The general trend in acoustic emission (AE) monitoring systems has been one of increasing complexity. This is particularly true in systems for continuous monitoring which are usually multichannel (perhaps 20 to 40) and incorporate a dedicated minicomputer. A unique concept which reverses this trend for selected applications has been developed at Battelle-Northwest, Richland, WA. This concept uses nonvolatile, postage stamp sized solid state digital memories to store acquired data in a permanent form which is easily retrieved. After data has been extracted the memories can be erased and reused. It also uses a fundamental method to accept AE data only from a selected area. The digital memory system which can be battery operated is designed for short term or long term (months) continuous, unattended monitoring. It has been successfully applied in laboratory testing such as fatigue crack growth studies, as well as field monitoring on bridges and piping to detect crack growth. The features of simplicity, compactness, versatility, and low cost contribute to expanded practical application of acoustic emission technology.

ABSTRACT

The basic theory of acoustic emission monitoring is established and the technology is being applied in a wide range of material experiments and structural analysis programs. In the course of this work, the general trend in acoustic emission (AE) monitoring systems has been one of increasing complexity. This is particularly true of systems designed for continuous monitoring of a structure. These systems are usually multichannel (in the vicinity of 20 to 40 or more channels) and require a dedicated computer for data processing and storage. Such systems may cost from $100,000 to $500,000. Some applications require this degree of sophistication. An example is simultaneous monitoring of a large material volume such as a nuclear reactor pressure vessel during hydrostatic testing to detect and locate defects.

There are many structural monitoring applications of AE, however, where the system complexity just described is not needed. In a structure such as a pressure vessel or a bridge, once initial inspection has been accomplished, a large portion of the material volume is of no real concern to continued structural integrity. There remain selected areas of concern such as known high design stresses (e.g., nozzle penetrations of a pressure vessel) or portions of a structure which are especially critical to the integrity of the total structure (e.g., certain suspension members in a bridge). To apply a complex AE system continuously monitor such selected areas over a long period of time would not only be very expensive but also may be impractical because an operator with the required skill may not be routinely available.

A unique concept for continuous AE monitoring in selected applications such as those described above has been developed at Battelle-Northwest. It reverses the trend to increasing complexity while retaining such important requirements as reliability, permanent data record, and easy retrieval of data for analysis. The original concept grew out of a special need in a program being performed for the U.S. Federal Highway Administration to apply AE to bridge monitoring.

INTRODUCTION

BNW Digital AE Monitor (DAEM) System(s) are designed for long term monitoring of identified areas of concern in a structure. Their concept is centered around a solid state programmable read-only digital memory (EPROM) which is used to record acoustic emission information. Electronic time gated logic circuitry restricts the acceptance zone for acoustic signals thus providing a monitor which can selectively accept information only from a pre-determined material volume in a complex structure. The digital memory provides the basis for reducing system complexity and system cost without sacrifice of sensitivity or versatility. These memories are intended for use as a pre-programmed instructional device for use in computer systems. Through the use of specially designed programming circuitry, they were adapted to use as a dynamic recording device for BNW's DAEM system. One very important feature of the PROM's compared to other types of solid state digital memories is the fact that they are nonvolatile, i.e., recorded information is retained indefinitely without continued power supply. The memories can be erased by exposure to ultraviolet light and reused after the stored data is recovered.

The PROM's currently being used are 16K memories. This capability is utilized to provide 1024 address locations with a capacity of 65,535 counts in each address. The programming is controlled on a time basis normally. When the preset accumulation period is complete, the data is stored and a new counting period is started immediately. This process continues in sequential manner until the monitoring is completed or all the memory addresses are used. When a memory is full or at the end of a test, the used memory is removed and replaced with a fresh one. The used memory is then read out to a digital printer to provide a hard numerical copy. The memory is then erased and reused.
TYPICAL DIGITAL MEMORY APPLICATION

DIGITAL MEMORY FEATURES

- NONVOLATILE
- PERMANENT STORAGE >6 YEARS
- HIGH STORAGE CAPACITY >66 MILLION COUNTS
- COMPACT
- EASE OF USE
- LOW COST
- LOWER POWER DRAIN
### AE Parameters Stored in Digital Memory

- Event or Ringdown Count
- Energy
- Peak Time
- Pulse Height
- Location
- Polarity

### Mechanical Parameters Stored in Digital Memory

- Load Cycle Number
- AE Position on Load Cycle
- Ramp Load Level
- Crack Opening Detector Level

### Data Listing from Digital Memories

**Battelle Northwest AE Test Profile**

AE TEST: I-2A~6B  
DATE: 5-8-78  
INSTR. GEOM. GEOM. NRC MTS  
LOAD: 7.0/70.0 KIP  
LOAD RATE: 2 Hz  
TOT CYCLES: 70,000  
DELTA CYCLES: 10,000  
EPROM: 2716  
PARAMETERS: ZONE AE 2.  
UPDATE: 100 CYCS  
ADDRESS: 106  
PT-PH CORRELATION: a1-a/b a/b =2-a/b b/c  

**EPROM Listing**

<table>
<thead>
<tr>
<th>H</th>
<th>F</th>
<th>6</th>
<th>D</th>
<th>J</th>
<th>6</th>
<th>8</th>
<th>0</th>
<th>10</th>
<th>V</th>
<th>3</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Valid PT-PH LD-VC Energy PT:**

- Load Cycle: 70,000
- Delta Cycles: 10,000
- EPROM: 2716
- Parameters: Zone AE 2
- Update: 100 CYCS
- Address: 106
- PT-PH Correlation: a1-a/b a/b =2-a/b b/c

**Block 001 (0000-0024)**

<table>
<thead>
<tr>
<th>Block</th>
<th>Total Valid PT-PH LD-VC Energy PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>00043</td>
<td>00011 00053 00004 00271 00011 00000 00000 00003 00002 00000 00004</td>
</tr>
<tr>
<td>00024</td>
<td>00004 00001 00002 00174 00003 00000 00000 00001 00000 00000 00003</td>
</tr>
<tr>
<td>00025</td>
<td>00000 00006 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00107</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00109</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00009</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00074</td>
<td>00001 00000 00001 00067 00001 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00101</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00011</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00009</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00003</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00004</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
<tr>
<td>00005</td>
<td>00000 00000 00000 00000 00000 00000 00000 00000 00000 00000 00000</td>
</tr>
</tbody>
</table>

**Other Parameters:**

- Parameters: ZONE AE 2
- Update: 100 CYCS
- Address: 106
- PT-PH Correlation: a1-a/b a/b =2-a/b b/c

**Data Listing:**

- Parameters stored in digital memory include:
  - Event or Ringdown Count
  - Energy
  - Peak Time
  - Pulse Height
  - Location
  - Polarity
  - Load Cycle Number
  - AE Position on Load Cycle
  - Ramp Load Level
  - Crack Opening Detector Level

- The data listing from digital memories includes a detailed table of values for various parameters, including load cycles, delta cycles, and energy levels.

- The data is organized in a block format, with each block containing information about the test parameters and their values.

- The EPROM listing provides a detailed view of the stored data, including the addresses of the data blocks and their respective values.

- The data is presented in a structured format, making it easy to analyze and interpret the test results.
Cumulative AE count for last 500 hours of test after specimen inspection. Total test time: 1447 hours.

Note: All bending, unload-reload counts, and known noise counts from installing metal cover and adjusting wave guide have been excluded from this data.

Start test 6/27/75 10:06 after shutdown for UT inspection of specimen.

Digital memory AE graph.

Single channel two parameter AE monitor.
Digital Memories

Multiparameter Digital Memory AE System

Stress Corrosion Cracking Digital Memory AE Monitor

Aircraft Digital Memory AE Monitor

Battery Operated Digital Memory AE Monitor for Highway Bridges