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Quantitative Acoustical Detection of Larvae Feeding Inside Kernels of Grain

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ABSTRACT An automated, computer-based electronic acoustic system was developed to quantify infestation of internally feeding larvae in a grain sample using spatial localization of insects in the sample. Localization was determined using arrival times of sounds produced by insect feeding activity as received by an array of acoustic transducers. In a test conducted with 0–3 fourth instars of the rice weevil, *Sitophilus oryzae* (L.), in 1-kg samples of wheat, the system overassessed the number of larvae present in 6% of the trials and underassessed the number of larvae present in 34% of the trials. When Federal Grain Inspection Service (FGIS) standards were applied in evaluating performance, the system was 92% accurate in grading "clean" grain and 64% accurate in grading "infested" grain.

KEY WORDS stored products, sound, detection

THE PRESENCE OF INSECTS in stored grain is a major factor in the determination of quality under current mandated industry standards. Currently, grain inspection involves counting the insects sieved from a defined sample, usually 1 kg. This procedure limits detection to externally feeding larvae and adults. Larvae of two economically important species, the rice weevil, *Sitophilus oryzae* (L.), and lesser grain borer, *Rhyzopertha dominica* (F.), feed inside kernels of grain and are not detected. If adults are not present, because they either have not yet emerged from infested kernels or have been removed by cleaning or other manufacturing processes, grain internally infested may be mistaken for uninfested grain. Current laboratory methods for the detection of internal feeders (X ray, carbon dioxide production, resonance spectroscopy) are costly and time consuming and generally not implemented. There is a need for a rapid, quantitative, and economic method for detecting both adults and larvae of major insect pests of grain.

Detection of insects in fruits and grain by amplifying their feeding and movement sounds was suggested by Brain (1924), but technical difficulties prevented the development of practical systems (Adams et al. 1953, Bailey & McCabe 1965, Street 1971). Recent technological advances (sensitive detectors, suitable band-pass filters, and inexpensive computers) have stimulated studies (Hagstrum 1988; Vick et al. 1988; Hagstrum et al. 1990, 1991) directed at the development of practical acoustic detection systems for stored-product insects. Although the latter studies have demonstrated a strong correlation between the number of insects in a sample and total acoustical activity, it is not sufficiently accurate for the rapid grading of an unreplicated grain sample.

This article describes a system (ALFID [Acoustic Location Fixing Insect Detector]) that was developed, constructed, and evaluated for accurately identifying the number of internally feeding larvae in grain samples. The system operates by determining the number of loci within a sample from which sounds are originating.

Materials and Methods

Operational Principle, Technical Implementation, and Operation. The transit time of a sound is directly proportional to the distance traversed. ALFID incorporates a linear array of acoustic sensors mounted in one wall of a rectangular grain sample container. By identifying the first and second adjacent sensors in the array to receive a particular sound, the location of the sound's source can be inferred to be within a volume bounded by a plane equidistant from the sensors and a parallel plane through the middle of the first sensor. During a defined sampling period, some minimum number of sounds originating from within the same volume indicates the presence of an insect in that volume. This empirically derived minimum number is utilized to reduce the probability of incorrectly identifying ambient and/or grain settling noise as being produced by an insect.

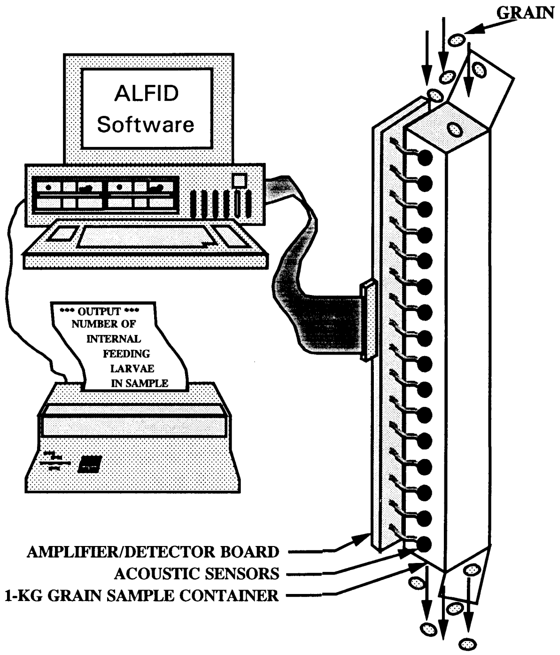

Fig. 1. User's view of the ALFID system in the field, showing its physical implementation. Grain sample container would be housed in a sound attenuation box.

From a user's perspective, the ALFID system (Fig. 1) includes a 1-kg grain sample container (76 by 5 by 4 cm) with a linear array of 16 (for spatial considerations and convenience with 16-bit oriented computers) piezoelectric acoustic sensors (2.8-cm diameter spaced 4.8 cm apart) mounted in one wall (76 by 4 cm) of the container. For field use, the container is oriented vertically to facilitate gravity loading and unloading of grain. A 16-channel electronic circuit board, positioned on an adjacent wall (for electrical noise considerations), locally amplifies (80 dB) and filters (1–10 kHz bandpass) the low-level analog output of each high-impedance sensor. Amplitude threshold detection is then used to delineate the arrival time of any received acoustic signal (Fig. 2). For field use, the grain container should be housed in a suitable sound attenuation box to reduce the effects of ambient noise. A cable from the circuit board connects the 16-channel detector outputs to a remote custom logic circuit implemented with 26 integrated circuit logic chips (gates, latches, and a one-shot from the standard 7400 low-power Schottky series). A computer interface for the custom logic circuit is provided by a commercial digital input/output board installed in a microcomputer that

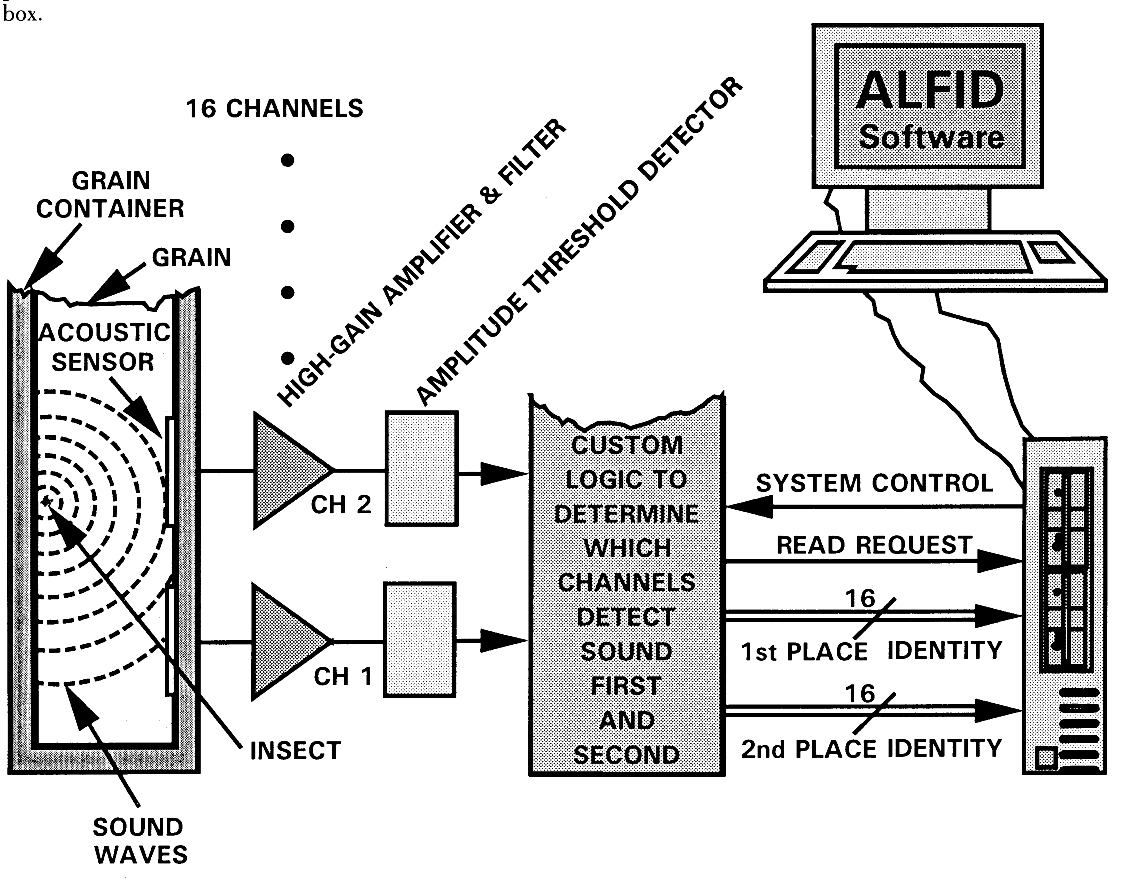

Fig. 2. Functional block diagram of the ALFID system portraying an insect-produced sound.