates the cable and the walls of the sheath, protecting the surface and reducing friction.

C.) The end caps are made of brass or other material which is wear resistant and will not damage the cable when the cable passes through the guide holes.

D.) The end caps and terminator tee fitting have full length cable slots t\so that they can be removed and replaced at any point in the cable and need not be threaded off the end of the cable causing long delays.

E.) The thread end cap slips over the cable and screws on to the tee fitting. When the cap is properly installed, the cable slot in the cap will not align with the cable slot in the tee fitting, locking the cable in the tee fitting.

F.) The tee fitting is designed to be attached by placing the mounting stem into a mounting hole and securing it in place with a removable pin.

G.) The overall length of the umbilical system is variable. With its built-in lubrication supply, length does not impose severe restrictions.

H.) The umbilical system permits the parapet boom to be mounted a considerable distance from and above or below the power head.

I.) If additional lubrication is required, dismount one of the terminator tee's, turn the mounting stem bottom-up, and pour oil into the bottom stem opening.

J.) If wear is discovered in the wire sheath, it can be replaced by removing a tee fitting cap and sliding the sheath off the end of the cable. A new sheath can be slipped over the cable into the umbilical cover and locked into place with the end cap.

Umbilical system module **2** (Fig. 1, Fig. 4, Fig. 5, Fig. 6 and Fig. 7) illustrate the detailed components of our umbilical system. Umbilical **2** is a flexible power transmission connector between power head **1** and parapet boom **2** (Fig. 1 and Fig. 3). The power in this case is the linear motion of drone positioning cable **8**.

We believe that our umbilical **2** is a unique application of a familiar appliance. A cable surrounded by a spiral wound incompressible wire sheath **18** (Fig. 4) is used to transmit rotary power as in a powered flex shaft. The other most common applications are as a control positioner where the cable has limited travel or when the travel of the cable is stalled. These two applications could be described as a throttle and a brake.

Our umbilical allows us to have continuous uninterrupted control and power transmission to equipment more than 1,000 feet from the power source.

The umbilical is a coaxial system in that a center cable **8** is surrounded by a tubular shaped wire wound sheath **18**. The wire sheath **18** has a tubular terminator tee fitting **16** attached to each of its ends. The final closure at the open ends of the terminator tee fitting **16** is a brass threaded end cap **17**. Covering nearly the entire umbilical is a pliable wire sheath cover **19**.

Positioning cable **8** support the weight of the inspection drone **4** at all times but when the drone is lifted cable **8** is put under considerable tension. Under these conditions wire sheath **18** acts as an incompressible tube regardless what shape it assumes.

This incompressibility feature prevents the cable **8** tension from moving the equipment attached to the ends of the umbilical **2**. The equipment acts as if it were connected by a rigid beam when, in fact, the connector is draped over and around obstacles.

The tee fitting **16** attached to each end of the wire sheath **18** are mounting fixtures which allow the umbilical **2** to be connected to other modules. These tee fittings **16** are threaded at the ends of all of their legs. The leg into which wire sheath **18** is inserted is called the tee bar **27**. The tee bar **27** has a wire sheath locking device **26** and has a cable entry slot **21** machined from end to end of the tee bar **27** (Fig. 4). The cable entry slot **21** allows the tee fitting to be removed from the cable at any point convenient.

The leg of the tee fitting, which is perpendicular to the tee bar, is the tee body mounting stem **25**. The stem is an anchor pin that is inserted into an umbilical terminator tee mount **15** when attaching the umbilical **2** to another module. A threaded cap **24** with a wide flange is screwed onto stem **25**. Cap **24** locks the stem **25** into mount **15** attaching the umbilical **2**.

At the extreme ends of the umbilical **2**, mounted on the tee bar are threaded brass end caps **17** (Fig. 4). The end caps **17** absorb the complete end thrust of the wire sheath **18** and therefore must be heavy duty construction. A cable guide hole **22** is drilled in the end of each cap **17** (Fig. 6). Brass is the preferred material because it is unlikely to damage the cable and wears well under abrasive conditions.

The end caps **17** have a cable entry slot **21** machined their full length and into the cable guide hole **22**. The cable entry slot allows the end cap to be removed and replaced at any point on the cable.

If a wire sheath **18** requires replacement, remove an end cap **17** and the sheath can be slid out of the umbilical **2**. The wire sheath slides off the end of the cable **8**. A replacement sheath **18** is fed onto cable **8** and slid into the umbilical **2**. The cap is replaced and work can begin, no system adjustments required.

The final umbilical **2** concentric component is a pliable sheath cover **19**. This pliable cover **19** is a dirt shield to protect the wire sheath from ingesting contaminates. The wire sheath, if not protected, would lay on roofs, sand and water.

The pliable cover **19** can be any material that is pliable, water resistant and compatible with lubricants. In most situations, the cover **19** needs to be very flexible but in conditions where vehicle traffic may damage the sheath, a stiff, heavy cover is required.

Under most conditions, a simple clamp or seal **20** will be adequate where the pliable cover **19** mounts on to the tee bar **27**. If necessary, the pliable cover can be sealed with a liquid tight compression fitting (Fig. 7). The pliable cover also acts as an oil reservoir. Lubricating oil can be added to the umbilical **2** by removing cap **24** adding a small amount of oil into mounting stem **25**. The oil will collect in low point of the umbilical and wet the cable as it passes.

This unique system works very well, suffers little wear and seems to have no length limitations.

The umbilical system allows the power head to be located at nearly any height or relationship to the other modules in the system. This inherent flexibility makes this system the first commercially viable unmanned façade inspection equipment.

The parapet boom module **3** (Fig. 1 and Fig. 3) controls and locates the drone positioning cable **8**, the guide cables **34** and **35** and the handling of the tension weights **42** and **43**. The parapet boom module **3** must be strong enough to perform as a light duty crane. The module must be light and flexible enough to be efficiently relocated every few minutes without any wasted motion. In addition to the above duties, the module is, in actuality, a camera boom. The positioning of the camcorder from the façade and the angle which the camcorder views the façade is critical.

The parapet boom **3** is the guiding device for the other movable portions of the system. The ultimate result of this equipment is to position a camcorder out in space so that it can, without interference, clearly and efficiently image the façade.

The main structure of the parapet boom module **3** is a rigid beam **31** (Fig. 3). This beam **31** made of metal and tubular in shape. It can be in one piece or made up of several pieces. Other materials and profiles can be used to meet job requirements.

The beam **31** is balanced on a fulcrum, which in this embodiment is a wheeled truck **28**. This truck can be rested on the parapet wall or roof and be rolled to a new location. The tires are soft and do no damage and safely grip the stone surface. The beam pivot mount which attaches the beam to the truck also pivots. This pivoting attachment permits the beam to be positioned at nearly any angle in reference to the wall. This provision permits the convenient negotiation of complex building shapes.

Beam **31** must withstand the loads imposed on it by the cables, weights and equipment suspended over the side of the structure.

Counter weight **30** (Fig. 3, "B-B") is attached to the rear of beam **31** to balance the loads from the opposite end of the beam **31.** The loading of the beam **31** by the forward cables is highly variable, therefore rear beam stand **29** is provided to level the beam and support the counter weight during these periods of fluctuating loads.

In reality, the purpose of the parapet boom **3** is to guide and support cables. There are two groupings of cables. One could be described as active and the second could be described as passive.

The active cable is the drone positioning cable **8** that raises and lowers the inspection drone **4** (Fig. 1). This cable is in motion during the actual inspection and is powered by a remote piece of machinery and controlled by a distant operator.

This cable **8** is brought to the parapet boom through the umbilical. The umbilical is attached to the parapet boom **3** by tee **16**. Cable **8** is guided under beam **31** and past the stand **29**, counter weight **30**, winch **37** and truck **28** to support shive **32**. Cable **8** passes over shive **32** and turns downward to be attached to inspection drone **4** (Fig. 1 and Fig. 9). Cable **8** raises and lowers the inspection drone as a camcorder **77** images the structure.

The passive cables are guide cables **35** and **36** which are only in motion when the equipment is being moved or set up.

The passive cable layout is the feature that makes the parapet boom so fast and versatile. The devices which make this speed and flexibility possible are two hand winches **37** and **38** mounted on the rear half of the beam **31** (Fig. 3). One winch **38** above the beam and one winch **37** below. These winches control the inter guide cable **35** and outer guide cables **36**.

The winches **37** and **38** put the handling and location of the weights **42** and **43** under the control of the rooftop operator.

This topside weight control is most critical when relocating the boom **3**. The roof top operator can lift these weights **35** and **36** and move over tree, buildings and other adjacent obstacles. If a particularly difficult obstacle is encountered, the weights **35** and **36** can be suspended in midair while that particular area is being inspected. In addition to normal bulk weights **42**, long slim pipe weights **43** have been developed. Pipe weights **43** are lowered from above down through trees or between closely spaced obstacles. The pipes **43** are then attached to anchors or stakes if high cable tension is required.

When high cable tension is required, the beam mounted winches **37** and **38** allow the operator to put the maximum tension on each cable **35** and **36** without damaging the equipment.

Umbilical System Module

Drawings Fig. 1, Fig. 4, Fig. 5, Fig. 6 and Fig. 7 illustrate the detailed components of an umbilical system **2**.

Umbilical system **2** is a flexible power transmission connector between the power head **1** and the parapet boom **3**. The power in this case is the linear motion of drone positioning cable **8**.

Drawing Fig. 4 is a center-line section of umbilical system **2** illustrating the relationship between the components. The intermost component is inspection drone positioning cable **8**. Inspection drone cable **8** is surrounded by a spiral wound wire cable sheath **18**. Cable sheath **18** is locked between two terminator tee fittings **16** by a wire cable sheath-locking device **26** in tee fitting body **16**. Tubular material is used to fabricate tee fitting body **16** and all open tube ends are threaded.

Each tee fitting **16** in section "AA" of Fig. 5 has a threaded end cap **17** which is the closure at the extreme ends of umbilical system **2**. Brass is the preferred material for end cap **17**. End cap **17** must be heavy duty to withstand heavy thrust loading. A hole is drilled in the center of end cap **17** which acts as a cable guide hole **22**. A cable entry slot **21** is machined the full length of a tee bar **27** of tee body **16** in Fig. 5 Section "AA" and of end cap **17** in Fig. 6. Cable entry slot **21** allows tee body **16** and end cap

17 to be removed and replaced on umbilical system **2** without removing cable **8**. Umbilical system **2** has tee fittings **16** at each end. Each tee fitting has a tee fitting mounting stem **25** which is used to attach the umbilical to its adjacent module. Umbilical mounting points **15** are built into power head module **1** and a parapet boom module **3** (Fig. 3) to accept a mounting system **25** of umbilical tee body fittings **16**. A removable mounting device **24** locks tee fitting **16** into mounting points **15** on power head **1** and parapet boom **3**.

The preferred configuration (Fig. 4) of removable mounting device **24** is a thread cap with an expanded thrust face.

A pliable cover **19** is installed over the exposed wire cable sheath **18**. Extra material is provided to allow pliable cover **19** to be slipped over tee bar **27** of terminator fitting body **16**. Pliable cover **19** has inside diameter slightly larger than the outside diameter of terminator tee bar **27**. An oil and dust seal **20** is installed to act as protective closure. Oil **23** is introduced into the umbilical system **2** through mounting stem **25** of terminator tee fitting **16**. Pliable cover **19** acts as an oil storage reservoir.

Inspection Drone Module

The inspection drone is a chassis which can be restructured to conform to the needs of a specific site or carry any combination of equipment.

An inspection drone chassis **52** is a lightweight structure assembled from prefabricated connectors **45** and standard tube stock **51**. The configuration incorporates the necessary hard points to mount single or multiple camcorder housings **54**, special lighting **55**, and additional battery packs **56**, and also to increase or decrease the chassis overall size.

Prefabricated connectors come in several forms: stock tees and elbows **45**, rotating connectors **46**, chassis roller guide assembly **47** with guide cable rollers **48**.

The four corners of drone chassis **52** incorporate prefabricated chassis guide assemblies **47**. The assembly consists of a strengthened fitting which has a guide cable slot **50**. At the inter end of guide cable slot **50** is a guide roller **48**. Guide cables **35** or **36** are inserted into guide cable slot **50**. After the guide cables **35** or **36** are inserted into guide cable slot **50**, a second guide cable roller **48** is installed, trapping the guide cable **35**or **36** between two guide cable rollers **48**. This system ensures a smooth, frictionless movement of drone chassis **52** along the guide cables **35** or **36**.

Drone chassis **52** has a mounting point for a drone location transmitter **5** and camcorder housing **54**, which has a mounting bracket **59** for a drone location visual display **6**.

Inspection drone **4** is stabilized by inter **35** and outer **36** guide cables and vertically positioned by drone positioning cable **8**.

The drone has sliding electrical brushes which contact inter guide cable **35** and the outer guide cable **36**. The guide cable brushes electrically connect the drone to guide cables **35** and **36**.

The guide cable brushes permit additional electrical power to be transmitted to inspection drone **4** and/or used to control on-board equipment by hard wire.

The guide cables **35** and **36** are tensioned by weights **42** and **43**. A weight spreader bar **57** maintains a fixed distance between the guide cables **35** and **36**.

Location transmitter **5** is attached to inspection drone **4** and contacts guide cable **36**. Mechanical connection **60** supports drone location transmitter **5** and aligns transmitter **5** with the outer guide cable **36**. Electrical connection **58** connects transmitter **5** to visual location display **6** mounted on camera housing **54** (Fig. 10).

Camcorder Housing **54** (Fig. 10)

A camcorder housing **54** is a weather cover which consists of a operable access door **79**. A camcorder mount **80**, a camcorder power connector **81**, a protective lens **82** and an adjustable mount **59** for the drone location visual display unit **6**.

Adjustable mount **59** has movable joints **83** that allow exact positioning of the visual display unit **6**.

Camcorder housing **54** is mounted on a rotating connector **47** which permits leveling the housing and horizontal centering.

Access door **79** allows the camcorder to be placed on its mount **80** and attached to the camcorder battery pack connector **81**.

A cooling fan **85** or a heater element **86** are operated when extreme conditions exist. Fan **85** and heater **86** require auxiliary battery pack (not shown).

The previous equipment covered in this application is only support for the critical module, the inspection drone **4** (Fig. 1 and Fig. 8). The control, stability, placement and consistency of movement of the inspection drone **4** is the result of our developmental efforts.

The actual function of the inspection drone **4** is to transport a camcorder. The camcorder images long, vertical strips of the building façade. The image strips are electronically assembled forming a mosaic of the building's exterior.

The overall compatibility of this imaging process is the result of smooth, vibration-free motion of the drone **4**. The power head **1** must deliver consistent cable dispensing at the proper rate. The guide cables **35** and **36** must maintain tension. The drone chassis **52** must be rigid and maintain camcorder alignment and move flawlessly.

Drawing Fig. I illustrates the general layout and relationship of inspection drone **4** to the other equipment in the system.

Inspection drone assembly **4** is made up of components chassis **52**, roller connectors **47**, camcorder housing mount **5**, lighting **5**, battery pack **56** and the mounting points for the drone location transmitter **5** and visual display **6**.

The chassis **52** (Fig. 8) is a general "E" shape with a backbone, two legs and a center camcorder support arm. In actual field practice this embodiment is regularly rearranged into every conceivable configuration.

The adaptation of the drone chassis **52** is possible by combining stock tubing **51** elbows and tees **45** with specially designed guidance and positioning hardware. Guidance of the chassis **54** is controlled by four roller connectors **47** (Fig. 8 and Fig. 9). The connectors **47** allow the chassis **52** to move on guide cables **35** and **36** without friction or vibration. Drawing Fig. 9 illustrates the details of roller connector **47** in relation to a typical guide cable.

Brass roller **48B** is removed from fitting **47**. The guide cable is inserted into the vertical cable slot **105**. The guide cable in the slot **105** contacts roller **48A**. Roller **48B** is reinstalled, trapping the guide cable between the two rollers. This roller arrangement is repeated at all four corners, assuring perfect alignment and frictionless movement.

Positioning of the camcorder is controlled by rotating connector **46**. Connector **46** is adjustable in left to right on a vertical axis and can be plumbed or tilted on a horizontal axis. This adjustment allows the camcorder to view any near-by wall at exactly the required angle.

As many as four camcorders can be adapted to this simple chassis. Each camcorder can be assigned to a particular area of interest, each camcorder having its own focus and lighting **55**. The camcorders are powered by a battery pack **56**. Lighting **55** has a heavy power draw requiring separate power packs (not shown).

The exact location of where a camcorder is located at any given moment is very critical. Each image recorded must have circumferential reference and a vertical reference.

The circumferential reference is the point on the wall viewed at center of the camcorder image. The angle at which this point is viewed is necessary. This information is recorded and a benchmark is cut into the parapet.

The vertical reference is a height and grade for each image. This height is accumulated by a drone location transmitter **5** and imaged by a drone location display **6**. These units are mounted on the drone chassis **52** and the camcorder housing **54**.

The operation of this equipment will be discussed later in this application.

Drone positioning cable **8** is attached to the drone chassis by connector **53**.

Weight spreader bar **57** is used to maintain a prescribed distance between guide cables **35** and **36.**

Drawing Fig. 10 illustrates a camcorder housing **54**. This camcorder housing is an enclosure that protects the camcorder from the outside elements. This housing **54** has an access door **79** that allows entry to place the camcorder on its mount and operate the camcorder.

Camcorder housing **54** is mounted on rotating connector **46** that is mounted on the camcorder support arm of inspection done **4** (Fig. 8). Connector **46** enables the housing **54** to be vertically plumbed and horizontally panned.

The front of the housing **54** has a protective lens that protects the camcorder lens from being contaminated or damaged.

Heater element **86** in cold weather maintains an internal temperature suitable for camcorder operation.

Cooling fan **85** maintains a flow of cooling air inside the housing **54** in hot weather. In very severe heat conditions, Pyrex protective lens, reflective exterior coatings, insulation and cooled compressed air can be used to protect the camcorder.

At night or in enclosed areas, lighting **55** is attached to the camcorder housing.

The camcorder is powered by one or more battery packs **56** attached to the inspection drone **4** (Fig. 8).

Location display mount **59** (Fig. 10) is attached to the front of the camcorder housing **54** and is aligned with the center of the camcorder lens. The display mount has two articulating joints, display adjusters **83**, which enable the mount to be very precisely adjusted. The display mount supports and positions the drone location display unit **6** so that it is visible to the camcorder. The importance of this capability will be discussed later in this application.

Drone Location System

The drone location system tracks the height of the drone above or below an arbitrary line or grade. Normally for practical job site use a chalk line or laser scanner is set at a convenient height above actual grade. For our equipment, about four feet is convenient, and is referred to as camera grade. Camera grade can be at several different levels around a structure but each is referenced to a single starting level. At the beginning of each camcorder inspection pass, the camcorder is positioned at camera grade for recalibration. To recalibrate the drone location system, the display is manually set to the camera grade or a known distance above a common reference elevation. By following this simple procedure anyone who is viewing the camcorder tapes will know the exact elevation of each image.

Drone Location Transmitter **5** (Fig. 10 and Fig. 11C)

Drone location transmitter is mounted at the lower outside corner of inspection drone **4** (Fig. 8). At this corner, cable **36** leaves fitting **47** of the drone chassis **52**. Cable **36** is threaded into the top of the transmitter (Fig. 12) past the calibrated wheel and out the bottom of the transmitter frame. The transmitter measures the accumulative length of cable that passes by the calibrated wheel. The transmitter communicates in one-tenth-of-a-foot increments indicating assent or descent of the inspection drone.

Calibrated Wheel Assembly **91** (Fig. 11)

Guide cable **36** is held against calibrated wheel **61** by adjustable cable idlers **62**. As the inspection drone moves up and down, guide cable **36** passes through the transmitter assembly. The friction of cable **36** on calibrated wheel **61** causes the wheel to rotate.

Wheel **61** rotates exactly one rotation for each linear foot of cable that contacts the wheel.

Main Shaft Assembly **90** (Fig. 11A)

Calibrated wheel **61** is mounted on main shaft **63** and causes the shaft to rotate. Shaft **63** is mounted on two bearings **64** and at one end of the shaft an auxiliary coupling **72**. Cam assembly **89** is mounted on shaft **63** and rotates with the calibrated wheel **61**.

Cam Assembly **89** (Fig. 11A)

Cam assembly **89** is cam **65** which, in this embodiment, has ten lobes. Special applications may require a different number of lobes. The purpose of cam **65** is to break each shaft rotation into ten equal parts. Each cam lobe **66** signals that one-tenth of a foot of cable **36** has passed calibrated wheel **61**.

Switch Assembly **71** (Fig. 11B°

Switch assembly **71** is the mechanism that turns rotating cam lobes **66** into electrical impulses. Cam follower **67** is positioned by pivot **70** so that it is on the same plain as cam **65** and perpendicular to shaft **63**. As cam **65** rotates, each lobe contacts follower **67** and deflects the follower in the direction of rotation. When follower **67** is deflected it contacts one of the adjacent switches **68** and closes an electrical circuit.

Which of the two switches **68** contacted is the result of the direction of rotation of cam **65**. The direction of cam **65** rotation is indicative as to whether the inspection drone has been raised or lowered one-tenth of a foot. Both contact switches **68** are connected to the electronic circuitry of drone location display module **6** (Fig. 11C, Fig. 10 and Fig. 8).

If a totally closed non-contact switching embodiment was required, sealed proximity switches **88** (Fig. 11C) could be substituted for contact switches **68** (Fig. 11B). Magnetic senders **88** (Fig. 11C) could be molded into the calibrated wheel **61**. Cam **65** could be replaced by a sealed ten-point magnetic armature. This sealed system would replace open system **71** (Fig. 11C).

Drone Location Display Assembly **6** (Fig. 1, Fig. 8, Fig. 10 and Fig. 11C)

Drone location display electrical circuitry **76** is connected to switch assembly **71** (Fig. 11B). Electrical circuitry **76** responds to pulses from switch assembly **71** and increases or decreases the elevation accumulated on LCD display face **75**. This system tracks the vertical location of the inspection drone **4** (Fig. 8) at all times.

Drone location display **6** (Fig. 10) is mounted on camcorder housing **54** by mount **59** and positioned by display adjusters **83**. Mount **59** is designed to place display face **75** so that when the camcorder is operated the display face readout is recorded. The LCD readout is back-lit and each camcorder image has a clear numerical elevation at the base of each picture. This readout is based on one-tenth-foot increments, but metric or units of measure can be used. The accumulative total is 9,999 units to 3 decimal places. A reset switch **92** is provided, which resets the readout to zero.

Camera Dolly Assembly **106** (Fig. 19)

Previously in this application we described our inspection drone **4** (Fig. 8). Inspection drone **4**, in essence, is a free-floating chassis that carries a camcorder and images the façade without contacting the structure. This system works very effectively for almost all high rise type structures.

We have discovered that certain types of structures require a different kind of inspection drone. Some structures are sited in locations where the wind blows at high speed every day of the year. Structures such as smoke stacks and dams have inclined walls and are best addressed by a wheeled drone that contacts the surface. In fact, we have developed a system for generating force to press the wheels firmly against the structure. Although this force is horizontally applied to a vehicle on a vertical wall, we call it ground pressure. For purposes of clarity, we call our wheeled inspection drone a camera dolly.

Drawing Fig. 19 illustrates the general layout of camera dolly assembly **106**. Main chassis **109** has bearings **112** to support a front axle **108** and a rear axle **113**. Rear axle **113** is narrow and the rear wheels **107** are close to the chassis. Front axle **108** is very wide when compared to the width of the chassis **109**.

Front bearing **112** allows the chassis **109** to be positioned near the left or the right wheel. The offset axle and wheel acts as an outrigger and stabilizes the dolly in adverse wind conditions.

Chassis **109** (Fig. 19) has a rigid camera post **110** and a camera arm **111**. Camera arm **111** is mounted on camera post **110** by movable fitting **114** which allows the arm to move along the post. Camera arm **111** is the mounting support for a camcorder housing (not shown). Rotating connector **46** allows the camcorder housing (Fig. 10) to adjust in relation to the imaged surface.

Attached to the rear of chassis **109** is the drone location transmitter **5** and mounted on camcorder house **54** is drone location visual display **6**. These units communicate through electrical connector **58.**

Drone Location System

The drone location system consists of two major components: drone location transmitter module **5** and drone location display module **6**.

Mechanical connection **60** attaches the drone location transmitter **5** to drone chassis **52**.

Electrical connection **58** electrically connects transmitter **5** to visual display **6** which is mounted to the camcorder housing **54**.

The transmitter module **5** (Fig. 11, Fig. 11A, Fig. 11B, Fig. 11C and Fig. 12) is made up of several subassemblies: a main shaft assembly **90**, a calibrated wheel assembly **91**, a cam assembly **89**, a switch assembly **71**, location visual display assembly **6** and an auxiliary assembly **78**.

Main Shaft Assembly **90** (Fig. 11A)

The main shaft **63** is a round, rigid shaft which is mounted on two bearings **64** and is free to turn.

Calibrated Wheel Assembly **91** (Fig. 11)

A calibrated wheel **61** is mounted on main shaft **63**. A guide groove **69** is machined in the circumference of calibrated wheel **61**. Transmitter **5** is aligned by its mechanical mount so that drone guide cable **36** passes over the face of calibrated wheel **61**. Cable **36** engages a guide groove **69**. Two adjustable cable idlers **62** maintain the alignment of the cable.

Cam Assembly **89** (Fig. 11A)

The cam assembly **89** consists of a cam **65** mounted on main shaft **63** and a cam follower **67** mounted on a pivot **70**.

Cam follower **67** is held on a plain perpendicular to the center line of main shaft **63**. Cam follower **67** is engaged by cam lobes **66** regardless of which direction cam **65** rotates.

Switch Assembly **71** (Fig. 11B)

A switch assembly **71** is comprised of two contact switches **68** which are activated by physical contact. Contact switches **68** are on adjustable mountings and can be accurately positioned. When cam follower **67** is displaced by cam lobe **66**, follower **67** contacts one contact switch **68** closing a circuit. The direction of cam rotation determines which circuit will be closed. The direction of the cam **65** rotation is indicative of the direction which the inspection drone **4** is traveling.

Cam **65** has one or more cam lobes **66**. Cam lobes **66** can be mounted on calibrated wheel **61** to actuate contact switches **68**.

Auxiliary Switching Figure 11C

Magnetic senders **87** can be mounted on calibrated wheel **61** or main shaft **63**. Proximity switches **88** mounted near these revolving senders will close a circuit.

Location Visual Display **6** (Fig. 11C, Fig. 8 and Fig. 10)

A mechanical mount **59** attaches location visual display module **6** to camcorder housing **7**. Visual display module **6** is composed of two subassemblies.

A display electronic circuit **76** and a LCD crystal display face **75**.

The location display electronic circuit transmitter transmits data to display circuit **76** which responds by increasing or decreasing the reading on display face **75**.

LCD Crystal Display Face **75** (Fig. 11C)

The data on display face **75** is viewed by the camcorder and recorded on the video tape.

A reset switch **93** resets the location display to zero to re-establish a datum line.

Auxiliary Assembly **78** (Fig. 11A)

Auxiliary equipment can be powered by rotating main shaft **63**.

A coupling **74** on main shaft **63** provides a connector to attach a rotary encoder **73**. Encoders **73** supply various kinds of information based on the characteristics of the rotational rates of main shaft **63**.

A calibrated wheel **61** is mounted on main shaft **63**. A guide groove **69** is machined in the circumference of calibrated wheel **61**. Transmitter **5** is aligned by its mechanical mount so that drone guide cable **36** passes over the face of calibrated wheel **61**. Cable **36** engages a guide groove **69**. Two adjustable cable idlers **62** maintain the alignment of the cable.

Cam Assembly **89** (Fig. 11A)

The cam assembly **89** consists of a cam **65** mounted on main shaft **63** and a cam follower **67** mounted on a pivot **70**.

Cam follower **67** is held on a plain perpendicular to the center line of main shaft **63**. Cam follower **67** is engaged by cam lobes **66** regardless of which direction cam **65** rotates.

Switch Assembly **71** (Fig. 11B)

A switch assembly **71** is comprised of two contact switches **68** which are activated by physical contact. Contact switches **68** are on adjustable mountings and can be accurately positioned. When cam follower **67** is displaced by cam lobe **66**, follower **67** contacts one contact switch **68** closing a circuit. The direction of cam rotation determines which circuit will be closed. The direction of the cam **65** rotation is indicative of the direction which the inspection drone **4** is traveling.

Cam **65** has one or more cam lobes **66**. Cam lobes **66** can be mounted on calibrated wheel **61** to actuate contact switches **68**.

Auxiliary Switching Figure 11C

Magnetic senders **87** can be mounted on calibrated wheel **61** or main shaft **63**. Proximity switches **88** mounted near these revolving senders will close a circuit.

Location Visual Display **6** (Fig. 11C, Fig. 8 and Fig. 10)

A mechanical mount **59** attaches location visual display module **6** to camcorder housing **7**. Visual display module **6** is composed of two subassemblies.

A display electronic circuit **76** and a LCD crystal display face **75**.

The location display electronic circuit transmitter transmits data to display circuit **76** which responds by increasing or decreasing the reading on display face **75**.

LCD Crystal Display Face **75** (Fig. 11C)

The data on display face **75** is viewed by the camcorder and recorded on the video tape.

A reset switch **93** resets the location display to zero to re-establish a datum line.

Auxiliary Assembly **78** (Fig. 11A)

Auxiliary equipment can be powered by rotating main shaft **63**.

A coupling **74** on main shaft **63** provides a connector to attach a rotary encoder **73**. Encoders **73** supply various kinds of information based on the characteristics of the rotational rates of main shaft **63**.

Parapet Clamp Assembly

Outside Clamp Leg

Beam **31** is inserted into beam socket **93** of an outside clamp leg **94**. Outside clamp leg **94** has a parapet rest **96**, an outside clamp face **97**, also a slot **105** and two pin holes **104** for a pin **102**.

Inside Clamp Leg

Beam **31** is inserted into beam socket **93** of inside clamp leg **95**. Inside clamp leg **95** has a parapet rest **96**, also a slot **105** and two pin holes **104** for a pin **102**. At the lower end of inside clamp leg **95** is a clamp compression screw **99**. An inside clamp face **98** is mounted on clamp screw **99**.

Outside clamp leg **94** and inside clamp leg **95** are connected at their upper ends by an adjustable compression bar **100**. Compression bar **100** is installed in slots **105** and held in place by pin **102** through pin hole **104**.

Pins **102** through holes **104** at the parapet level of clamp leg **94** and clamp leg **95** are used to mount an adjustable tension chain on each side of the clamp legs.

Camera Dolly Assembly **106**

Wheeled camera dolly assembly **106** (Fig. 18) is built on a main chassis **109** which has a front axle bearing **112** and a rear axle bearing **112**. A front axle **108** and a rear axle **113** are installed into these bearings **112**. Front axle **108** is considerably wider than the main chassis **109** which enables the main chassis **109** to be positioned far to either side of the front axle **108** centerline. Rear axle **113** is the width of main chassis **109** keeping both rear wheels **107** close to main chassis **109**.

Main chassis **109** (Fig. 18) has a camera post **110** attached near the front of the chassis. Camera post **110** has a camera arm **111** mounted on it by a movable fitting **114.** Rotating connector **46** is mounted on the opposite end of camera arm **111.** Rotating connector is the mounting point for camcorder house **54**, additional fitting can be assembled to mount multiple camcorder housings.

Drone location transmitter **5** (Fig. 18) is mounted at the rear of main chassis **109** by mechanical connector **60**. Electrical connector **58** runs from location transmitter **5** through chassis **109** and attaches to display electrical circuit **76** mounted on the camcorder house **54** (not shown).

Camera Dolly Cable Assembly **23** (Fig. 18)

Drawing Fig. 14A illustrates the camera dolly cable assembly layout. The camera dolly is omitted from Fig. 14A so that the cables can be clearly seen. Ground pressure cable **120** is tensioned between parapet attachment **122** and cable winch **121**. Cable **120** is placed under as much tension as possible to increase its resistance to being pulled away from the structure's wall. The purpose of cable **120** is to guide the camera dolly in a straight path up the wall. Cable **120** will also be used to hold the dolly firmly against the wall.

Drone positioning cable **8** raises or lowers the camera dolly **106** as it makes imaging passes on the structure. Camera dolly **106** is shown in Fig. 14B to illustrate its relationship to the cable assembly. One of the functions of ground pressure cable **120** is to guide camera dolly **106** in a straight path up and down the structure wall. Camera dolly **106** must have an attachment that follows the guide cable **120** and keeps the dolly chassis **106** aligned with the cable. Roller shoe **116** (Fig. 13, Fig. 13A, Fig. 15 and Fig. 16) is such an alignment device.

Roller shoe **116** (Fig. 13 and Fig. 13A) is a long, narrow shape with rollers along its bottom. Cable **120** is confined in this narrow shape and runs on hardened steel rollers **124**. Each roller **124** has internal bushings and turns on a steel pin **133** pressed into parallel holes **136**. Roller shoe **116** is positioned and stabilized by two radius rods

125, one rod on each side of chassis **109** (Fig. 18). These rods are attached to the chassis **106** by pin **130A** and to the roller shoe by pin **130B**.

Ground Pressure

Roller shoe **116** and its radius arms are a passive guidance mechanism. It will follow guide cable **120** but it contributes no thrust to force the camera dolly against the structure. Force must be exerted on the roller shoe **116** to lift against ground pressure cable **120**. Cable **126** has a cable eye **132** on each of its ends and one end of cable **126** is attached to pin **130B** at the roller shoe **116** (Fig. 13A). There are two cable **126** units required, one for each side of chassis **109**. Both cables travel upward and over the top of a shive **119** and are attached to a mechanism that, through cable **126**, applies force to roller shoe **116**.

Our camera dolly has two optional force generating mechanisms, one adjustable and one non-adjustable. Drawing Fig. 15 and Fig. 15A illustrate our adjustable ground pressure assembly **115**. The adjustability assembly **115** is based on a turnbuckle **128**, which tensions a spring **129**. Spring **129** has a wire yoke **135** which attaches to both cable **126** which apply a lifting thrust to roller shoe **116**. This adjustable system is used for light duty applications where the weight of the camera dolly is supported by positioning cable mount **134**.

Drawing Fig. 17 and Fig. 17A illustrate the layout of our non-adjustable ground pressure assembly **115**. Please note that in the adjustable system the pair of cables **126** travel upward and pass in front of shive **119** and turn rearward.

Cable **126** in our non-adjustable system (Fig. 17 and Fig. 17A). Both of these cables pass behind shive **119** and turn forward. Both of the cable **126** are brought together forward of the main chassis **109** and are attached to cable **8** attachment **53**. This cable arrangement is a very powerful method of exerting lift on the roller shoe. The full weight of the camera dolly has been converted from a downward force to a horizontal force, thrusting the camera dolly against the wall.

Camera Dolly Cable Assembly **123** (Fig. 14A)

Camera Dolly **106** is mounted at attachment point **53** to drone positioning cable **8** which supports its weight. A ground pressure cable **120** (Fig. 14A) under tension, guides and applies ground pressure through a ground pressure assembly **115** (Fig. 16 and Fig. 18).

Ground Pressure Cable **120** (Fig. 14A)

A parapet attachment **122** supports the upper end of ground pressure cable **120**. The lower end of cable **120** is attached to cable winch **121**. Winch **121** is attached to weight **42** or anchored **44** to an immovable object. Attached to winch **121** is a cable support shive **32** and an umbilical terminator mount **15**. Umbilical tee **16** is mounted in mount **15**.which attaches the umbilical **2** to cable winch **121**. The umbilical **2** bring drone positioning cable **8** to shive **32A**. Positioning cable **8** passes under shive **32A** and up and over shive **32B**.

After passing over shive **32B**, the cable turns downward to be attached to camera dolly assembly **106** (not shown). This embodiment functions with the power head **1** at ground level. With a simple rearrangement of components, the power head can be at roof level.

Ground Pressure Assembly **115** (Fig. 15 and Fig. 17)

Ground pressure assembly **115** is a mechanism for exerting pressure against the structure wall by the camera dolly.

Camera dolly main chassis **109** has a positioning cable mount **134** and on each side of the chassis (Fig. 16 and Fig. 18) is mounted a cable shive **119**. Cable shives **119** support and guide the two lift cables **126** used in the adjustable and the non-adjustable assemblies.

A roller shoe **116** (Fig. 15) rides under pressure cable **120** and is stabilized by two radius arms **125**. Radius arms **125** are attached to the main chassis by mounting pin **130A** and to the roller shoe by mounting pin **130B**. Rollershoe **116** (Fig. 15A) has a series of parallel pin holes **136** drilled through both walls of the shoe **116**. A roller is positioned in the shoe and a roller pin **133** is installed into the wall of the shoe through the roller and out the other parallel hole. Rollers **124** have internal bearings and are made of hardened steel.

Lift cable **126** is a piece of steel cable with a cable eye **132** on both ends.

Adjustable Ground Pressure Assembly

A cable eye **132** (Fig. 17) is attached to both ends of pin **130B** (Fig. 15). Cable **126** passes up in front of shive **119**. Shive **119** re-directs cable **126** toward the chassis rear and cable eye **132** engages a yoke **135**. A cable **126** is required on both sides of the chassis starting at mounting pin **130B** and attaching to yoke **135**. Yoke **135** is attached to a tension spring **129** that is attached to a tension adjuster **128**. Tension adjuster **128** is attached to the main chassis **109** by an adjuster mount **127**.

Non-Adjustable Ground Pressure Assembly

A cable **126** is attached to each end of mounting pin **130B** by engaging cable eye **132**. Cable **126** extends upward to the rear of shives **119**. Cable **126** passes over the top of shive **119** and turns forward toward the front of the chassis. Both cable eyes **132** are connected to drone positioning cable **8** by attachment **53**.

Special Accessories

A parapet clamp, as shown in Fig. XX, is used in circumstances when standard parapet boom XX is not practical.

A screw clamp XX locks the parapet between jaws XX and XX requuiring no counter weight.

A special wheeled camera dolly Fig. XX is used on inclined surfaces or when high wind conditions exist. Wheeled dolly XX has four wheels, two spread wide apart on the front axle and two wheels close together on the rear axle. The width of the front of the dolly body is narrow compared to the width of the front axle XX. The dolly body can be located to either side of the axle center line to offset the dolly body on the axle.

The wheeled dolly XX requires a guide cable XX under tension to hold its wheels against the structure wall.

An offset upper cable bracket XX supports the upper end of a guide cable XX. A winch XX which is attached to a weight, or anchored to a solid structure, is attached to the lower end of the guide cable XX. Winch XX is used to apply tension to guide cable XX stabilizing the wheeled dolly XX.

The upper guide cable bracket XX has a cable shive XX which guides the dolly lifting cable XX.

The lower guide cable XX tensioning winch XX has an umbilical terminator mounting point XX and a cable shive XX which guides the dolly lifting cable XX.

A low profile roller sled travels on a tensioned guide cable and centers the main body of the dolly over the guide cable.

A cable XX is attached to the roller sled XX and passes up to a cable shive XX and rearward to connect to a wall tension spring XX. Tension spring XX is attached to adjustable rear spring mount XX.

The dolly-lifting cable is attached to the main body of the dolly. Dolly-lifting cable XX passes upward and over cable shive XX, then downward passing under the dolly and under cable shive XX before entering umbilical XX.

Dolly-lifting cable XX is driven by the power head XX at the opposite end of umbilical XX.

Main dolly body XX acts as a chassis connecting the front and rear axles and as a mounting point for the wall tensioning assembly and a mounting point for battery pack

XX. A camera post XX is attached to the forward end of dolly body XX. A camera arm XX is mounted on camera post XX by a friction-fit coupling which permits vertical relocation of the arm on the post.

Camcorder housing XX is mounted on camera arm XX by rotary fitting XX which is adjustable in transverse angle to the imaged surface.

Mechanical fitting XX attaches location transmitter XX to the rear of dolly body XX. Electrical connection XX connects location transmitter XX to location display XX, which is mounted on camcorder housing XX.

What Is Claimed Is:

1. An apparatus for remote inspection of building facades, comprising:
an inspection drone for traversing the building facade, the inspection drone having an imaging device for recording images of the traversed regions of the facade;
a support structure for supporting and guiding the inspection drone in a selective path along the building facade; and
a position indicating device for indicating the position of the inspection drone relative to one or more predetermined reference points, and recording the respective indicated positions for each of the recorded images of the facade.

2. An apparatus in accordance with claim 1 in which the apparatus further comprises means for assembling a plurality of separate images of the building facade into a single composite image.

3. An apparatus in accordance with claim 1 in which the support structure for the apparatus further comprises a pressure assembly for biasing the inspection drone against the building facade.

4. An apparatus in accordance with claim 3 in which the pressure assembly maintains positive engagement of the inspection drone against a building facade regardless of the angle at which the building facade extends.

5. A method for remote inspection of a building facade, comprising:
providing an imaging device;
traversing a plurality of selective regions of the building facade with the imaging device;
providing a position indicating device for indicating the position of the imaging device relative to one or more reference points; and
continuously recording the location of the imaging device as it traverses the building facade to correlate the images with respective locations.

6. A method in accordance with Claim 5 in which two or more of the recorded images are assembled into a composite image.

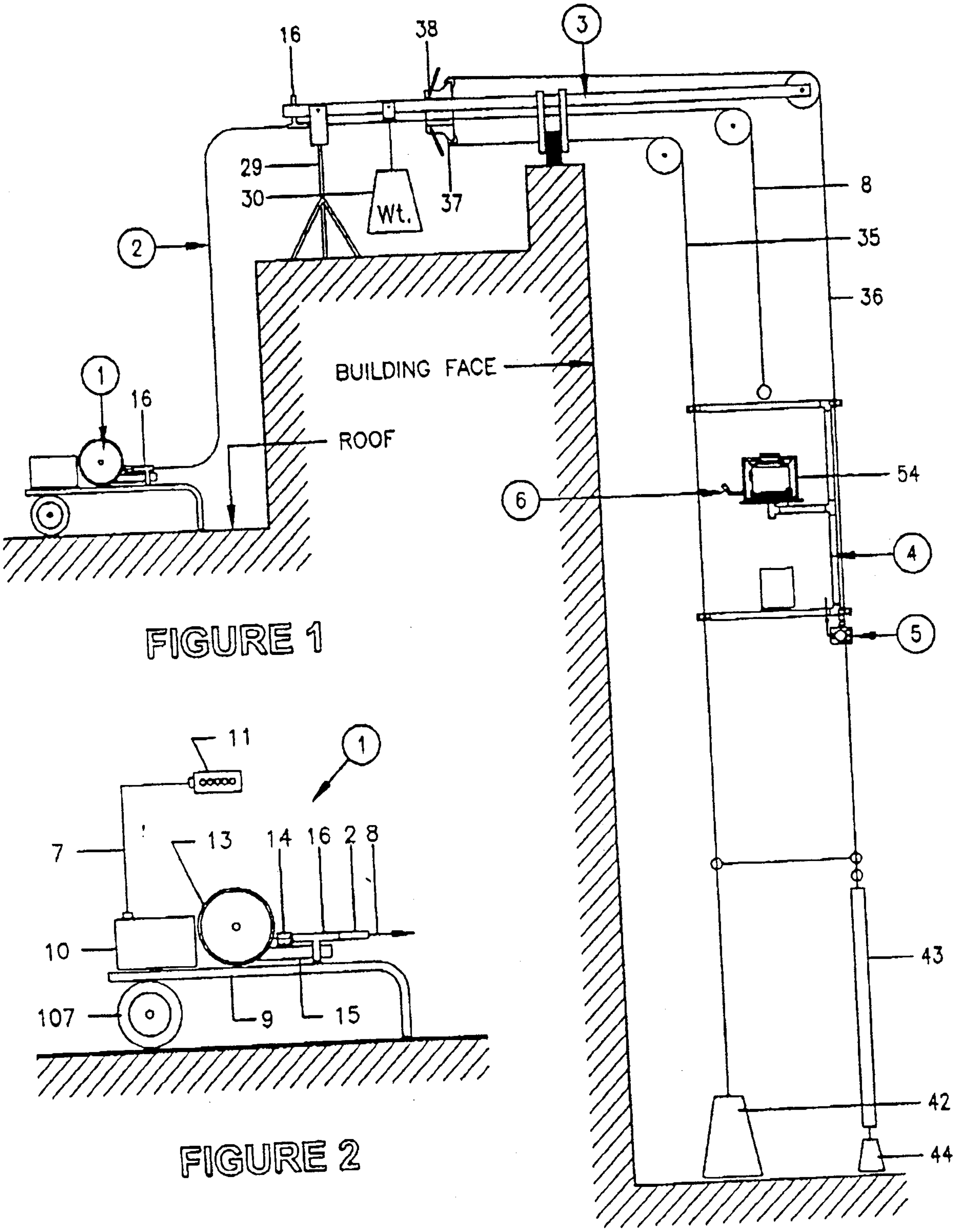
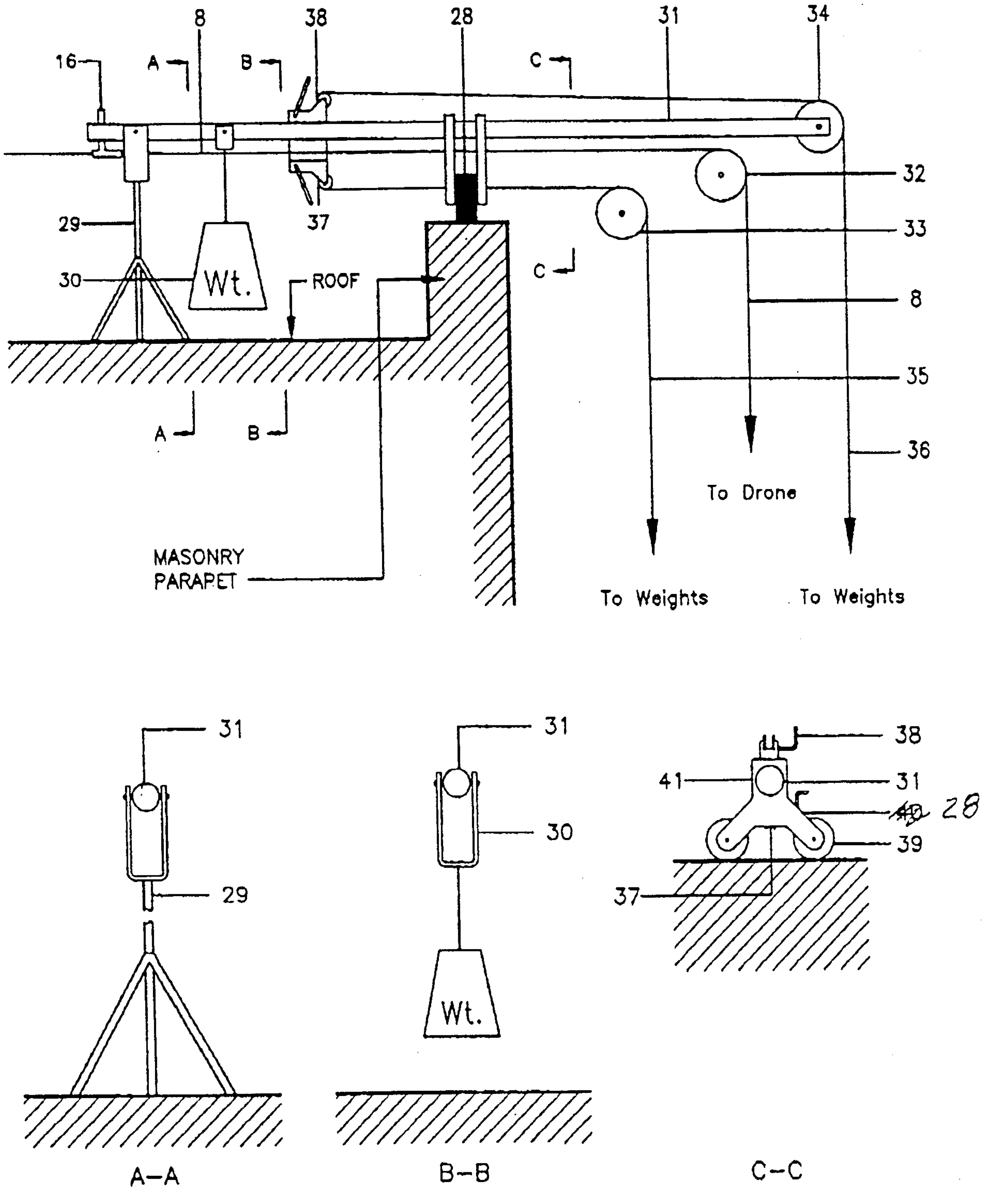


FIGURE 1

FIGURE 2


16
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35
36
To Drone
MASONRY
PARAPET
To Weights
To Weights
A
B
31
29
A–A
31
30
Wt.
B–B
38
41
31
28
39
37
C–C

FIGURE 3

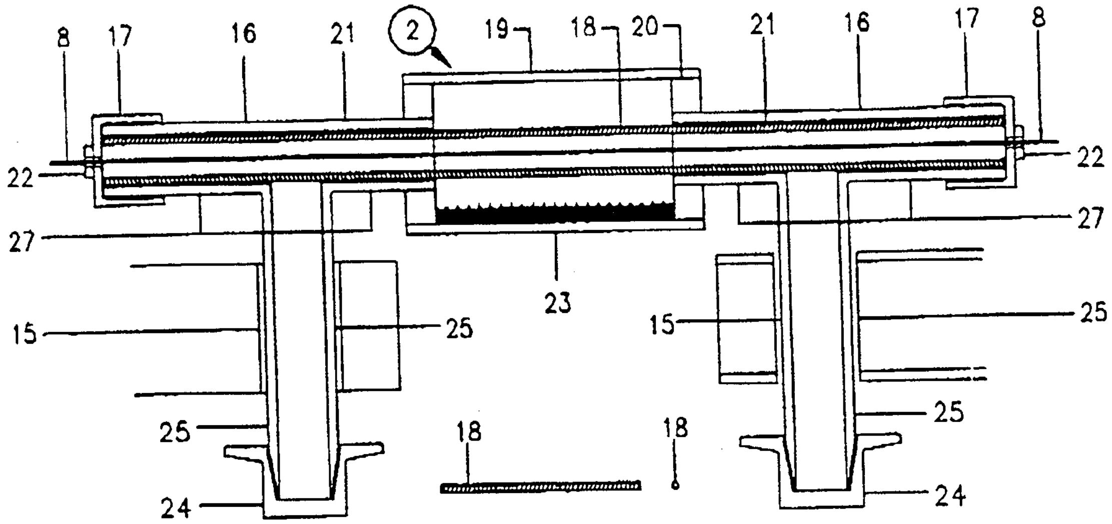


FIGURE 4

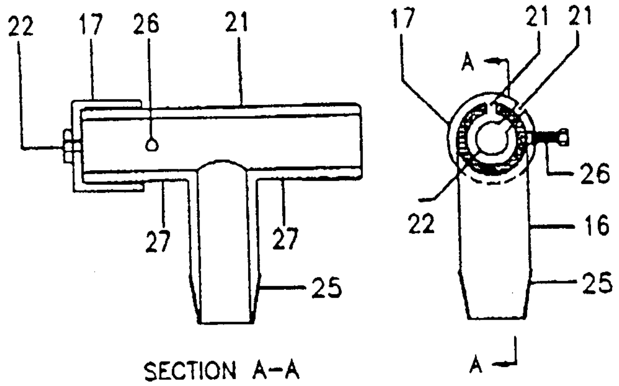


FIGURE 5

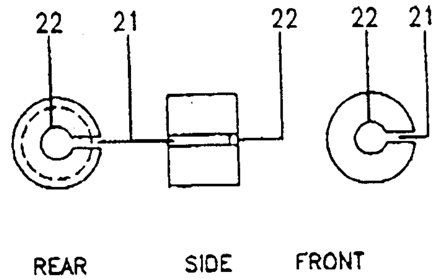


FIGURE 6

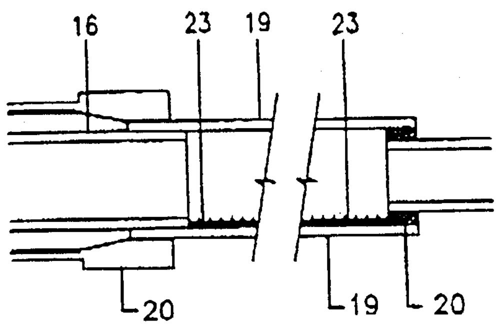
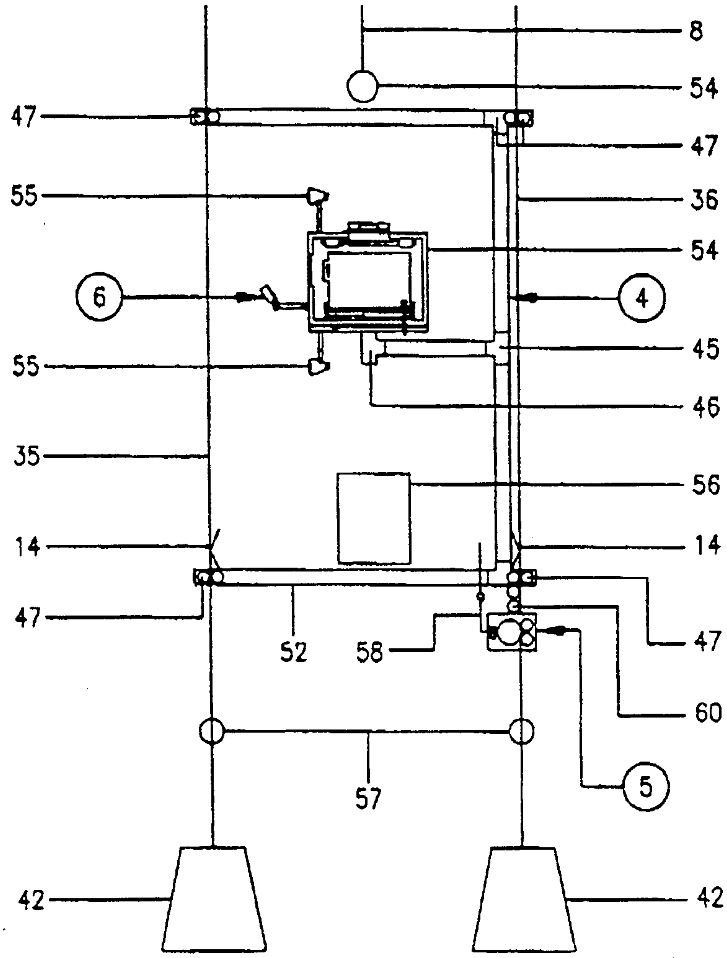


FIGURE 7



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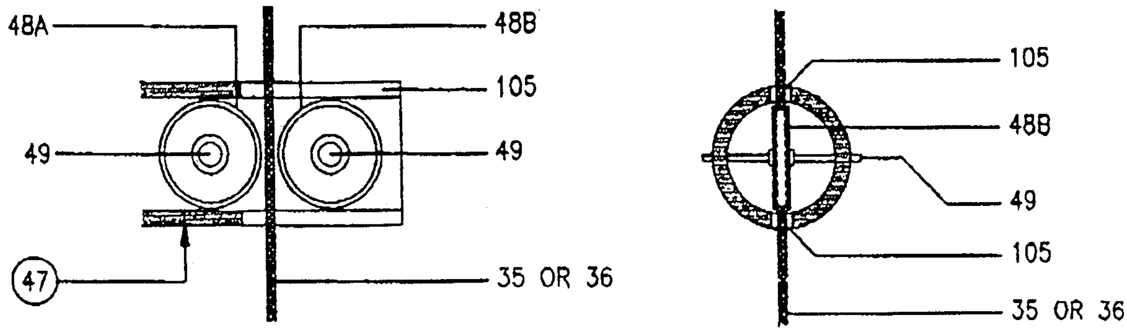

FIGURE 9

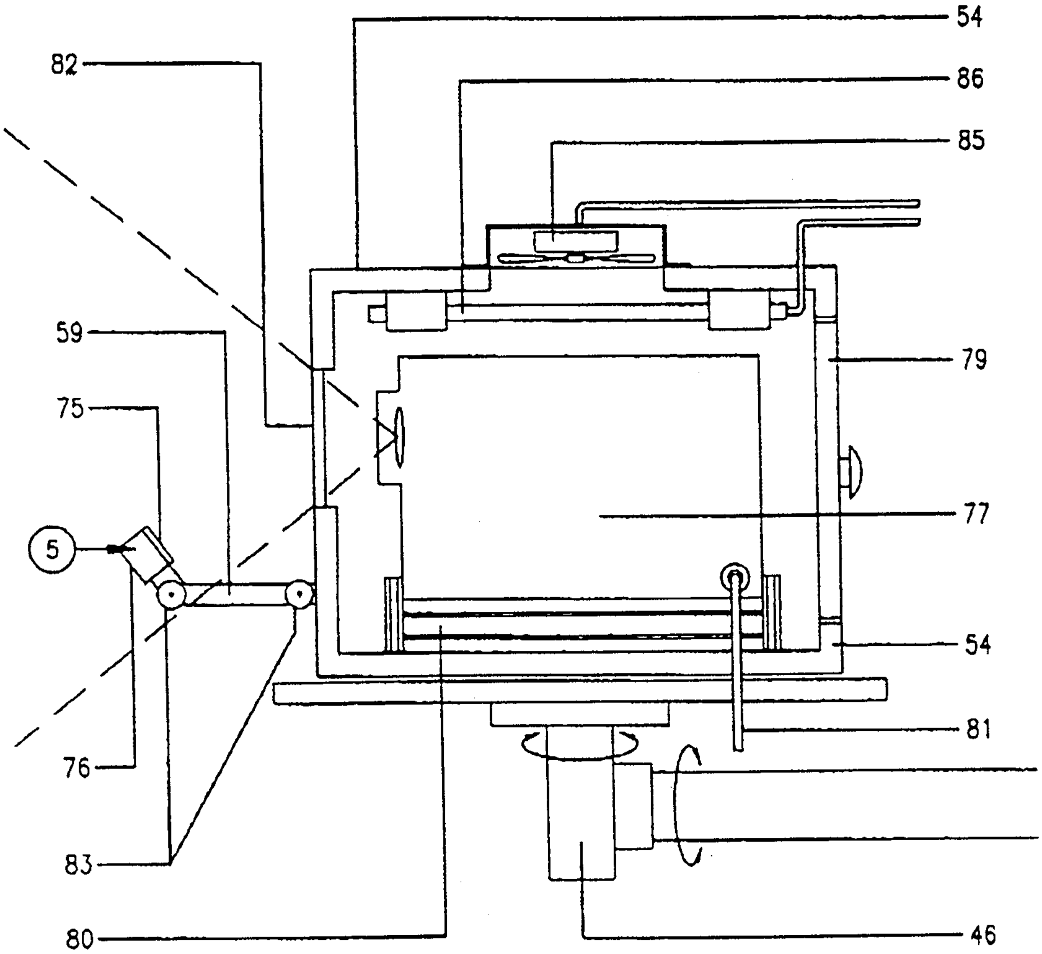

FIGURE 10

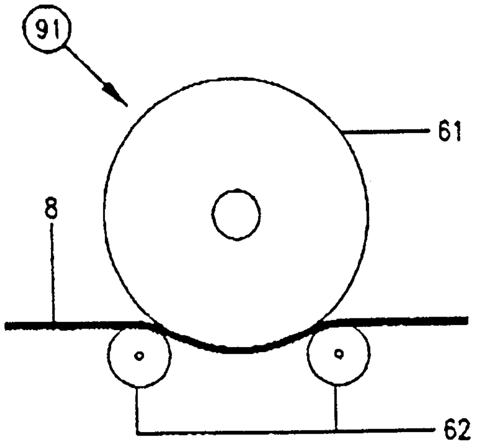

FIGURE 11

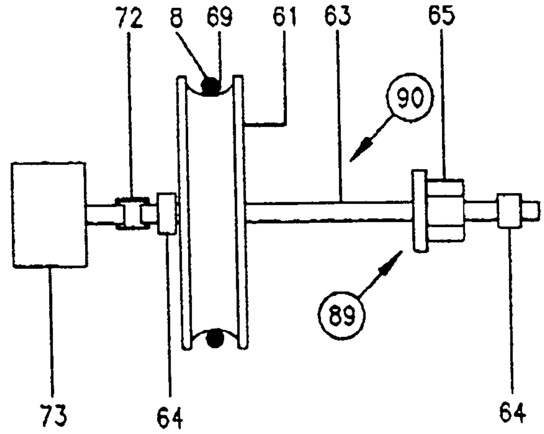

FIGURE 11A

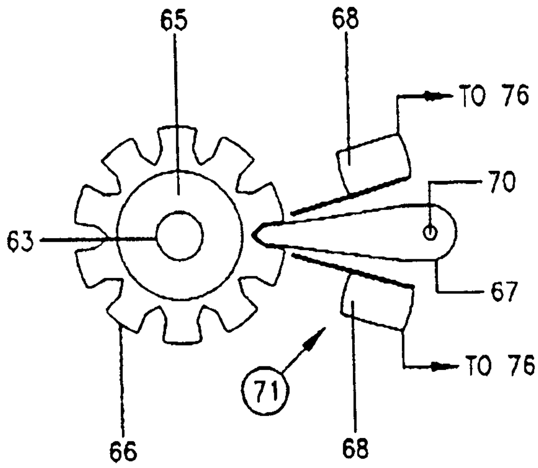

FIGURE 11B

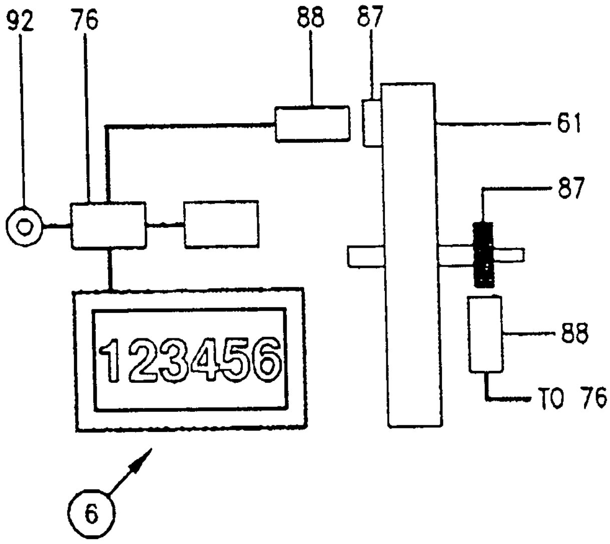

FIGURE 11C

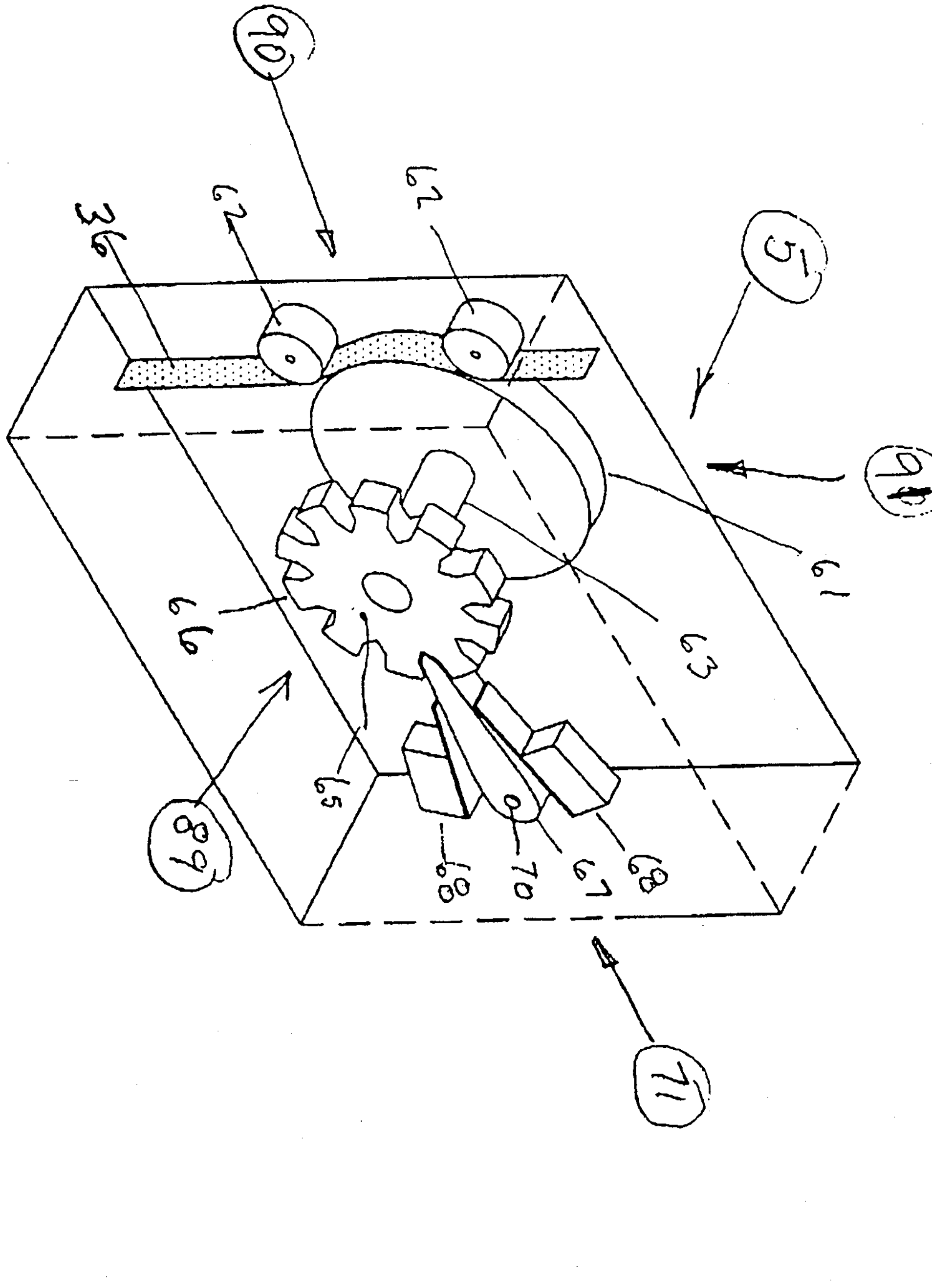

FIGURE 12

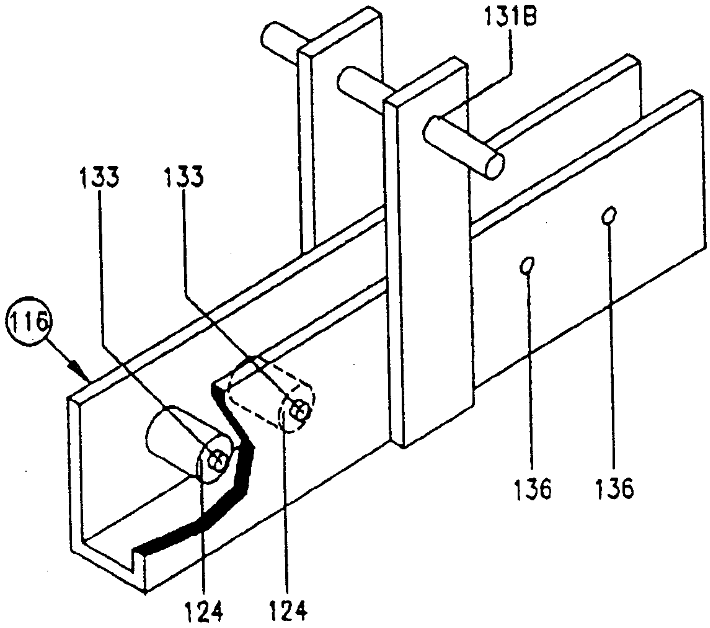

FIGURE 13

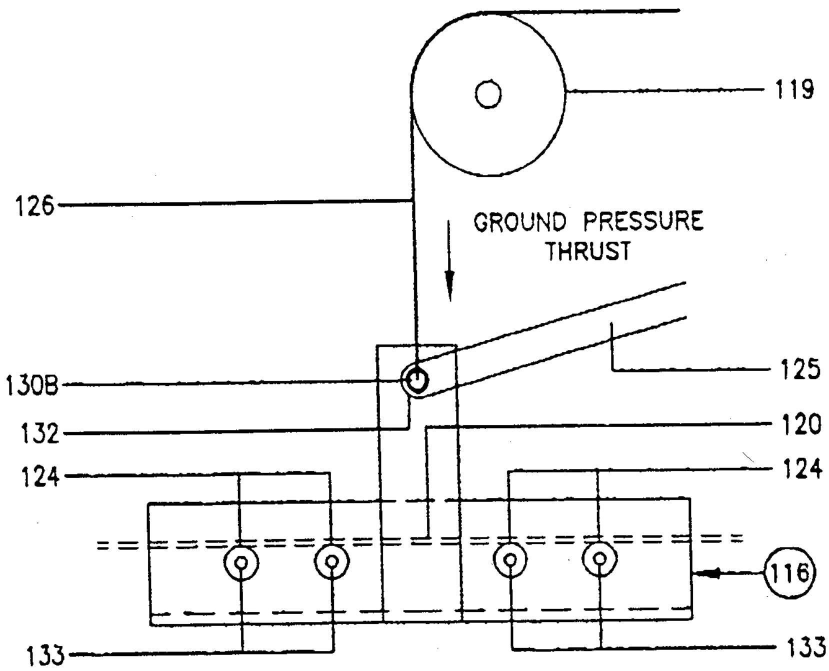

FIGURE 13A

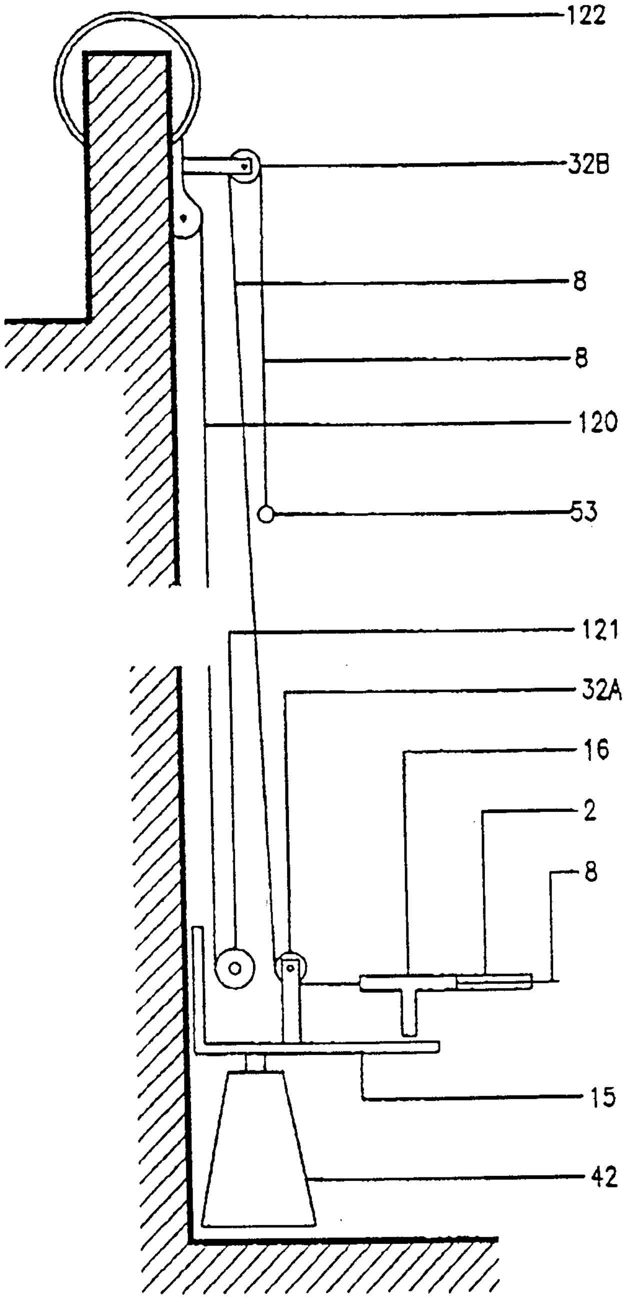

FIGURE 14A

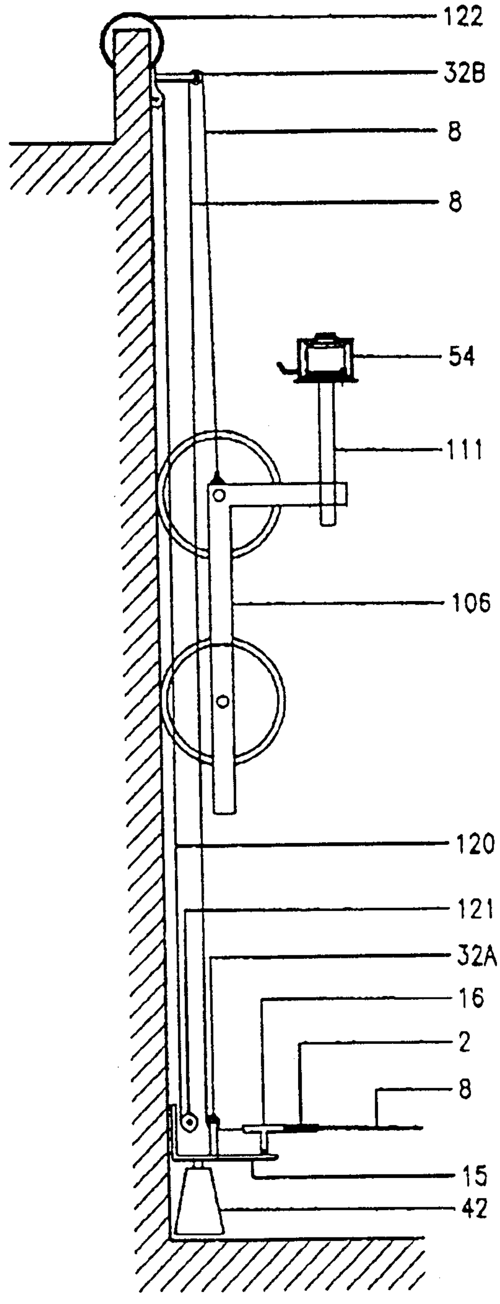

FIGURE 14B

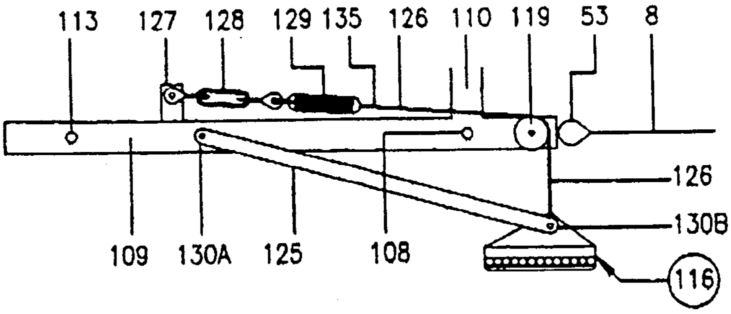

FIGURE 15

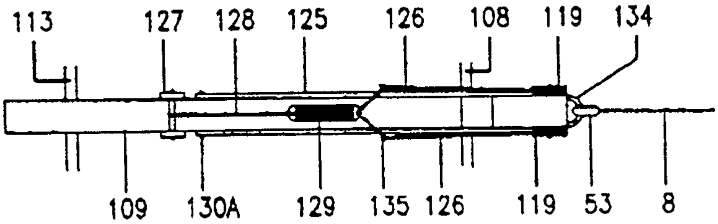

FIGURE 15A

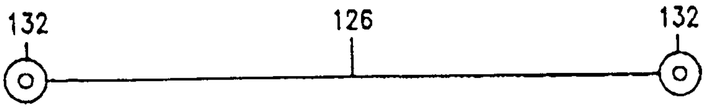

FIGURE 16

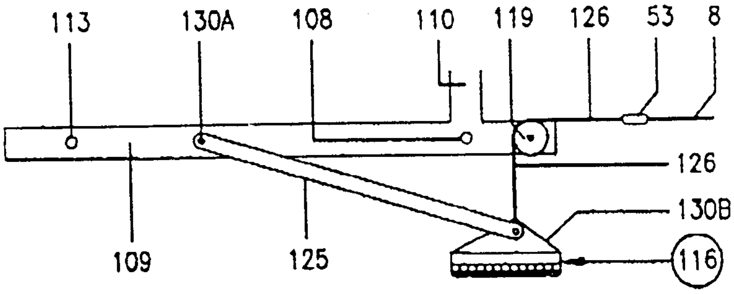

FIGURE 17

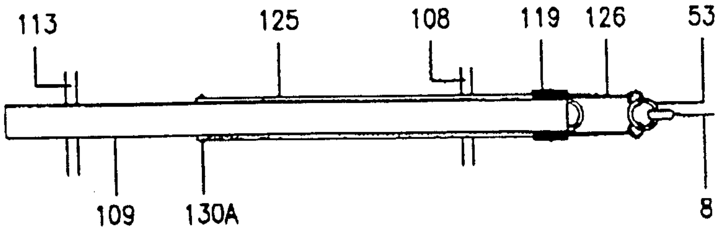

FIGURE 17A

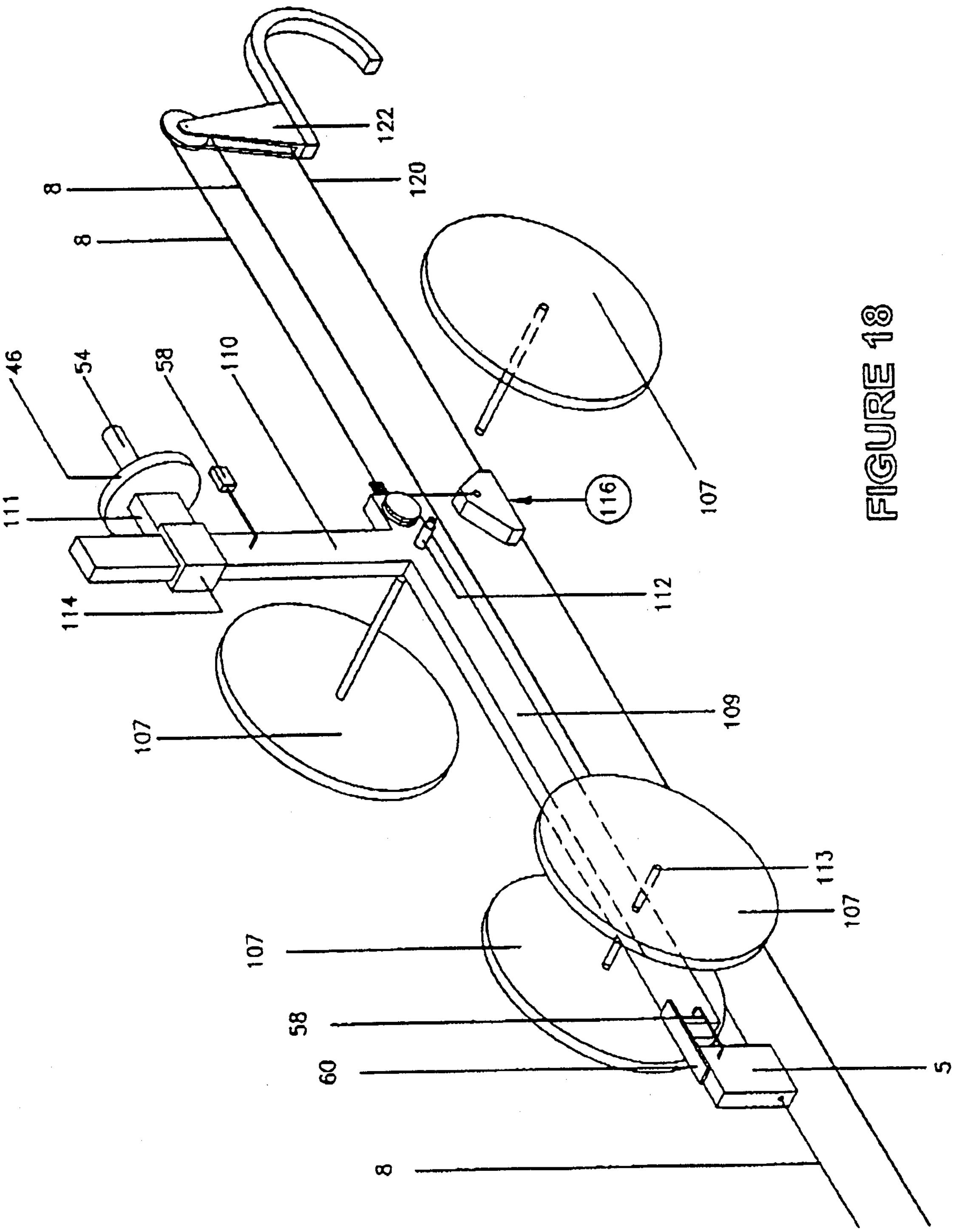
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FIGURE 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/27071

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04N 7/18
US CL :348/128, 143
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/128, 143, 36, 61, 82, 113, 114, 118, 119, 125
IPC(6): H04N 7/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,550,376 A (MACIEJCZAK) 29 OCTOBER 1985, FIGS. 1-8.	1 AND 3-5
--- Y		--- 2 AND 6
Y	US, 5,563,650 A (POELSTRA) 08 OCTOBER 1996, FIGS. 6, 8, AND 9.	2 AND 6
Y	US 5,350,033 A (KRAFT) 27 SEPTEMBER 1994, FIGS. 1-22.	1-6
Y	US 4,910,593 A (WEIL) 20 MARCH 1990, FIGS. 1, 2, 6, AND 7.	1-6
Y, P	US 5,742,335 A (CANNON) 21 APRIL 1998, FIGS. 1 AND 4-6.	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search: 08 MARCH 1999

Date of mailing of the international search report: 07 APR 1999

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