1. INTRODUCTION

Acoustic Systems Incorporated (ASI), a Houston, Texas based company, is an established leader in leak detection, with over twenty years experience in the development of quality hardware and software products. ASI specializes in on-line real-time pipeline monitoring using acoustic techniques which provide unique advantages for pipeline leak detection, including:

- Minimal time to detect and locate leaks, typically within one minute of leak occurrence
- Very accurate leak location calculation, typically to within +/- 30 meters or +/- 0.1% of monitor span
- Extremely low false alarm rate (typically less than one per year)
- Used for most of pressurized pipelines, including single phase liquid, single phase gas and multi-phase flow pipelines
- Very sensitive, detect and locate very small leaks
- Detect leaks with or without (shut-in) flow, steady state as well as various transient operations (valve open/close, pump shut down/startup, flow increase/decrease, etc.)
- Very easy to install and operate
- Continuous leak detection with loss of communications
- Minimum maintenance, no calibration required
- Used for automatic valve shut off upon detection of leak
- Decreased risk to people and environment
- Reduced financial loss for product and for clean-up in case of accidents

ASI’s Acoustic Leak Detection Systems (ALDS) employs proprietary hardware for on-line real-time leak detection and associated hardware and software for supervising communications, structuring databases, data analysis, decision-making, report and display generation and issuing alarms. Systems employ combinations of radio, fiber optic and hardwire communications with either personal or mainframe computers for operator interface. Applications include liquid, gas and multi-phase flow pipelines, and consist of single transmission lines, networks, gathering lines, subsea lines, single and multiple product transfer lines.

The WaveAlert® system is the only leak detection system with an establish record of not only detecting leaks but automatically shutting in pipeline valves to limit environmental damage and possible casualties. This can only be accomplished with a minimum number of false alarms. (See section 6.1 for a detailed example).

1.1. Acoustic Systems Incorporated
Taft Communications Systems Incorporated, pioneered acoustic leak detection monitor technology for pipeline applications; the direct forerunner of the ASI ALDS system. The first client was Tennessee Gas Pipeline Company.

Taft Communications was renamed Bethany International in 1973. In September, 1978, Crutcher Resources Corporation purchased Bethany under a pooling of interests and Bethany became CRC Bethany International, Inc. Scientific Software Intercomp, a software company, purchased CRC Bethany in 1983. ASI was incorporated in the State of Texas in December 1983 and purchased the CRC Bethany Hardware Division (including patents, license agreements and inventory) on February 1, 1984.

Since 1984, ASI has worked continuously to keep hardware based monitoring techniques at the forefront of leak detection technology. ASI’s ALDS has been installed worldwide (Figure 1-1) on pipelines including gas, liquid and multi-phase flow.

![Installations Around the World with Various Pipelines](figure1-1.png)

**Figure 1-1: Installations Around the World with Various Pipelines**

### 1.2. Facilities

ASI headquarters are located in Houston, Texas, USA, with a branch office in New Jersey and a network of marketing representatives covering the globe.

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9803 Whithorn Drive  
Houston, Texas 77095-5026, USA

*Telephone:* (281) 345-9995  
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Website: www.wavealert.com
2. REAL TIME LEAK DETECTION

2.1. Pipeline Monitoring

Moving fluids by pipeline is an energy-efficient means of transportation, proven safe and effective over years of industry experience. In recent years, total mileage of installed pipelines has increased dramatically. This trend is expected to continue. A wide variety of fluids are transported by pipeline, including crude oil, natural gas, water and refined petroleum products. Many other liquid and gaseous industrial products, such as carbon monoxide, ammonia, phenol, cumene, acetone and copper slurry, are moved by pipeline.

Responsibility for a pipeline and its operations lies with the operator. Pipeline leaks are rare, but present serious problems when they occur. The most serious problem is the release of hazardous substance. Even if the release is not life threatening, there is concern over the effect of emissions on the environment and upon public image.

An unchecked leak represents loss of valuable product; clean up costs; increased hazard to life and environment; and cost to public image. The amount of product loss in a monitored pipeline depends upon:

- Minimum detectable hole size
- Elapsed time from leak to action

Additional costs include loss of service and repair expenses. The time required, to return a pipeline to service after a leak occurrence, can be greatly reduced by timely leak location information. The WaveAlert® Leak Detection System provides leak occurrence and location information quickly and accurately based upon direct measurements.

2.2. Leak Statistics

The following statistics show causes of known worldwide pipeline failures for recent years.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Damage</td>
<td>58 %</td>
</tr>
<tr>
<td>Material Failure</td>
<td>18 %</td>
</tr>
<tr>
<td>Corrosion</td>
<td>15 %</td>
</tr>
<tr>
<td>Construction Faults</td>
<td>6 %</td>
</tr>
<tr>
<td>Others</td>
<td>3 %</td>
</tr>
</tbody>
</table>

**Table I: Causes of Known Pipeline Failures**

The majority of leaks are caused by third-party intervention, such as bulldozers, backhoes or theft. Additional causes include ground movement, earthquakes, corrosion and washouts under riverbeds. Material failures and improper operating procedures that cause damaging transient pressures or pressure surges have also been reported as causing leaks.
3. ACOUSTIC LEAK DETECTION

Acoustic Leak Detection Systems (ALDS) are used on both liquid and gas pipelines as well as multi-phase flow pipelines to detect leaks quickly and provide a means of limiting product loss.

With over 20 years of worldwide applications, Acoustic Systems Incorporated (ASI) ALDS has proven to be the most effective, true real-time, on-line leak detection method. Acoustic Systems Incorporated has improved leak detection technology from many years of field proven applications providing the quickest leak detection, high sensitivity, precise leak location accuracy and low false alarm rate with minimum maintenance requirement. These improvements were made by developing and applying advanced data processing techniques such as differential filtering, moving average filtering, proprietary ‘SMART DRIVE’ for adaptive dynamic threshold adjustment, as well as various repetitive filters. One of these developments, the patented Signature Signal Matching Filter, is especially effective. The real-time signal is continuously compared against signature leak profiles for the particular operating and geometric conditions. These profiles were developed from a database established from over 20 years of experimental and field leak tests. This technique not only drastically reduces the false alarm rate (one alarm a year or less), but also significantly improves the sensitivity and leak location accuracy. This system will also detect leaks with shut-in flow (zero flow rate in the pipeline). With the use of GPS (Global Positioning System) it not only improves leak location accuracy, but also allows for continuous leak detection during the loss of communications.

3.1. System Configuration

The WaveAlert® VII ALDS is shown in Figure 3-1.

The ALDS includes three major assemblies and associated communications links:

- WaveAlert® VII Site Processor (including Acoustic Sensor Assembly)
- MasterComm™ VII Node Processor
- ASI Leak Computer with SCADA Software

System operations are summarized in Figure 3-2.
3.1.1. WaveAlert® VII Site Processor and Acoustic Sensor Assembly

The WaveAlert® VII Site Processor and Acoustic Sensor Assembly are located along the pipeline (usually at valve sites or other designated locations) and comprise two separate assemblies.

The WaveAlert® VII Site Processor monitors inputs from one or more acoustic sensors and distinguishes a leak signal from other pipeline noises. The enclosure (Figure 3-3) is a standard 19-inch rack mount instrument case.

The WaveAlert® VII Site Processor can be located within a standard 19-inch rack mount electronics cabinet and can be sited either in an equipment shelter, in a NEMA-3R (rain tight) enclosure or waterproof enclosure for underground installation.

3.1.2. MasterComm VII Node Processor

The MasterComm™ VII Node Processor serves as the central processing unit for the ALDS. It polls WaveAlert® VII Site Processors in turn. During each poll cycle, it stores digital and analog values including the time of any acoustic event registered. By comparing times of arrival of an acoustic event at two WaveAlert® VII Site Processors, it determines if a leak has occurred, locates the
leak, categorizes its size and issues appropriate messages to the ASI Leak Computer.

The MasterComm™ VII enclosure is physically identical to the WaveAlert® VII enclosure.

**Acoustic Sensor Assembly**
- Produce 4-20 mA dynamic acoustic signal

**WaveAlert® VII Site Processor Assembly**
- Convert acoustic signals from analog to digital
- Compute correlation of dynamic pressure with mask leak profile
- Compare correlation with threshold
- Perform system tests
- Set flags indicating acoustic event
- Uses GPS receiver to synchronize data sampling between WaveAlert® VII sites
- Report to MasterComm™ VII Node Processor when polled

**Communications Link**
- Provide two way communications between WaveAlert® VII Site Processor and MasterComm™ VII Node Processor

**MasterComm™ VII Node Processor**
- Integrate information from WaveAlert® VII Site Processors
- Analyze physical data (Leak/No Leak)
- Originate updated polling requests for monitor stations.

**ASI Leak Computer or Host Computer**
- Maintain system database
- Provide operator interface
- Produce appropriate displays, alarms and messages
- Generate leak signal for valve control

![Figure 3-2:Summary of System Operations](image)

### 3.1.3. Communication Link

The communication link between WaveAlert® VII Site Processors and the MasterComm™ VII Node Processor is a dedicated two-way half-duplex link. It
may include radio, hardwire landline, fiber optic sections or any other dedicated communication links.

3.1.4. ASI Leak Computer and SCADA Software

The ASI Leak Computer with SCADA Software provides user interface with the ALDS via Video Screens, Keyboard, Audio Alarms and Printer. ASI can provide either a turnkey system featuring a Personal Computer with SCADA software or provide a detailed interface specification to permit interface to a mainframe computer with SCADA software.

Figure 3-3: Outline Drawing of the WaveAlert® VII Site Processor and MasterComm™ VII Node Processor Enclosures.

3.1.5. WaveAlert® VII and MasterComm™ VII Hardware

The WaveAlert® VII Site Processor and the MasterComm™ VII Node Processor incorporate advanced signal processing hardware.

The WaveAlert® VII Site Processor uses the following circuits:
The MasterComm™ VII Node Processor uses the following circuits:

- Power Supply
- Signal Processor Circuit
- (Optional) Auxiliary Interface Status I/O Circuit

**Figure 3-4: Outline Drawing of the Acoustic Sensor Assembly**

Notes:
1. Enclosure is rated NEMA-4.
2. Approximate total weight of the Transducer Assembly provided by ASI is 40 lbs. (18.14 kg).
3.1.5.1. Power Supply Circuit
The Power Supply consists of an advanced switch-mode DC/DC converter, which accepts raw DC input and generates required system voltages. Input to output isolation of 500 VDC is provided, as well as output current limiting, automatic restart, and input transient suppression.

3.1.5.2. TMS-320 Signal Processor Circuit
The TMS-320 Signal Processor Circuit is the central control subsystem of the Site and Node Processors. It consists of a TMS-320 signal processor with associated clock, interface and memory circuits. It generates control and timing signals, provides communication oversight, provides digital filtering to discriminate against noise caused by pumps, opening or closing of valves, or other normal pipe operations and performs internal self tests to assure proper system operation. This also consists of various ASI patented proprietary data processing algorithm

3.1.5.3. Signal Conditioner Circuit
The primary functions of the Signal Conditioner Circuit are galvanic isolation and filtering of signals from the Acoustic Sensor Assembly.

3.1.5.4. Auxiliary Interface Status I/O Circuit
The optional Auxiliary Interface Status I/O Circuit allows the WaveAlert® VII to perform application specific tasks. Standard inputs are two electrically isolated analog inputs and twelve optically isolated status inputs. Standard output is via twenty, 2 ampere, dry, NO/NC contact.

3.1.5.5. Modem Circuit
The Modem Circuit features a full duplex modem for modulation and demodulation of signals and an output for transmitter keying with variable built-in delay, accommodating individual key-to-transmit characteristics. The Modem Circuit is a true repeater, reforming each digital message stream to reduce noise levels in daisy-chain applications.

3.1.6. ASI Leak Computer
The ASI Leak Computer may be either a dedicated personal computer for smaller systems or a mini-computer (which may timeshare). The ASI Leak Computer communicates with one or more MasterComm™ VII Node Processors. Usually this is via direct connection conforming to the RS-232C standard.

3.2. Measuring Techniques
3.2.1. Directional Dual Element Acoustic Sensor Arrays
In a typical installation, it is often necessary to locate acoustic sensors near pumping stations and active flow control valves; usually sites of high noise levels. To discriminate against this off line noise, directional acoustic sensor arrays consisting of two acoustic-sensing elements separated by a distance of 50 to 100 meters (165 to 328 ft) are used at the ends of protected pipeline sections.
This dual element sensor array forms a directional filter, rejecting noise from one direction, but detecting a signal from the other.

The WaveAlert® VII S1 Site Processor employs a single acoustic sensor, sensitive to acoustic signals originating from either direction. This configuration is used at intermediate locations along the pipeline, away from compressor stations, control valves, etc.

Figure 3-5: Algorithm for Determining Leak Location
3.2.2. Leak Location

Leak Location is determined from times of arrival of the acoustic signal at two adjacent WaveAlert® VII acoustic sensors. Figure 3-5 shows the algorithm for the case of a single product in the pipeline between sites. The rupture occurs at time \( t = 0 \) shown by the middle clock. The signal travels away from the leak in both directions and arrives at the acoustic sensors at later times. If the rupture is farther from site 1 than site 2, clock 1 runs longer than clock 2.

The leak location, \( S \), is measured from site 1. \( D \) is the distance between sites. Notice that if \( t_1 = t_2 \), according to the location algorithm, the leak is located at the midpoint of the pipeline segment. If \( t_1 < t_2 \), the leak is located left of the midpoint.

3.2.3. Leak Declaration

Leak declaration decisions are made by the MasterComm™ VII Node Processor from information supplied by WaveAlert® VII Site Processors. Decisions are based upon requirements that:

- More than one WaveAlert® VII Site Processor recorded an acoustic event
- The acoustic signal source is found to originate at a location on the protected segment of the pipeline
- The potential leak event signals received from two or more local Wavealert® Processors are verified by proprietary data processing and identification algorithm at the MasterComm™.

![Diagram of leak location and declaration process](image)

**Figure 3-6: Muting Zones Adjacent to Wavealert® VII Sites**
3.2.4. Muting Zones

Noise from sources located beyond the ends of the protected section of the pipeline which result in acoustic event declarations by more than one WaveAlert® VII Site Processor will be determined to be within the leak location accuracy from the near acoustic sensor. Since the majority of false event declarations are produced by off line acoustic sources, the false leak alarm rate is greatly reduced, if acoustic signals observed outside of the protected zone can be excluded. However, due to the uncertainty associated with location calculation, a muting zone is declared on either side of each acoustic sensor within which that WaveAlert® VII is not allowed to contribute data leading to a leak declaration (See Figure 3-6.) Thus, at the ends of the pipeline, protection is not afforded for a short distance (determined by the leak location accuracy) from the B transducer. At intermediate WaveAlert® VII sites, even though the local WaveAlert® VII cannot contribute to a leak decision for leak signals originating within its muting zone, one active WaveAlert® VII located on either side can contribute data for a decision. Thus, protection is provided at intermediate sites.

3.2.5. Detection Time

The maximum time required to detect a leak is the sum of:

- Travel time for an acoustic signal from the leak site to the farthest monitor site, equal to the distance between adjacent monitor sites divided by acoustic velocity in the pipeline medium.
- Time for the Node Processor to poll all Site Processors twice and compute leak location. Scan time includes communications delays such as radio keying time.

Typical time of detecting and locating leak ranges from 10 seconds to 1 minute.

3.2.6. System Performance

Minimum detectable leak size depends upon several factors, which include:

- Static pressure in the pipeline
- Distance of the WaveAlert® VII from the leak
- Pipe diameter and wall thickness
- Background noise levels of the pipeline
- Fluid properties

The leak threshold setting of a WaveAlert® VII Site Processor depends upon the typical noise level in the pipeline during normal operation and the signal-to-noise ratio required to achieve a satisfactory false alarm rate. These factors depend upon the design and operation of the pipeline. ASI performs a sensitivity analysis of the line to determine the minimum detectable theoretical leak size, location accuracy, maximum detecting time and optimum placement of WaveAlert® VII Site Processors on the pipeline. A data sheet for data used to perform this sensitivity analysis is enclosed in the Appendix of this document.
3.2.7. Signal Profile

A signal produced by a simulator field leak test on a liquid line is shown in Figure 3-7. The acoustic signal was created by rapidly opening a ball valve through a flow controlling orifice plate. The signal has been filtered through a band pass filter. The signal amplitude is 78 mbar. The orifice was 15.7 mm (0.62 inch) diameter with a static pressure of 57 psig and was located 6.4 km (4 miles) from the acoustic monitor. This profile is typical of liquid bearing pipelines. Signal amplitude increases with hole area and pressure and decreases with pipeline cross section. The signal profiles changes with products and with different degrees of dispersion and attenuation during propagation. The unique feature of the signal profile and its change while propagating along the pipeline is the basis of the ASI proprietary mask filter for pattern recognition.
3.2.8. Sensitivity

Figure 3-8 shows how minimum detectable hole size versus distance between acoustic monitors varies for different pipe diameters. Actual sensitivities depend upon the fluid in the pipeline, static pressure and background noise conditions.

In order to minimize false alarms, all acoustic leak events must pass the multi-layer proprietary verification algorithm at the MasterComm. Due to the positive pattern recognition technique used in this system, a true leak can be identified even in noisy environments (low signal to noise ratio). A leak is not declared unless an acoustic event is detected by two monitors, one upstream and one downstream. Since a leak can occur randomly at any point between these two monitors, a key determinant of detection sensitivity is the leak distance from the farther of two adjacent monitors.

The system is most sensitive for a leak, which is located at the mid-point of the pipeline segment. Worst case occurs when the leak is farthest from one of the monitors and close to another monitor.

3.2.9. False Alarm Rejection

Wavealert® VII Site Processors employ multiple techniques for reducing false alarm rates:

- Dual element directional array acoustic sensors at ends of the pipeline. The recommended pipeline distance between transmitters is 50-100 meters (165 to 328 ft).
- ASI’s matched filters use the signature of a leak from ASI proprietary database as a mask against which real-time acoustic
signals data compared. The ASI proprietary database was built over twenty years of efforts compiling from both field leak data as well as experimental leak test data for various pipeline operating conditions and different transporting fluids. This allows a fingerprint matching type of positive identification on the true leak signal and drastically reduces the possibility of false alarm and increases the detection sensitivity.

- Digital high pass and low pass filters with adjustable roll-off frequencies.
- Moving average filter to suppress higher frequency noise.
- Dynamic threshold logic utilizes the ASI proprietary “SMART DRIVE’ auto-adjust mechanism in distinguishing abnormal noise from true leak signals. The ASI ‘SMART DRIVE’ program continuously scans, computes, and verifies all incoming data and automatically adjusts the dynamic thresholds based on the ASI proprietary expert logic developed over years of experiences. This will further reduce the false alarm rate.
- Repetitive Filters to suppress cyclic pipeline noise and other various unusual noise sources.

False alarm rate is also a function of frequency of activity (sudden pressure changes on the pipeline associated with operating changes and background noise.) By use of the above filters false alarms have been reduced significantly. The false alarm frequency is expected to be less than three per year (typically less than one per year) for a commissioned system.

3.3. Available Configurations

The WaveAlert® VII D Site Processor is configured to monitor one or two dual element, directional sensor arrays at the end of a protected pipeline segment. The WaveAlert® VII S Site Processor monitors one or two single element sensors.

Site Processor configurations are summarized in Table II. The last number in the designation is the total number of sensor elements supported.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Sensor Configuration</th>
<th>Total Number of Sensor Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>WaveAlert® VII S1</td>
<td>Single sensor ........................................1</td>
<td></td>
</tr>
<tr>
<td>WaveAlert® VII D2</td>
<td>Directional sensor array ..................2</td>
<td></td>
</tr>
<tr>
<td>WaveAlert® VII S2</td>
<td>Two single sensors * ............................2</td>
<td></td>
</tr>
<tr>
<td>WaveAlert® VII D4</td>
<td>Two directional sensor arrays ..........4</td>
<td></td>
</tr>
<tr>
<td>WaveAlert® VII D3</td>
<td>One single sensor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One directional sensor array* ..............3</td>
<td></td>
</tr>
<tr>
<td>WaveAlert® VII SR1</td>
<td>Single sensor, remote Wavealert® processor</td>
<td></td>
</tr>
</tbody>
</table>

* For monitoring parallel lines

**Table II: Available Configurations for WaveAlert® VII Site Processors.**
4. SOFTWARE

The WaveAlert® VII Leak Detection System employs three basic software/firmware systems. Software/firmware tasks within these systems are shown in Figure 4.1.

4.1. WaveAlert® VII Site Processor Firmware

Site Processor instructions are supplied in ROM and contain local operating instructions for the WaveAlert® VII including data gathering, housekeeping, first line data processing and analysis, decision making, communications and self-test instructions.

4.2. MasterComm™ VII Node Processor Firmware

MasterComm™ VII Node Processor Firmware provides instructions for communications with Site Processors, data storage, data processing and analysis decision-making (leak vs no leak, leak location and size), self-tests and communications with the ASI Leak Computer. Node Processor firmware is configured specifically to each installation.

4.3. SCADA

SCADA software residing in the ASI Leak Computer includes: information and communications management instructions for transfer of data between the ASI Leak Computer and MasterComm™ VII Node Processor(s), database management information and instructions for the organization, maintenance and security of the system, historical (operating) information, instructions concerning organization and content of printed reports; and format and contents of graphic displays.

The system database maintained under SCADA contains scaling constants to convert binary numbers to engineering values (psig, mbar, etc.), system operating parameters (alarm threshold values, digital filter parameters, etc., which are downloaded to the MasterComm™ VII Node Processor and hence to individual WaveAlert® VII Site Processors and historical information (times, pressure values, flag settings, flag clearings, events declared, etc.)

Leak Event reports are displayed on the ASI Leak Computer terminal and printed, whenever, an event flag is set by any WaveAlert® VII Site Processor. A representative display is shown in Figure 4-2. Other printed system reports can be provided daily, displaying system parameters, performance summaries, etc.
WaveAlert® VII Site Processor Firmware (ROM)
1. Data acquisition
2. Local data analysis
3. Built in tests
4. Report preparation
5. Communications
6. Local valve control

MasterComm™ VII Node Processor Firmware (ROM)
1. Data analysis (Leak/No Leak?)
2. Leak Location
3. Leak Size
4. Built in tests
5. Communications
6. Automatic valve control on leak decision

ASI Leak Computer or Host Computer with SCADA Software
1. Communications
2. Database organization and management
3. System reports
4. Graphics format
5. Remote valve control

Database Contents
1. Scaling constants
2. System parameters
3. Alarm parameters
4. Historic Data

Figure 4-1: System Software/Firmware Structure
Figure 4-2: Representative Leak Display at ASI Leak Computer
5. SYSTEMS

Typical ALDS installations are shown on the following pages.

Figure 5-1 shows an installation consisting of two WaveAlert® VII D2 (dual element sensor array) Site Processors on a single pipeline segment. Dual sensor directional arrays are used to attenuate noise entering the pipeline at the ends of the protected segment. The WaveAlert® VII D2 Site Processors communicate with the MasterComm™ VII Node Processor either via dedicated landlines or by half duplex radio link. One MasterComm™ VII Node Processor can monitor up to twenty Site Processors, collecting and analyzing system data and communicating with the ASI Leak Computer. Multiple MasterComm™ VII Node Processors can be used for larger systems.

![Figure 5-1: Two WaveAlert® VII D2 Site Processors Monitoring a Simple Pipeline](image)

Figure 5-2 shows a similar system in which the personal computer communicates with a central mainframe computer via a secondary communication link, permitting centralized monitoring of multiple Leak Detection Systems and providing data for a permanent record as part of an integrated risk management program.

Figure 5-3 shows a long transmission line. WaveAlert® VII D2 Site Processors with directional sensor arrays are located at ends of the monitored pipeline segment near compressor stations or other sources of acoustic noise. WaveAlert® VII S1 Site Processors with sensors at intermediate block valve sites provide fail-safe shut-in valve control in case of need. The system uses a
combination of radio links and landlines for communication between WaveAlert® VII Site Processors and MasterComm™ VII Node Processor.

Figure 5-2: ASI Leak Computer Communicating With A Central Main Frame Computer

Figure 5-3: WaveAlert® VII Monitoring a Transmission Line
Figure 5-4 shows a similar system used to monitor parallel transmission lines. Figure 5-5 shows a more complex installation monitoring a network.
6. TYPICAL INSTALLATIONS AND APPLICATIONS

Since 1979, WaveAlert® ALDS have been installed and used worldwide for various applications (liquid, gas, as well as multi-phase flow pipelines). ASI’s customer list includes companies such as ABB (Russia), BEB (Germany, a Shell/Esso subsidiary), Chian-Shen Power Plant (Taiwan), Chinese Machinery Corporation, China Light & Power, CPC (Taiwan), ESSO (Australia), Fluor-Daniel, HPCL (India), Mobil, Northwest Pipeline, Sarpon (Italy), Shell, Taiwan Power Company, Sunoco, Western Gas, etc. ASI’s customer list is available upon request.

6.1. ESSO AUSTRALIA LPG Pipeline

A WaveAlert® IV system was installed in 1982 to monitor a 10-inch ESSO LPG pipeline in Australia. The system was upgraded to a WaveAlert® VII system in 1998. The ESSO LPG Pipeline provides an excellent example of the reliability of Acoustic Leak Detection.

ESSO required a fully autonomous leak detection system requiring no operator intervention so that when a leak is detected, the leak detection system must quickly shut-in the pipeline with no further input from personnel. Therefore, the leak detection system must not only detect and locate small leaks, but also do so with a very low number of false alarms. Throughout these years of service, the WaveAlert® ALDS has achieved this difficult task with only two false alarms while detecting two actual leaks.

Figure 6-1: Diagram of the ESSO LPG ALDS with leak detected on November 24, 2000
6.1.1. System Configuration

Six WaveAlert® VII site processors are used to monitor the 188 km pipeline. The system is configured to monitor valve status and provide independent pressure measurements from each WaveAlert® site. Each WaveAlert® Site Processor controls an isolation valve. With control of isolation valves the WaveAlert® system will automatically shut-in the pipeline when a leak is detected without any human intervention.

6.1.2. System Operation

This type of installation allows for the fastest possible response to a leak and clearly demonstrates the level of false alarm rejection the WaveAlert® System has achieved. **On July 19, 1999, a leak occurred midway on the LPG pipeline and was detected by the WaveAlert® system, which automatically shut in the pipeline preventing a potentially disastrous accident and possible casualties.** This is the only known occurrence of any type of leak detection system automatically shutting in a pipeline on the occurrence of a leak. **Again, on November 24, 2000, a leak caused by a work crew burying fiber optic cable was detected and located within 100 meters (see Figure 6-1). The block valves were automatically shut off within one minute preventing another potential disaster.**

6.2. Mobil West Coast Methane Gas Pipeline

![Diagram](image)

**Figure 6-2:** Diagram of the Mobil West Coast Methane Gas ALDS
6.2.1. System Configuration

ASI Acoustic Leak Detection monitors are installed on a Mobil West Coast 14 inch methane gas pipeline. The line is 2.85 miles long and protected by WaveAlert® VII Site Processors at each end. The pressure of the gas in the line is about 75 psi, with a flow rate of 3800 Mscf/hour. The confirmation of a leak event is performed by proprietary firmware residing on the MasterComm™ VII and displayed on the central mainframe computer video terminal located at Dallas, Texas. It is critical that any occurrence of a leak on this segment be detected and located within seconds, due to the hazardous nature of the product.

6.2.2. System Performance

Tests, using standard leak test procedures, were conducted to establish threshold settings, verify the sensitivity of the system, confirm the acoustic velocity in this particular pipeline and the time required to detect and locate the leak.

Leaks were simulated in the line at a leak site located 1.43 miles from the refinery end of the line (see Figure 6-2). A two-inch ball valve in series with an orifice plate was used in the tests. Several tests with different orifice sizes were conducted. The sensitivity of the system under average flow conditions was determined to be well within specified performance. The system displayed accurate leak locations within 53 feet of each leak test.

Detection-time, also was determined. All leaks were detected within 7 seconds at the refinery end. A leak occurring at one end of the segment is detectable at the other end within 13 seconds. (Detection time and leak location accuracy improves as the leak occurs closer to the midpoint of the line).

6.3. Sunoco Frankford Plant Chemical Pipelines

![Diagram of the Sunoco ALDS](image)

**Figure 6-3: Diagram of the Sunoco ALDS**
In 1999 Sunoco selected the WaveAlert® ALDS to meet local requirements for leak detection on three chemical pipelines. The WaveAlert® VII system was installed on each of the phenol, acetone and cumene pipelines (Figure 6-3). These pipelines ran from the plant to loading docks on the Delaware River.

6.3.1. System Configuration

The system is configured to monitor all three pipelines while ships are being loaded at the dock and also while the pipelines are shut-in. Since the pipelines load ships infrequently (as little as once per week) Sunoco was required to have a leak detection system, which would operate at high sensitivity during zero flow conditions. Since the WaveAlert® ALDS is not based on flow measurement it will maintain high sensitivity without flow in the pipeline.

7. ANALYSIS FORM
### Requested By

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<th>Fax Number</th>
<th>E-Mail</th>
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### Pipeline Data

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<th>Length(s) of Line(s) (miles or km)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Downstream Pressure (psi)</th>
<th>Upstream Pressure (psi)</th>
<th>Pressure Gradient (psi/mile)</th>
</tr>
</thead>
</table>

### Gas Data

<table>
<thead>
<tr>
<th>Specific Gravity of the Gas</th>
<th>Ratio of Specific Heats of the Gas</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Average Compressibility</th>
<th>Viscosity (poise)</th>
<th>Flow (MMSCF/D)</th>
</tr>
</thead>
</table>

### Liquid Data

<table>
<thead>
<tr>
<th>Bulk Modulus of the Liquid (psi)</th>
<th>Density of the Liquid (lb/cu. ft.)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Viscosity (poise)</th>
<th>Flow (barrels per day)</th>
</tr>
</thead>
</table>

### Other Data

- Does SCADA system already exist? If yes, describe what type.
- Does a communication system already exist? If yes, describe what type: Radio  Microwave  Hardwire  Dedicated Phone Line
- Draw a diagram of pipeline to be studied. Provide: location of branches, location of block valves, instrumentation hardware, control room, populated area and environmentally sensitive areas

### Desired Sensitivity

<table>
<thead>
<tr>
<th>Hole size (inches or mm)</th>
<th>Accuracy of Location (feet or meters)</th>
<th>Speed of detection (seconds)</th>
</tr>
</thead>
</table>
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