ViTech Systems Inc.
126 Viscount Drive
Williamsville, New York 14221

Electronic Safety Device for Construction Workers

April 29, 2004

Final Performance Report for

NIOSH Grant: 5 R44 OH03497-04

Principal Investigators:

Rajendra V. Kulkarni (09/30/1999 – 09/29/2000)
Edward J. Coonly (09/30/2000 – 09/29/2003)

Electronic Safety Device for Construction Workers

Table of Contents

Electronic Safety Devices for Construction Workers

ABSTRACT

This research included the development of two electronic safety devices: (i) Moving Hazards Warning (MHW) device for eliminating `struck-against' accidents, and (ii) Edge Detector (ED) device for eliminating `fall' accidents

Ultrasonic sensors powered by small rechargeable batteries, and controlled by microchips were packaged into two prototype safety devices: (i) A moving Hazard Warning (MHW) Device, and (ii) An Edge Detector (ED) Device. Each of the safety devices can be built into the rear side of the tool-belt or waist-belt. The devices will warn the worker via sound and vibration alarm whenever he/she is closer than a safe distance from the approaching equipment or the edge of the roof/open-sided floors, respectively.

A device using radio frequency (RF) sensor was also tested.

In all U.S. private industry, 119,250 (4.2% of the total) injuries occurred due to the workers 'caught-in / between-equipment', in 1996. In the same year, 6,112 work-related fatalities occurred. Of these 6112 fatalities, 236 fatalities occurred due to falls, and 429 were caused due to workers caught-in / between equipment. This research developed electronic device prototypes to eliminate these two accident types.

In a preliminary survey of workers, 93% of them said that they find the devices useful and will use them. Assuming a 50% utilization of the developed products, the anticipated savings are estimated to be $500 million per year in construction industry alone. The utilization of these products by all private industry, which will happen with time, will save a total of $2.0 billion annually.

During field tests in high winds the prototype devices did not give expected and reliable results. A similar but lesser effect was seen while equipment noise was present. More research is required to overcome these environmental problems.

SIGNIFICANT FINDINGS

Two prototype devices, using ultrasonic sensors, were developed and field tested with promising results. However, the following limitations of the devices were noticed:

i. The high winds that are a common weather condition at construction sites move the acoustical wave (ultrasonic signal) in the direction of air flow. This movement can cause the acoustical wave to miss reflecting off of an impending target thus not returning a pulse back to the receiver. This problem would allow a false safe status. Though not as great a problem as wind, construction area noises also caused false readings. These findings show that for reliable operation the environment of use must have some maximum airflow and noise restrictions. These devices may be used reliably in indoor environments.

ii. Devices using radio frequency (RF) sensors gave accurate results and were not effected by most weather conditions including winds (lightning can interfere with proper operation) or acoustical noise. However, the long term health effects of RF devices close to the body of the worker have to be studied before an electronic device using RF sensors is approved for commercial applications.

TRANSLATION OF FINDINGS

The two electronic devices, using ultrasonic sensors, developed in this research can be advanced for commercial use in controlled environments. ViTech Systems Inc. will make efforts to approach appropriate funding sources, such as venture capital or private companies to refine these devices for high wind and high noise environments.

SCIENTIFIC REPORT

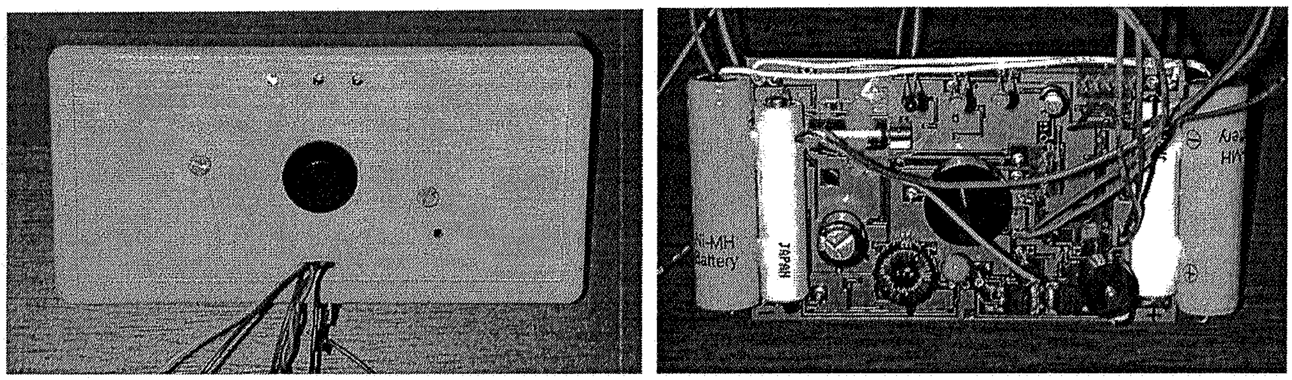
1. Electronic circuit Developed

The electronic circuit was designed which transmits an ultrasonic pulse, receives the echo, and processes the signal. Some of the challenging tasks included reducing the receiver noise level with the aim of detecting smaller echoes and increasing the range. This included optimization of the system gain, tuned amplifier, and demodulation response time. Another difficult task was to optimize transmitter drive circuit, especially the transformer, to match with the chosen transducers. First, several 40 KHz, and one 25 KHz, piezoelectric (ceramic) transducers were selected on the basis of preliminary tests for the best compromise of range and echo acceptance angles. The transformer step-up ratio was 1:10 and the secondary inductance and coupling capacitance was tuned to the operating frequency. Typically the transmit signal is an 8 to 20 cycle pulse train. While the prototype in this research was developed using the piezo electric ultrasonic transducers that are currently available, customized sensors will be required to increase the range of the echo.

A dual battery power supply was chosen, which was controlled by a second, small microcontroller. This controller also acts as a system failure alarm. If the main microcontroller fails, an audible alarm sounds (and LED illuminates).

If the small unit itself fails, the main microcontroller will detect the fault and sound the alarm. If the first power supply, or associated two 1.2-volt NiCd cells fail, the second supply will be turned in. The smaller battery of the second supply has about 30% of the capacity of the main supply.

The final production model is shown in (Figure 1b). It is mounted in a case (Figure 1a), to be mounted on a waist belt. The block diagram of the Safety Device is shown in Figure 2; Both of the devices use the same design, except the software that controls the alarms.



(a) Case with Transducer in the Center

(b) Electronics with two Battery Supplies

FIGURE 1: Electronic Safety Device Hardware

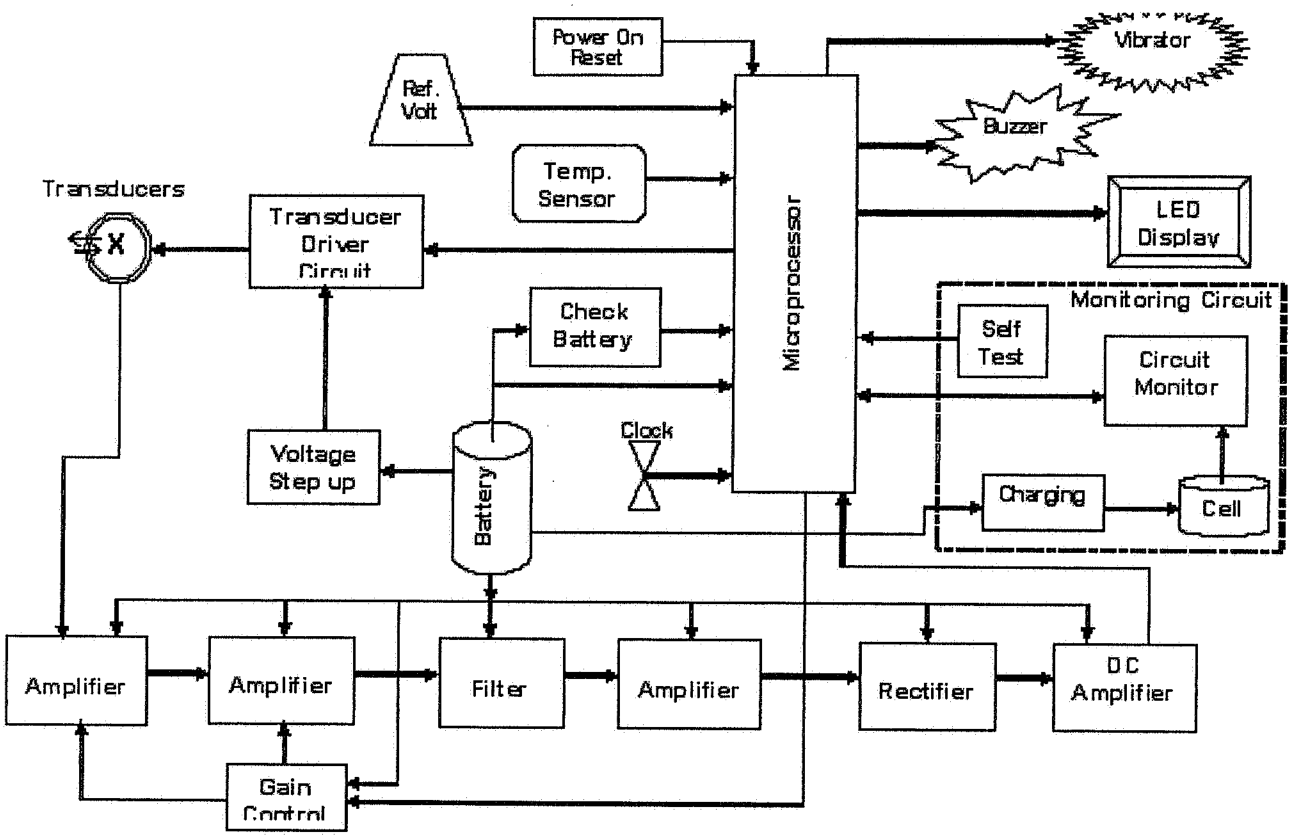


FIGURE 2: Block Diagram of the Safety Device

Typical echo pulses (at the a/d input) are shown in Figure 3, below:

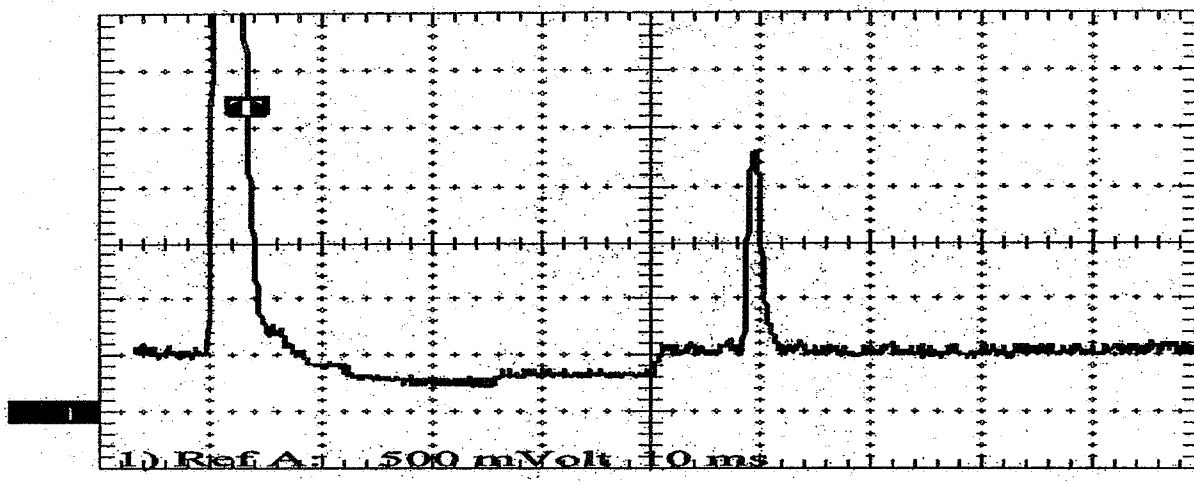


FIGURE 3: Oscilloscope Trace of Transmitted Pulse and Echo

2. Software Development

The software, first, was developed in PIC assembly language. It was later noticed that complex calculations for changing speeds and time were very tedious in assembly language, requiring more lines of code resulting in more memory demand. The software code for the microcontroller was subsequently rewritten in C, instead of assembly language, to allow more complex signal calculations to be implemented. The program detects approaching objects and turns on audible (and visible) alarm when an approaching object is detected. The pitch of the alarm increases as the object approaches the device. Receding objects do not turn on the alarm and nor do speeds not within the normal vehicle speed range of 3 to 10 mph.

3. Range and Angle Tests

Measurements of the maximum echo detection range for a large, highly reflective object (corner reflector) are shown in Figure 4a and 4b. The range at 0° (straight ahead) is 45 feet using a 25KHz transducer, which is adequate. A moving object at about 5 mph will sound the alarm as it reaches 30 ft, which is marginal. However, the detection range for less reflecting objects, including even large objects with curved surfaces, such as vehicles, was much less. Therefore we consider the transducers tested so far to have less than adequate range, for the Moving Hazard Warning (MHW) Device, but more than adequate for the Edge Detector (ED) Device. Better and customized transducers and transformers will be required for a higher accuracy of the MHW device.

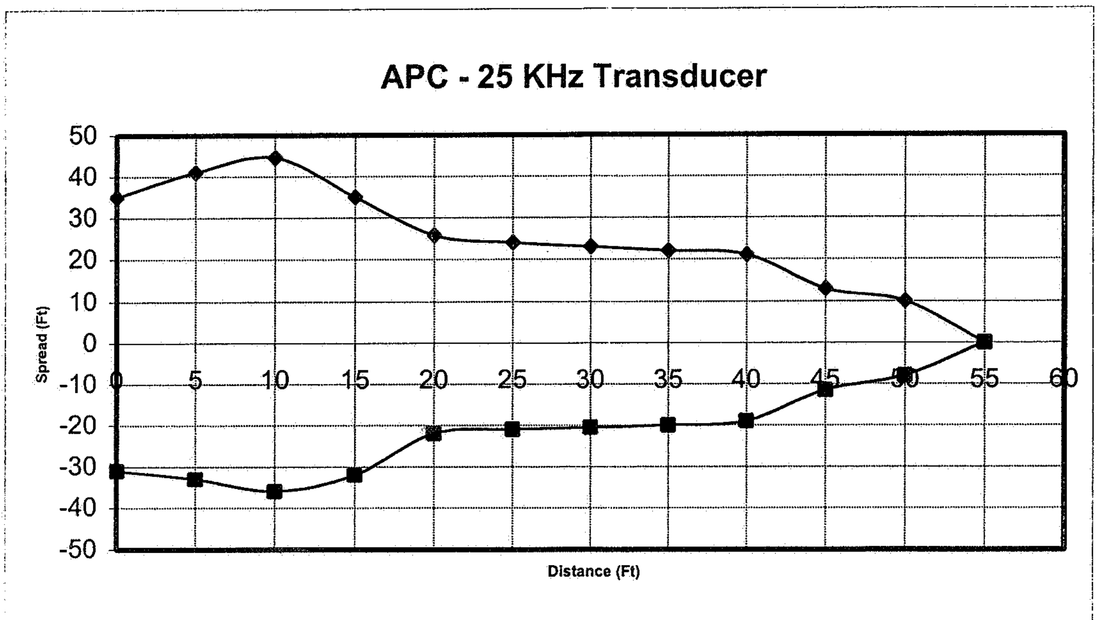


FIGURE 4(a): Measurement of Range as a Printout of Angle
(APC Transducer, Date of Measurement: 09/13/2000)

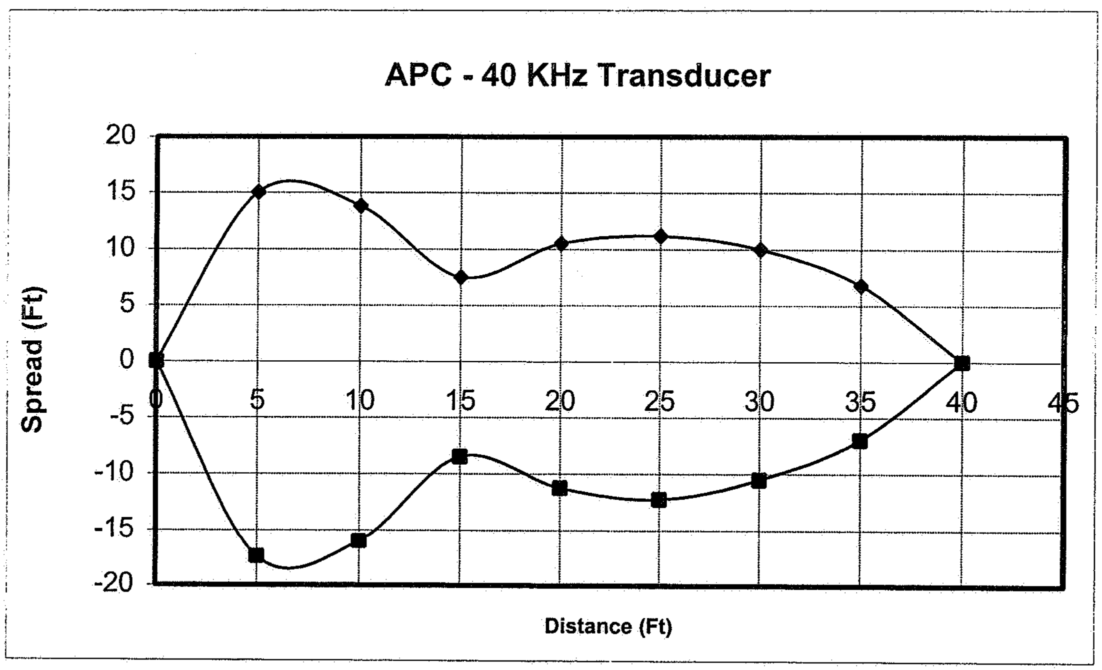


FIGURE 4(b): Measurement of Range as a Printout of Angle
(APC Transducer, Date of Measurement: 09/13/2000)

4. Evaluation of Step-Up Transformers

The Transformer secondary impedance was selected to match the impedance of the Transducer at the transmit/receive frequency. The turns ratio had to be such that the proper drive (voltage & current) could be supplied. The magnetics of the transformer must not saturate (collapsing the wave) while in use. To select the most appropriate transformer, we acquired several transformers. A good many of them were rejected due to large size. Sixteen of them were evaluated, results of three transformers are shown below. The traces pictured below show that the 2 smaller Transformers (Figure 5a, 5b and 5c) are in saturation thus unable to provide the energy necessary to maximize the Transducer output.

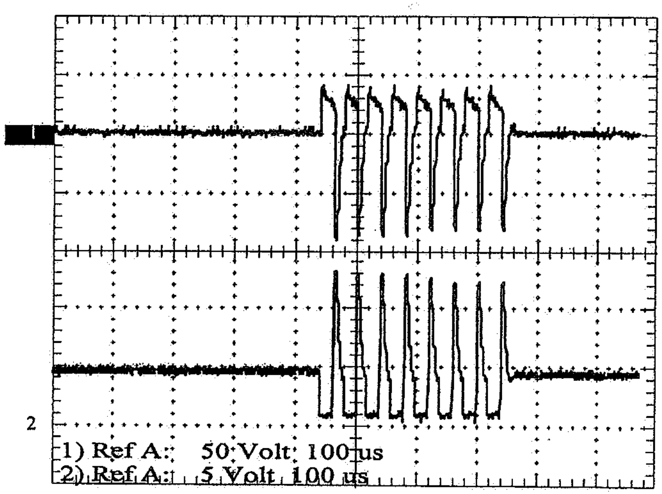


FIGURE 5a.

BH Electronics model Q10586
Size 0.8" x 0.825" x 0.410"
Test signal 25KHz, Burst 8 cycles,
5 Volt (peak to peak), square wave

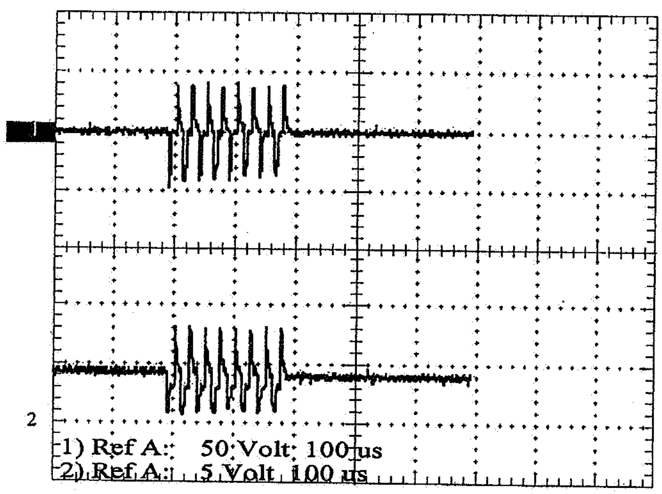


FIGURE 5b.

Cooper model CTX01-15116-X2
Size 0.36" x 0.47" x 0.42"
Test signal 40KHz, Burst 8 cycles,
5 Volt (peak to peak), square wave

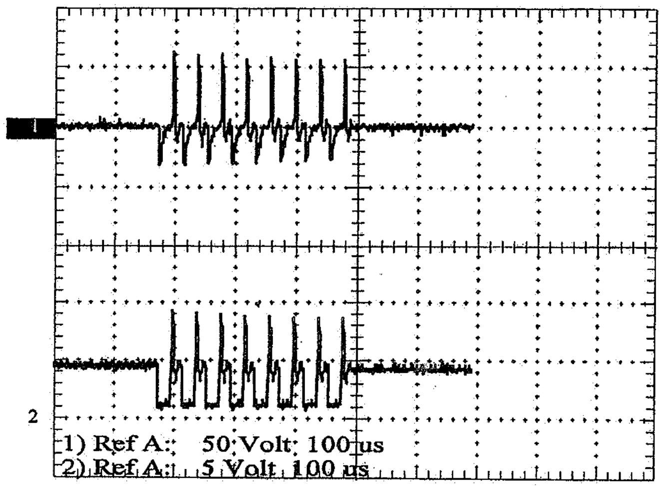


FIGURE 5c.

Midcom model 31032
Size 0.24" x 0.345" x 0.25"
Test signal 25KHz, Burst 8 cycles,
5 Volt (peak to peak), square wav

FIGURE 5: Oscilloscope Trace of Pulses at Transformer

USEFULNESS Of FINDINGS

OSHA has found that:

(i) 'Roofs and scaffolds' are the major locations of fatalities due to falls,

(ii) Approximately 75% of the fatalities due to being 'struck by' a machine involve heavy construction equipment.

This project included eliminating 'falls from roofs and scaffolds' hazards, and 'struck by' equipment hazards, two of the four major hazards found in the OSHA study. The physics of these two hazards is illustrated in the following sections.

(a) Struck-against, and Caught-in/under/between Accidents

These accident types (hereinafter called `struck-against' accidents) total 14% of the construction work-site accidents, with an average cost of $14,530, per accident. An example of these accident types is shown in Figure 6, where the worker while guiding a power loader is hit from behind by a bull-dozer working in the same general area.

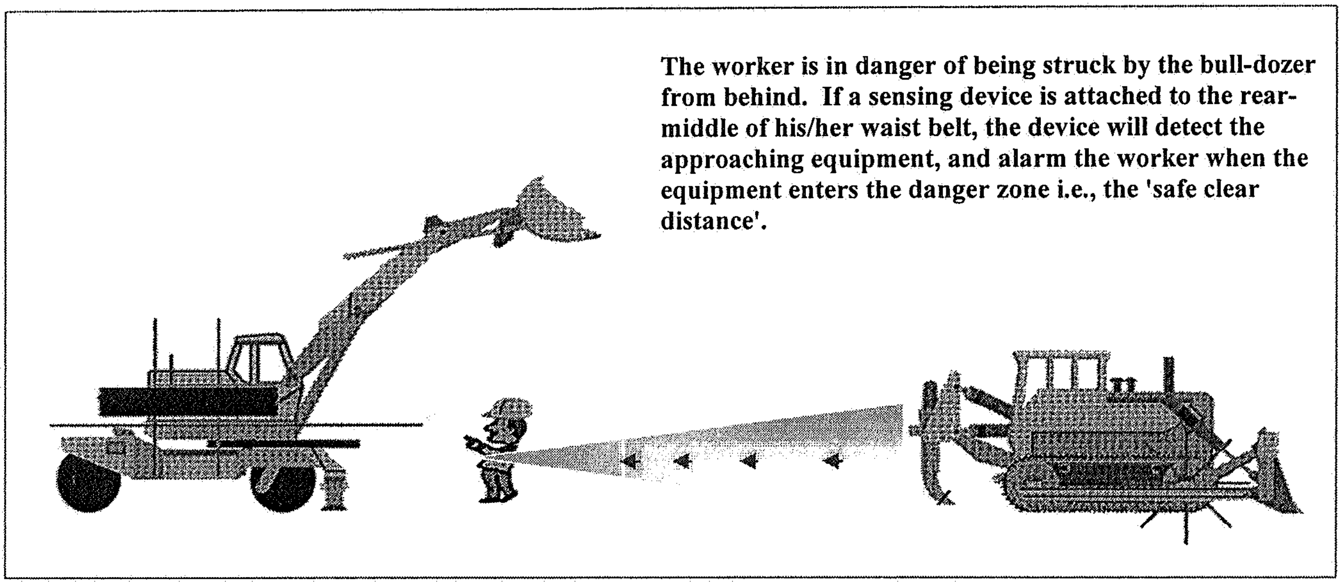


FIGURE 6: The Moving Hazard Warning (MHW) Device Concept

(b) Falls from Roofs, and Open-sided Floors/Platforms

Falls from the roofs, open-sided floors/platforms (hereinafter called `fall' accidents) total 4.9% with an average cost of $34,093 per accident. An example of these accident types is shown in Figure 7.

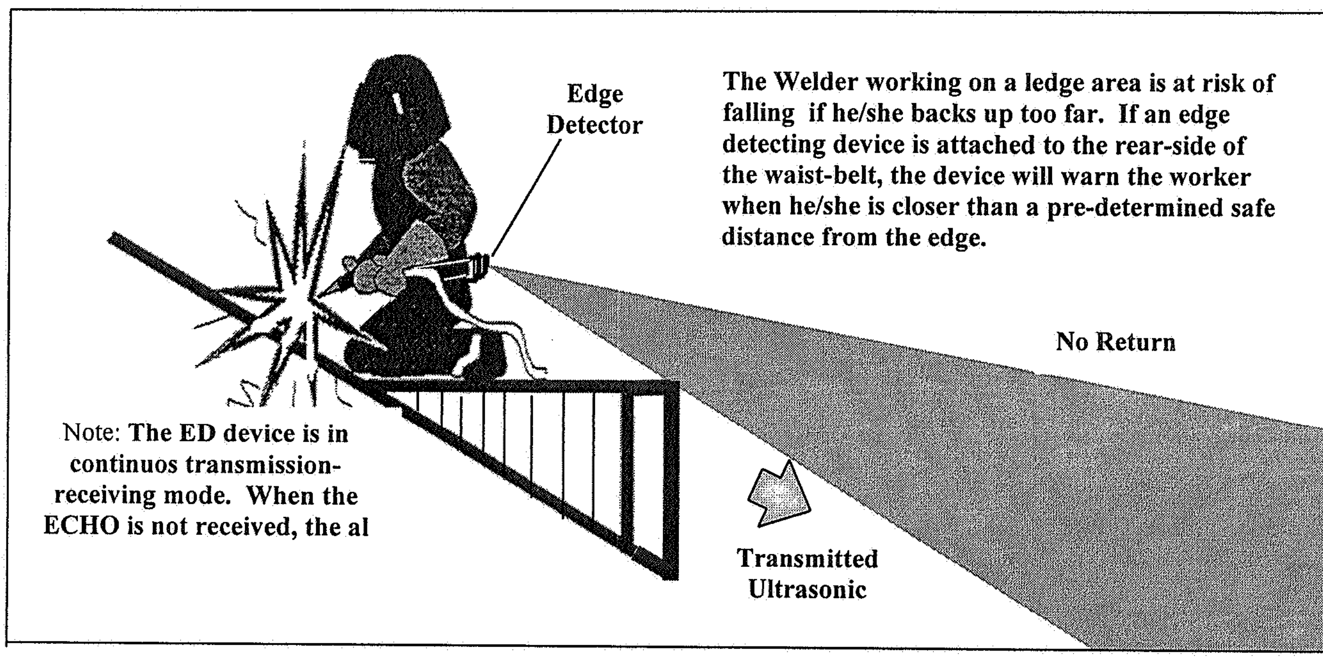


FIGURE 7: The Edge Detector (ED) Device Concept

Ergonomically designed electronic safety devices will be acceptable to construction workers. The prototype devices developed in this research were field tested on construction workers, some of them commented as below:

"The workers agreed that the construction safety field needs to make better use of today's technology. .....Behavior based safety programs and attitude adjustments have improved the safety of our work-sites a great deal. It is now the time for the technology advanced devices such as these two units to take the construction safety into the twenty-first century. I feel that with a little training, these devices could drastically reduce the number of 'struck-by' and fall related accidents."

Ultrasonic sensors here not provided a fail-safe technology application for the outdoor industry such as construction, due to high winds, rain, and snow. More research is needed to overcome these environments.

Electronic devices using radio frequency (RF) sensors will be usable at the construction sites.

PUBLICATIONS

The following two publications will be attempted this year.

i. Ultrasonic Technology in Worker Safety

ii. Electronic Safety Devices for Construction Workers

MATERIALS AVAILABLE For OTHER INVESTIGATORS

The following materials are available for other investigators from: ViTech Systems Inc.
126 Viscount Drive, Williamsville, New York 14221; e-mail: smohan@adelphia.net

i. Circuit Diagrams of the devices
ii. Field Test Results

The other investigators will be required to sign normal nondisclosure agreements.