Technology for En[illegible]y Corporation
10770 Dutchtown Road □ Knoxville, TN 37922 □ (615)966-5856

GENERAL DESCRIPTION

LOOSE PART MONITORING SYSTEM

TEC MODEL 1430

TEC

Customer Bulletin

Technology for Energy Corporation
10770 Dutchtown Road
Knoxville, Tennessee 37922
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MODEL 1430 LOOSE-PART MONITORING SYSTEM

POOR ORIGINAL

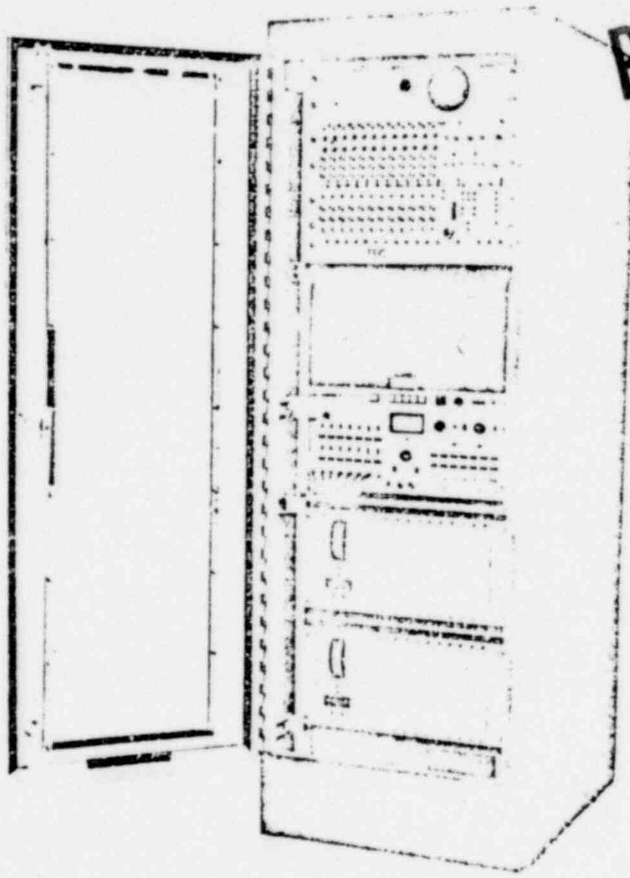
Basic Analog LPM

Meets NRC Requirements

Unique Impact Detectors

Special Alert Criterion

Deliberate Plant Maneuver Detector



Optional Digital-Controlled LPM

Microprocessor Controlled Trend Analysis

Special Diagnostics

Locator Software Available

Data Records on Floppy Disk

12-CHANNEL VERSION OF TEC MODEL 1430 LPM SYSTEM

This modular system contains complete signal conditioning and data processing instrumentation needed for a quality-assured Loose-Part Detection Program, in accordance with the requirements of U.S. Nuclear Regulatory Commission's Guide 1.133.

TEC has developed both analog-based and digital-controlled LPM systems. The TEC-1430 basic system is a prerequisite for assembly of the complete digital system.

In addition to supplying the hardware and software that comprises the 1430 system, TEC offers consulting and field measurement services to assist the customer in implementing the full Loose-Part Detection Program.

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FEATURES

System Sensitivity and Alert Level
The system sensitivity is commensurate with the goals established by the NRC Regulatory Guide 1.133. The Alert Level is optimized for each channel by analysis of the signal at all operating conditions. The system, therefore, remains operable during start-up periods when loose-part impacting is most likely to occur.

First Alert Display
Front-panel LED displays provide identification of the first alert channel. All other involved channels are also indicated.

Tape Recorder Control
The tape recorder can be controlled from the front panel or it can be placed in an auto-start mode.

Deliberate Plant Maneuver Detector
This module will inhibit the alarm whenever a defined plant maneuver occurs.

Audio Monitor
A switch-selectable audio monitor allows station personnel to listen to the output of any channel.

FEATURES OF DIGITAL CONTROLLED SYSTEM:

Microprocessor-Controlled Trend Analysis
The rms signal level for each channel is monitored, read into the microprocessor, statistically correlated, and stored on disk for subsequent trend analysis. This provides data that cannot be obtained with analog tape recording.

Sensor Channel Performance Checks
Microprocessor controlled signal trend analysis is used to test for and identify degraded channel performance. This approach greatly simplifies the "once every 24-hour" channel checks required by NRC Regulatory Guide 1.133.

Deliberate Plant Maneuver Monitor
Because the system remains active, detection of impacts resulting from these maneuvers serve as an automatic check of the system's operability, as well as characterizing the noises of normal plant maneuvers.

Records
All data records (time, event, peak amplitudes, rms levels, etc.) are stored on a floppy-disk that can be periodically removed, filed, and replaced with a new disk. By using this simple and inexpensive method, a permanent history of the plant's Loose-Part Detection Program is maintained in a compact form.

Options
a) Custom software for additional diagnostic capability.
b) Automatic impacting devices for option checkout and calibration.

FOR FURTHER INFORMATION, CONTACT:

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1. INTRODUCTION

In recent years, the use of electronic monitoring and surveillance has taken on new and expanded roles in the nuclear energy industry. In addition to vibration analysis of machinery, one area of surveillance presently receiving considerable attention by both industry and regulatory agencies is loose parts monitoring. Unfortunately, the consequences of implementing an inadequate LPM System on a NSSS can be worse than not having a system at all. If alarm warnings are given without enough information to evaluate the nature of the event, the result can be detrimental to plant availability, personnel exposure and safety.

A survey of the status of field operational loose parts monitoring systems revealed the need for decreased false alarms and improved characterization of impacting events (i.e., estimating their location, rate and energy) in addition to detection.[1] The U. S. Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.133, "Loose Part Detection Program for the Primary System of Light-Water-Cooled Reactors," emphasizes this need, stating that a well-developed system should enable discrimination of the signals induced by the impact of a loose part from those signals caused by normal plant manuevers, and that there should be diagnostic procedures to determine the significance of a loose part. The NRC Guide describes programmatic methods for detecting and evaluating a potentially safety-related loose part during "preoperational testing and the startup and power

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[1] R. C. Kryter, C. W. Ricker, and J. E. Jones, Loose Parts Monitoring: Present Status of the Technology, Its Implementation in U.S. Reactors, and Some Recommendations for Achieving Improved Performance, Progress in Nuclear Energy, Vol. 1, pp. 667-672, Pergamon Press, 1977.

operation modes." Besides recommended system characteristics, including sensor requirements, sensitivity and data acquisition modes, the guide discusses the formulation of a loose parts detection program for submittal to the Commission. Among other things, the program should contain a summary of the available diagnostic procedures, a description of a surveillance requirement ensuring channel operability, and guidelines for the report to be submitted to the NRC within two weeks of the initial notification of the presence of a loose part. Obviously, these requirements reflect the basic need to establish a loose parts monitoring (LPM) surveillance and diagnostics program built and supported with state-of-the-art technology.

TEC has developed both analog-based and digital-controlled LPM systems. The analog-based LPM system is referred to as the TEC-1430 Basic LPM system. The TEC Basic system is a prerequisite for assembly of the complete digital system, which provides unique diagnostic capabilities through the use of microprocessor-controlled trend analysis.

TEC's loose parts monitoring systems meet the requirements of NRC Regulatory Guide 1.133. TEC's modular systems contain complete signal conditioning and data processing instrumentation needed for a fully qualified loose part detection program.

2. TEC-1430 BASIC LPM SYSTEM

The TEC-1430 Basic Loose Parts Monitor (LPM) is a modularized acoustic detection, analog processing, and annunciation system providing real time detection and recording of impact noises in primary coolant systems of nuclear power reactors. Frequency range, signal to background ratios, and rate-of-occurrence of impact events are subjected to manually programmable conditioning for optimization of system sensitivity and ALARM thresholds. Under an ALARM condition, the system starts recording all individual channel outputs and identifies the First Alert channel providing instant diagnostic information to operating personnel. Primary interconnecting cables between in-and-out-of-containment system components are routed through the top of the enclosure to a distribution panel for quick and convenient access. Signal processing, recording, and annunciator equipment is mounted in a NEMA-12 enclosure having AC power connected to high quality isolation transformers. The system is seismically qualified as Class IE.

The standard configuration of the Basic 1430 system contains up to 16 channels of input signals. Because eight channels are usually sufficient for monitoring a LWR system, the 16-channel system can be used to simultaneously monitor both units of typical two-unit nuclear power plants.

The LPM sensors are radiation resistant, high-temperature, piezoelectric accelerometers which are mounted on studs and sealed to mounting blocks.

2.1 TEC 932 Amplifier

The TEC 932 differential amplifier provides calibrated gain steps to a total gain of 1,000 with a frequency response commensurate with the most commonly used impact detection range. Each amplifier provides a current regulated voltage for powering the remote charge converters. Output signals are taken directly through the back-plane connector to the impact detector module. A front-panel-mounted connector is provided for convenient access to the conditioned signal for viewing on oscilloscopes, spectrum analyzers, or, for external analog recording. The 932's low-pass filter aids in attenuating any spurious electrical spikes which contribute to false LPM alarms.

2.2 TEC-1432 Impact Detector

If changes in plant operating conditions cause the background noise to increase, then alert levels which are set on absolute values of signal measurement would be in jeopardy of causing false alarms. The alert level should be a function of the steady-state background noises associated with the operating condition. The proper functioning of the TEC LPM system during plant startup, when background conditions are varying, is achievable because of the capabilities of the 1432 Impact Detector Module. This module accepts analog signals from the TEC-932 amplifier module, measures and seperates the long and short term RMS fluctuations, and transmits results to a comparator circuit. Internal switch-selectable time constants are provided for optimizing impact thresholds relative to the long term background noise variations. A convenient single LED indicator light provides a constant display of channel status.

Two front-panel-mounted BNC's are provided for monitoring the TEC-1432 analog outputs:

a. BACKGROUND - This is the long-term-average rms over a time selected by the internal switches.

b. SIGNAL - This output signal is the short term rms value of the amplified signal minus the background.

The alert output of the 1432 module is a digital signal indicating an impact. This signal is derived by comparing the "W signal" output with the "background" output. To indicate an alert the "W signal" voltage must exceed the background voltage multiplied by a factor of "K". For steady non-fluctuating signals, the "W signal" output is at 0 volts and a sudden increase or burst of signals will cause the "W signal level" to go positive. The important parameter "K" is controlled by a potentiometer that is accessed by inserting a screw driver through the small hole in the 1432 front panel. This is to prevent it from being tampered with once a system is calibrated. For operator convenience, a momentary contact toggle switch is provided on the 1432 front panel. When this switch is depressed to the "BKGND" position, the background signal voltage (+ rms) is put onto a meter located on the audio/switch panel. Similarly, when this switch is depressed to the "THRESHOLD" position, a voltage (- rms) equal to the alert level is put onto the meter. This monitoring capability gives the operator an easy way to check the background level and the alert level without having to enter the circuitry with test equipment.

The status LED located on the 1432 front panel is another operator convenience. This LED glows "green" indicating normal operation, and glows "red" when the 1432 module indicates an "alert", a possible loose part. It will return to green after depressing the reset switch on the speaker-relay panel. If the background level is too low due to insufficient system gain or a defective sensor, the status LED will blink "red". Likewise, if the background level is abnormally high, the status LED will also blink "red". The blinking red condition overrides the alert indication and indicates a problem that needs attention. The 1432 Impact Detector module is a TEC standard "single width" module. All signals are connected through the P.C. board edge fingers to prevent the need for cabling to the front panel. The front panel has two BNC outputs: "Background" and "W signal" for monitoring or subsequent processing.

2.3 TEC Model 1433 Alarm Module

The TEC Model 1433 Alarm Logic Module provides a third method of reducing false loose parts alarms. The 1432 impact detector informs the 1433 module when the alert level has been exceeded. Then, the alert criterion register is notified and the first alert indicator begins flashing the appropriate channel number. If that channel and/or other channels repeatedly exceed the alert level, an alarm latch sets the local alarm and the remote annunciator and automatically starts the analog tape recorder. Otherwise the system simply resets itself and continues its sampling routine.

A ten-turn alert-level adjustment sets the magnitude of the peak signal-to-background ratio that must be exceeded before an event is stored in the alert criterion register. The magnitude of this ratio is calibrated from 0 to 10 and is read directly from the potentiometer dial.

For the case in which the First Alert criterion is not met, the display will be automatically reset at the end of the ten second period.

2.4 TEC Model 1438 Audio/Switch Panel

The audio/switch panel contains a system test circuit, an rms meter and an audio channel select switch (32 positions) with speaker, volume and tone controls.

The 1439B contains a switch for selecting its power from the Unit 1 or Unit 2 power supplies. The Audio Monitor Controls provide unit and channel selection, audio amplifier frequency bandpass and gain levels. There is a test switch which activates a test signal for verifying the operational integrity of the audio amplifier system. Simulator Controls provide for the insertion of accelerometer simulation signals into the 932 amplifiers for testing the system. Annunciator Controls provide alarm annunciator control, namely; inhibition of alarm, testing of alarm without interfering with the normal operation of the system, and resetting the alarm annunciators.

A meter, reading in volts rms, is located on the panel. Switching the background signal on the alert level for any channel into the meter is achieved by depressing a toggle switch on the 1432 panel of that channel.

2.5 TEC 1439A Remote Alarm Driver

The alarm driver consists of a power oscillator for a Sonalert SN P428 audible alarm and a relay driver transistor for activating a remote annunciator relay. A high level signal from the TEC-1439 module activates the alarm driver. A low level deactivates the driver. This circuit is located on a small printed circuit board mounted on the speaker panel at the top of the 1430 rack assembly.

2.6 TEC-1436 Recorder Control

The TEC-1436 provides three methods for remotely controlling the operation of the TEC/PR-280 tape recorder: 1) Manually from the 1436 front panel, 2) auto-start from the 1430 system, or 3) fully under CPU control from a host computer.

2.7 TEC-1434 Deliberate Plant Manuever Detector

The LPM system is designed to minimize false alert signals. The Deliberate Plant Manuever Detector (DPMD) enables loose part impact signals to distinguish from those signals induced by normal hydraulic, mechanical and electrical plant transients. The DPMD will inhibit the alarm whenever there occurs a defined plant manuever which has associated with it a logic level signal that is input to the DPMD.

3. LPM DIGITAL-CONTROLLED CAPABILITY

The TEC LPM system described in Section 2 contains the interface points for upgrading the Basic LPM to a fully computer-controlled LPM.

3.1 Microprocessor, Floppy Disk and CRT Display

Many desirable features of a Loose Parts Monitoring System are optimized by using digital data acquisition, processing, analysis and storage. These features include: first events capture, direct measurement of event characteristics, large dynamic range, capability of real-time trend analysis, instant access to selected data, and simplicity of data storage. TEC's LPM System reads the outputs of the impact detectors into a microprocessor, stores recent information in circular memory, and subsequently enters it onto a floppy diskette.

All data records (time, number of events, peak amplitudes, rms levels, etc.) are stored on a floppy diskette that can be periodically removed, filed and replaced with a new diskette. This procedure takes about one minute. Under normal conditions (no loose parts), the diskette would require replacement about every three months. By using this simple and inexpensive method, a permanent history of the plant's LPM program is maintained in a compact form. A visual display of the recorded data for each channel is obtained by entering the channel number and activity number of interest on the keyboard. The information is automatically displayed on the CRT.

3.2 Deliberate Plant Manuever Monitor (TEC Model 1434)

The Deliberate Plant Manuever Monitor (DPMM) is an advanced version of the DPMD described in Section 2.7. Whereas the DPMD only detects that some manuever has occured, the DPMM provides for individual recognition of 16 deliberate plant manuevers (DPM). If a larger number of DPMs is to be considered, any number of single DPM signals can be ganged into one channel of the DPMM. It is important to realized that all system measurement capabilities can be active during a DPM, but the alarm is disabled. This means that the acoustic signal associated with these normal menuevers can be measured and their main characteristics can be ganged into one channel of the DPMM. For certain selected logged on disk. Everytime a DPM occurs, the microprocessor routes the following data set to temporary memory and to disk:

1. the date and time of the DPM
2. the type of DPM (1 thru 16)
3. the channel(s) affected,
4. the short-term rms peak for the channel(s),
5. the most recent value of the long-term rms for the channel(s).

Since the most acoustic characterization of many routine manuevers becomes permanently stored on disk, this data can be used to check that certain manuevers are occurring without abnormal behavior. (This becomes very helpful when, in fact, the presence of a loose part is confirmed.)

Certain DPMs can be used for "channel checks" (NRC Reg. Guide 1.133: "... the qualitative assessment of channel behavior during operation, including, where possible, comparison of the channel indication or status with other indications or status derived from

independent instrument channels measuring the same parameter). An example of a channel check is: During stepping of control rods (DPM type), check that the number of events for each of certain channels is greater than some predetermined value. It is possible for some DPMs to be used for "channel functional tests" (NCR: "... the injection of a simulated signal into the channel as close to the primary sensor as practicable to verify operability including alarm functions"). Any DPM causing a disturbance which satisfies the alarm criteria (as defined below) can be routinely and automatically used as a channel(s) functional test(s).

The DPM is addressable from the keyboard. Any number of the 16 alarm inhibit commands can be activated or disabled manually in a few seconds. This is convenient for adjusting the system's behavior during early use (learning mode with respect to DPM-induiced signals).

3.3 Software

The software which will be provided with the digital LPM system controls the data acquisition, recognizes the alarm criteria and assists in the diagnostics. Here, we give some examples of the available data displays.

3.3.1 Automatic Regular Scan. The system samples the long-term rms values for all channels. For each channel, the hourly average is computed and stored in memory. (Whenever a coded DPM occurs, values at that time are not entered into the computation of the average of the long-term rms). For each channel, the microprocessor's circular memory holds, for display upon request, the last 168 hours of record (one week) as well as the last 60 minutes of record (one hour).

3.3.2 Alert - Triggered Scan. Whenever the short-term rms value of any channel exceeds the detect level, the following information is stored in temporary memory and on disk:

1. the date and time of the alert
2. the channel of the alert
3. the short-term rms peak for that channel
4. the most recent value of the long-term rms for that channel.

The last ten Alert Scan data sets are instantly available upon keyboard address. All data sets are available from disk.

3.4 Impact Calibrators

TEC recommends the use of TEC's optional software-controlled impact calibrators. These high-temperature solenoid-activated devices will automatically perform channel checks every 24 hours, in accordance with Regulatory Guide 1.133.

3.5 Special Diagnostics

TEC's special diagnostic features include a LP locator. All of the basic measurements that are required for using the TEC LPM locator software are already performed by TEC's digital LPM system.

Computation of the probable location of an impact is based on both the arrival sequence at the affected sensors and relative amplitude analysis. It is important to strategically place the sensors azimuthally on the structure. TEC recommends the locations of the sensors. The TEC Locator Software will compute the location of each impact relative to the first sensor activated. It uses the data from the activity scans to compute the impact site. If only two sensors are activated, an approximate location is assigned along the line (on

the vessel's surface) connecting the two sensors' locations. However, not all impacts can be located, even approximately, because of the complex acoustic paths along the reactor internals. TEC's software can recognize when the data is ambiguous.

For each impact, which is assigned a location, an estimated impact energy can be obtained. This is possible because once the impact site relative to the first-hit sensor is known, the sensor's corresponding Umax value is related to the impact energy. When the locations and corresponding estimates of impact energies for many impacts have been obtained, averaging the impact energy values, for impacts in certain regions of known flow velocities, permits estimates of the size of the loose part. Note: It is very important to understand that without the capability of loose parts location, estimates of size or mass cannot be properly made. Furthermore, without data from multiple impacts of clearly the same loose part, statistical averaging techniques cannot be used, and any size estimates would be unreliable. It is for this reason that the assessment of safety implications for a loose part which impacts many times is often easier than for the case of a loose part which impacts a few times and is never heard from again!

3.6 Identification of a Loose Part

The procedure of identifying or characterizing a loose part depends on the features of the system. First, in order to confirm that the detected impact noises were caused by a "loose part" (detached and drifting) it is best to be able to observe that the impacts are not all occurring at the same place. Sometimes, one can infer this from the

audio output. However, if a loose part locator is being used, it first serves the fundamental need of being able to recognize that the impacts are produced by a "loose-part."

Second, ability to estimate where the part began its journey often helps in reducing the number of possible identities. In the general system, the "first-hit indication" helps in estimating where the part comes from.

3.6.1 Assessment of Severity. Once the presence of a loose part has been confirmed, there are two sources of data for use in the process of assessing the severity of impacting, with respect to safety implications. One source is the LPM system records and diagnostics, the other is supplemental plant data, including closer scrutiny of certain process or control signals. Here, we address only the former source of data. The procedures for the latter source are as varied as the possible types of loose parts. The Regulatory Guide, 1.133, points out some of the potential degradations of reactor safety associated or caused by loose part(s). If any of these are highly suspected because of interpretation of the loose part data, then specific scrutiny of plant data can be performed, until the suspicions are affirmed or abandoned. (One motivation for having comprehensive LPM data is to be able to methodically and quickly proceed with preparation of the follow-up report which the NRC requires within two weeks of the initial notification of a loose part.)

Types of Safety-Related Loose Parts: (paraphrasing NRC)

1. "A loose part can be indicative of failure or weakening of a safety-related component"

Relevant Questions by TEC: Is the part truly loose and drifting? Where did it come from? Is it big or small?

2. "A loose part can contribute to component damages and material wear by frequent impacting"

   Relevant Questions by TEC: How often does it impact? Where does it impact? What are its impact energies at the various points of impact?

3. "A loose part can cause partial flow blockage"

   Relevant Questions by TEC: Has the part become lodged? Where was it last detected? (The answers to these questions are useless unless they are obtained very quickly.)

4. "A loose part increase the potential for control-rod jamming and for generation of increased levels of radioactive crud"

   Relevant Questions by TEC: Where is it impacting? How often? What is its probable size?

The TEC digital LPM system provides quick answers to all of the above questions. In fact, we posed these "relevant questions" and designed the TEC system to give the answers. Furthermore, TEC's system is designed to require only very simple and standardized operator interaction to acquire and utilize the LPM data.

VIBRATION AND LOOSE PARTS MONITORING SENSOR LOCATION (UNIT 1, TYPICAL FOR UNIT 2)

LPM Channel	Channel Status	Sensor Location
1	Active	RPV Head Lug, 240°
2	Active	Bottom of RPV, Thimble Tube, #34
3	Active	Steam Generator 1 Inlet side, Elev. 669
4	Active	Steam Generator 2
5	Active	Steam Generator 3
6	Active	Steam Generator 4
1	Alternate	Steam Generator 1
2	Alternate	Steam Generator 2
3	Alternate	Steam Generator 3
4	Alternate	Steam Generator 4
5	Alternate	RPV Head Lug, 0°
6	Alternate	Bottom of RPV, Thimble Tube, #24

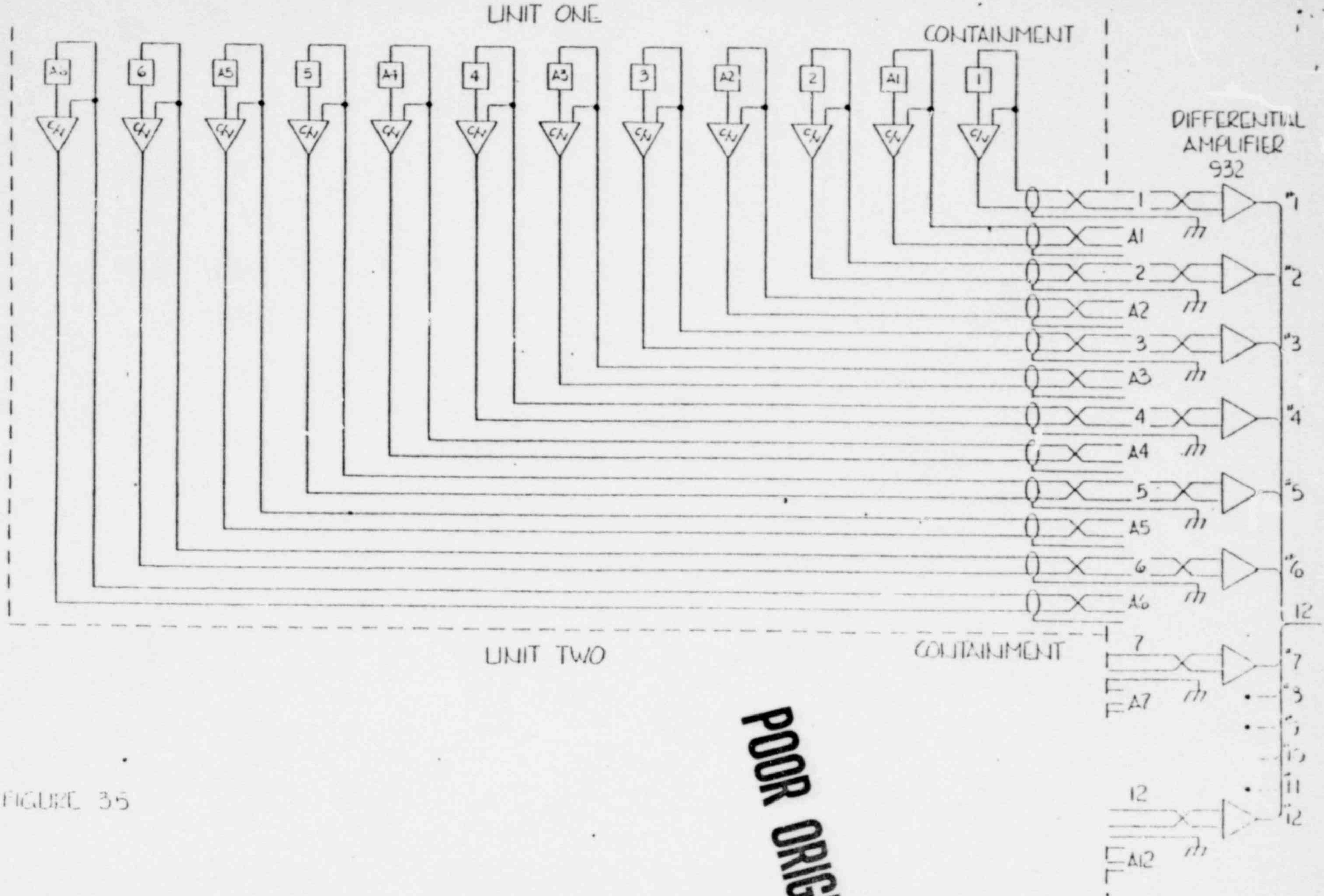
UNIT ONE
CONTAINMENT
UNIT TWO
CONTAINMENT
DIFFERENTIAL AMPLIFIER 932
1
A1
2
A2
3
A3
4
A4
5
A5
6
A6
7
A7
12
A12

FIGURE 35

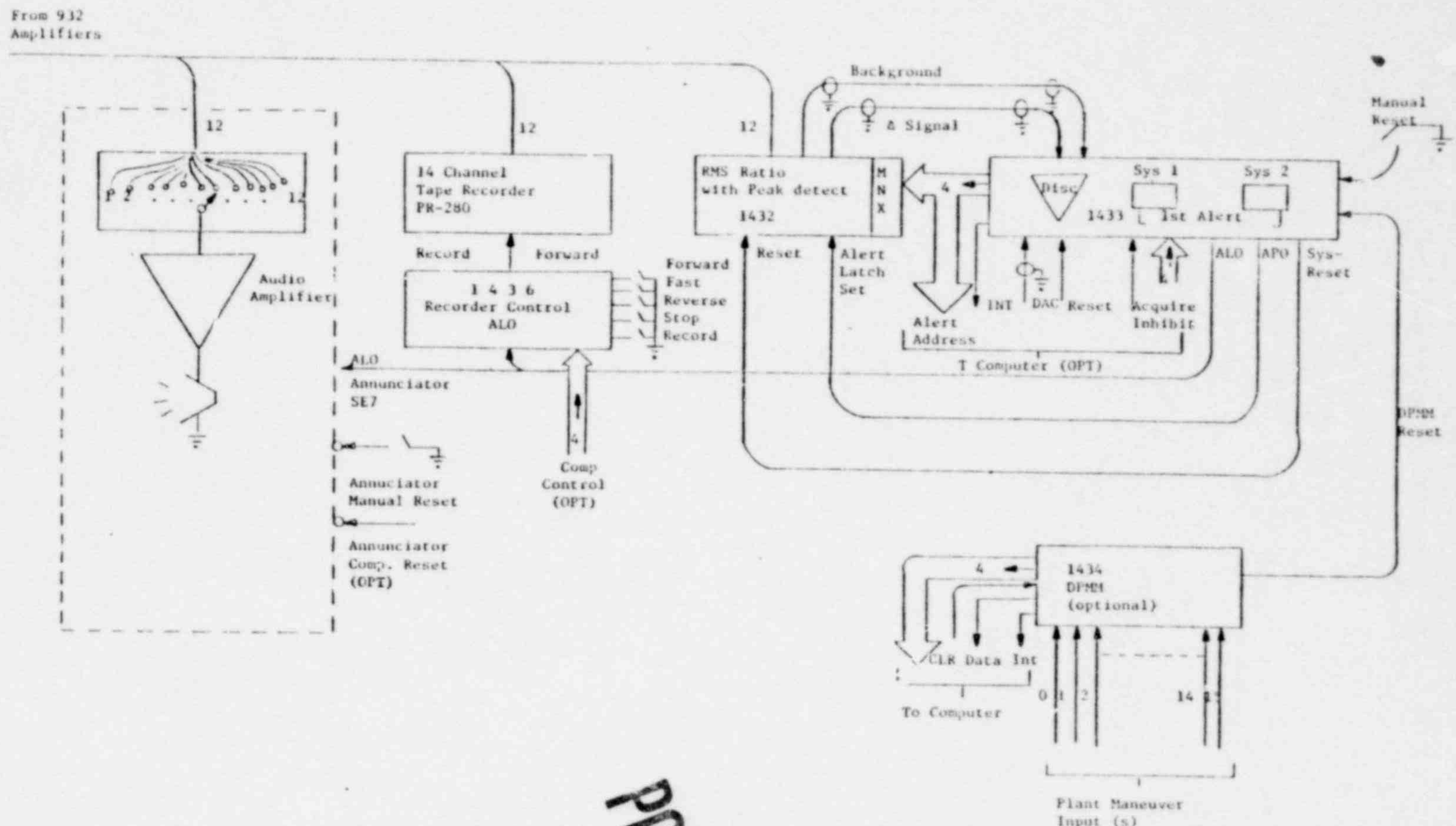

Figure 2.6
TEC - 1430
LPM
Block Diagram
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POOR ORIGINAL

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