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Fastest Deep Borewell accident rescue system with accuracy and sure survival

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Abstract - India being the biggest user of ground water in the world with many abandoned bore wells in all over the country. Improper sealing of abandoned bore wells causes many accidents related to this. India, has witnessed some of the most tragic and helpless incidents, which touched deeply which forced us to look into the matter seriously. Bore well rescue operation is one of the most difficult, complicated and prolonged processes, requires due diligences and care. It is not only difficult to lift the child out of the narrow confines of the bore well, but also of high risk due to the unknown parameters in side bore well, such as humidity, temperature and oxygen. The enough to time required for the operations is long enough to lose many precious lives and even the survival of the victim with serious injuries. This scenario has created an open challenge to the whole society to aim in development of an innovative concept to handle the bore well rescue operations. By designing and constructing a portable bore well rescue machine, which may be quick in action, cost effective and accurate will be meaningful. Here all external apparatus used to support the child trapped inside are combined in one system. The proposed rescue machine consists of actuators, linkage mechanism, rope and belt retractor mechanism, and thus to rescue the child with safety with minimum human interference.

Key Words: Retractor mechanism, linkage mechanism, actuator, cumulated system, abandoned bore wells, rescue machine, rope mechanism

1. INTRODUCTION

Today water scarcity is the major problem faced by human society, which lead to the making of a large number of bore wells. Farmers in India primarily depend on underground water for their agriculture. There is a sharp decrease in underground water level due to the increasing number of bore wells being dug in the same region. Owing to increasing population, urbanization and lesser land holdings, deep bore wells are dug extensively to extract ground water. Because of this the bore wells get dried up frequently and in many cases, the bore wells were left abandoned without proper closure. These abandoned bore wells have become death pits and have taken many innocent lives nationwide. Wide research has enabled us to understand that, India is the biggest user of ground water in the world, who is drawing around 230 billion cubic meter of groundwater per year. There are approximately 27 million bore wells in India and many bore wells are dug due to the scarcity of water, low rain fall, drought and depletion of underground water. When the water gets dried, the motor along with casing pipe are removed carelessly, and the outer surface of bore well is left open. Reports from 2009 say that, more than 40 children fell into the bore well consecutively in various places.

A bore well is a narrow deep hole drilled into the ground from which water is drawn through a pipe and pump. Bore wells are typically small in diameter ranging from 4.5 inches (low-capacity bore well) to 12 inches (high-capacity bore well). Bore wells tap into water-bearing soil or rock layers called aquifers, and can go as deep as 1,500 feet into the ground. In 1970 the bore well technology was introduced as a measure to counter the scarcity of water. When the bore well dries up and is no longer in use, its cover which is generally made of cast iron and PVC pipe is removed, leaving behind a naked hole. The removal of pipe and the cast iron show that the well is no longer in use. Bore wells are also classified based on yield as, high capacity bore well (HCB): having casing pipe diameter of 10 or 12 inches and depth >80 m with design, yield in the range of 20,000 gph to 45,000 gph. Medium capacity bore well (MCB) are bore wells, of casing pipe diameter 8 inches and depth >80m, with design yield in the range of 10,000 gph to 20,000 gph. In low capacity bore well (LCB), casing pipe diameter 6 inches and depth 30 m to 50 m with design yield in the range of 1500 gph to 5,000 gph.

Bore well accidents in the last many years resulted in numerous bore well incidents since 2006. The actual number of incidents may be more since many incidents go unreported. The age of children trapped in the bore wells ranged from 2 years to 9 years. Analysis of a state wise Pie chart (Fig 1), indicates that Haryana, Gujarat, Tamil Nadu top the list of the bore well accident states.

Hyperthermia is elevating body temperature due to failed thermoregulations that occur when a body produces or absorbs more heat it dissipates. Children fall into the bore well and die due to the lack of food, water and oxygen. With the increase in depth, the temperature also increases which makes it difficult for the child to tolerate. These conditions lead to hyperthermia with heavy sweating, rapid breathing and weak pulse, causes confused or intoxicated behavior. As the blood pressure drops, heart rate and respiration rate will increase and the heart attempts to maintain adequate circulation. The decrease in blood pressure can cause blood vessels to contract reflex, resulting in a pale or bluish skin color in advanced cases. Young children, in particular may have organ unconsciousness leading to death (Table 1).

Most of the bore well accidents happen in rural areas. Small diameter Bore wells are used for domestic and construction purposes in the cities. In the villages, the bore wells are dug for domestic, agriculture and construction purposes. When underground sources are drained, the pipes are pulled out, and they forget filling mud in the holes because of ignorance. Small children, while playing, slip and get trapped in the bore wells. Yet there is no proper device or technique to rescue the victim safely without delay. A parallel hole is dug in most cases and then a horizontal path is made to reach and pull the victim from the bore well (Fig 1.3). But it takes nearly 27-30 hours to dig the parallel pit. The delay to rescue leads to the death of the child. It is a time consuming process and also requires energy and expensive resources, which are not easily available. There is also more chance of injuries to the child inside the well. In most of the cases, the child rescue operation has been a failure due to the difficulty to lift the child out of the narrow confines of the bore well. It is time that we look for an alternate solution by which we can save the child.

We have developed a machine that can take out the trapped body in a systematic way. It will be a light weight machine that can be setup easily into the bore well to hold and pull the trapped body. It is a specialized rescue device, which is instrumental in saving precious lives by reducing the risk with the objectives, to make an effective rescue mechanism for deep bore wells, to design a bore well rescue mechanism for bore well size between 25cm to 45 cm, to design a cost effective device which can be made available to every corner of our country, with less time of operation and increased chance of survival. It is designed with multiple rescue techniques and necessary life support system.

There are Prosthetic Bore Well Rescue System (PBRS) for rescuing trapped children from bore well in short time. Newly developed revolving and stabilizing mechanisms is used for safe holding of child. The different proximity non-vision sensors are used for detecting depth, temperature, human condition, pressure and existence of any gas (1), multi-purpose prosthetic bore well system where manipulator, sensory devices, controllers, power conversion unit are the main components of the design, also provides an option in crack detection inside the composite rocket casings, pipelines and boilers (2). A plan of bore well rescue robot based on haptics technology, which is a tactile feedback technology that uses touch sensitivity by applying forces, vibrations or motions to the user (3). Another device describes a wireless sensor fusion system, in the mechanical gripper systemic arm to assist the rescue operation. Humidity, temperature, CO and other gaseous levels from the bore well is detected by using multiple sensors. In this system microcontroller is used which has low speed operation than arm (4). Another plan developed and working of a mechanical device that can be utilized for the salvage of kids caught in bore-wells. The plan is roused by considering the purposes behind the disappointment of beforehand existing strategies. A key feature of the device is its ability to lift a child with the assistance of a safety cage, instead of a grasping mechanism. The device has the capacity to contract the size to lower into the bore-well, thereby not affecting the wall. The joint angles have a facility of rotating 360 degrees, empowering the device to find a gap in any direction, without hurting the child. The radial movement of the device helps it to function in a bore-well ranging from 25.4 cm to 45.72 cm in diameter (5). Yet another system developed with a computerized machine to rescue the child. They use servo motors to hold the child and safety balloons provide an additional safety to the child. This includes hand drawn sketches to computer generated design and a prototype consisting of four mechanisms. A gear mechanism is turned with the help of a motor, which in turn pushes 3 blocks arranged at 120 degrees from each other towards the side of the bore well (6). Another device describes the designing of Smart child rescue system consisting of PIR sensors which help to sense only humans irrespective of the external conditions (7). Another systemic system which attached pneumatic arms for picking up the child and for communicating with the child, a teleconferencing system is also attached to the system (8).

The existing methods of rescuing having limitations such as, rescue operation takes long hours leading to the death of the child, quantity of oxygen is less inside the bore well, more manpower, energy and cost are required for the rescue operations, there is no special equipment to rescue the child from the bore well, visualization of trapped child is difficult, rescue of child without hurting and wounding is risky, most of the rescue operation fails as it

depends on factors like the type of soil, diameter of the bore well and the depth at which the victim is stuck. In certain places, soil tends to be loose and sandy, making it more susceptible to collapse. In hilly regions, drilling requires heavy machinery as the soil is rocky. All these factors have to be considered when someone is going for such operation. All the current available systems to save the child are less effective and costly; there is a need for the society to develop new technique which is efficient and effective where the bore well rescue machine is capable of moving inside the same bore well where the child has been trapped to perform various actions to save the child.

2. Social Relevance

It is an issue of national as well as social concern and an early step in the way of developing an instrument for the rescue of borer well victims is desirable. After studying all the cases, it paved the way to make a machine which can pass through the bore well and hold the trapped body in least minimum time. With this machine, there is no chance of damaging victim's body and we call this machine as "Bore well Rescue Machine.

2.1. Social Impact

Each and every life in this world is valuable. One life supports the other in some or other ways and hence it is the moral duty of the society, to save the innocent lives at risk. Today's young children are the future of our society. The success of our country lies in their hands, hence we cannot let them suffer and lose their life. As an Engineer, it is our responsibility to develop various systems and machines to help these struggling lives from danger. This approach provides a way in which a life can be saved, whether it may be of a human or an animal, from the open bore wells in a shorter span of time.

2.2. SUMMARY ANALYSIS OF THE BOREWELL ACCIDENT DATA

The histogram (fig 1.2) reveals that out of 34 cases that were reported, the highest number of accidents occurred in the years 2007 and 2014. Children between the age of 2 and 9 were the victims of the bore well accidents. It is noticed that more boys (21) had met with the accidents than girls (13). In India, more than 70% of the children did not survive the incident. They died either in the bore well itself or in the hospital after the rescue. Only about 20% of children (7 out of 34) have been rescued successfully. The ultimate status of 10% of the cases reported is not known.

Major group of the children met with the accident while playing near the abandoned bore wells, which were not properly closed or sealed (Fig 4). The project aims to design a rescue machine to save the innocent struggling life stuck inside the bore well in a shorter span of time. The relevant information was gathered from literature survey and the primary characteristics of the different bore well rescue system was studied. A comparison was made of the operating strategies and their success rate. The challenges and constraints were identified and the design was planned to overcome all the hurdles. The functions of the system were established. Static structural analysis was done after the creation of 3D CAD Model. Analysis software such, 'Ansys workbench' has to be used for finding out the values of 'Von Mises stress', 'total deformation' and 'factor of safety'. The analysis results are in safe limits.

2.3. ESTABLISHING FUNCTIONS

A survey was conducted on the accidents that occurred in and around the country and also based on the data of measurement of different age groups of children, we established the functions. Children under 10 years are major victims (92%), most accidents happen while playing in the open grounds, so age of victim fixed between 3 and 10, dimension of children aged 3…HIP > (19''/2=24.13 cm), dimension of children aged 10…HIP > (31''/2=39.37 cm),

MINIMUM HOLE DIMENSION >10''+SHAKE ALLOWANCE = 25 cm, MAXIMUM HOLE DIMENSION>16''+SHAKE ALLOWANCE= 45cm. Shake allowance is taken because hole dimensions are changed when the pipes are taken away.

3. Materials and methods

The system consists of pulley, rope mechanism, grippers, warn pinion gear and actuators. Solid works is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. Solid works is published by Dassault Systems. Solid works uses parametric feature-based approach which was initially developed by PTC (Creo / Pro-Engineer) to create models and assemblies (fig 1.4).

3.1. WORKING MECHANISM

System is taken inside the bore well using pulley and rope mechanism, first gripper (Fig 1.5) to reach up to the child by visualizing through camera A/V output. The Rescue operation starts with placing of stand along with pulley in a suitable position that enables to pick and drop the device easily. After the equipment is connected to the rope through hook joint, it is allowed to move into the bore well.

Child's live position is captured through camera; with the help of light source, the camera sends the image of bore well to the screen on ground surface. The rescuing device is let into the bore well until the camera captures the image of child. When it captures the image of child the movement of device is stopped. The position of the child is analyzed through camera. The oxygen concentrator senses the presence of oxygen in and around the child. If the presence of oxygen percentage is low, it cause breathing problem to child and in such case, the concentrator sends the oxygen to the child from ground surface. The temperature sensor in the device will measure the temperature inside the bore well. The lower part of the system consists of two circular structures to grip the victim. The first circular metal plate (Rope guide) consists of a groove which holds the rope inside. The motor is supported by a cage which consists of two plates fixed at the top and bottom end. One end of the rope is connected to the motor, wound round the pulley. The circular rope guide is positioned down by observing the position of the child. Once the rope guide is inserted on the hands of the victim, the motor is switched on.

As the Motor is run, the rope is released from the groove of the rope guide and tightened round the hands of the child. The motor applies rotational power via to the worm. A worm gear consists of a shaft with a spiral thread that engages and drives a toothed wheel. The worm rotates against the pinion and the screw pushes on the teeth of the wheel which enhances the rotation of the pulley which winds the rope round it. Because of the friction between the worm and the wheel, it is impossible for a wheel with force applied to it to start the worm moving. Thus it does not reverse the direction of power. As the vertical actuator engages, the spring on the rod, above the cage is compressed and the entire assembly is pulled up. This causes the victim to move up to adjust the position. The actuator displacement is adjusted so that the victims shoulder is positioned above Belt 2. The distance between the two circular plates can also be adjusted by sliding the vertical member and fixing to suite the position of the child.

Then by engaging the three actuators placed on the top disc plate, the L shaped pipe connected to the actuator shaft and the vertical member is pulled and it enables the circular belt to tighten round the shoulder which provides protection to the child. As the links get closer, the diameter of the belt reduces. The spiral spring connected to the circular belt expands and the shaft rotates the belt which reduces in length (belt retractor mechanism), thus gripping the child tightly. Once the child is gripped from suitable position, then the system is taken out from the bore well by pulling the rope thus the child can be safely taken out from the bore well using this mechanism. Further treatment will be given after pulling out the child.

3.2. DESIGN PROCESS:

After defining the problem, we gathered information from Literature survey that provided inspiration for our project and helped us to improve on the outcomes. We defined the basis of our project and specific requirements for it. Then we

planned and compared ideas to decide on the best features for our rescue machine. We identified the basic mechanism and developed 2D model of the design. Later it was modified considering the constraints of the basic structure and developed the 3 D CAD model. Then static structural analysis was performed.

3.3. COMPONENTS AND SPECIFICATIONS

The upper part of the device (Fig 1.6) consists of the LA20 actuator and 3, LA12 actuator connected to the vertical member. It is supported by the Shaft Guide. The LA 12 Actuators are placed on the Top disc. The Shaft of the LA 20 Actuator is connected to the pipe which passes through the top disc. The Lower part consists of the motor supported by the cage with Rope Guide and the Retractable Belt supported by the vertical member, which can be slided to adjust the length. The motor is connected with the worm-pinion gear and pulley.

The top disc of thickness 5 mm and diameter 250 mm supports the three LA 12 Actuators and its material is mild steel. The Cage top disc forms the upper part of the cage. The pipe which is connected to the shaft of the actuator is welded on it. The diameter is 180 mm and thickness is 5mm. The Cage bottom disc forms the lower part of the cage on which the motor is supported. The diameter is 240 mm and thickness is 5mm. The spring of length 18.6 cm is fixed on the pipe connected to the shaft of the actuator. The rope guide pipe of length 150 mm is connected to the rope guide and the Cage bottom disc through which the rope passes to the Rope Guide groove. T bolt of diameter of 25mm and length 140 mm, connects the top cage disc and bottom cage disc. Pulley of outer diameter 25mm and inner diameter of 13 mm is connected to pinion shaft of worm wheel. The rope is wound on the pulley when the motor is engaged. Rope guide of outer diameter 220 mm is used to support the rope in its groove. Vertical member of thickness 2 mm is fixed to the shaft of the actuator. Sliding vertical member connected to the outer belt, passes through the groove of the vertical member. The actuator LA12 is an alternative to small-scale hydraulic and pneumatic systems. The LA12 is cost effective and ideal for application requiring short linear movements. It is a very reliable and robust actuator that can handle almost any situation and challenge.

3.4. Features:

Permanent magnetic motor; 12 or 24 V DC, 750 N, maximum thrust, depending on load and spindle pitch, maximum speed is up to 40 mm/sec, 19 to 130mm -stroke length. It is an ideal compact design with built-in dimensions 245 mm (up to 355 mm), Piston rod and back fixture in high-strength plastic, IPX1: protection class, It is provided with built-in end stop switches, noise level: max 60 dB. LA20 actuator is a slim inline actuator. The high lifting capacity of 2,500 N and its small form factor makes it ideal for wide range of application. Some of the benefits that LA20 Inline offers are, it has high lifting capacity, exchangeable cable, compact and slim design. The LA20 inline finds use in various applications where space is limited or size is important. Load in push 2500 N, load in pull 900 N**,** Protection class: IPX4, IPX6**,** 24V DC motor, 20-300 mm stroke length**,** built-in dimensions: 170 mm + stroke length (minimum 220 mm)**,** static safety factor: 2.5 in push and 5.0 in pull and noise level: max 58 dB.

3.5. STATIC STRUCTURAL ANALYSIS

Finite element analysis (FEA) is the process of simulating the behavior of a part or assembly under given conditions so that it can be assessed using the finite element method. These simulations are conducted using software that helps to locate the potential problems in a design including areas of tension and weak spots. Static structural analysis (fig 1.7A, B, C), was done on bore well device using the analysis software, ANSYS Workbench 2020. Static structural analysis is used to estimate the ability of the machine which depends on its strength and the amount of stress it can withstand without deforming (table 2). Static Structural

analysis is executed on the device to acquire information about the stresses that affects it and also the structural deformation it will undergo after experiencing certain amount of stress due to the force and the load that device has to hold up.

3.6. Process

The analysis begins by selection of material properties, importing Geometry and meshing, which is an important step in the process. It is the basis of making the structure a finite element structure. After it is segmented into finite number of element, the boundary condition is specified. It specifies the parts of the structure which will be fixed and the parts which get affected by the force or stress. The parts are subjected to appropriate amount of force by applying directed forces on it, thus the structure is analyzed for stress, deformation and factor of safety by using appropriate analysis tool in ANSYS.

The Von misses stress is fundamentally a standard that decides whether the structure is in a state of failure or not. It primarily defines a formula using which the stresses in different directions of the three axis x, y and z are combined to give von misses stress. The criterion which decides whether the structure is in a condition of failure is that, if the von misses stress is greater than the yield stress of the material, then the structure is in a condition to breakdown. The best suitable material for the components was Mild Steel.

3.7. Import geometry

The 3D geometry of the components is imported in ANSYS. The type of file is IGES. After importing the geometry, the 3D model is then meshed. It is important to divide the complex geometry of the structure into small parts for analyzing complex structures, as the effect of force and load or the stress will not be the same on all parts of a huge and complex structure.

In finite element analysis, meshing is used to divide a given structure into finite number of elements. Each element is analyzed for the effect of stress and deformation. Mesh size and element shape is chosen during meshing. Mesh size is done by convergence test. To establish suitable Mesh size, analysis for several different mesh sizes is performed to notice where high deformations occur. Then the Mesh size is determined. And the element shape is taken based on the element type; the element type can be one dimensional, two dimensional, 3 dimensional. We have chosen the two dimensional type as two of the dimensions of the components are very large in comparison to the third dimension. The element shape is tri and quad in 2 D elements. We have opted the quad shape as more accurate result is given as the number of nodes is more and more deformation occurs.

3.8. BOUNDARY CONDITIONS

Boundary conditions play an important role in the analysis. It decides the degrees of freedom of different parts of the device. Defining the boundary conditions is one of the most important parts of preparing an analysis. Fixed support and force applied, is an essential part to ensure accurate result. The stress (66.66MPa) is maximum near the central part of the disc and directional deformation is on the peripheral region of the disc. The stress is less than the yield stress and factor of safety is more than one and hence it is safe.

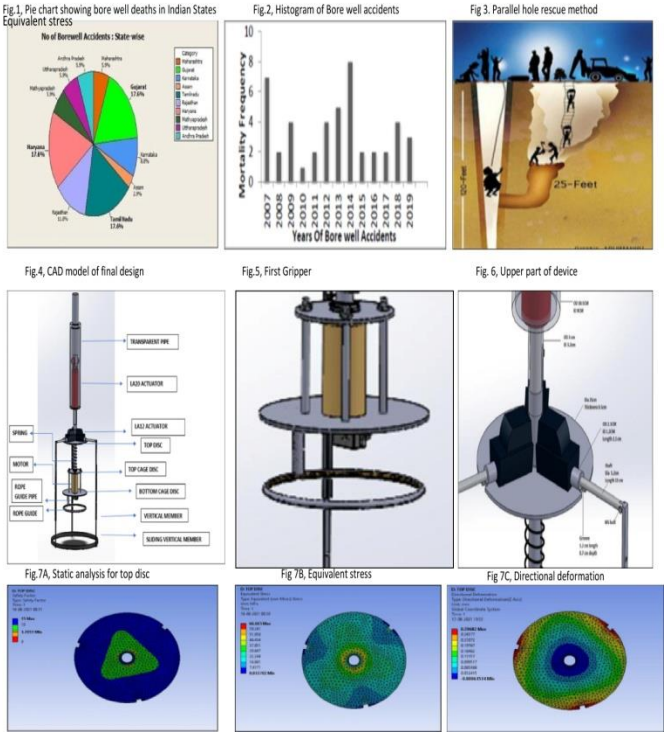
Table1. Comparison of Operation Strategy

NAME	Fatehveer Singh	Sujith Wilson	Timmanna Hatti	Prince	Bipasha	Roshan
Age	3 years	2 years	6 years	5 years	4 years	4 years
Gender	Male	Male	Male	Male	Female	Male
Depth of borewell	150 ft	88 ft	300ft	60ft	120ft	150ft
Operation duration	110 hours	48 hours	190 hours	49 hours	12 hours	35 hours
Child position	Upright		Upright with hands up	Upright	Upright	
Operation strategy	Parallel borewell of 36 inches was digged to pull the child out.	Attempted to pull the boy out by trapping his hand in a rope. However, the boy slipped and fell deeper into the well.	A robot was used. The robot managed to get to a depth of 150ft before being cramped for space. A parallel hole was also digged.	The nearby dried well and the borewell was connected by using 3ft diameter iron pipe.	Made a horizontal boring.	A vertical tunnel at a distance of 9ft from the borewell was dug by the rescue team.
Remark	Died two days before the body was pilled out.	The child did not survive	A small portion of soil in the borewell fell on the child during robot's attempt.	He was rescued from borewell safely and alive.	She was rescued.	The child was rescued by the team.

Table 2, Material properties

Density	7850 kgm^{-3}
Youngs modulus	2.1E+5MPa
Poissons ratio	0.303
Bulk modulus	1.7766E+5 MPa
Shear modulus	2.47E+4 MPa
Tensile yield strength	2.47E+02 MPa
Tensile ultimate strength	8.41E+02 MPa

Figure 1



4. CONCLUSIONS

It can be concluded that by static structural analysis, the knowledge about the total deformation and stress can be obtained which can prevent damages in bore well machine and can also be helpful in designing the machine with optimum structural strength and reliability. The proposed Bore well rescue machine can give the fastest and safest way to rescue trapped victims in bore wells. This system is intended to conquer the disadvantages of present conventional bore well rescue systems. We realize that the proposed system can catch and hold the child firmly, so that we can save the victim successfully.

The design for the rescue machine is complete as it is provided with separate life supporting instruments involving the video surveillance to monitor the child's motion, light to eliminate the darkness, a communication system to interact with the trapped child to know its situation and oxygen system, are all integrated together forming an entire rescue system. This design dominates the old existing rescuing methods as it has all the individual instruments to monitor , support and save the child by pulling up to the surface. Human life is precious. Our bore well child rescue machine is a significant attempt to save the struggling life stuck in the bore well. Moreover, the unique capability of movement of vertical pipes makes wide scope of application for this machine in manufacturing industries and other relevant fields. The current bore well rescue machine is designed to suite the various bore well dimensions. Mechanism used round us is cumulated in the system to make the machine user friendly and reliable saves time. It is cheaper than the parallel hole method. All external apparatus used to support and save the child trapped inside the bore well are cumulated in one system. High reliability, lesser chance of slipping as the child is gripped by hand and shoulder. The proposed rescue robot gives optimal performance within less time as compared to manual methods and with safety. We like to conclude that we will be able to rescue the victim using our bore well rescue machine without causing any damage or injury.

There is a considerable range to develop the mechanical models to save the child who slipped into the bore well. Research can go into this area of making it an automated one which would not be so easy, but can be of great help if achieved. We can use the above projects in many applications by adding additional components to the existing device. By using the ultrasonic sensor we can find the child in the bore well and also find the distance between the child and borehole which will help to save the child quickly. Gas sensors enable the

detection of the harmful gases. The device can be further developed in small scale industry, with innovation can be used to lift load in various industry. The system can be varied in various scales and modified with which animals that are struck in pit or canals can be rescued. It can also used for better applications for engineering works under earth surfaces.

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