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IMAGING GAMMA-RAY CONTRABAND DETECTOR FOR EMPTY LIQUID TRANSPORT CONTAINERS

QUARTERLY REPORT

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Prepared for:

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1. INTRODUCTION

This quarterly progress report is the first for this program and covers the period from contract award through November 15, 1994. (Each submission is due 15 days following the end of the quarter, per CDRL for this contract.) The program is for the development of an imaging gamma-ray contraband detector for empty liquid transport containers.

This work follows a feasibility study carried out by Science Applications International Corporation (SAIC) for the U.S. Customs Service under U.S. Department of Transportation (Research and Special Programs Administration) Contract Number DTRS-57-89-C-00155; "Final Report, Tanker-Truck Contraband Detector System," SAIC Report No. 15-0351-03-2333-000, January 26, 1993.

Section 2 presents a review of that study, showing the effectiveness of the gamma-ray "imaging system" for detecting even small contraband packages through a thick-walled, high-pressure transport tanker. As a corollary to that study, the data were evaluated for a high-speed inspection, and inspection of a tanker truck in traffic, and a brief account of that study is presented. In the inspection of either a parked or fast-moving tanker truck, the method of displaying the gamma-ray picture is of utmost importance for revealing the presence of contraband to an inspector that is likely to have had relatively little training. Some early modes of displaying the gamma-ray picture are discussed in this section.

Following the presentation of these early developments, the progress of the present program is presented in Section 3. This includes the gamma-ray source, the detectors and data processing functions that are in the final design stages, and the data display format that is in the more embryonic stage of development. A few summary remarks appear in Section 4.

2. EARLIER WORK

As mentioned above, a feasibility study was carried out by SAIC for U.S. Customs Service, utilizing a gamma-ray source and a small array of detectors on hand and an empty tanker truck that had been confiscated at the USA/Mexico border in San Diego with a load of about 8000 pounds of cocaine. The truck was nominally empty, reentering this country for another load of liquified petroleum gas. When emptied in Mexico, there is residual gas in the tanker, which must therefore be kept under pressure in this "empty" state. It is, therefore, not feasible to conduct a visual inspection inside. Because of the 8000 pound load, the contraband was detected by weighing. Smaller, but still "profitable" loads cannot be detected in this manner because of weight variations due to different residual-gas content and other variables.

The confiscated tanker truck, with manhole-cover removed, is shown in Figure 1, with a Cs-137 gamma-ray source to the left and a bank of gamma-ray detectors and associated electronics to the right of the tanker. Both source and detector array were located on their individual trolley, and the trolleys were moved together on their tracks so as to scan the contents of the tanker between them.

The manhole cover shown at the top of the tanker in Figure 1 had been opened a long time, so that all the explosive and toxic fumes were gone. This made it possible for us to place a stack of relatively small packets of various materials representing cocaine, say, in different states of packing density. An array of these packets, as loaded in the tanker, is shown in Figure 2. A description of each packet, including its density, its lateral thickness (as seen by the interrogating gamma rays), and its contents (i.e., sugar, flour-salt mix, etc.) is presented in Figure 3.

Note that the detector located 18" above the bottom of the tanker will detect the packets marked as A, B, C, and D as the source and detector scan the length of the tanker truck. The results of this 18" scan are presented in Figure 4 (without packets A, B, C, and D) and Figure 5 (with the packets). Note how well even these small packets, only 6" to 8" across, can be detected through 3/4" of the tanker steel wall. This property arises from the use of the higher energy gamma rays (Cs-137; 662 keV gamma rays) that are just as transparent to steel (in units of gm/cm^2) as for cocaine, say.

A computer-monitor display of the line scans of Figures 4 and 5 comprises one option for data presentation to the border inspector. A block diagram of the operating system, presented in Figure 6, shows a series of similar scans, one for each detector height above tanker bottom. The shaded region for each scan represented material in the tanker that is not suppose to be there. The operator can tell that it is not suppose to be there from his knowledge of the tanker structure. Alternatively, he could compare these scans, presented at the bottom half of the screen, with the same scans (presented at the top half of the screen) taken previously on an empty tanker of the same make and kept available in the computer memory (and called out by the operator for a comparison).

This mode of inspection was one of the earliest candidates considered. Other modes are being considered, the most promising one being perhaps a simple variant of the above, a variant that "does without the joystick." An example of this is shown in Figure 7, upper right, where a computer screen is segregated in two halves; the upper half shows the gamma-ray picture for a reference tanker of the same make, a picture that is stored in the computer memory for rapid access, and the lower half shows a picture of the tanker presently under inspection.

3. PRESENT PROGRAM

3.1 OVERVIEW

The goal of this program is to develop a tanker-truck contraband detection system and demonstrate it on a tanker truck stuffed with simulated contraband, as shown in Figure 1. Vic Pocaro of the U.S. Customs Service, Washington D.C., (202) 927-1991, will be working with John Shaver, COTR for this project (U.S. Army Electronic Proving Ground, Attn: STEWS-EPG-EE, Fort Huachuca, AZ 85613, (602) 538-4939) in determining a site for the demonstration and obtaining the use of a loadable tanker truck. The possibilities range from using the same, or a similar tanker truck near the San Diego border, as in the abovementioned U.S. Customs Service sponsored feasibility study, to a demonstration at Fort Huachuca, AZ, if a suitable tanker truck can be located. Vic Pocaro is contacting the San Diego U.S. Custom Service staff to explore possibilities for a demonstration near the San Diego-Mexico border.

The system is comprised of the elements shown in the schematic diagram of Figure 7, namely a gamma-ray source on one side of the tanker, a linear array of gamma-ray detectors on the opposite side, a trolley and trolley tracks on each side, a synchronous motor for each trolley to move the two trolleys in synchronism along the tanker, data processing/transmitting electronics at the detector, and a data crunching computer, with appropriate user-friendly display, remote from the tanker-screening trolleys.

3.2 THE GAMMA-RAY SOURCE

The source and source holder, shown in Figure 8, are on order from the Ohmart Corporation. The source is 1000 mCi of Cs-137, and is contained in a shielded source holder with a collimator that is electrically shuttered: It will close in a "fail-safe" position with power loss, and will normally be opened when the source and detector-array trolleys begin their synchronous motion along the tanker truck. The tanker truck scan will always begin about a foot or so behind the end of the tanker so that automatic normalization of the detector counting (i.e., the "zero-based" counts) is achieved and stored in the computer for a "drift-free" standard.

The source height will be adjustable, and will be set at the level of the bottom of the tanker. This minimizes the "clutter" (tires, frame, etc.) that will be in the way of the gamma-ray picture (see Figures 1 and 7), and that would otherwise tend to mask the presences of hidden contraband.

Delivery of the source and source holder is scheduled for mid-December 1994.

3.3 THE DETECTOR ARRAY AND SIGNAL-PROCESSING ELECTRONICS

Figure 7 shows a linear array of detectors that reaches high enough to intercept all the gamma-rays passing through the tanker, top to bottom. The actual array will utilize 48 gamma-ray detectors and will be about 9 feet high, top to bottom. A single detector is shown in Figure 9 next to the data-processing electronics circuit. The circuit shown consists of a pulse-amplification and pulse-shaping circuit at the very bottom, a digital pulse-height discriminator (comparator), scaler (accumulator, or counter), and an RS 45 serial communication link. An aluminum "ground plane" can be seen separating the top (digital) and bottom (analog) circuitry.

The circuitry is 7-1/2" long and accepts signals from 16 each of the 1-1/2" diameter, 1-1/2" long NaI (Tl) scintillators, photomultiplier tubes, and tube bases, one of which is shown in Figure 9. There will be three each of such 16-channel circuits that will process the counts from the 48 NaI detectors. This circuitry is being designed, fabricated, and tested by SAIC's Military Products Division, and consists of a modification of their 16-channel units previously built for SAIC's CdTe linear X-ray-detector arrays being developed for hospital CAT scanners. The modifications consisted of a faster amplifier system (1/4 microsecond pulse-shaping time constant versus 1/2 microsecond), and of a separate RS 45 serial communication link for each 16 channels of gamma-ray-counter data input. Both changes were made to handle photomultiplier-tube pulses (and at an extremely fast count rate) and to transmit these data over at least 100 feet of transmission line (and with a capability of rapid readout for the present, and for any future high-speed tanker truck applications, such as inspection of a tanker truck in traffic).

Since the design modifications were required in any case, for the present program, the circuitry was designed "into the future," i.e., for a fast-scanning capability, at little or no extra cost to the program. If the need for an ultra-fast scanning capability should arise, as in the example of scanning a tanker truck in traffic shown in Figure 10, we would simply increase the Cs-137 source strength by a factor of 3 to 10 (depending on the "mission profile"), or replace it with a fast-shutter-speed 420 keV X-ray source with highly hardened (filtered) beam, and reprogram the computer. (Interest in the in-traffic operation has been expressed by Jim Petrousky of the Office of Special Technology.)

Delivery of the gamma-ray detectors (mounted on multiplier tubes) and photomultiplir-tube bases is scheduled for mid-December 1994. The 16-channel circuit boards are designed and manufactured, and will be stuffed with components (wired) and ready for testing by early December.

The testing of the 16-channel circuits will begin in December, and will include read-in formatting to the data-crunching computer. Software development will begin in late December or early January 1995.

3.4 DATA DISPLAY FORMAT

The block diagram presented in Figure 6 shows one option for displaying the "gamma-ray picture" in a mode that optimizes the capability of the operator to detect the presence of very small packets of contraband. However, it is not likely that a tanker truck will be depressurized and loaded with very small packets, considering the costs of such an operation and also considering that the interdicted tanker truck had a load of about 8000 pounds of cocaine. Therefore, it is more likely that a quick-look capability will be more useful. In this mode, the entire gamma-ray picture is presented, rather than a "piecemeal picture", thus helping the inspector make a decision based on the integrated mass-distribution layout.

A quick-look capability is offered in a display of the type shown in Figure 7. There, the upper half of the screen shows a profile of a tanker of the same make, known to be empty, and stored in the computer memory for rapid access. In the lower half of the screen is shown a gamma-ray picture of the tanker presently under inspection. This comparison readily shows up lumps of mass (such as hidden contraband) where there should not be any. But even before this "reference" picture is available, this side-to-side view of the tanker's insides is so clutter free that the inspector knows pretty well beforehand where there is "lumpiness" from the tanker structure. (Figure 2, a view inside the tanker, shows it to be completely empty except for the vertical fill pipe and the "anti-slush" barrier behind it in the picture. All other tanker lumpiness in the gamma-ray picture can be seen by the inspector; it is all outside the tanker. Thus, even before a standard, contraband-free picture can be taken for reference, the type of display shown in the lower half of the screen can be highly useful.)

Because of these considerations, it is most likely that the "quick-look" display format, showing the entire tanker gamma-ray picture, will find greatest acceptance by the inspector operating the gamma-ray contraband inspection system. Mass differences in the gamma-ray picture can be displayed in many ways. These include brightness alone on a black-white display, or a color-coded display of density variations. We will likely get useful input regarding these choices from U.S. Customs Service, Research and Development staff members, and other user-associated individuals.

3.5 THE TROLLEYS, TRACKS, AND MOTORS

The trolleys and their contents are being designed in a way that facilitates rapid assembly, and also rapid disassembly for transport and relocation at another inspection site. This will help provide the element of surprise, should that be useful. This mechanical design will be carried out in December and early January.

4. CONCLUSIONS

The long-term delivery items, including the critical 16-channel-circuit development, are on schedule. In parallel with the gamma-ray-imaging contraband detector development, we expect to work with the program COTR and the U.S. Customs Service Research and Development staff in planning a useful demonstration of the system on a tanker truck at a location where potential users of the system can evaluate its effectiveness and perhaps suggest other related applications.

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Figure 1. Contraband - Detector Measurements in Progress: Shuttered Cs-137 Gamma-Ray Source (Raised Position) on Left, and Detector Bank (Raised Position) on Right.

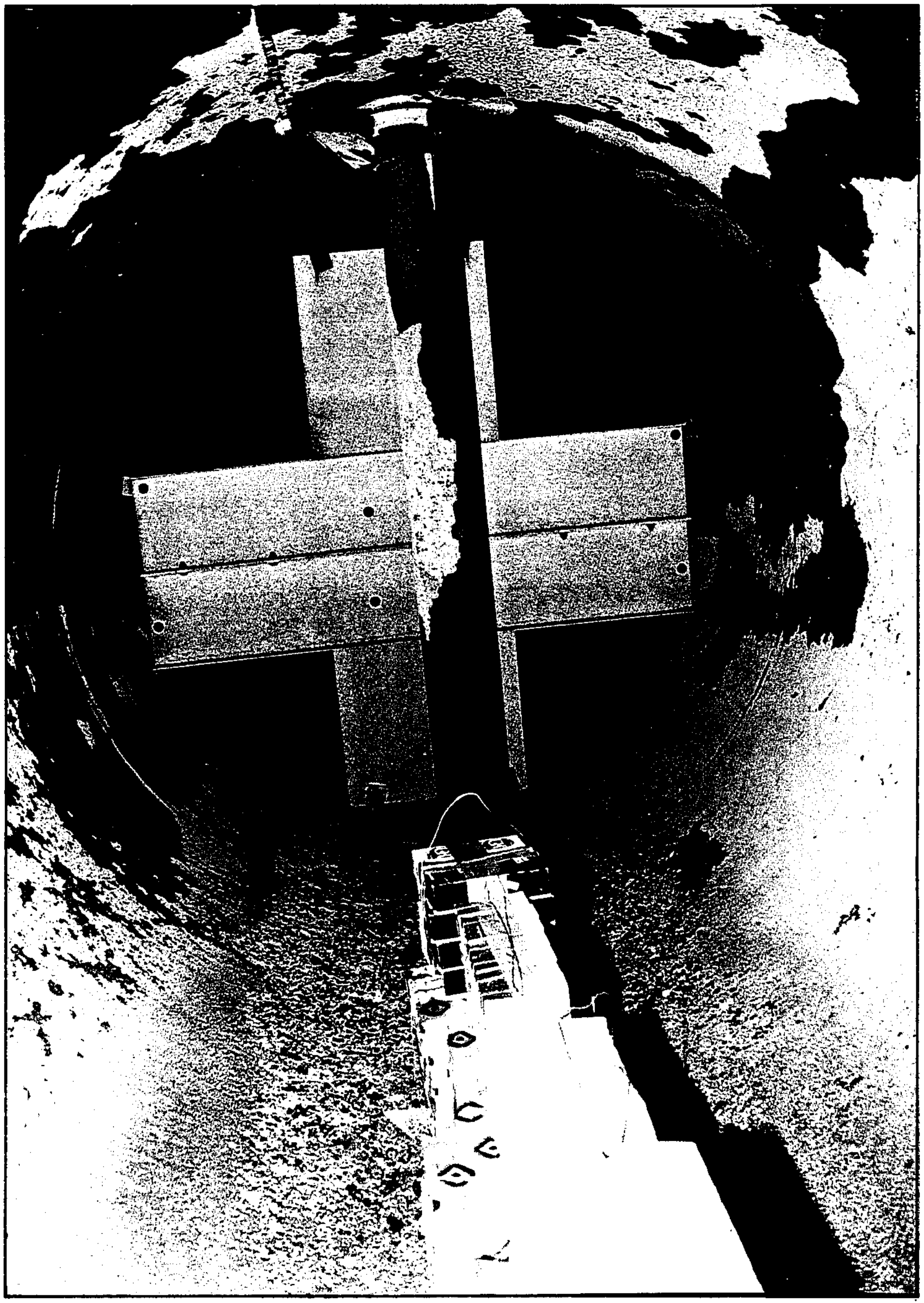

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Figure 2. View Inside Tanker Showing Anti-Slush Barrier, Loading Pipe, and Four Different Contraband - Simulation Packages Atop Packets of Xerox Paper

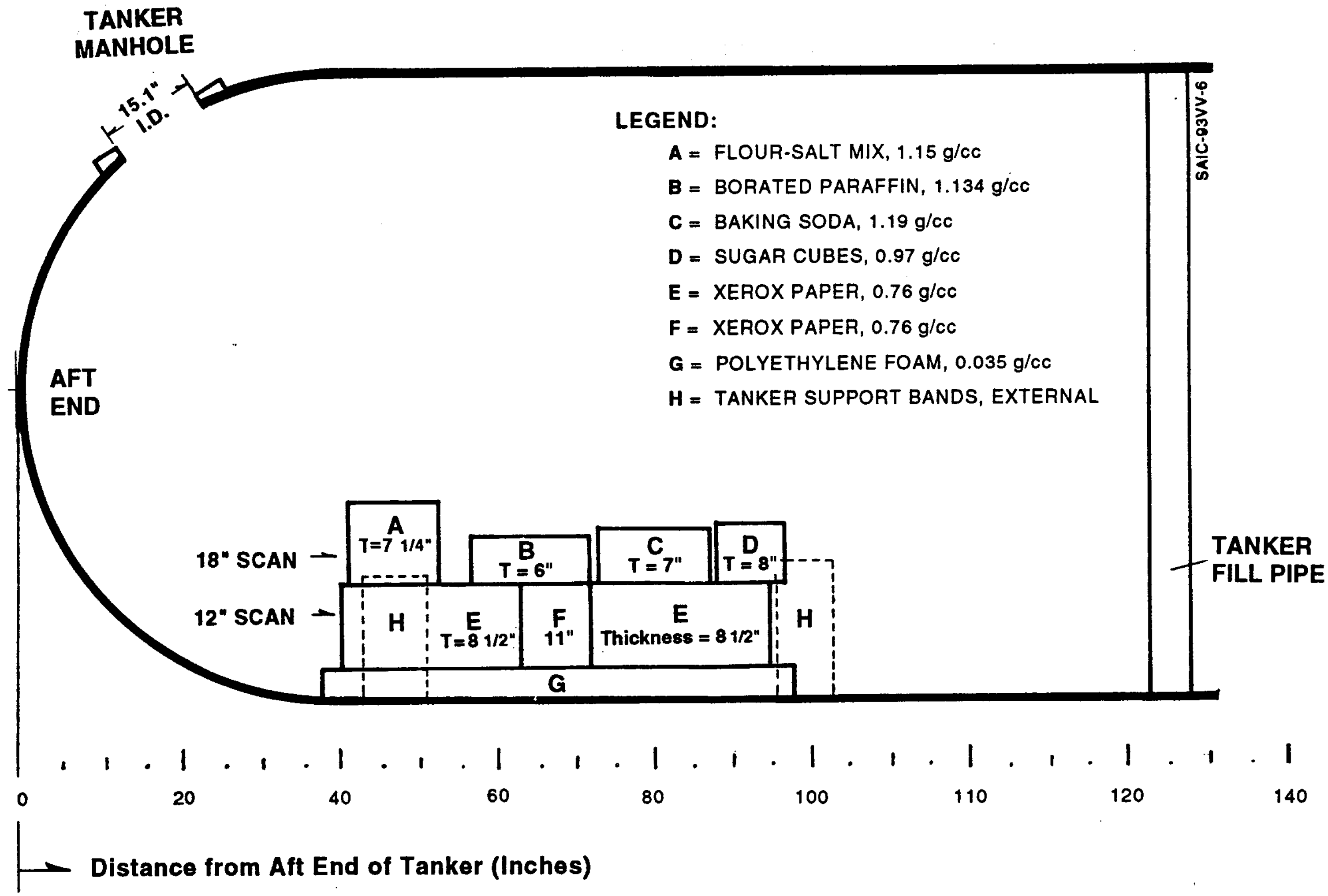

Figure 3. Scale Drawing of Simulated Contraband Loaded in Tanker.

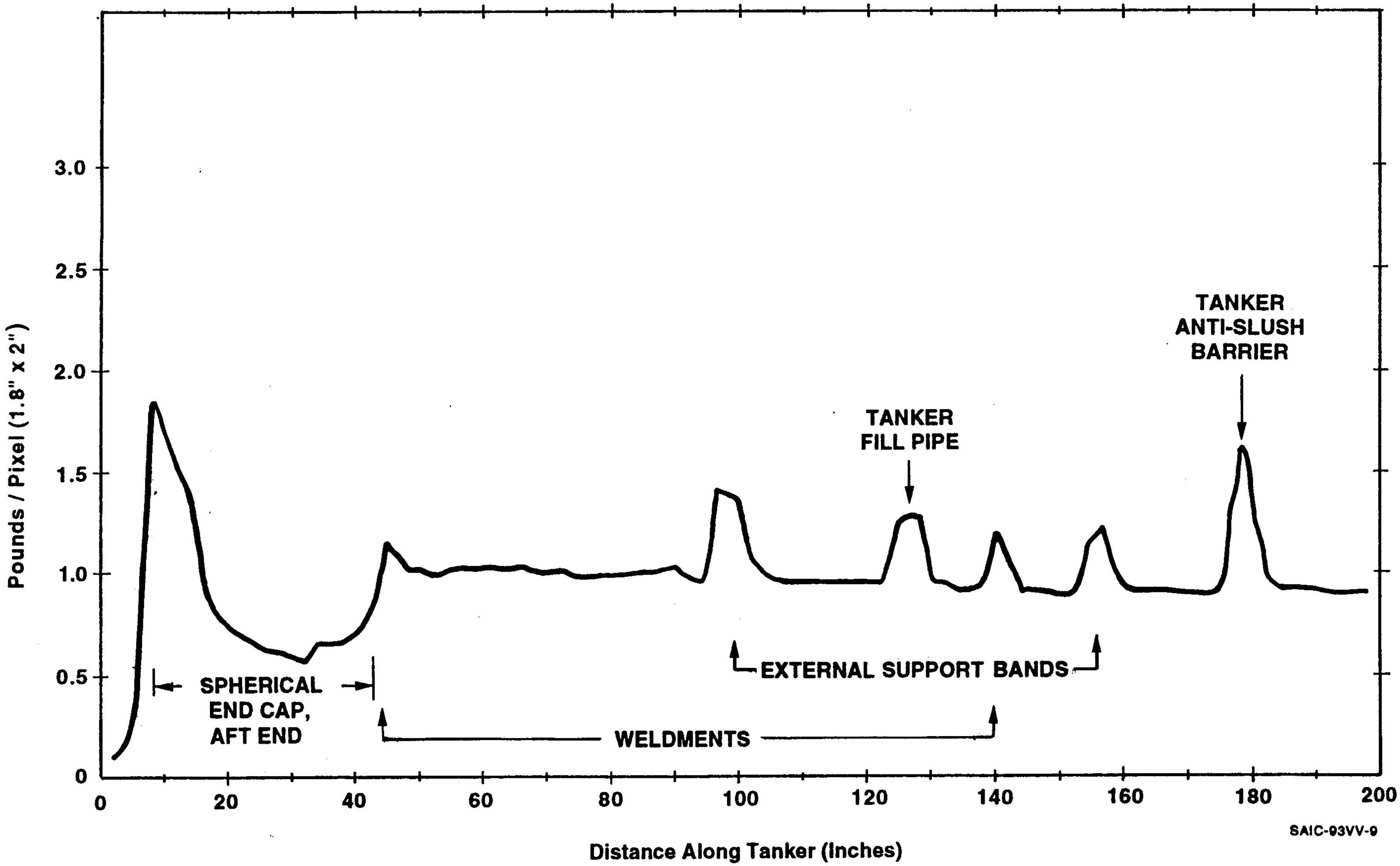

Figure 4. Tanker Truck Single-Detector Scan 18 inches above Bottom: No Simulant in Place.

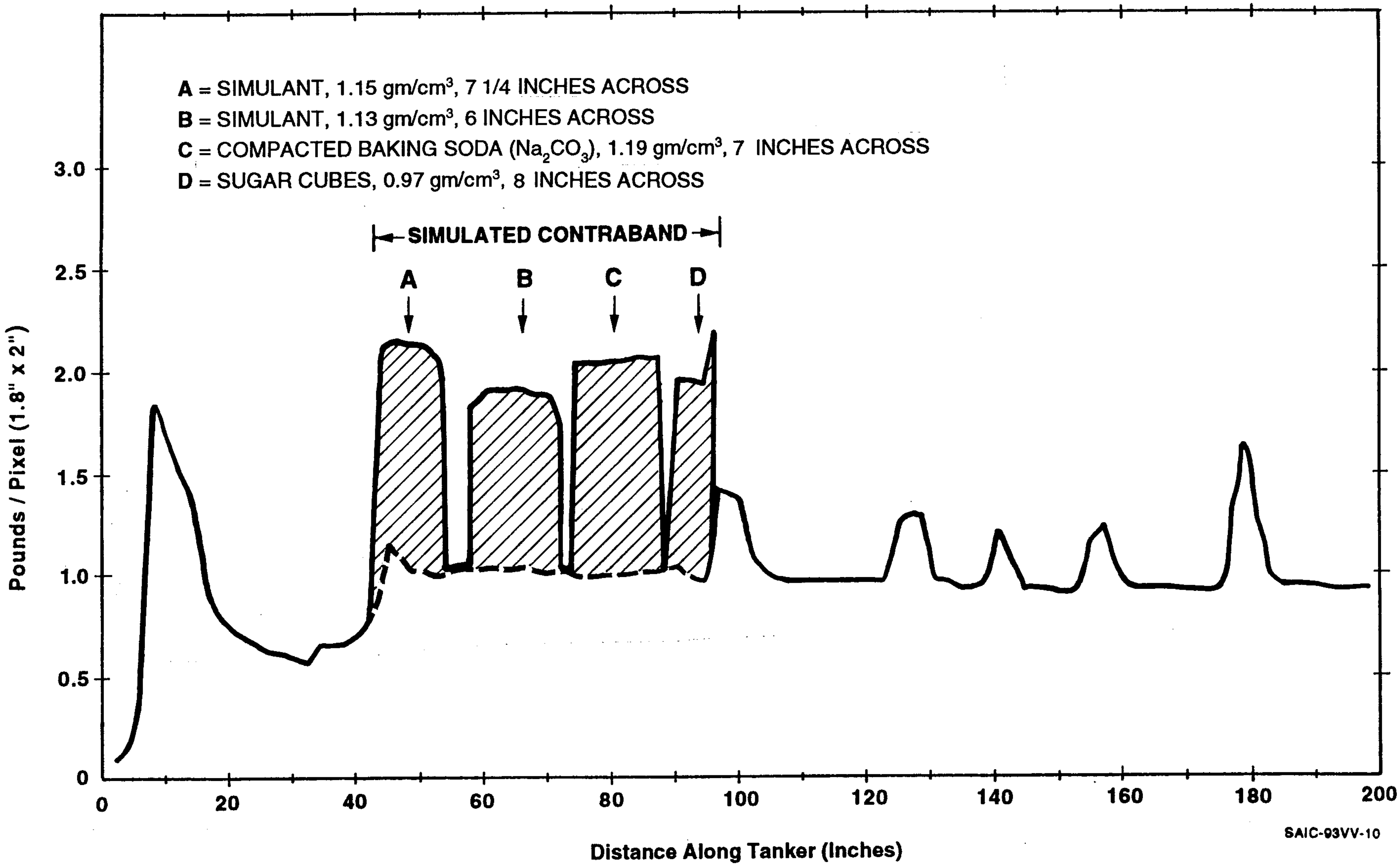

Figure 5. Tanker Truck Single-Detector Scan, 18 inches above Bottom, with Four Simulants in Place.

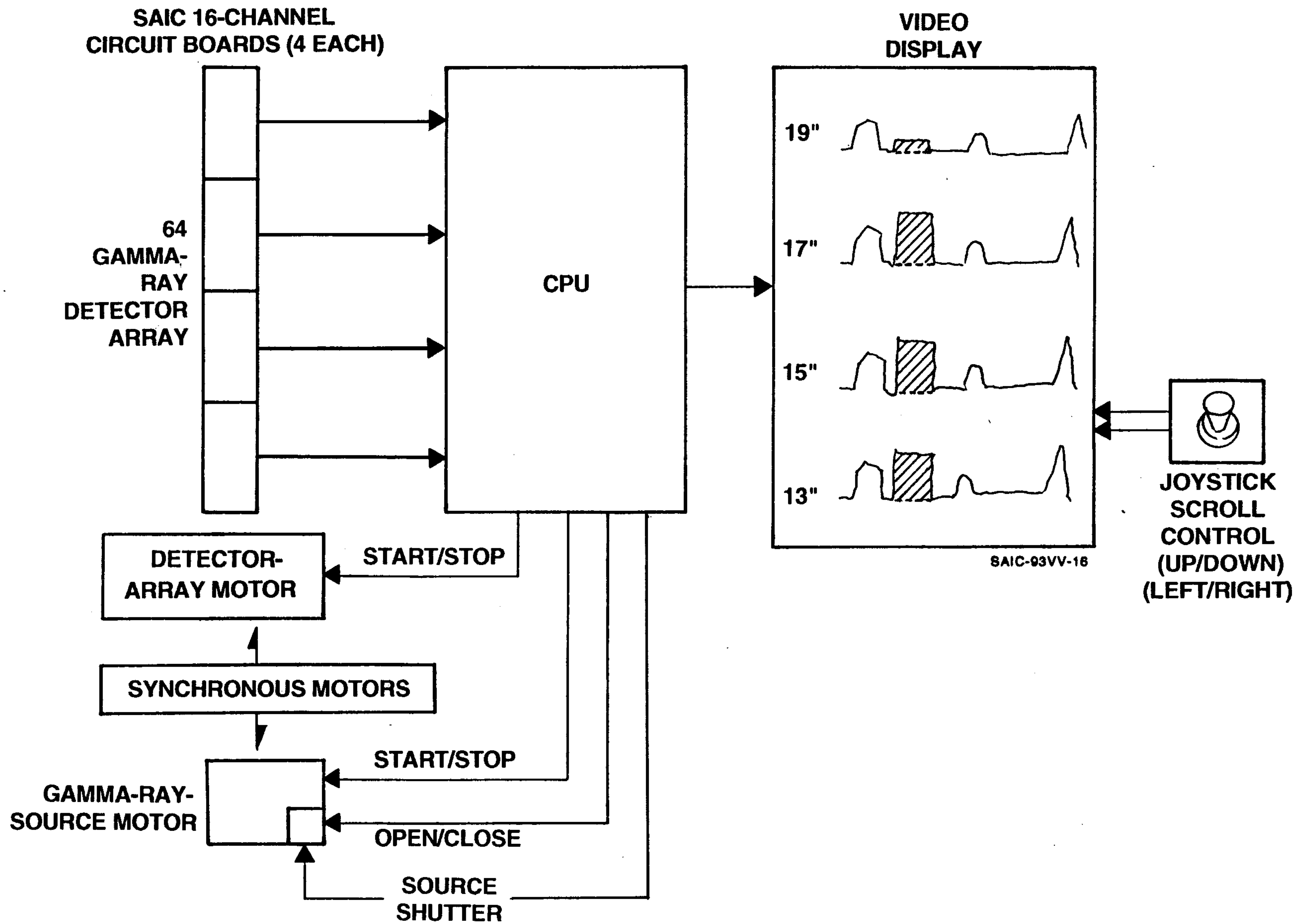

Figure 6. Block Diagram of Linear-Scanner, Contraband-Detector System.

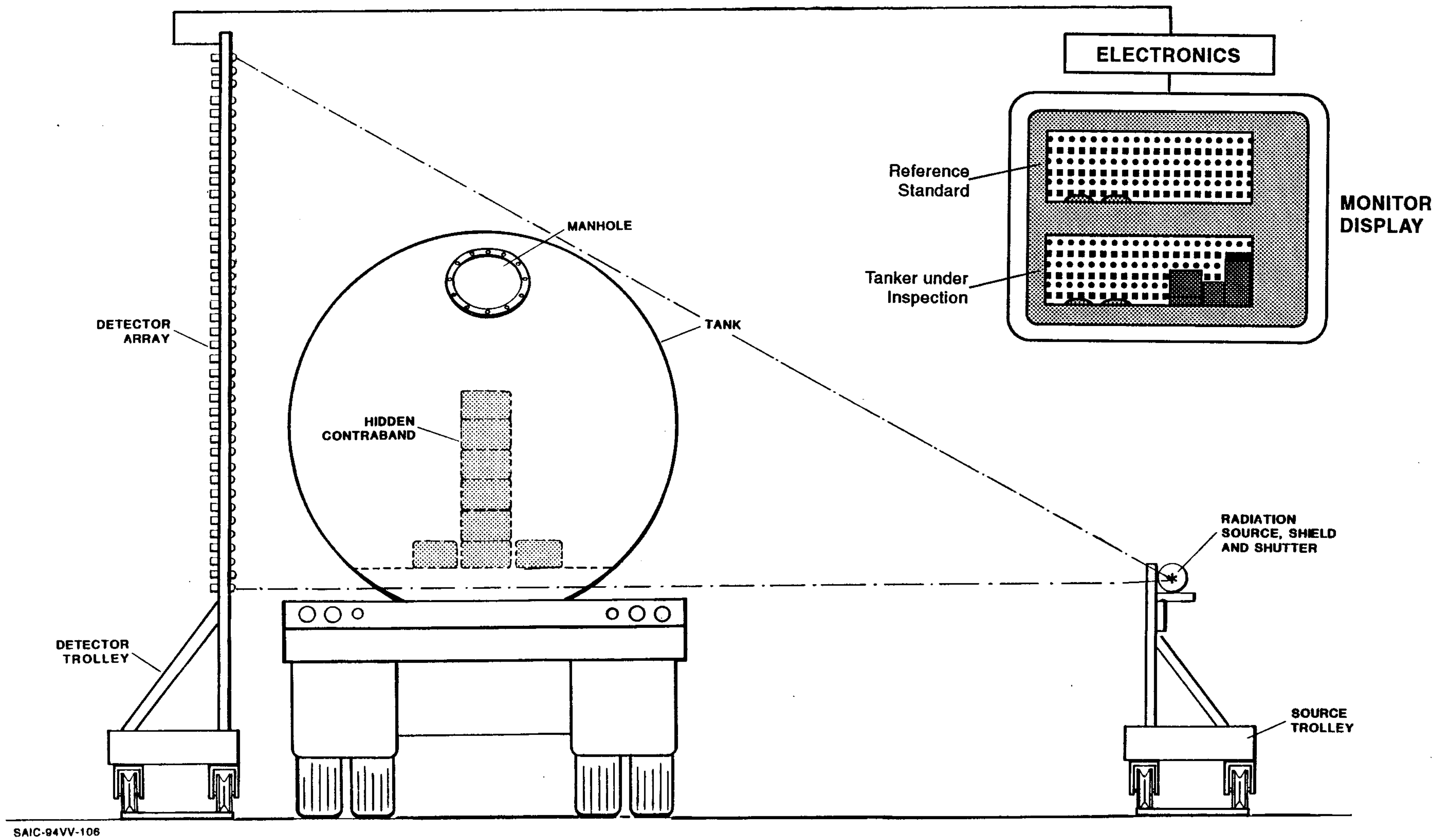

Figure 7. Schematic Diagram of Contraband Inspection System for Tanker Trucks.

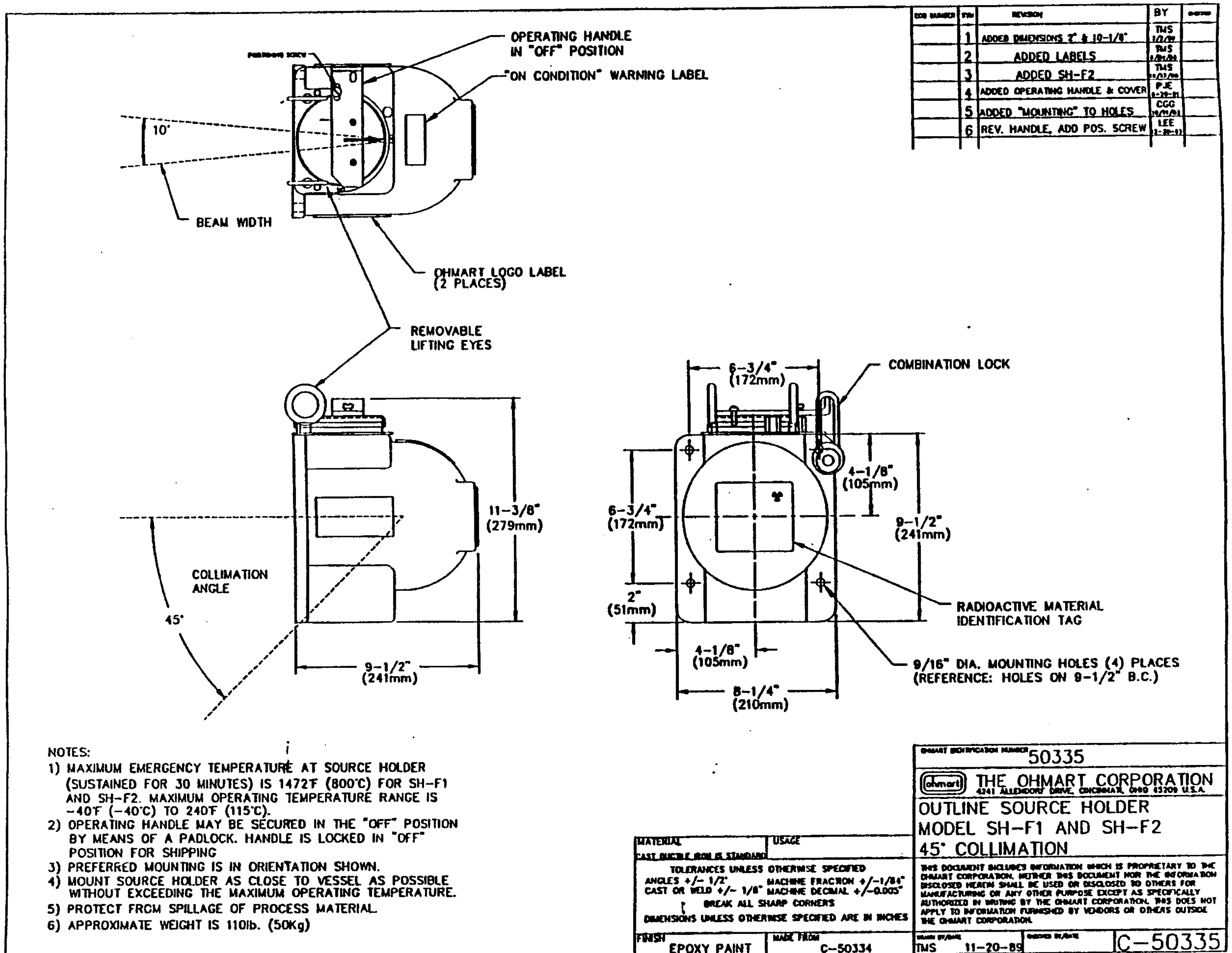

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Figure 8. Cs-137 Gamma-Ray Source/Shield/Collimator. Electric Shutter is not shown.

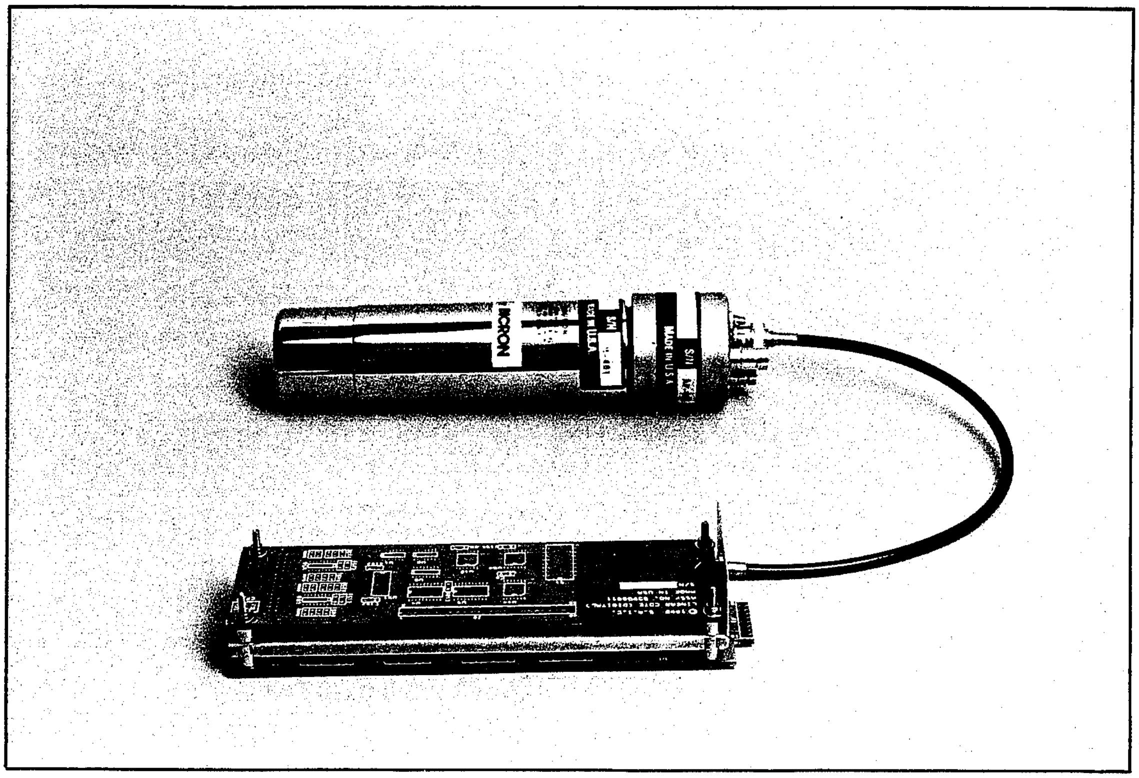

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Figure 9. Detector, Photomultiplier Tube and Tube Base (above); 16-Channel Analog Circuit Board and Digital Circuit Board (below).

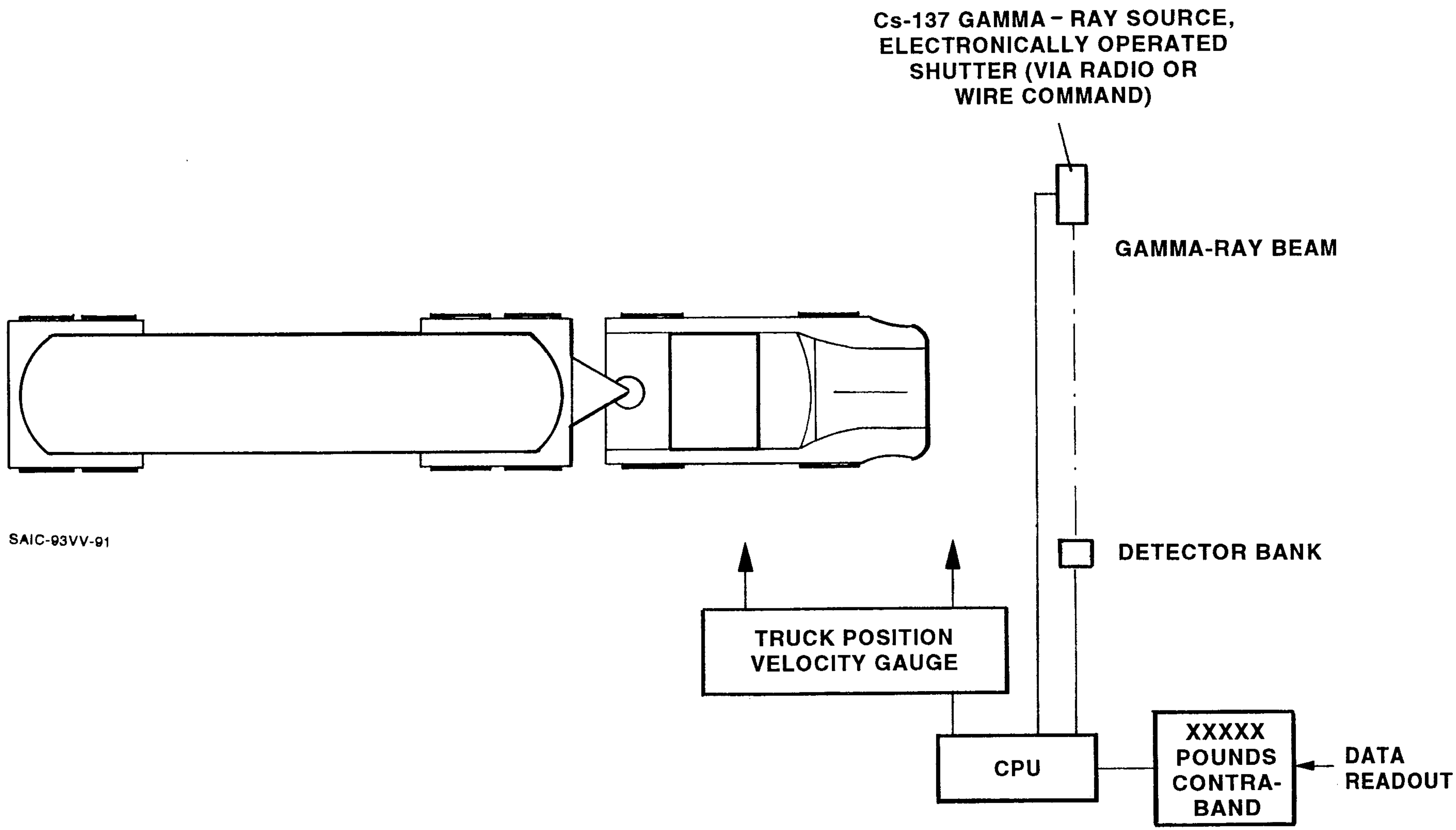

Figure 10. High-Speed, Tanker-Truck Contraband Detector.