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STUDY OF PIPE INSPECTION AND CLEANING ROBOT

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ABSTRACT

A pipe inspection robot is device that is inserted into pipes to check for obstruction or damage. These robots are traditionally manufactured offshore, are extremely expensive, and are often not adequately supported in the event or malfunction. This had resulted in associated environmental services limited. A New Zealand utilize of this equipment, facing significant periods of down time as they wait for their robots to be the repaired. Recently, they were informing that several robots were no longer supported. This project was conceived to redesign the electronics control systems one of these PIR, utilizing the existing mechanical platform. Requirements for the robot were that it must operate reliably in confined, dark and wet environments and provides a human wears with a digital video feed of the internal status of the pipes. There robot should as much as possible incorporate off the shaft components, cheap, and potentially onsite repair. This project details the redesign and constructions of such robots. It employees there electronic boards integrated with mechanical components and provides video feedback via custom graphical interface although at the prototypes state the electronics has been successful with cost of less than a length of the original robot purchase prize.

I. INTRODUCTION

Inspection robots are used in many fields of industry. One application is monitoring the inside of the pipes and channels, recognizing and solving problems through the interior of pipes or channels. Automated inspection of the inner surface of a pipe can be achieved by a mobile robot. Because pipelines are typically buried underground, they are in contact with the soil and subject to corrosion, where the steel pipe wall oxidizes, and effectively reducing wall thickness. Although it's less common, corrosion also can occur on the inside surface of the pipe and reduces the strength of the pipe. If crack goes undetected and becomes severe, the pipe can leak and, in rare cases, fail catastrophically. Extensive efforts are made to mitigate corrosion. Pipe inspection is necessary to locate defects due to corrosion and wear while the pipe is transporting fluids. This ability is necessary especially when one should inspect an underground pipe. In this work, Pipe Inspection Robot (PIR) with ability to move inside horizontal and vertical pipes has been designed and fabricated.

The robot consists of a motor for driving and camera for monitoringstation to the contrary. Robotics is one of the fastest growing engineering fields of today. Robots are designed to remove the human factor from labor intensive or dangerous work and also to act in inaccessible environment. The use of robots is more common today than ever before and it is no longer exclusively used by the heavy production industries the inspection of pipes may be relevant for improving security and efficiency in industrial plants. These specific operations as inspection, maintenance, cleaning etc. are expensive, thus the application of the robots appears to be one of the

most attractive solutions. Pipelines which are tools for transporting oils, gases and other fluids such as chemicals, have been employed as major utilities in a number of countries for long time. Recently, many troubles occur in pipelines, and most of them are caused by aging, corrosion, cracks, and mechanical damages from the third parties. Currently, the applications of robots for the maintenance of the pipeline utilities are considered as one of the most attractive solutions available should have high magnetic susceptibility and should be good conductor of electricity. The materials are copper and so on. But aluminum is chosen as the materials for the linkages and central body because of its much-desired properties.

Aluminum has lightweight and strength; it can be used in a variety of applications. Aluminum alloys with a wide range of properties are used in engineering structures. The strength and durability of aluminum alloys vary widely, not only because of the components of the specific alloy, but also because of heat treatments and manufacturing processes. The materials used for this machine are light and rigid. Different materials can be used for different parts of the robot. For optimum use of power the materials used should be light and strong. Wood is light but it is subjected to wear if used for this machine. Metals are the ideal materials for the robot as most if the plastics cannot be as strong as metals. Material should be ductile, less brittleness, malleable, and high magnetic susceptibility. Among the metals, aluminum is the material chosen for the linkages and the common rod, which is made as hollow for reduction in weight. However, other materials are chosen for the motor. The materials chosen for the motorshould have high magnetic susceptibility and should be good conductor of electricity. The materials are copper and so on. But aluminum is chosen as the materials for the linkages and central body because of its much-desired properties. Aluminum has lightweight and strength; it can be used in a variety of applications. Aluminum alloys with a wide range of properties are used in engineering structures. The strength and durability of aluminum alloys vary widely, not only because of the components of the specific alloy, but also because of heat treatments and manufacturing processes. Another important property of aluminum alloys is their sensitivity to heat. Workshop procedures involving heating are complicated by the fact that aluminum, unlike steel, will melt without first glowing red.Aluminum alloys, like all structural alloys, are also subject to internal stresses following heating operations such as welding and casting. The problem with aluminum alloys in this regard is their low melting point, which make them more susceptible to distortions from thermally induced stress relief. The toughness, as measured by crack propagation energy, decreases as yield stress increases. At the same yield stress, the under aged structure has greater toughness than the over aged structure. Nowadays, there are going on a lot of studies in the field of robotic for inspec- tion. One of many environments where the robots are used is pipe inspection for instance steam chest plants. In this sector the maintenance and inspection are a main issue. In fact, this helps to guarantee high standards of safety and perfor- mance. The conventional inspection methods require to disassembling complex, large and heavy parts and not always all the spots are easily reachable. Moreover all the operations need days or even weeks to be executed, this means high cost for the company and gas turbine power plant is unusable. After these consid- erations it is obvious that a company has huge interest in a better and faster inspection procedure. Inspection robots help to guarantee this aim. They can be placed in specific points to detect defects and also locally repaired,at least the part with an error must be disassembled. An automatically operated machine that replaces human effort was difficult to imagine; in the view of appearance or perform functions in a humanlike manner. By extension, roboticengineering deals with the design, construction, and operation of robots. A robot is a mechanical or

virtual artificial agent, which has a brain of its own. In practice, it is usually an electro- mechanical system, which by its appearance or movements conveys a sense that it has intent or agency of its own. There were more than one million robots in operation worldwide in the first half of 2008, with roughly halfin Africa. Commercial and industrial robots are in widespread use, these robots performed jobs with greater accuracy with no labor cost and more reliable than humans. Robots can be placed into roughly two classifications based on the type of job they do. The first category includes tasks which a robot can do with greater productivity, accuracy, or endurance than humans, and the other category consists of doing dirty, dangerous or dull jobs which humans find undesirableThere are many areas where robots can be replaced for human; amongst them pipelines is one of the most challengeable areas. Pipelines have been used in major utilities for long time. Over billions of places from huge plants to an individual house, robots are employed by people. But; many troubles like aging, corrosion, erosion, cracks and physical damages from third parties, have occurred in pipelines. Therefore, maintenance of pipelines is essential in order to keep them functional, and moreover the continuation cost for these activities are being increased. Even with the above mentioned problems in pipeline, people still prefer them. The reason being, pipelines are used in transporting substances through a mere pipe. Most of the time liquid and gases are sent through pipes. Pneumatic tubes that transport solid capsules using compressed air are also being used. Like gases and liquids, any chemically stable substance can be sent through a pipeline. Hence sewage, slurry, water, and even beer pipelines exist. With this knowledge we can classify pipelines with respect to the substance that it carries. We will look at each one in detail. Dmitri Mendeleev in 1893 suggested pipelines for transporting Petroleum; most countries have employed these pipelines. These pipes started to get widely used around the world. In the year 2007, the total length of oil and gas pipelines in world was almost two millions km, and in the United States had 793,285 km oil/gas pipelines. Pipelines are generally the most economical way to transport large quantities of oil or natural gasover land. Compared to railroad, they have lower cost per unit with higher capacity. The material used in manufacturing Oil pipes are from steel or plastic tubes with inner diameter typically varying from 4 to 48 inches. Most pipelines are buried underground at a typical depth of about 3 to 6 feet. The oil is kept in motion by pump stations along the pipeline, and usually flows at a speed of about 1 to 6 m/s. Multi-product pipelines are used to transport two or more different products in sequence on the same pipeline. Usually in multi-product pipelines there is no physical separation between the different products. Some mixing of adjacent products occurs, producing interface. This interface is removed from the pipeline at receiving facilities and segregated to prevent contamination. Oil contains varying amounts of wax, or paraffin. In colder climates wax accumulation may occur within a pipeline. Often these pipelines are inspected and cleaned using pipelineinspection gauges. There are varies gauges available like PIGS also known as SCRAPERS. These devices are launched from PIG-launcher stations and travel through the pipeline to be received at any other station down-stream; Cleaning wax deposits and material that may have accumulated along the line. This is one of the most used pipelines all around the world and an ancient method as well. The first people to transport water were the Romans to transport large aqueducts water from higher altitudes by building the aqueducts in graduated segments that allowed gravity to simply push the rushing water along until it reached its intended destination. As time passed by hundreds of pipelines were built throughout Europe and elsewhere, and along with flour mills. The ancient Chinese also made use of channels and pipe systems for public works. The infamous Han Dynasty court eunuch Zhang Rang (189 AD) once ordered the engineer Bi Lan to construct a

series of square-pallet chain pumps outside the capital city of Luoyang. These chain pumps serviced the imperial palaces and living quarters of the capital city as the water lifted by the chain pumps were brought in by a stoneware pipe system. We will discuss water pipeline in detail as we go on.

1.1 Problem Statement

- Now a days many of industries used different diameter pipes for different application like to carry chemicals, high pressure steam and gasess hence there may be chances of problems like corrosion , leakages.
- It is not possible to avoid all these problems manually.
- The mud inside the pipe can reduce the efficiency of the water flow.
- The conventional method is very difficult and tiring.

1.2 Objectives

- To traverse a robot inside a pipe with forward and backward motion and should also do vertical climbing in pipe.
- It should be able to move in various diameters of pipe.
- To build a fully autonomous pipeline cleaning robot.
- To design a robot that can move horizontally and vertically inside the pipe.
- To construct a robot that can minimize the mud and scale inside the pipe.

1.3 Scope

- The reason of scoping the project work to a boundary is to ensure the project will be done in a systematic manner and prevent overlapping of work occurs. This project focuses on cleaning the inner of the pipeline water system.
- In industril pipe lines and gas pipe lines it is applicable to detect crack and leakages.
- Its applicable for to detects the problem of blockage in pipe .
- Its applicable for long and different diameter of pipes ,claning and spray painting.

1.4 Methodology

Methodology used for whole processing of Robot is given below; this methodology gives way about how work is to be carried out in systematic way. It is standard process of describing process, how it is done in simplest manner.

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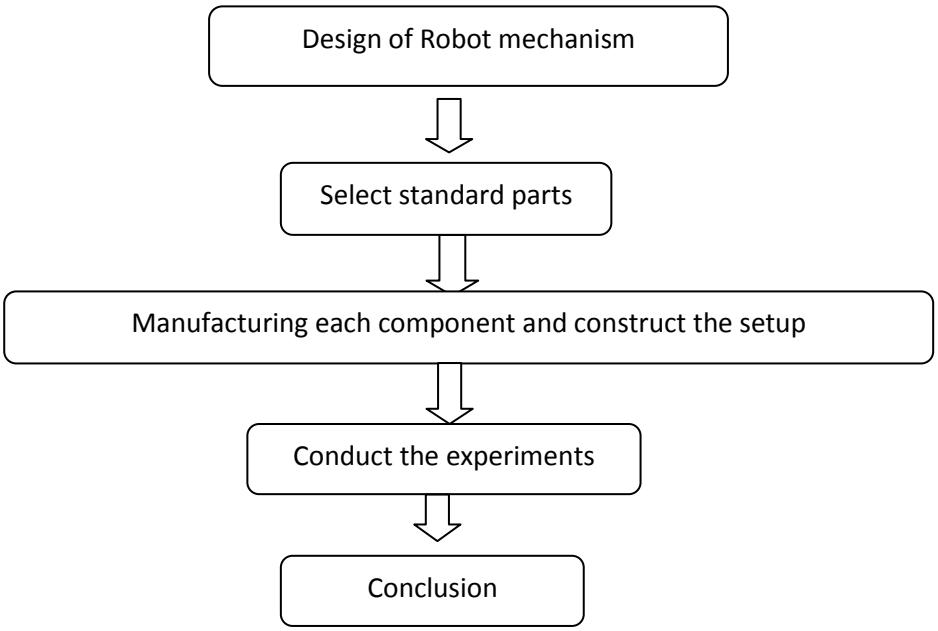

Fig no.1.1 Flow diagram

- **DESIGN: -**Design consists of application of scientific principle, technical information, and imagination for development of new mechanism to perform specific function with maximum economy and efficiency. Hence careful design approach has to be adopted. The total design work has been split into two parts.

1. System design 2. Mechanical design

- **SYSTEM DESIGN:**

System design is mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on frame at system, man-machine interaction, no. of controls, position of controls, working environments, of maintenance, scope of improvement, weight if machine from ground level, total weight of machine and a lot more. In system design we mainly concentrated on the following parameter:-

- **System selection based on constraints**

  Our machine is used in small-scale so space is major constrain. The system is to be very compact so that it can be adjusted in small space.

- **Arrangement of various components**

  Keeping into view the space restrictions all components should be laid such that their easy removal or servicing is possible. Every possible space is utilized in component arrangements.

- **Man machine interaction**

  Friendliness of machine with the operated that is operating is an important criterion of design.

- **Chances of failure**

  Losses incurred by owner in case of any failure are important criterion of design. Factor of safety while doing design should be kept high so that there are less chances of failure. Moreover periodic maintenance is required to keep unit healthy.

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- **Servicing facility**

  Layout of components should be such that easy servicing is possible. Those which require frequent servicing can be easily disassembled.

- **Scope of future improvement**

  Arrangement should be provided in such way that if any changes have to be done for future scope for improving efficiency of machine.

- **Height of machine elements from ground**

  All the elements of the machine should be arranged to the height from where it is simple to operate by operator. Machine should be slightly higher than the waist level, also enough clearance should be provided from the ground for cleaning purpose.

- **Weight of machine**

  Total weight depends on the selection of material of all components as well as their dimensions. Higher weight will result in difficulty in transportation; it is difficult to take it to workshop because of more weight.

➢ **MECHANICAL DESIGN:**

In mechanical design the components are listed down and stored on the basis of their procurement, design in two categories namely.

1. Designed parts
2. Parts to be purchased

Mechanical design phase is very important from the view of designer as whole success of project depends on the correct design analysis of the problem.

Many preliminary alternatives are eliminated during this phase. Designer should have adequate knowledge about physical properties of material, load stresses and failure. He should identify all internal and external forces acting on machine parts.

These forces may be classified as,

a) Dead weight forces

b) Friction forces

c) Inertia forces

d) Centrifugal forces

e) Forcesgenerated during power transmission etc.

Designer should estimate these forces very accurately by using design equations. If he does not have sufficient information to estimate them he should make certain practical assumptions based on similar conditions which will almost satisfy the functional needs. Assumptions must always be on the safer side. Selection of factors of safety to find working or design stress is another important step in design of working dimensions of machine elements. The correction in the theoretical stress values are to be made according in the kind of loads, shape of parts & service requirements Selection of material should be made according to the condition of loading shapes of products environment conditions & desirable properties of material provision should be made to minimize nearly adopting proper lubrications method.

II. LITERATURE REVIW

- **Central Frame:-**

Central body is the frame of the robot. It supports all other components and holds batteries at the centre of the body. The joints are brazed on the central frame at 120 degrees. The central body is drilled and its ends are threaded internally for the insertion of pencil batteries and closing with externally threaded caps. Wireless camera is fixed at one end of the frame.

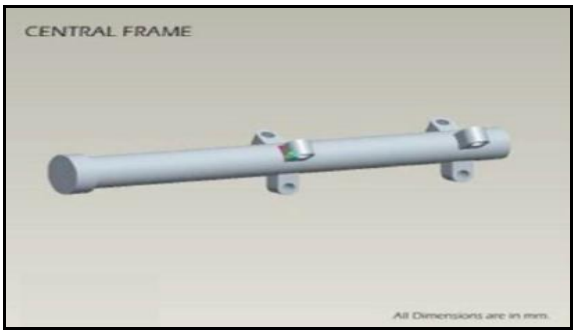

Fig. No.2.1 Central Frame

- **Translational Element:-**

Translational Element is the movable part in the robot which slides along the central body for repositioning in case of pipe diameter variation. This element is drilled at the centre for the translating along the central body. This will restrict the links to some extreme angles beyond which it could not be translated. The extreme angles are found to be 15 degrees and 60 degrees. The joints are brazed on the translational element at 120 degrees for the links to be fixed onto it.

- **Compression Spring**

A spring is an elastic object used to store mechanical Energy. Spring used here is made out of hardened steel. Compression spring is mainly used to exert tension. The purpose of spring is as follows:The force that the mini robot mechanism exercises on the pipe walls is generated with the help of an extensible spring.

The helical spring disposed on the central axis assures the repositioning of the structure, in the case of the pipe diameters variation.

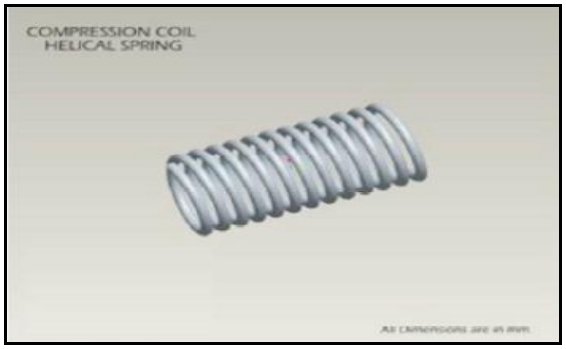

Fig.no.2.2 Compression Spring

- **Links:-**

Each resistant body in a machine which moves relative to another resistant body is called Kinematic link or element. A resistant body is which do not go under deformation while transmitting the force. Links are the major part of the robot which translates motion. Links are connected to form a linkage. The mechanism involved here is a 4 bar mechanism which has 3 revolute pairs and1 single prismatic pairs as depicted.

Inspection robots are used in many fields of industry. One application is monitoring the inside of the pipes and channels, Recognizing and solving problems through the interior of pipes or channels. Automated inspection of the inner surface of a pipe can be achieved by a mobile robot. Because pipelines are buried underground Typically, They Are in contact with the soil and subject to corrosion, where the steel pipe wall oxidizes, and effectively reducing wall thickness. Although it's less common, so corrosion can Occur on the inside surface of the pipe.

Nevertheless, damage shut the occurs, Which Reduces the strength of the pipe. If crack goes undetected and becomes severe, the pipe can leak and, in rare cases, fail catastrophically. Extensive efforts are made to mitigate corrosion. Pipe inspection is Necessary to locate defects due to corrosion and wear while the pipe is TRANSPORTING fluids. This ability is Necessary Especially When one shoulder stand to inspect underground pipe. In this work, fabricated of inspection robot (PIR) with ability to move inside horizontal and vertical pipes has been designed and. The robot besteht of a motor for driving and camera for monitoring, All are being controlled by the operator through a joystick while receiving the video signal of the camera on a monitor. The inspection device is a PC-based design uses did mechatronic principles to Ensure a purposeful interaction between the robot and its environment.

The inspection of pipes' may be relevant for Improving security and efficiency in industrial plants. These specific operations as inspection, maintenance, cleaning, etc. are expensive, ran thus the application of the robots Appears to be one of the most attractive solutions. Which pipelines are tools for transporting oils, gases and other fluids: such as chemicals, have been employed as major utilities in a number of countries for long time. Recently, many troubles Occur in pipelines, and most of them are caused by aging, corrosion, cracks, and mechanical damages from the third parties. Currently, the applications of robots for the maintenance of the pipeline utilities are-considered as one of the most attractive solutions available

- **Kinematics Of Mechanism**

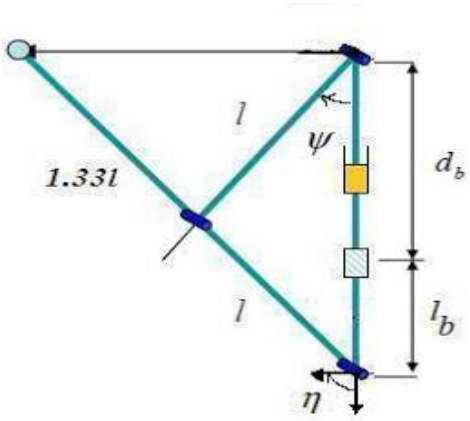

Fig. No.2.3kinameticsmechanisc

This is a four-bar mechanism Consisting of three revolute and one prismatic joins as Depicted. Ran thus, the motion of all joints revolute can be Described in terms of the displacement d_b .

- **STATIC ANALYSIS**

In order to decide the actuator size, it is Necessary to perform the static analysis. Assume did in Figure, F_{cx} and F_{cz} denote the reaction force and the traction

force exerted on the four-bar by the driving wheel, respectively. Now applying the virtual work principle to the free-body diagram gives

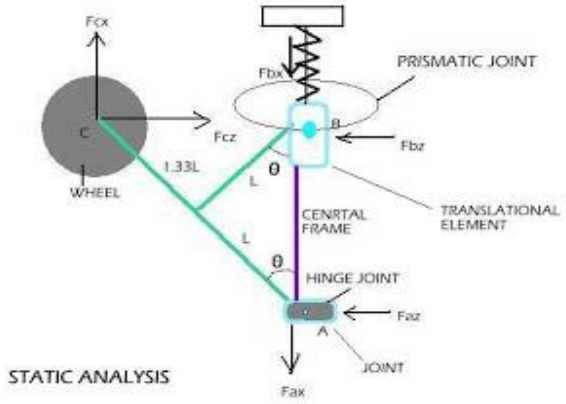

Fig no.2.4 Statics analysis

- **Inspection Process**

A run to be inspected will either start from an access pipe leading at an angle down to the sewer and then run downstream to a manhole, or will run between manholes. The service truck is parked above the access point of the pipe. The camera tractor, with a flexible cable attached to the rear, is then lowered into the pipeline. The tractor is moved forward so that it is barely inside of the pipeline. A "down-hole roller" is set up between the camera tractor and the cable reel in the service truck, preventing cable damage from rubbing the top of the pipeline. The operator then retires to the inside of the truck and begins the inspection, remotely operating the camera tractor from the truck

Pulling The Camera Backwards

For small diameter pipes there may not be enough room for the tractor mechanism. Instead, a somewhat rigid "fish" is pushed through the pipe and attached to a rope at the access point near the truck. The fish is then pulled to place the rope along the pipe. The rope is then used to pull the inspection pig and cable through the pipe. Detaching the rope, the cable is then used to pull the pig backwards as the pipe is inspected on the monitor (this is the method shown in the illustrations below).

Much of the analysis of what was viewed in the pipeline is conducted at the time of the inspection by the camera operator, but the entire inspection is always recorded and saved for review.Using software you can easily record digital video and simplify the analysis process, here are some samples of different applications available on the market:

III. APPLICATION

So many today's mobile robots are used for inspection, surveillance, monitoring and nondestructive tasks. Some current applications are as below:

- Allow inspection of inaccessible and / or hazardous equipment or work areas.
- Provide on-line inspection / maintenance without loss of equipment / plant availability & remove humans from potentially hazardous work situations.
- Provide information about the health and condition of critical plant components to Facilitate decision-making regarding plant life management
- Reduce equipment / plant downtime and improve maintenance and inspection procedure thorough better coverage and documentation.
- The robot has great application in accessing the regions of pipe in which human doesn't have reach. It could be mounted with a camera which would send us pictures of inside and would help in our inspection.
- It could be fitted with ultrasonic sensors and can pin point us the location of a hole.
- It even has an application in painting up the old installed pipe from the inside very easily.
- It could be even used for the dosing purpose through a pipe as its pitch is fixed we could attach some material to be dosed and control the feeding of the material inside where we want.

IV. ADVANTAGES

•It able to easy to find defects and cracks.

•Robot able to give fast response.

•It's useful for pipe cleaning.

•it is warless operated and easy to control.

V. CONCLUSION

For the short summarized, this paper discusses about the pipeline cleaning robot that actuated using five micro DC motors. This project is implemented using dsPIC130F4011 which was programmed using the C Language and a motor driver L293D as a mean to move those motors. Besides, the infra-red sensor is used to detect the obstacle in front of the robot.As a conclusion, all objectives for this project were managed to achieve. The objectives are:

i. To build a fully autonomous pipeline cleaning robot.
ii. To design a robot that can move horizontally and vertically inside the pipe.
iii. To construct a robot that can minimize the mud and scale inside the pipe.

This project is successfully designed, implemented and tested. The main function for this project was achieved. Everything that we learned was applied in this final year project. Students can improve the skills to make mechanical and electronic designs that very useful after graduate and in working life after that. For the next

robot development, it is hoped that this robot can be reconstructed with some modification to improve the abilities and to provide benefits in future also be able to be marketed or commercialized.

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