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COMMERCIALIZATION OF THE ELECTRONIC GRAIN PROBE INSECT COUNTER

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ABSTRACT

Technology transfer in the form of a Cooperative Research and Development Agreement (CRADA) has been entered into with OPI Systems, Inc. of Calgary, Canada, a company that produces automated stored-product management systems, to refine for manufacture ARS' proprietary Electronic Grain Probe Insect Counter (EGPIC) System (U. S. Patent No. 5,646,404). The system automatically provides information about the presence and extent of insect infestations in bulk-stored agricultural products without the necessity of entering the storage structure. EGPIC uses an array of perforated tubes (probes) distributed throughout the bulk stored product. Insects wandering in the stored product crawl into the tubes and then drop down past electronic sensors that send counts back to a central computer. Insect counts are automatically analyzed, resulting in displays of population distribution estimates. These displays provide an early warning, allowing managers to maximize the efficient usage of fumigant or controlled atmosphere control strategies. The real-time system data also provides immediate feedback on the effectiveness of the applied control measures. System refinements addressed pertain to (a) the efficient production of the sensor head, (b) the optimization of the probe body entry hole array, and (c) the modification of the EGPIC electronics to interface with the existing OPI Systems data transmission architecture. Commercialization of EGPIC will provide the agricultural industry with a safe, effective tool for monitoring insect populations, which is an essential component of any Integrated Pest Management program.

INTRODUCTION

With the use of an infrared beam, the EGPIC monitoring system sheds light on insect infestation problems in stored-products. Insect monitoring and population density estimates in stored-products are essential for making informed management decisions. Spatial analysis techniques can be used to generate population density contours from the numbers of insect detected at an array of discrete sites. In an Integrated Pest Management (IPM) program, economic threshold analysis can be use to determine when it makes financial sense to initiate insect control measures. Also, with spatial representations of insect population densities, it is possible to reduce control costs by use of targeted treatments (Brenner *et al.,* 1998).

Current monitoring technology includes traditional sampling which involves the gathering and visual inspection of stored-product samples to determine the number of insects per unit volume. More recently, the deployment of fixed traps throughout or around the stored products for an extended time period, followed by their visual inspection, provides a greater detection sensitivity to low insect densities (Lippert and Hagstrum, 1987; White *et al.,* 1990; Reed *et al.,* 1991). This sensitivity is sometimes enhanced by the use of insect attractants in the trap. However, both of these methods have the limitations of being labor intensive, providing limited temporal availability of population data, and accessibility problems in detecting insects throughout the stored product due to the size and nature of storage structures. In addition, increased concerns for worker safety have necessitated the use of elaborate safety equipment and procedures, making it more difficult for workers to have access to the stored products.

The automated EGPIC computer-based system addresses these limitations with the following benefits. It provides continuous, real-time data at a central computer that is indicative of population densities. The data are obtained from sensors distributed throughout a storage facility. These real-time data can be used to make proactive management decisions, nipping a problem in the bud rather than reacting after damage has already occurred. These data can also provide instant feedback on the efficacy of control methods without causing any misleading disruption of insect behavior or interruption of the control method in progress. Such feedback allows control parameters to be adjusted for maximum efficiency while minimizing cost. For example, in controlled atmosphere environments or in low level recirculatory fumigation systems, the dosing levels can be minimized while still insuring that the target level of insect control is achieved. These dosing levels can even be controlled automatically by the same central monitoring computer. All this is achieved with much lower labor costs and safety risks then that incurred with manual monitoring techniques.

EGPIC TECHNOLOGY

The EGPIC design incorporates the properties of insect probes traps, which are perforated cylindrical tubes with insect collection receptacles, that are pushed into the stored product mass (Fig. 1). This methodology, having been commercially available for many years in its passive form and therefore familiar to the agricultural industry, is useful for monitoring adults of crawling insects such as weevils and grain beetles, which crawl into the holes in the probe trap body and then fall down into the trap receptacle. Much research has been performed on trap catch interpretation, including the relationship among number of insects captured, population density and temperature, and when to initiate control measures (Fargo *et al.,* 1989; Hagstrum *et al.,* 1991, 1998). The EGPIC system adds time-stamps to the insect count data, which provides the opportunity for trend analyses that was not possible before. With this technology, insect control strategies may be based on population trends within the sampling period rather than on only periodic knowledge of insect numbers at the end of a sampling period.

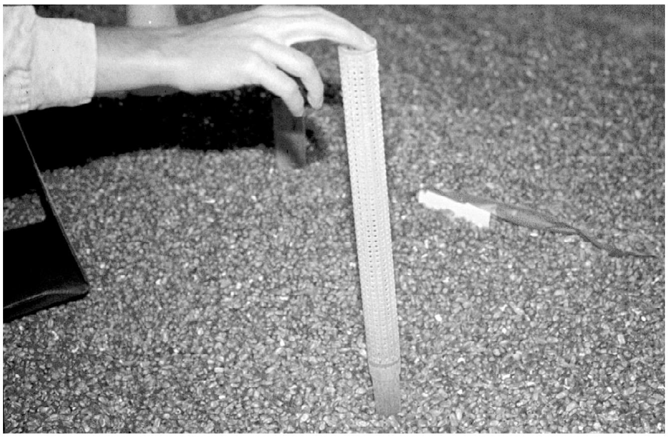

Fig. 1. A commercial passive probe trap being pushed into stored grain.

Fig. 2. An insect drops through a cutaway EGPIC sensor head. The insect snapped its own picture in mid-fall when it intersected the infrared beam (between the dark semicircular transducers), triggering an electronic flash.

The EGPIC system incorporates the use of an infrared beam at the bottom of the probe body to sense the insect as it falls through the beam (Shuman *et al.,* 1996). Much of the EGPIC research effort has gone into the design of the sensor head to insure that only falling insects ever cross the beam (Fig. 2), and that they only produce one electronic count per insect when they do (Epsky and Shuman, 2000; Shuman *et al.,* 2000). The beam, generated by an infrared diode and received by an infrared phototransistor, is wider than the insects it is meant to detect. Therefore, the insect falling through the beam only makes a slight decrease in the light intensity reaching the phototransistor. The EGPIC's sensitive electronic circuitry detects this slight decrease and converts it into a time -stamped insect count. The probe body used in the EGPIC system has insect entry holes that are angled upward in towards

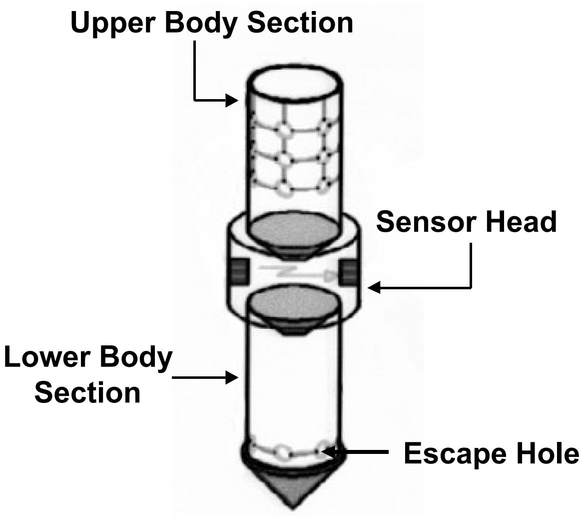

Fig. 3. An EGPIC probe with escape holes to prevent insect buildup that would necessitate frequent maintenance.

the center of the probe so that gravity helps keep dust and debris out of the probe. Only the insects, which readily climb up the 45 degree incline, enter the probe and are counted. The commercially available probes (Storgard WB Probe II, Trécé, Inc., Salinas, CA with straight holes and the Trappit Insect Probe Trap, AgriSense-BCS Ltd., UK with downward slanted holes) do not have this uphill feature. However, since their receptacle contents must be visually inspected, the dust and debris are more of a nuisance than a cause of count errors. It had been demonstrated that inversion of the AgriSense probe reduced dust and debris without reducing insect counts (Subramanyam *et al.,* 1989), leading to the use of inverted AgriSense probes in the prototype models. Although the prototype models still incorporate a trap receptacle to validate the system's counting accuracy, commercial versions of the probe will have an extension tube with holes at the bottom that will attach to the bottom of the sensor head (Fig. 3). This will allow the captured insects to escape and thus eliminate the need of emptying the trap on a regular basis. The computer-acquired insect count data can be automatically displayed in many ways including time dependant histograms and spatial analysis population contours. For example a histogram, displaying data (Tom Phillips, unpublished data) obtained with prototype EGPIC system in a field test, demonstrates the efficacy of a phosphine (PH_3) fumigation and its rate of action (Fig. 4). Using EGPIC data from another field test (Arbogast *et al.,* 2000), two 3-D spatial analysis graphs show (Figs. 5a, b) that, although the dominant insect population in a bin was killed off by a PH_3 fumigation, a small population in the center of the bin (probably in the dense fines where the PH_3 penetration was limited) continued to survive.

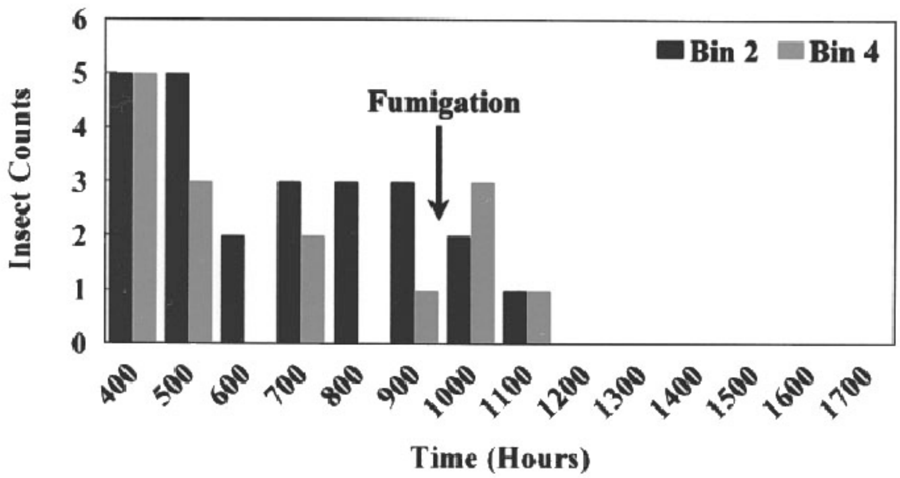

Fig. 4. Collecting EGPIC data (in two bins) during a phosphine fumigation shows a cessation of insect activity within two hours.

EGPIC COMMERCIALIZATION

Process

The commercialization process began with the application for, and awarding of, a U.S. Patent (Litzkow *et al.,* 1997) for the EGPIC system. Currently, OPI (meaning "Ounce of Prevention Insurance") Systems, Calgary, Canada, is in the process of negotiating an exclusive license for the EGPIC technology. A USDA Cooperative Research and Development Agreement (CRADA), established in January, 2000, with OPI Systems, is supporting the refinement of the EGPIC technology and its integration into OPI Systems' existing data transmission architecture for purposes of EGPIC's anticipated commercialization. OPI Systems is a developer, manufacturer, and distributor of state-of-the-art grain storage management systems that include temperature cables, level and humidity sensors, and automated control of aeration, chillers, and other stored product quality optimization technologies.

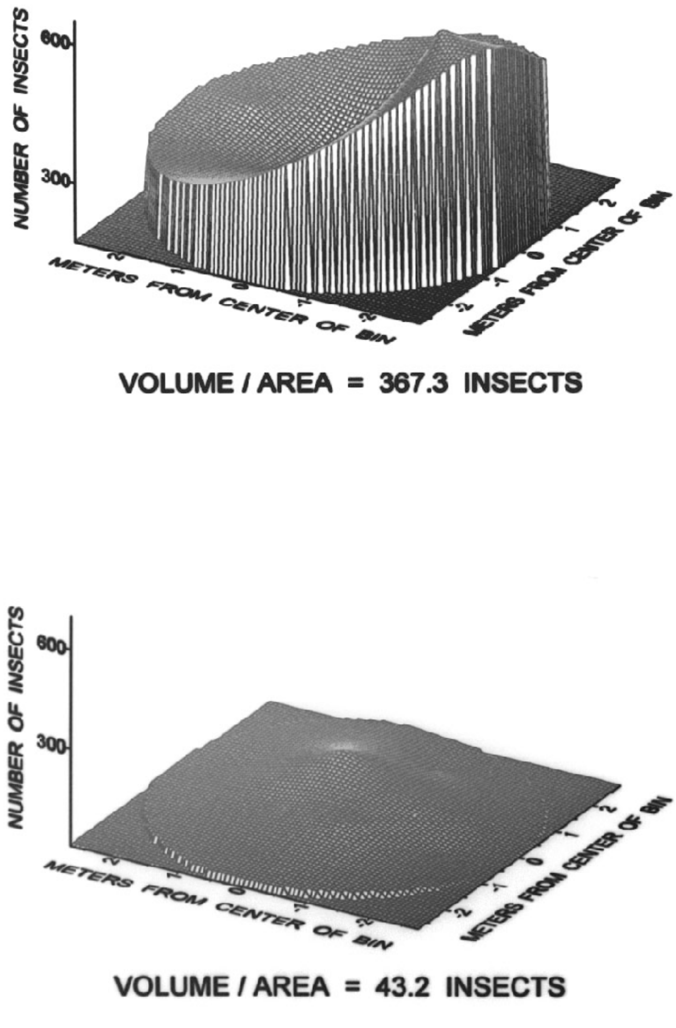

Fig. 5. Three-dimensional graphs created using spatial analysis on EGPIC field test data show a heavy infestation (a) reduced but not eliminated (b) by a bin fumigation.

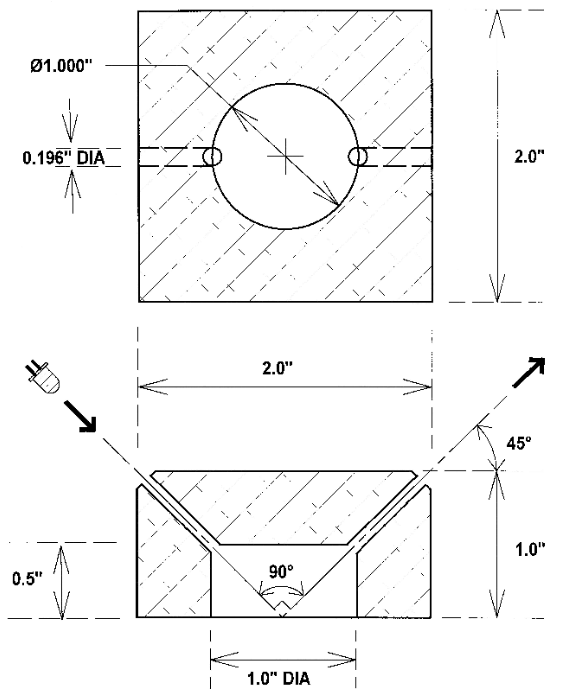

Fig. 6. An infrared surface reflection tester constructed to evaluate different materials.

Refinement under the CRADA

During research conducted with EGPIC prototype models, it was found that internal infrared reflections in the sensor head reduced count accuracy and sensor performance. During this refinement phase, a surface reflectance tester was constructed (Fig. 6), to measure the relative infrared reflectance of different plastic materials. From these tests, black nylon 6/6 (extruded) was selected for the sensor heads because of its low reflectance (Fig 7), high strength, and machinability. Further tests with the black nylon using different surface treatments (Fig. 8) indicated that a sand blasted surface provided the minimum reflectivity. For this reason, the internal surface of the sensor head is sand blasted during the manufacturing process. The sensor head design was also modified to be machined from a single (rather than three) piece of nylon (Fig 9). This insures that the critical position and the orientation of the upward funnel relative to the infrared beam is maintained, and also reduces manufacturing costs. The lower funnel is now a separate (commercially available) piece that is force fit into the sensor head. The probe body was elongated to increase its insect active capture length to 40 cm with 210 holes (an array of 10 rows by 21 holes) and also to house a 10 cm “translator” circuit board. The PVC probe body, which is now being manufactured by a custom designed, computer-controlled lathe (Fig. 10), is also force fit into the sensor head. The sensor head and the probe body are being manufactured by Analytical Research Systems, Inc. (Gainesville, FL), which has also played an important role in the refinement of the EGPIC design.

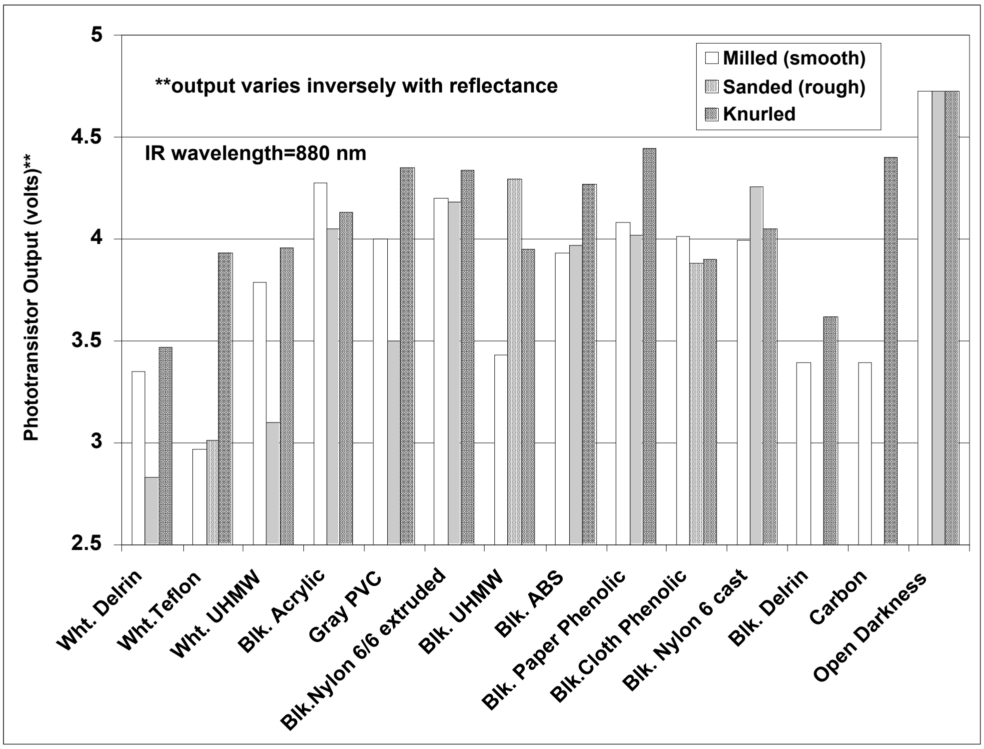

Fig. 7. Relative infrared reflectance of plastic samples with three different surface treatments.

The translator circuit board, mounted in the probe body to minimize the infrared phototransistor low-level analog signal lead length, was designed to be maintenance free by incorporating a self-adjusting bias control section for the phototransistor, a programmable sensitivity control, and a micro-controller chip for accumulating the time-stamped insect counts and communicating with OPI Systems digital transmission network. It also incorporates a temperature sensor mounted in the middle of the probe body active area since the temperature in the vicinity of the probe is needed to help interpret the significance of the number of insect captured. Insects falling through the infrared beam generate pulses, each with a different amplitude. In most applications, one of the smallest insects of concern is *Cryptolestes ferrugineus* (Stephens), the rusty grain beetle. Using a histogram distribution of pulse amplitudes obtained with rusty grain beetles (Fig. 11), a lower limit for the EGPIC sensitivity was selected to be approximately 75 mV in order to provide high (>95%) count accuracy for this species while minimizing count errors due to smaller insects and debris. A method was developed to adjust all probes to this sensitivity, independent of the relatively large mechanical and electrical tolerances associated with the infrared beam transducers. This method consists of dropping a precision metal ball through the exact center of the infrared beam (Fig. 12) and then adjusting the programmable sensitivity threshold level of each new EGPIC probe to just be able to detect the ball. Tests conducted with a variety of steel ball sizes (Fig.13) indicated that a 0.4 mm diameter metal ball provided just the right sensitivity adjustment.

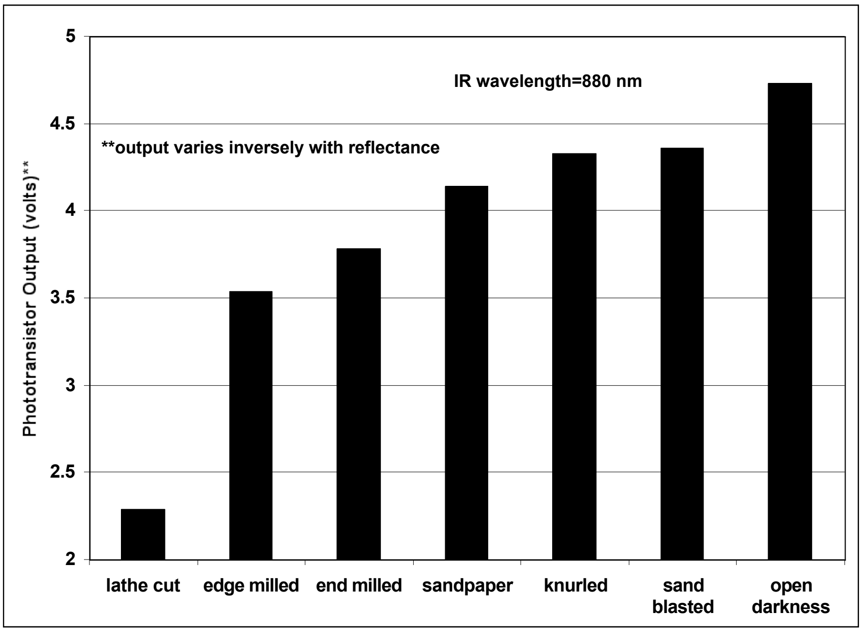

Fig. 8. The relative infrared reflectance of black nylon 6/6 (extruded) with different surface treatments.

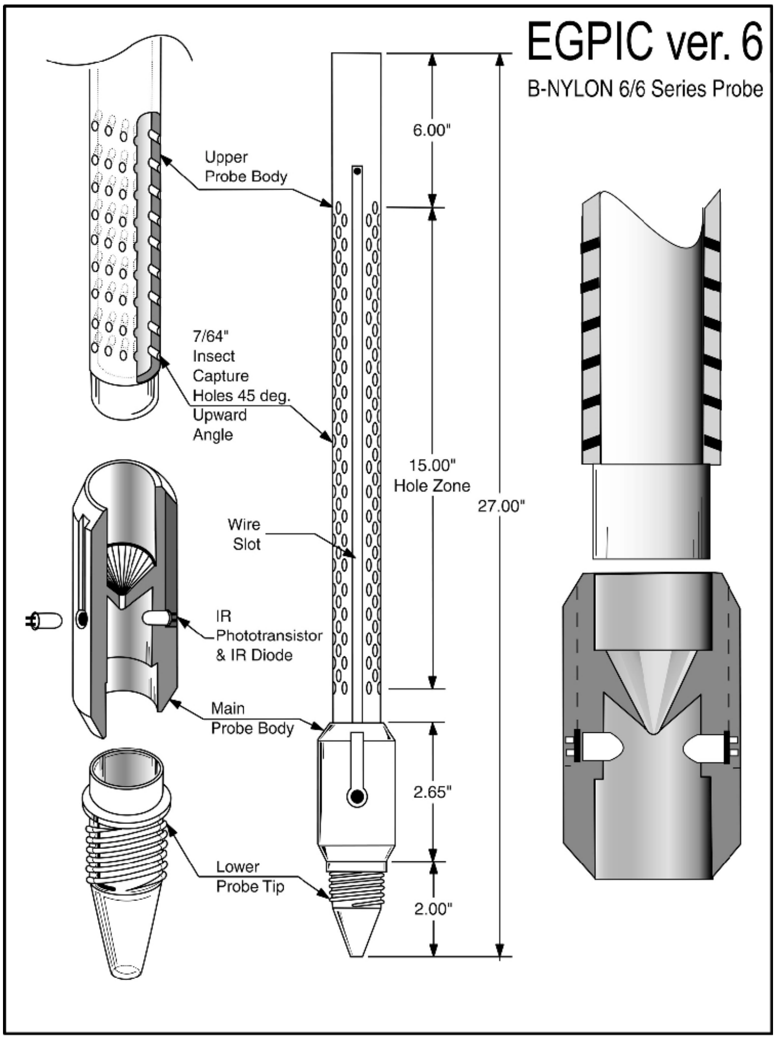

Fig. 9. The EGPIC probe to be commercial released, detailing its one piece sensor head and its custom manufactured 210 hole probe body. The electronic "translator" circuit board will be mounted the top no-hole section of the probe body.

CONCLUSION

The OPI-EGPIC system, scheduled to be distributed for beta field testing by the end of the year 2000 and commercially released during the spring of 2001, will be the first automated insect monitoring system available to the agricultural industry. This timely release will help in the current effort to protect stored products from insect damage while simultaneously reducing the amount of fumigant used and increasing the economic viability of various fumigant alternatives.

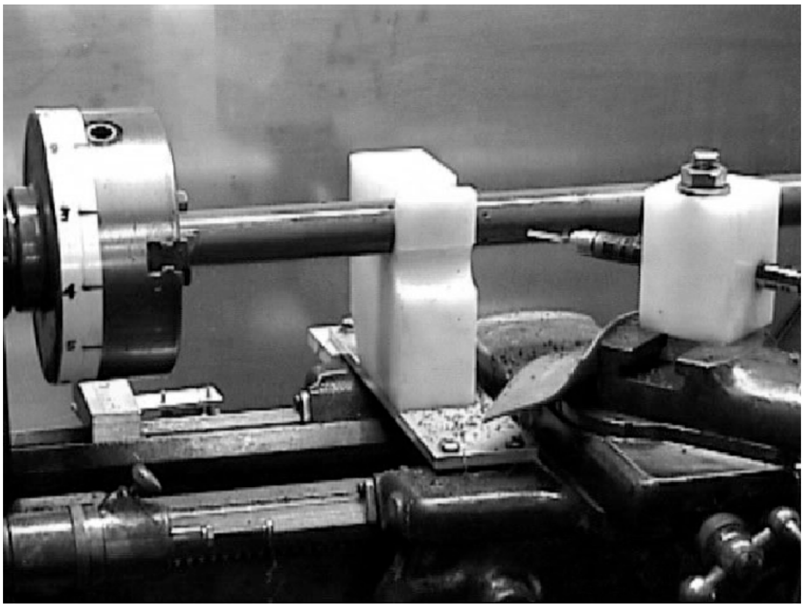

Fig. 10. Close-up view of the computer-controlled lathe designed to automatically rotate, translate, and drill a PVC tube with 45 degree holes.

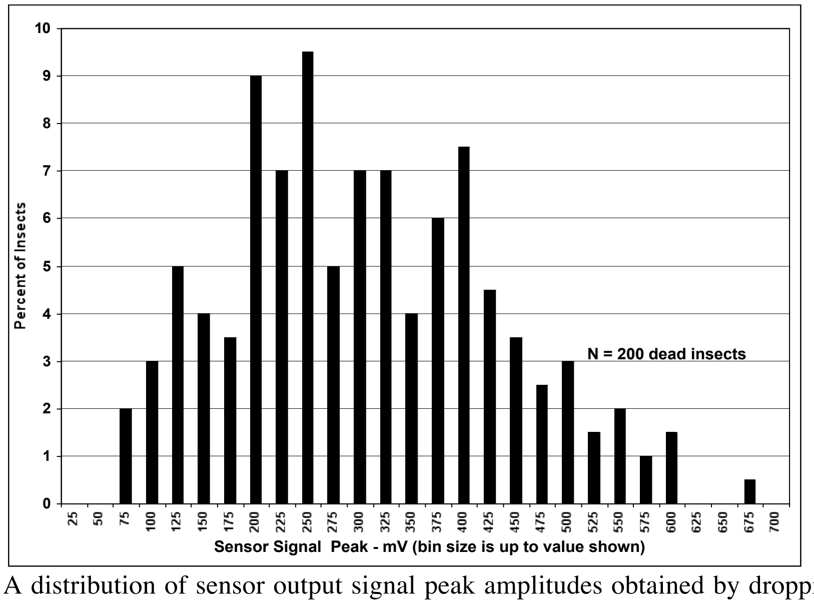

Fig. 11. A distribution of sensor output signal peak amplitudes obtained by dropping rusty grain beetles through an infrared beam. The variance is due to the random orientation of each insect as it passes through a different part of the non-uniform intensity beam.

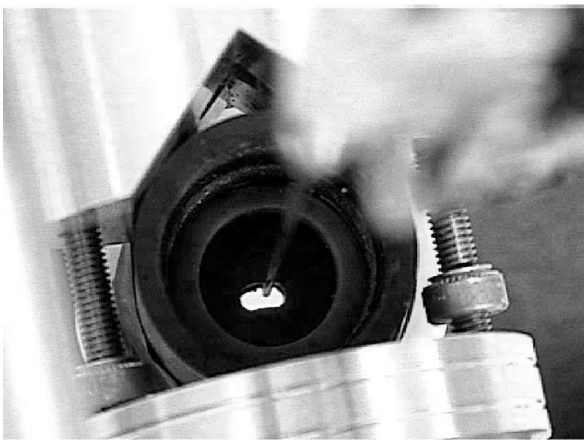

Fig. 12. A laboratory setup using a glass tube to drop metal balls through the exact center of the infrared beam in the sensor head.

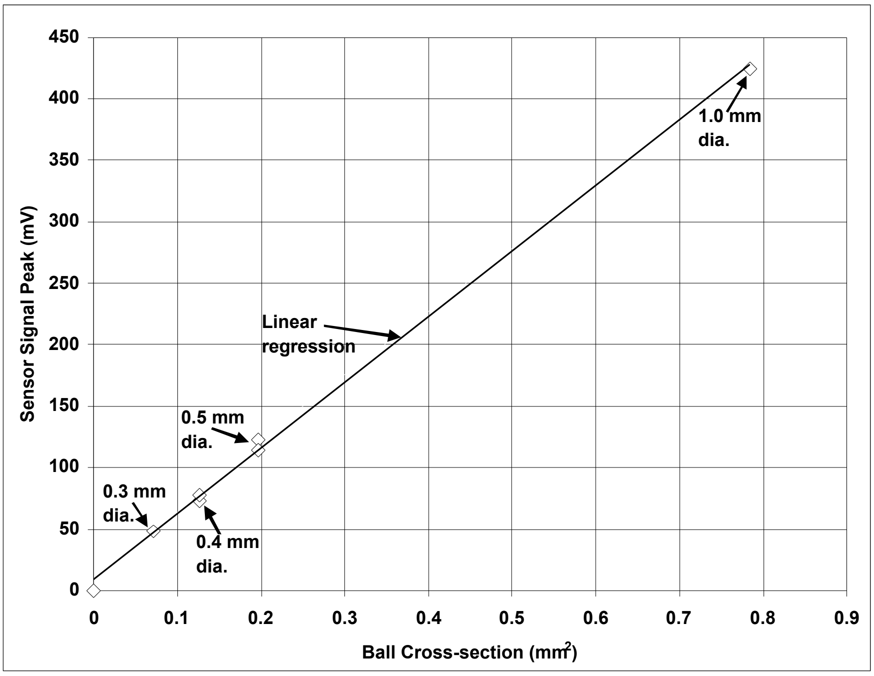

Fig. 13. A linear relationship is observed between the cross-sectional areas of metal balls (i.e., the size of their shadows) dropped through the center of the infrared beam and the resulting sensor output signal peak amplitudes.

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