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Internet-based Early Warning System

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Declaration of author's rights

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Abstract

Internet Technology is increasingly influencing the way we live and work. Homes having Internet access are becoming a norm everywhere. In the UK alone, there are nearly 8 million households with Internet access at home according to a new government figure. Internet access worldwide is growing at a rate of about 40 to 50 percent annually. Money investments in e-commerce by companies are also growing rapidly. The Internet has already become an essential tool for communication for both people at home and at work. It also creates a whole new market for business of all kinds. In fact, many companies are already working, developing and providing all sorts of Internet-based services and applications for people at home. The main driving force behind this was the development of the e-service system and growing consumer demand for interactive service that provides for better living, convenience, security and entertainment.

The aim of this project was to create and provide an Internet-based service that could bring benefits to both the energy sectors and end users. There are also considerable benefits for the environment. At the same time the quality of life can be improved for users who subscribe to such a system. The proposed services developed within this study can be classified as "Internet-based Early Warning Systems". The main objective of a service such as this would be to provide early warnings to a system supervisor responsible for monitoring and acting on any alert conditions. Early actions could then be taken to prevent any problem situations from occurring or to minimise any negative impacts. This can benefit the customer and also the environment.

The project work started with a literature review and covered the general development of the e-service system. Areas of application for an early warning system were considered. These are addressed in the report. The application chosen for implementation was that of "Gas Leak Detection". In essence, this is aimed at providing protection to consumers against of possibility of gas leaks and subsequent danger of explosion.

A general description of the infrastructure of the early warning system is given in chapter two of the report.

A series of research studies relating to gas leak behaviour is covered in chapter three. These studies assessed the concentration distribution behaviour when gas escapes into a room or enclosed space. The location and positioning of the gas detection sensors were reviewed to assess the optimum detection capabilities. In addition, various sensor technologies were reviewed to assess their advantages and disadvantages.

Chapter four covers the basic concept of the data acquisition system and its operational function. Chapter five studies the communication links between hardware and systems and the problems that are likely to affect the development of a system with respect to data transmission.

The conceptual design of the gas leak early warning system is covered in chapter six. A detailed explanation is given addressing each functional requirement deemed necessary in such a system.

Finally, a conclusion would be covered in chapter seven.

Contents

Chapter One

1.0 Introduction to e-Service System

Since Internet access has become popular at home as well as at work, the demand on high-speed Internet access increases at a rapid pace. Expectations as to its usefulness are also on the increase, and there is also a growing demand for the interactive services that make life easier and safer.

Broadband Internet technology and the newly developed Mobile Internet have made the idea of "Interactive home" possible. New services can be developed, able to be used at any time of the day or night. People will be able to communicate more effectively, access information, and monitor and control various functions in their homes from virtually anywhere just by using the Internet and the mobile phone.

The e-service system is a specially designed system that allows all sorts of technologies to join together so that various interactive services can be provided to consumers. The e-service system is, in fact, an Internet based service delivery platform that effectively integrates Broadband Internet, the Mobile Internet and the Home Network. The system features a set of system software and hardware, and a service gateway (e-box) located in the subscriber's home. The e-box integrates the home network with the Internet and the e-service centre, and can be seen as the remote unit of the system. A wide range of electronic appliances can also be connected to the e-box, enabling the delivery of various services. All centralised functions are located within the e-service centre, which house a number of servers.

The concept of interactive home also drives new technologies being developed for the e-service system. Bluetooth will allow wireless communication between home appliances. 3G, smart phone and screen phones will enable more content to be delivered at higher speed. And a secure, open service delivery platform will ensure that services are delivered to the home, safely and efficiently.

1.1 Internet Based Services for Early Warning System

The number and types of services that could be offered by the e-service system is enormous. However, in this project only services that could deliver benefits to the energy sectors and environment will be considered. After many brainstorming sessions and detailed researching the author decided to create an Internet-based Early Warning System as a service for the e-service system. The Early Warning System could be applied to many different areas and bring in various benefits dependant on the application area. Several examples are discussed briefly below:

1.1.1 Low Temperature Warning

Some 50,000 people die every year in the UK as a result of cold, and hypothermia is one of the most deadly cold-induced conditions. People affected most are the elderly and babies under one year old. However, keeping the house warm could easily prevent hypothermia. The adoption of the Early Warning System for providing low temperature warning could help prevent death caused by hypothermia. The concept is to enable the early warning system to pinpoint the house where the temperature is dangerously low, and the operator can then use the control function within the system to adjust the temperature within the house for the occupants, or send someone to the house to investigate the problem (e.g. problems with heating system and so on). This system would be beneficial to elderly and disabled people who may have problems in adjusting heating settings to cope with seasonal temperature drops.

1.1.2 Carbon Monoxide Warning

Carbon monoxide is odourless, colourless and tasteless. It is difficult to detect. However its effects are deadly. Every year at least thirty people in the UK die from carbon monoxide poisoning and many more are hospitalised. Survivors of severe poisoning are sometimes left with disabling psychological and neurological problems that last for years. Although it is possible to install carbon monoxide alarms very easily and cheaply nowadays, people often forget to change the batteries for the alarms making them useless. The adoption of the Early Warning System for providing carbon monoxide warning should be able to help prevent death from carbon monoxide poisoning. The idea behind this is to allow the Early Warning System to pinpoint the house where high levels of carbon monoxide exist, allowing the operator to turn on appropriate ventilation to prevent the gas building up. The operator could also pass a warning to the occupants by making a telephone call to ensure their safety, or even send in rescuers if necessary. This system would be beneficial to everyone and provide a much-needed safety net.

1.1.3 High Energy Consumption Warning

Matching the energy demand is an important job for the energy industries. Under production could lead to power cuts which could cause chaos to society and damage the economy of the country as most machines in use in business and manufacturing require electrical energy to operate. On the other hand, over production reduces the profit margin to the energy company, wastes energy resources, and emits carbon dioxide to the atmosphere unnecessarily. At present, energy generators rely on energy forecast models to predict energy demand on a day-to-day basis. However, by adopting the Early Warning System the energy sector would be able to manage the energy use more efficiently. The idea behind this is to use the Early Warning System to monitor the energy consumption of each city within the country. A warning would be given to the operator when any city uses more energy than their usual energy consumption pattern. The operator could adjust their energy production to ensure the demand is met, or by agreement, turn off some non-critical appliance operation temporarily within the residential sector, so that the extra demand could be cancelled out. In return, the occupants who agree to the turn off will be offered a discount on their own energy bill.

1.1.4 Gas Leak Warning

In recent years, explosions caused by gas leaks have claimed many lives. At present, there are no systems designed for use in the residential sector to protect the occupants against gas explosion. In this project, the author implements the Early Warning System in this particular sector to give the occupants protection against gas explosions caused by gas leak and also prevent exposure to the gas unknowingly. The reason that the author is in favour with this particular idea rather than the three mentioned earlier is because preventing gas leaks not just provides a safer place for people to live, but it also brings benefits to the energy sector and the environment. Gas escapes to the atmosphere not only waste energy resources but also cause severe environmental impact and that is exceptionally true for natural gas or methane. The idea behind this is to use the Early Warning System to pinpoint the house where there is a gas leak. The operator can take immediate actions to stop the leak, for example, turn off the gas supply remotely, or send an engineer or technician to the scene to get the problem fixed.

There are many more services that could be offered through the Early Warning System, however, from now on the project focuses only on the development of the Early Warning System for use in gas leak detection and prevention.

1.2 Gas Leak Threat

Even though all gas-related products are highly tested for safety before they are made available to the market, there are still gas-related accidents happening all over the world. Most accidents related to gas are causing by unexpected gas leaks and gas accumulations. What happens to the gas then depends on the nature of the gas and the immediate environment. Usually gas leakages can pose a threat to life in three ways:

1. Combustible gas can gather and reach a density at which it can ignite and cause explosion.
2. Toxic gas can cause illness, paralysis or death if inhaled.
3. Any gas in sufficient quantities will displace oxygen and therefore pose a serious risk to life.

At the present time, most buildings are equipped with a combustible gas supply (e.g. natural gas) for providing heat, hot water and cooking for the occupants. This kind of gas is very useful but when a leakage occurs and accumulates without notice, it can be very dangerous, and lead to an explosion, causing damage to buildings, and loss of life. In 1971, Scotland's worst gas explosion happened at Clarkston. Twenty-two people died when a gas build-up demolished a shopping complex. In 1996, a shopping mall in Brazil exploded. It was caused by a gas leak and killed 44 people and injured 400. In December 1999, there was a gas explosion in Lanarkshire, Scotland. A family of four were killed in that instance.

Lanarkshire gas blast scene

Lanarkshire gas blast scene

1.3 Legal Requirements

Nowadays, it is a requirement by law that in the UK all installations of gas products installed by qualified professionals. Similar requirements apply in many other countries. Regular maintenance and safety checks are recommended for all users. Some countries such as the U.S. require all property owners with under or above ground gas piping systems to undertake the responsibility for maintenance of their own gas distribution facilities. A leakage survey must be conducted at least once a year. No doubt, such actions could significantly improve the safety aspect of gas equipment and reduce the chance of potential gas leaks. However, just regular checks cannot guarantee that a hazardous situation will not arise. Interference with, or failure of, gas equipment can lead to accidental gas escapes. In fact, accidents like those mentioned earlier continue to happen in many countries, including those well developed such as the U.S. and Germany. These accidents suggest that regular checks may not be sufficient to prevent such tragic accidents happening again.

1.4 Environmental Impact of Gas Leaks

There are other issues which are so important that the potential for gas leaks eliminated. Natural gas is the primary source of fuel used in UK homes. It is a very clean fuel for combustion because the by-products are mainly water vapour and carbon dioxide. Carbon dioxide will still be produced during the combustion process of natural gas, but it is still much cleaner than burning many other fossil fuels. However, the main concern of natural gas use is its main constituent methane (typically between 80-99% by volume depending on the source). This is a more harmful greenhouse gas than carbon dioxide when released to the atmosphere. In addition, leakages are a significant source of methane release to the atmosphere, causing considerable impact on the environment. The leakage of natural gas (or methane) worldwide has been reliably estimated to be in the region of 1.1% of total throughput.

1.5 Gas Leak Prevention

Gas leaks are always undesirable, for safety, financial, health and environmental reasons. In this project a new kind of energy service was developed to prevent gas leaks with the use of Internet technology. A system was designed for condition monitoring and subsequent notification of relevant organisations (such as the gas supplier and the fire department) of any suspected leakage of natural gas in buildings. This would enable effective and immediate action to be taken to prevent explosions and death. The system could also be adapted for monitoring the presence of toxic gases (such as carbon monoxide) in buildings, coal mines and warehouses that are used to store toxic and flammable gases, as well as monitoring gas leaks in residential buildings. However, to narrow down the area of research, only natural gas and the residential sector is considered in this report.

1.6 Aim and Objective

The aim of the system is to provide 24 hours continuous detection capability of potential gas leaks and to monitor any concentrations in assigned areas (e.g. rooms, empty spaces under building and so on). A notification with details of the gas types and concentrations would be sent to the organisations if a gas leak is detected, through the Internet connection. The information would be viewed through a web browser. In very bad situations the gas supplier would be able to turn off the gas supply immediately and remotely through the browser with a specially designed gas supply switch.

Chapter Two

2.0 System Concepts

The system comprises four fundamental steps:

1. Gas monitoring
2. Data Processing
3. Data Transmission
4. Data Display

The subject to be monitored is, of course, the leakage of natural gas in buildings. In order to have a fully functioning system, all buildings such as houses and warehouses must have gas detection sensors installed in assigned areas. All the measurements from the sensors will be collected by a data acquisition system and processed into a desirable format. The "e-box" will then send all the processed data to a web server, to enable the operators to view the information online using a web browser. Figure 2.0.1 illustrates the operation of the system in graphical format.

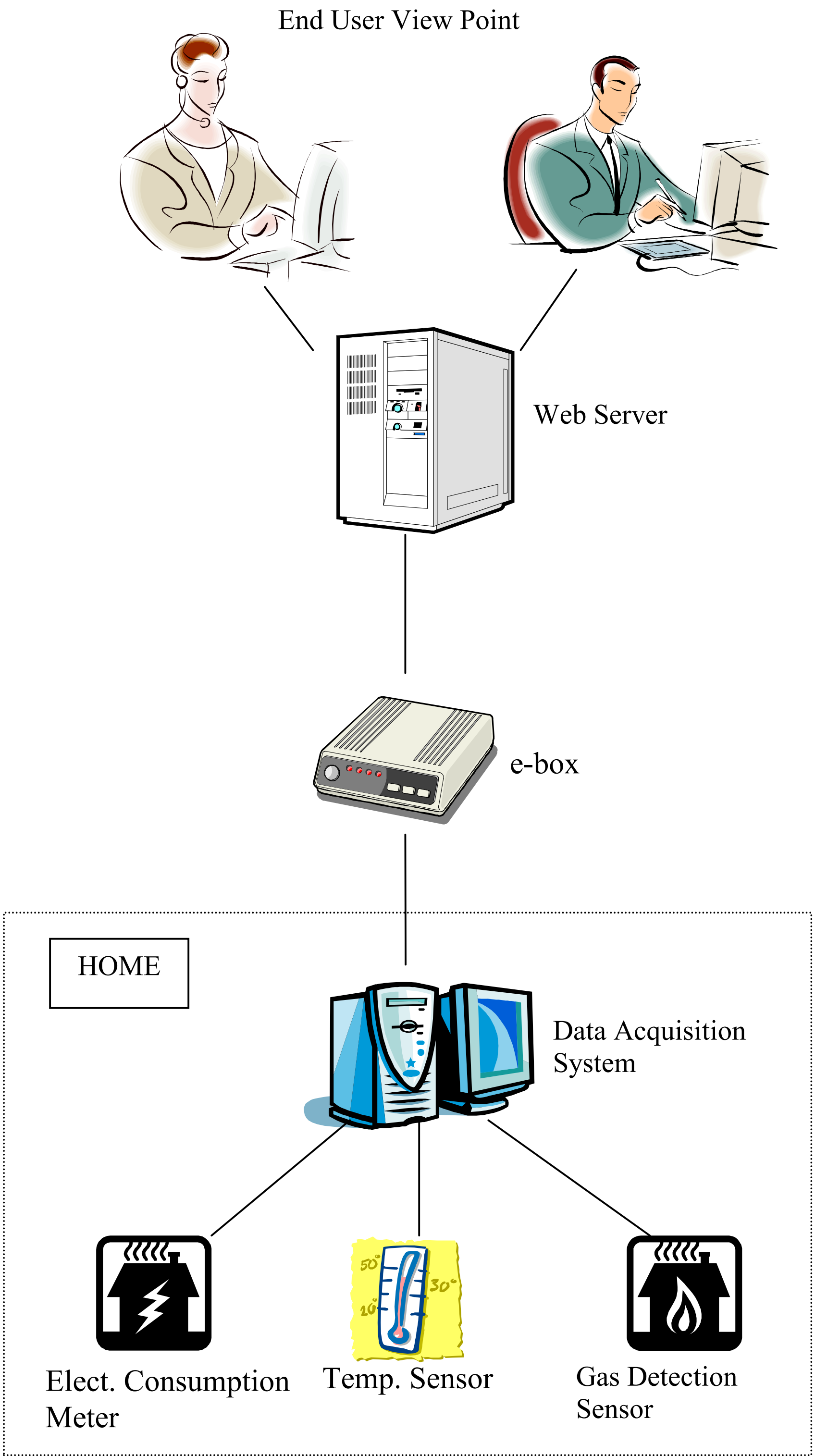


Figure 2.0.1, Internet Based Early Warning System

Chapter Three

3.0 Gas Detection

Understanding of the process in which leaking gas mixes with air, how the mixture is formed, and how the mixture distributes itself throughout a building is essential. This information can have significant influence on the way the sensors should be installed and the type to be used. The combustion properties of the gas-air mixtures are also important if the objective is to minimise gas explosions.

Gas explosions in buildings are rare occurrences. Not all gas leaks lead to an explosion because specific conditions in respect of the concentration of gas are needed before an explosion can occur. In addition, high legal safety standards govern the correct installation of gas pipes and appliances. However, gas leaks could still damage the environment and human health.

For an explosion of any gas-air mixture to occur, a number of conditions have to be met. Gas, air, and a source of ignition must all be present. The concentration of gas in the mixture must be within a certain range (also known as the *limit of flammability*) in order to allow a flame to propagate through the mixture. If the gas leak detection system is able to warn the operator before the gas concentration reaches the lower flammability limit, an explosion could be prevented. Thus it is very important to place the sensor(s) in a position that can provide accurate readings. There should be no area or volume within the enclosure where the gas concentrations are allowed to reach the lower flammability limit that could cause an explosion.

Fuel	Flammability Limits (% v/v gas)		Auto - Ignition Temperature (K)	Min. Ignition Energy (milli-joules)
	Lower	Higher		
Methane	**5**	**15**	**813**	**0.29**
Ethane	**3**	**12.5**	**788**	**0.24**
Propane	**2.2**	**9.5**	**723**	**0.25**
Butane	**1.9**	**8.5**	**678**	**0.25**

Figure 3.0.1, Combustion properties of common gases

3.1 Gas Concentration Distributions

The density of gas being released, characteristics of the source of gas leakage, and ventilation are the main factors which influence the build-up of gas concentration within an enclosure. In general there are two types of gas concentration profiles based on the gas specific gravity. Gases heavier than air, such as propane and butane, tend to form a layer near the floor as shown in Figure 3.1.1. Gases lighter than air, such as natural gas, tend to form a layer near the ceiling as shown in Figure 3.1.2.

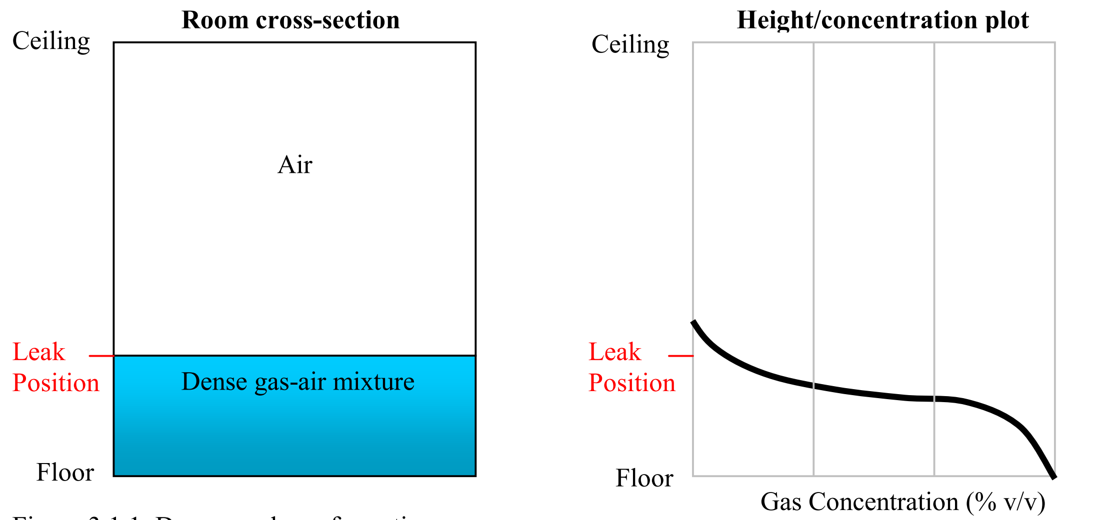


Figure 3.1.1, Dense gas layer formation

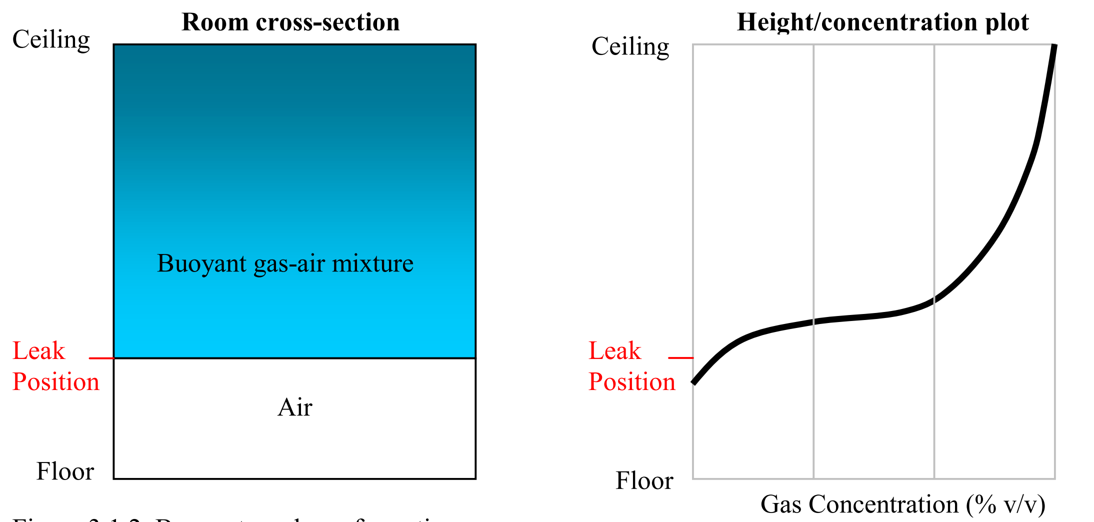


Figure 3.1.2, Buoyant gas layer formation

The above diagrams illustrate the general concentration profiles when gases, both lighter and heavier than air, are released into an enclosure. In order to apply the gas leak early warning system to residential buildings, it is necessary to understand the actual concentration profile of natural gas when it is released into a room since it is the primary source of gas used in UK homes.

British Gas Midlands Research Station has carried out experiments in which natural gas was released into a test room 2.74m high with a volume of 20.6m^3. The experiments were undertaken using leaks of natural gas at domestic supply pressure with leakage rates of between 0.4 to 9.5m^3/h and gas escape velocities ranging from 0.8 to 88m/s. An important conclusion drawn from these experiments is that for leaks of natural gas which occur near the floor, the time taken for uniform conditions to become established within the layer which is formed is short. When the buoyant gas is released some way below the ceiling, a layer of essentially uniform concentration is formed very quickly between the point of leakage and the ceiling. Thus it is a misconception to assume that, following the onset of leakage, a layer of high concentration is formed at the ceiling, which then gradually increases in depth downwards with time.

Figure 3.1.3 is concluded from the experiments under unventilated condition. With the leak near the ceiling a shallow layer of high concentration mixture is formed. However, if the leak takes place near the floor, the room volume between the leak position and the ceiling will be filled with a mixture of a lower concentration. The general shape of these concentration profiles is maintained throughout the duration of the leak as shown is Figure 3.1.4. The same conclusion can also be drawn for gases heavier than air except that the concentration profiles will be inverted with maximum concentrations occurring at the floor.

Natural gas concentration profiles under the influence of ventilation are in Appendix A. The general shapes of these ventilated profiles remain very similar to those under zero ventilation.

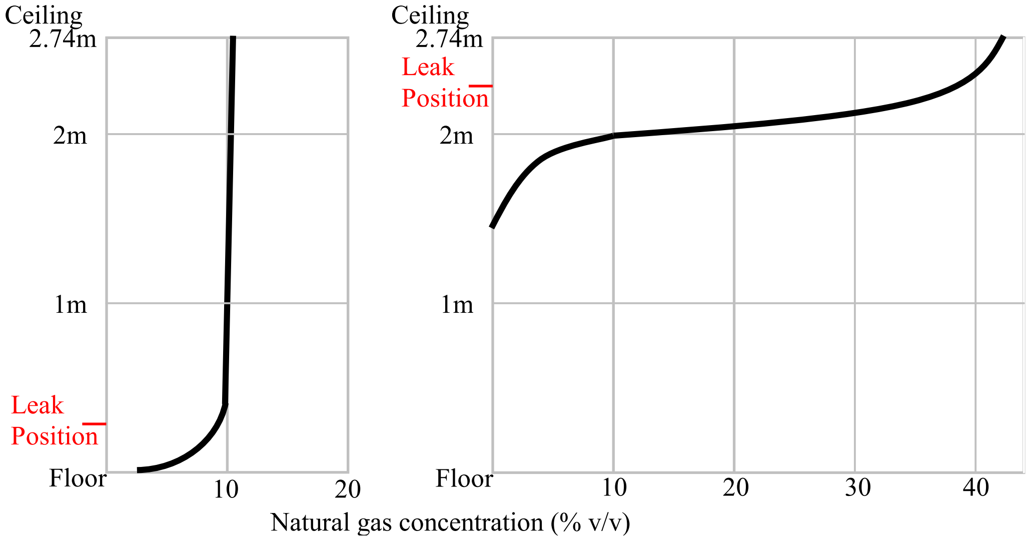


Figure 3.1.3, Natural gas distribution profiles in an unventilated room

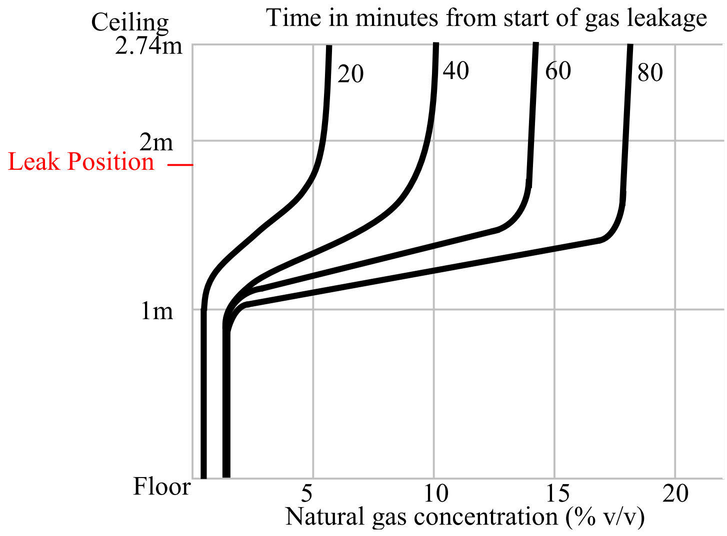


Figure 3.1.4, Natural gas distribution profiles with time in an unventilated room

3.2 Sensors Positioning

Selecting the location for the placement of gas sensors involves a number of considerations since there are many factors that could affect gas concentration distribution. Thus evaluations of gas leakage risk in a building and the physical location of sensors must be carried out. The assessment process is critical for identifying the potential consequences of a gas leak to humans and the environment. Based upon these assessments, the numbers, type and locations of the sensors can be decided. This chapter ONLY provides the basic concept of positioning the sensors. The author would not encourage readers to carry out the risk assessment and installation process on their own. Always consult a qualified professional.

The results of experiments conducted by the British Gas Midlands Research Station are shown in Figure 3.1.3. There is a range of heights that is acceptable for locating the gas sensor in order to detect the leakage of natural gas within the flammability limit in the room. The possible height for placing the sensor is highlighted by two blue lines as illustrated in Figure 3.2.1. For a near floor leak, the sensor could be installed virtually at any height between the leak position and the ceiling. For a near ceiling leak, the range of heights that are suitable for placing the sensor is very narrow.

To increase the detection flexibility, the sensor should ideally be installed in such a position that both near-floor and near-ceiling leakages can be detected. This is particularly important where, for example, a gas supply pipe within a room runs vertically from ceiling to floor. Another case would be for gas supply points situated at different level, e.g. one feeding a central heating system high up on the wall and another supplying a cooker at a lower level. A potential gas leak could occur anywhere and the leak position could be at any height. Natural gas however, by it nature, will form a layer near to the ceiling. It is logical therefore to assume that the optimum location for the sensor would be the ceiling or very near to the ceiling.

This is indeed the best location for the sensor. The gas concentration is found to be highest at this position. Placing the sensor on the ceiling or near the ceiling may increase the distance between the leak point and the sensor, particularly if the leak is near to the floor. However, the time taken for uniform conditions to be established within the gas layer formed is short, thus the distance effect is negligible.

Therefore, to achieve effective detection of buoyant gas leaks such as natural gas, the sensor should be installed near to the ceiling. For detecting gas that is heavier than air, the sensor should be installed near the floor. In all cases, the sensors should ideally be placed somewhere close to possible sources of leaks as illustrated in Figure 3.2.2.

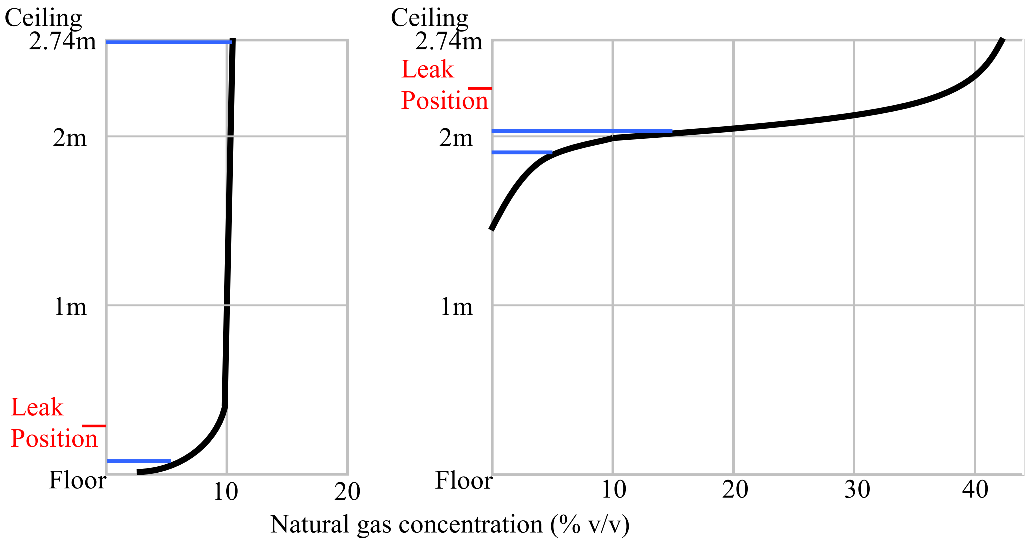


Figure 3.2.1, Possible height for detecting natural gas

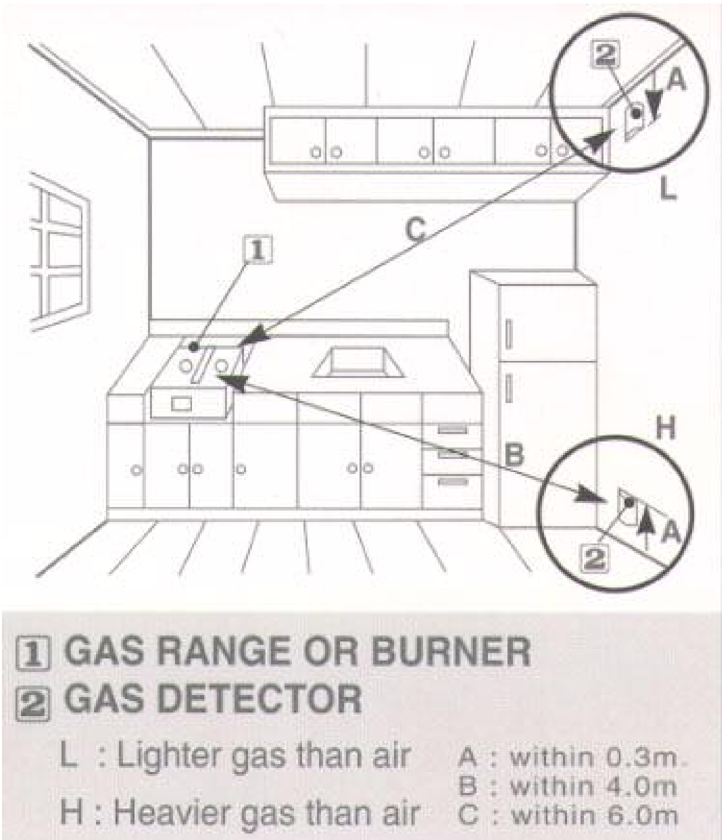


Figure 3.2.2, Typical positions for installing gas detection sensors (exact distance may vary dependant on the sensor design)

3.3 Gas Sensor Technology

There are several gas sensor technologies that could be used for this system. Each of them has their advantages and disadvantages. These will be discussed briefly in this chapter along with their principles of operation.

Sensor Type	**Detectable Gas**
Catalytic Bead	Combustible Gas
Semiconductor	Combustible Gas and Toxic Gas
Infrared	Combustible Gas and Carbon Dioxide
Electrochemical	Oxygen and Toxic Gas

Figure 3.3.1, Different types of gas sensor technologies and their applications

3.3.1 Catalytic Bead Sensors

These sensors are used to monitor combustible gases. This design is poison-resistant and provides reliable zero stability and linear response to combustible gas over a wide temperature range.

The sensors consist of two catalytic beads as shown in Figure 3.3.1.1. One bead is passivated so it will not react with combustible gas. The other bead is catalysed to promote a reaction with combustible gas. When the catalysed bead reacts with combustible gas it heats up, this increases its resistance and, in turn, increases the output signal. This is then translated into a percentage of LEL (the Lower Explosion Limit) for the target gas.

To nullify the effects of changes in ambient temperature and relative humidity, a Wheatstone bridge circuit is normally used along with the beads.

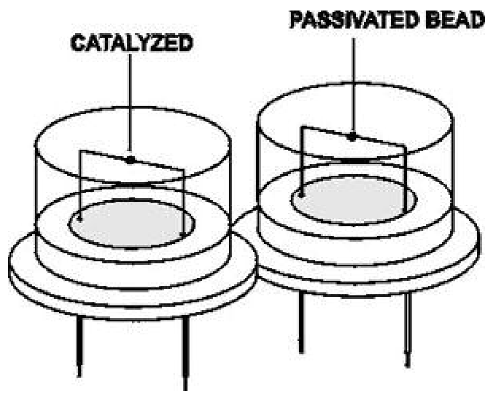


Figure 3.3.1.1, Catalytic Bead Sensor

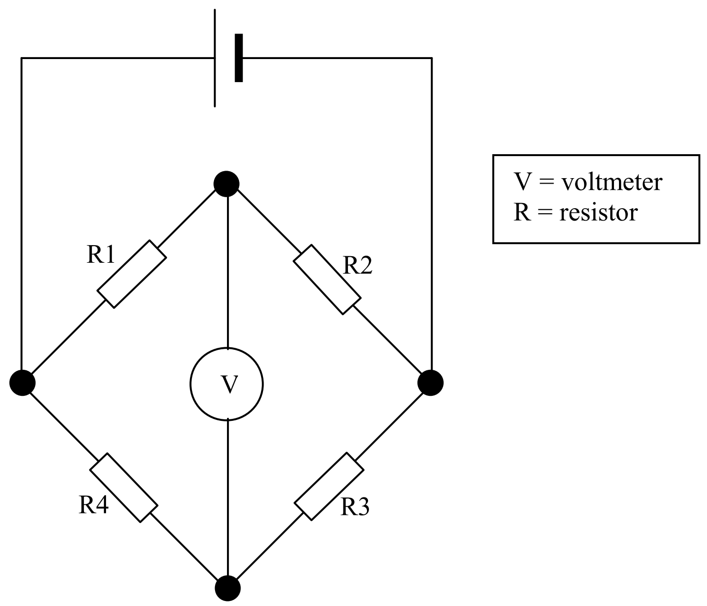


Figure 3.3.1.2, Typical Wheatstone Bridge Circuit

Advantages:

Catalytic Bead sensors are low cost devices that allow continuous monitoring enabling leaks to be detected very quickly. There are no moving parts within these kinds of sensors therefore mechanical failure is non-existent.

Disadvantages:

Some sensors respond to gases other than those they are required to detect. These kinds of sensors require quarterly calibration and do not have a long life span.

3.3.2 Semiconductor Sensors

Semiconductor sensors have a resistance in air that is affected by oxygen adsorbed on the surface of the sensor. Oxygen atoms capture electrons on the semiconductor surface, thereby increasing its resistance.

The sensors can be impregnated with dopants such that the sensor's resistance changes when specific gases displace adsorbed oxygen. This resistance change is converted into a reading of concentration.

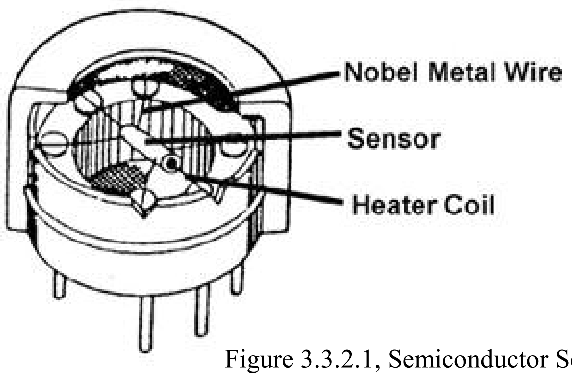


Figure 3.3.2.1, Semiconductor Sensor

Advantages:

Semiconductor sensors have a very long lifetime (approximately 10 years) and they are inexpensive. They have the ability to detect a wide range of gases. Usually, this kind of sensor is used to detect gas at source giving a rapid response and providing continuous monitoring. Like catalytic bead sensors, they have no moving parts that can cause mechanical failure.

Disadvantages:

Semiconductor sensors have very low selectivity since they can detect a wide range of gases. They also have a higher susceptibility to false alarm states compared to other technologies. This kind of sensor could be oxidised and become dormant (i.e. not respond to a real gas leak) when they have not been exposed to gas for some time. Calibration of this kind of sensor is also more difficult and time consuming due to the fact that they provide a non-linear output.

3.3.3 Electrochemical Sensors

These sensors are fuel-cell-like devices consisting of an anode, cathode, and electrolyte. The components are designed to react with a specific toxic gas when it is diffused into the cell. This reaction generates a current which is measured and converted into a concentration value (*percent by volume* for oxygen and *parts per million* for toxic gases). The cell is diffusion limited so the rate the gas enters the cell is solely dependent on the gas concentration. The current generated is proportional to the rate of consumption of the subject gas in the cell.

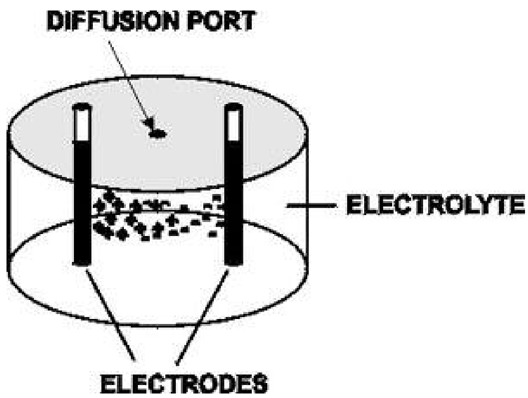


Figure 3.3.3.1, Electrochemical Sensor

<u>*Advantages:*</u>

Low cost devices that allow continuous monitoring such that a leak can be detected very quickly. There are no moving parts within these kinds of sensors and therefore mechanical failure is non-existence.

<u>*Disadvantages:*</u>

Some sensors respond to gases other than those they are required to detect. These kinds of sensors require quarterly calibration and do not have a long life span.

3.3.4 Infrared Sensors

Infrared sensors use spectrophotometric techniques for detecting gas. Most combustible gases absorb infrared light energy at defined wavelengths. The principle of the infrared sensor is based upon the absorption of the infrared light at a specific wavelength as it passes through the gas. The greater the amount of gas present, the more light energy absorbed. The resulting absorbance spectrum is then analysed to determine the constituents of the gas.

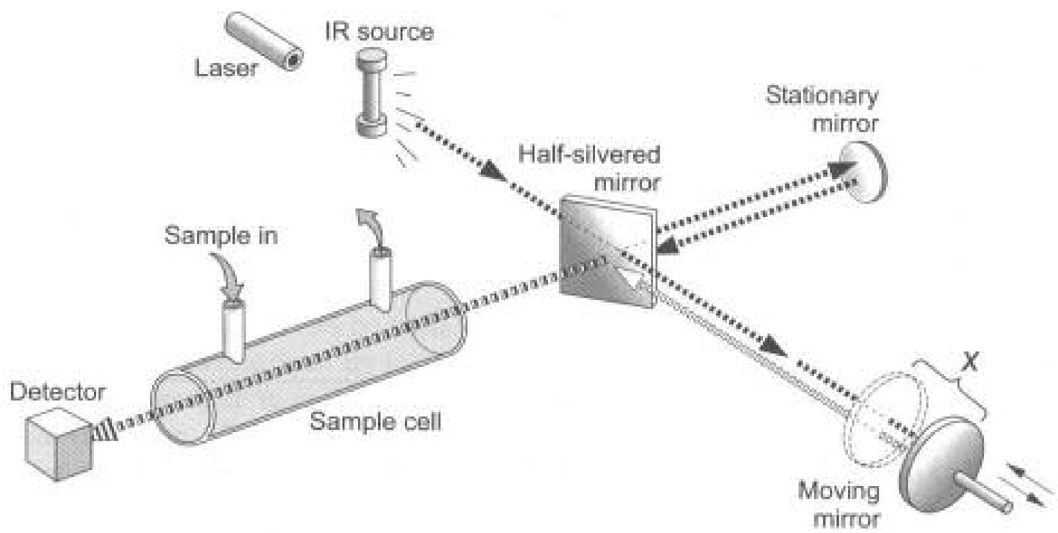


Figure 3.3.4.1, Basic Fourier Transform Infrared spectrometer

Advantages:

Infrared is the most accurate gas detecting method. It provides very good sensitivity and low risk false alarms. And it is very cheap to maintain since there are no consumables involved.

Disadvantages:

Infrared sensors are very expensive and because of that sensors are typically kept in a central location and connected to multiple detection points through sample tubing. As a result, significant time-lag can exist between a leak occurring and its detection. Mechanical failure is also an issue with this kind of sensor.

Chapter Four

4.0 Data Acquisition and Handling Systems

The gas leak detection system cannot be complete without a Data Acquisition and Handling System (DAHS). It provides two important functions which cannot be eliminated from the overall system. These functions are:

1. Control of the automatic functions of the system
2. Handling the data from sensors

Technical details of a DAHS are not discussed in this report, however a brief description of the system is given in this chapter.

The gas leak detection system cannot operate with gas sensors alone because all the data generated by the sensors has to be processed into a useful and understandable format before it can be transmitted, recoded and displayed either to humans or other machines. Usually this feat can be achieved within a single Data Acquisition and Handling System. However in practice, control functions are usually separated from the DAHS by using a data logger, programmable logic controller (PIC), or a separate microprocessor system. This separation provides more flexibility for both control, data acquisition and reporting. A simple structure diagram of the DAHS is shown in Figure 4.0.1.

The control system is in charge of all the automatic operations such as calibration, alarming of detection and system fault. The control system also performs data processing functions such as converting analogue data into digital form, calibration drift corrections, diluent corrections and other calculations necessary to convert the data into required units. Data can also be averaged over specified periods. Limited data storage (e.g. a week or so) for backup short-term failures are also possible with a controller.

On the other hand, DAHS focuses mainly on the editing, recording and displacing of the data. Most DAHS used today are PC-based or have a DEC - VAX platform, and run either UNIX, QNX or Windows NT operating systems with a commercial data acquisition program. Regardless of how the DAHS software is developed, some basic functions must be performed. These functions include those associated with system control, data acquisition and manipulation, and data handling functions such as editing, recording, displaying and reporting.

There are also certain requirements the DAHS software has to fulfil such as when data is acquired continuously from a bank sensor, it is not practical to record or report all the data received by the system. As a result:

- All data acquired is not recorded
- All data records are not reported

The system must also be able to warn the operator by "flagging" an error message if the system does not receive any data from the sensors in the ways it should be. Such a system check up could be organised. Today, there are many standards established by the US, International Standards Organisation, and a number of European countries for certifying systems (hardware, software, backup procedures and so on) that involve monitoring and measuring gas emissions. These standards (Figure 4.0.2) could be used as a guideline for a gas leak early warning system.

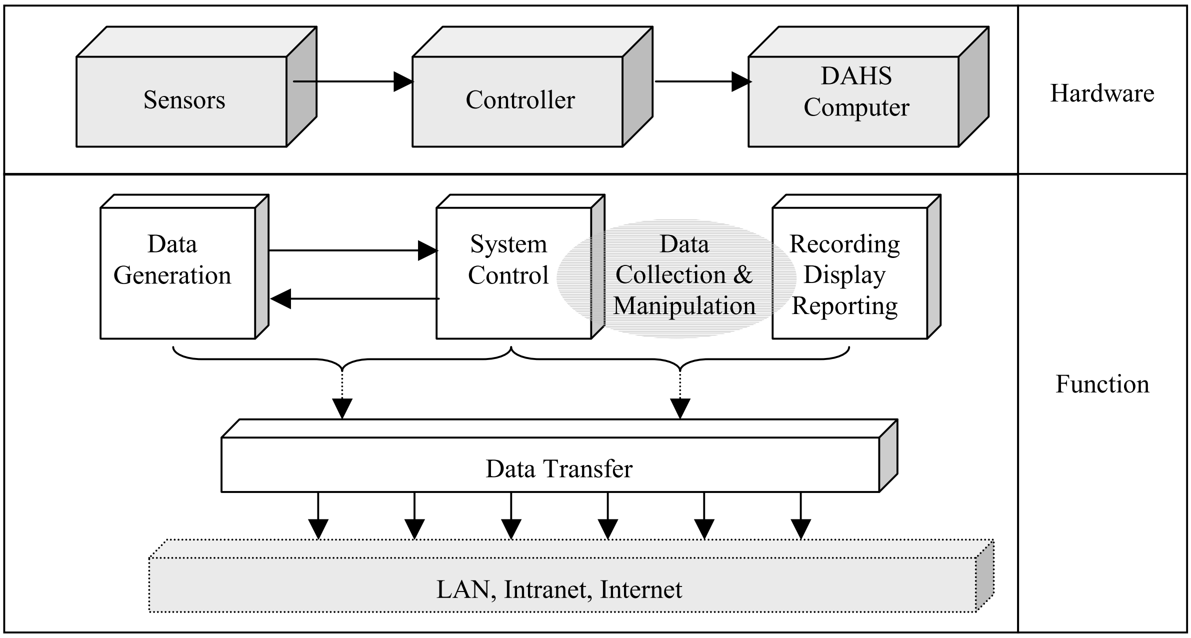


Figure 4.0.1, System Control and DAHS

International Standard Organisation (ISO) Standards	
ISO 7935:1992	SO2 – performance characterisitics for automated measuring methods
ISO 10155:1995	Automated monitoring of mass concentration of particles – performance characteristics
ISO 10396:1993	Sampling for the automated determination of gas concentrations
ISO 10849:1996	NOx – performance characteristics for automated measuring methods
ISO 14164:1993	Determination of velocity and volume flow rate – automated method
Other National Certification Standards	
United Kingdom	MCERTS

Figure 4.0.2, Performance Specifications and Standards

Chapter Five

5.0 Data Transmission

It is important that the different hardware and systems are able to communicate with each other (e.g. the sensors, DAHS, e-box and web server). They all have to be connected together in a robust way with either a physical or wireless link. The link provides a path for the data to be transmitted from one system to another. There is no standard approach for managing and transmitting the data. One thing is for certain, they all require some basic information technology and an associated system in order to ensure succeful and effective operation.

Interconnection network (or Internet) is a huge global networking system for computers and IT equipments. It allows data and information to be transferred in a very short time from one computer to another remotely situated computer which may or may not be in the same building or even in the same country. The development of global networking systems has removed the barriers of space and time which previously limited the communication abilities of individuals. It has improved co-operation between groups on a global scale. As a result, a global networked system could virtally collect information and data, and thus control other interconnected systems around the world at any time. This would provide enormous data acquisition and control function potential.

The Internet is intended to interconnect a wide range of information technology equipment. This equipment may vary in design and operation from brand to brand e.g. the sensors and the DAHS software mentioned in this report earlier. The data type that the DAHS system handles and the internal processing that it undertakes may vary as well. In order to be able to communicate successfully, these various sytems must have a common “language” for the exchange of data.

5.1 Standardisation

There are various different coding systems in existence for the task of mapping data generated by user applications into binary code. This is the language that computers can understand. For example, ASCII is the format widely used for both computer and data interchange purposes. The EBCDIC character set is used widely within IBM. There are many different representation formats for graphics (e.g. jpeg and tif), video signals (e.g. avi and wmv), media information (e.g. mpeg and m1v) and so on. Without an agreed standard, it is impossible for data to be exchanged between systems using different and incompatible formats.

Standardisation is always a problem for newly developed technology since there is no standard for designers to begin with. As a result, different systems made by different companies may or may not be fully compatible with each other. This problem has affected both home Internet users and Internet service providers (ISP) in the past. When the 56k modem was launched to the market, there were two totally incompatible standards used in the 56k modem technology; X2 for 56k modem made by US Robotic, and K56flex for 56k modem, made by all the other manufacturers such as Hayes and Motorola. In order to allow Internet users to be able to connect to the Internet, all the ISP's have to install two different systems to provide the support for both X2 and K56flex format users. Alternatively, the Internet users have to subcribe to an ISP that supports the format they are using. This results in, increased operational costs for the ISP and restricted choice for the users. The problem was not solved until September 1998 when a new standard V.90 was introduced by the International Telecommunication Union (ITU). Now consumers with the new standard-compliant 56k modems are able to choose from a virtually limitless number of ISPs that are also standard-compliant. This has increased the flexibility and reduced the operating costs for the ISPs, since only one system is required for providing support to the users.

It is likely that the Early Warning System will suffer a similar problem at the early stage of the implementation process if there is no early agreement on the standard which should be adopted. The standardistaion of the Internet is still an ongoing process, however, there are certain standards that have already been made, such as the standardistion of TCP/IP as the networking protocol. There are still many standardistion requirements which have to be addressed with the system, e.g. the protocol for linking the sensors to the DHAS and to other hardware, the data formats used within the system, and so on. Without these standardisation requirements, the system will become less compatible and users may be forced to use hardware or software that does not fully serve their own requirements in order to keep the system running.

Chapter Six

6.0 System Design

The basic and essential components required by the gas leak early warning system have already been discussed in the previous chapters. It is time to move on to the main part of the project which is the design of the system end user viewpoint, so that the data gathered by the data acquisition system can be viewed with normal web browsers through the Internet. Although all modern data acquisition systems have their own graphical display and networking functions, it would be very expensive for all computers to have the same commercial data acquisition software installed in order to view the data. The use of web browsers along with the specially designed viewpoint system is an economical but powerful alternative approach for accessing the data.

The layouts of the viewpoint are very important to the Early Warning System. It has to be clear and easy to navigate. Therefore the layout of each level has to be carefully designed. Their functions and purposes are explained in detail in the rest of this chapter.

6.1 Selection of Connection Type

Two types of viewpoint design can be employed for the gas leak early warning system. One is aimed at PC systems with broadband connection, and the other is for PC systems with slow Internet connection. Although the e-service system is aimed to provide services to broadband Internet users there are still many areas in the UK not yet connected to this technology. Also, most laptop computers are equipped with slow speed wireless connection. Thus, it is necessary to provide a specially designed viewpoint system for those who need to access the early warning system for information via computer with a less powerful Internet connection, using for example a 33.6k or 56k modem. To allow the operators to decide which viewpoint system to be used, based upon their computer power, a special viewpoint with selection of connection type has to be made. The design is shown in Figure 6.1.1.

Both narrowband and broadband designs would provide virtually the same information to operators except that a different format layout would be used. The viewpoint system for broadband connection would be use more graphical approaches and also provide more interaction between the operator and the system. On the other hand, the viewpoint system for narrowband connection would use a more text-based design to reduce congestion of the bandwidth.

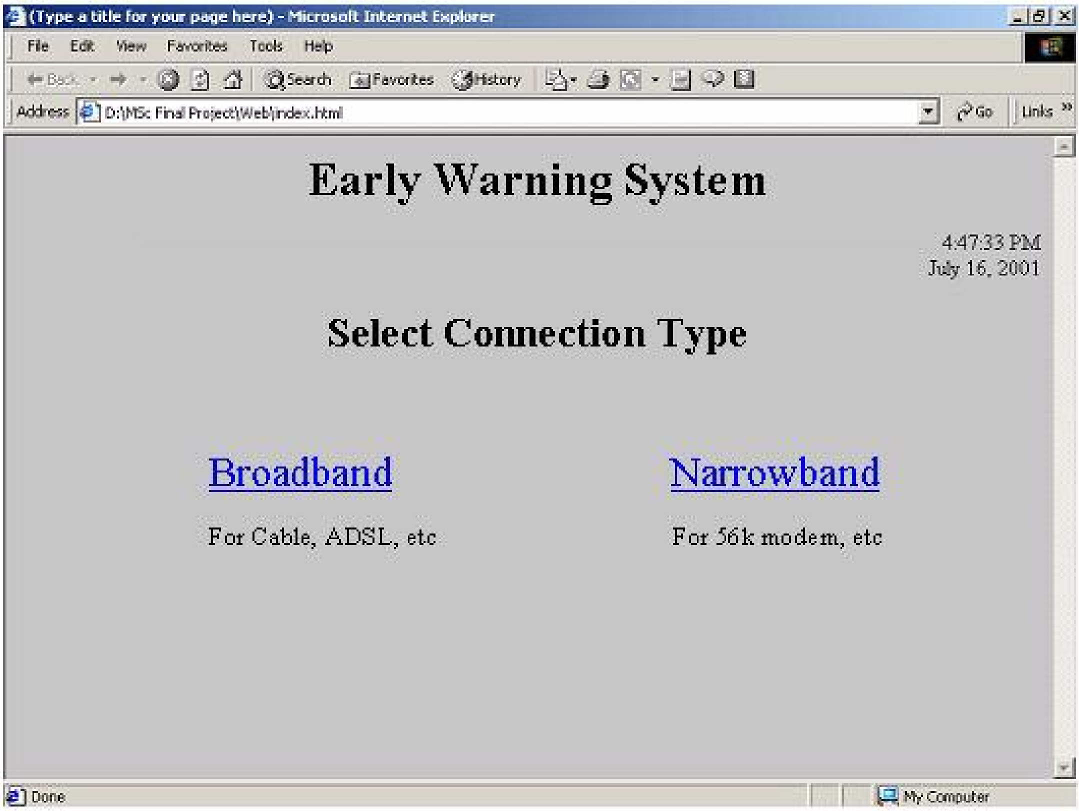


Figure 6.1.1, Viewpoint for user to select the preferable connection method

6.2 Security

To prevent unauthorised personnel and hackers from accessing the Early Warning System and viewing private information, a secured login page would have to be used. The design would be very simple and it is shown in Figure 6.2.1. Every single viewpoint of the Early Warning System as well as the login page has to be protected by using the latest encryption technology such as SSL throughout. Access information such as the date, time, user ID and the IP address of which the PC has been used to access the website has to be recorded into a secured log file. This could be used to help track back identify and prosecute those who deliberately attacked the system. An ISO reference model is shown in Figure 6.2.2. It is important that all new communication protocol would conform to the standard model.

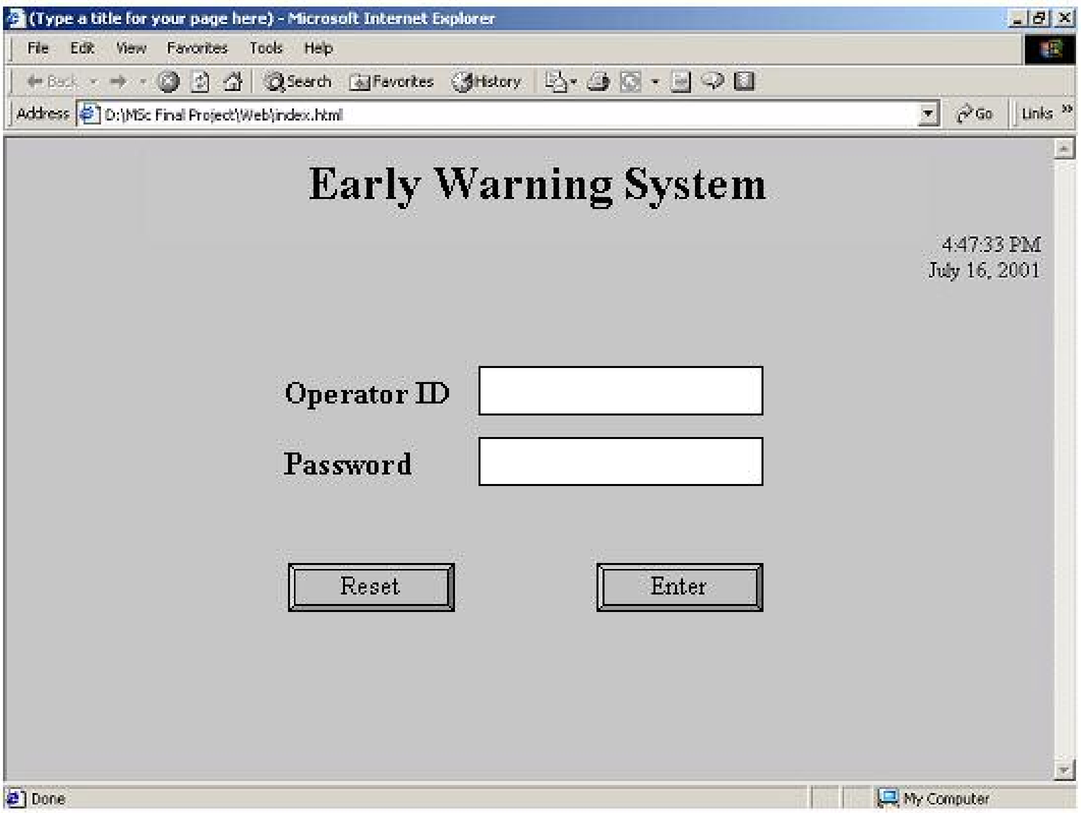


Figure 6.2.1, Login Page

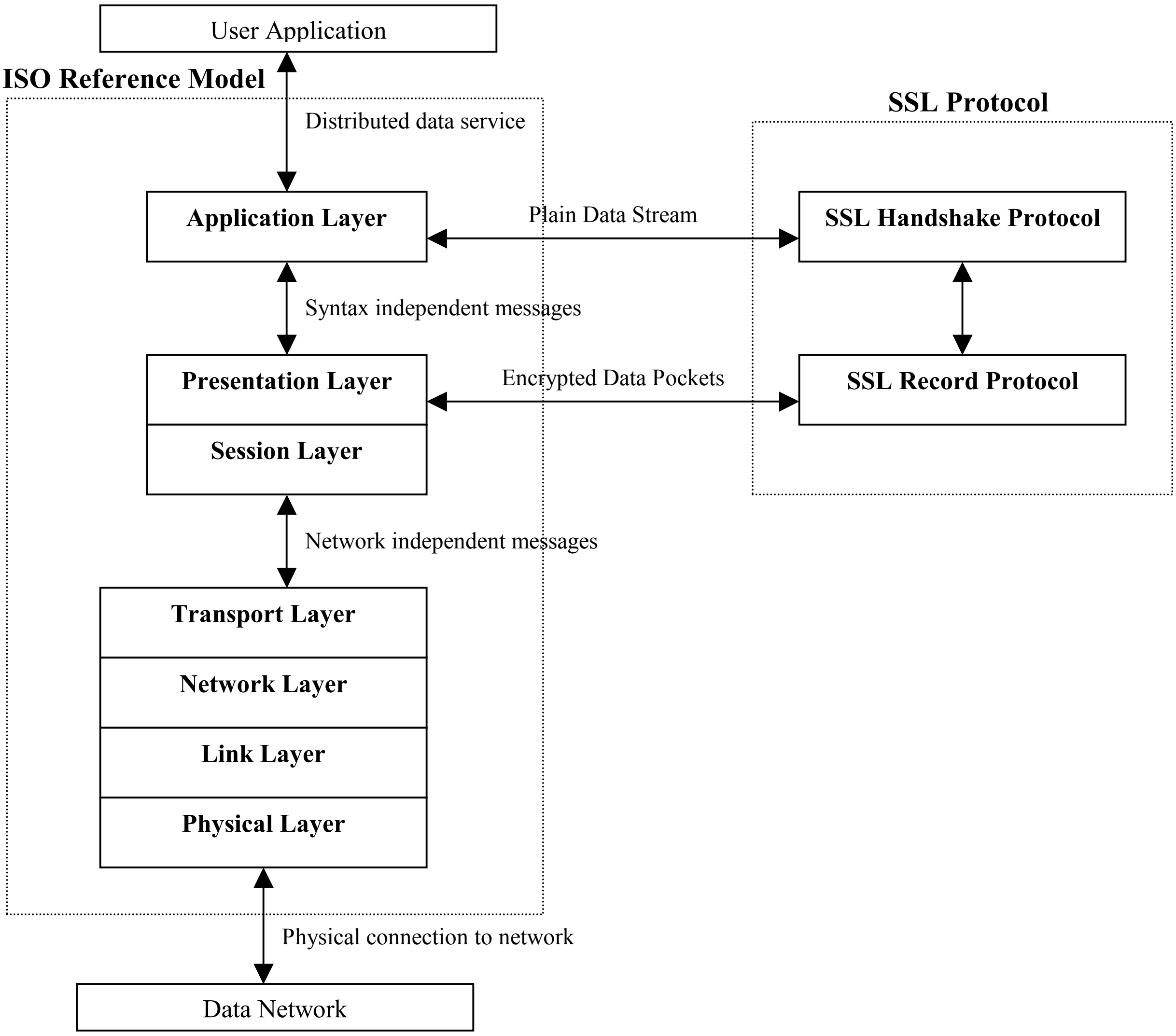


Figure 6.2.2, SSL and ISO Reference Model

6.3 Design of the Early Warning System

6.3.1 Regional Level Warning Viewpoint

The following viewpoint design is aimed for the broadband connection users. After selecting the appropriate connection type (broadband in this case), and logging in to the system, the operator would be redirected to this viewpoint where information regarding gas leaks would be found. The viewpoint design is shown in Figure 6.3.1.1 below.

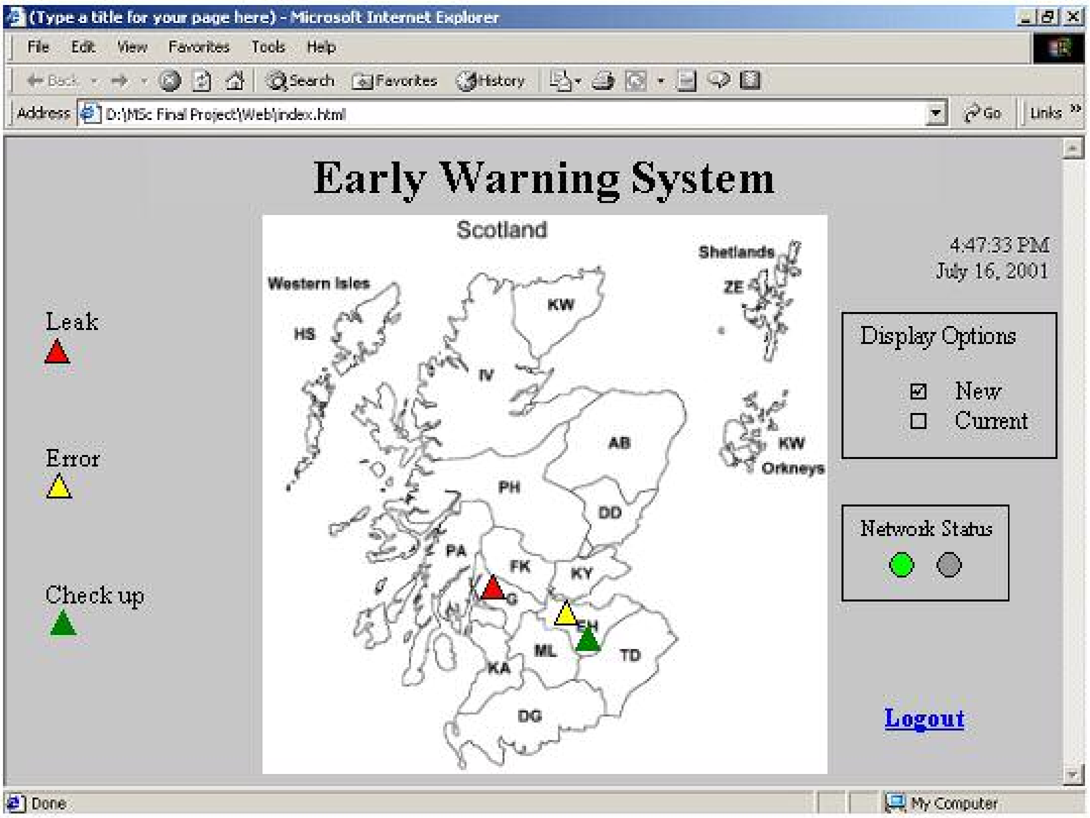
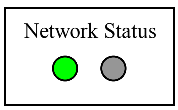


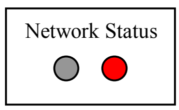
Figure 6.3.1.1, Regional Level Warning Viewpoint - Interactive Scottish map with general postcode division

The map in the middle of the viewpoint has to be built interactively and also divided into appropriate postcode divisions. When there is a detection of a gas leak, a system error, or simply a system check due, a triangle with a specific colour code corresponding to the detection type (e.g. leak, error and check up) would appear on the area where the detection is received. For example, Figure 6.3.1.1 indicates that there is a gas leak in the G area (i.e. Glasgow), and a system error and check-up warning in the EH area (i.e. Edinburgh). At this stage the operator would not be able to tell exactly where the leak, error and check-up is, however, the operator could click on the area where there is a warning to redirect to the next viewpoint (Figure 6.3.2.1). Here, more detailed information could be reviewed.

One important requirement for the viewpoint system is that every single viewpoint used must be able to refresh itself automatically. This is because the information within the Early Warning System changes all the time. In order to display up-to-date information through the browser, constant refreshment is required. The network status function on the right hand side of the viewpoint window is to provide a constant network connection check (e.g. using ping) between the local PC and the web server, such that any network error, failed connection or unsuccessful refreshment could be spotted quickly. The network status function is an important system reliability measure. Their graphical meanings are described below.



This is no problem with the network connection



There is a problem with the network connection

All viewpoint windows have a customisable display option which would allow the operator to change the way the viewpoints should be displayed in the future. If the operator selected "New", any new viewpoint would be displayed in a new browser window. If the operator selected "Current", any new viewpoint would be displayed using the current browser window.

Current time and date would also be presented within all the viewpoints, and this information would be recorded on every single viewpoint when printed. It is a very standard piece of information which is useful for organising and keeping files, data and information.

As mentioned earlier, under certain situations, the operator might have to use a computer with a less powerful Internet connection to access the early warning system. An example would be those working at a scene of a gas leak and requiring to access the system for information using a laptop computer. Thus, the regional level warning viewpoint would need to be simplified so that it is more bandwidth friendly.

The design of the regional level warning viewpoint for use with narrowband computer is shown in Figure 6.3.1.2.

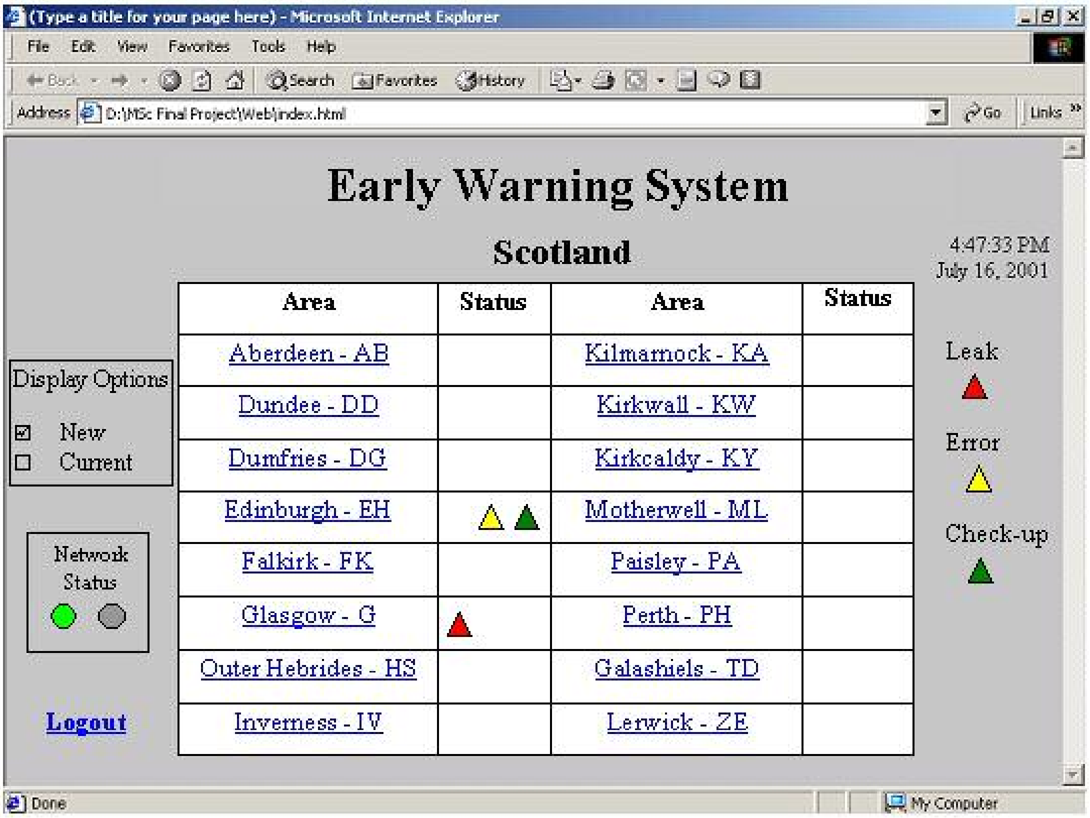


Figure 6.3.1.2, Regional Level Warning Viewpoint for narrowband Internet connection - An interactive table with all Scottish regions.

The regional level warning viewpoint for use with a narrowband system is shown in Figure 6.3.1.2 above. It uses the same structure as the one for the broadband connection. In fact, the basic functions are identical except that this one uses an interactive table instead of an interactive geographical map to reduce the use of bandwidth. All regions within Scotland are presented in the table using hypertext links, which would direct the operator to the narrowband version of the local level warning viewpoint (Figure 6.3.2.3). The operation of this viewpoint is also very similar to the one designed for the broadband connection. When there is a gas problem detected within a particular region, a warning with specified colour (i.e. red for gas leak, yellow for system error, and green for check-up due) would be displayed beside the hypertext link that belongs to that particular region under the column *status* as shown in Figure 6.3.1.2.

6.3.2 Local Level Warning Viewpoint

The local level warning viewpoint is only accessible by clicking on the postcode area on the regional level warning viewpoint (Figure 6.3.1.1) where a triangle warning has been flagged up.

Once the local level warning viewpoint is accessed, a detail map is presented. The example in Figure 6.3.2.1 shows the "G" postcode area. Any areas with a gas problem would be identified using the same triangle colour code as before. For easy viewing an enlarged map is shown in Figure 6.3.2.1a.

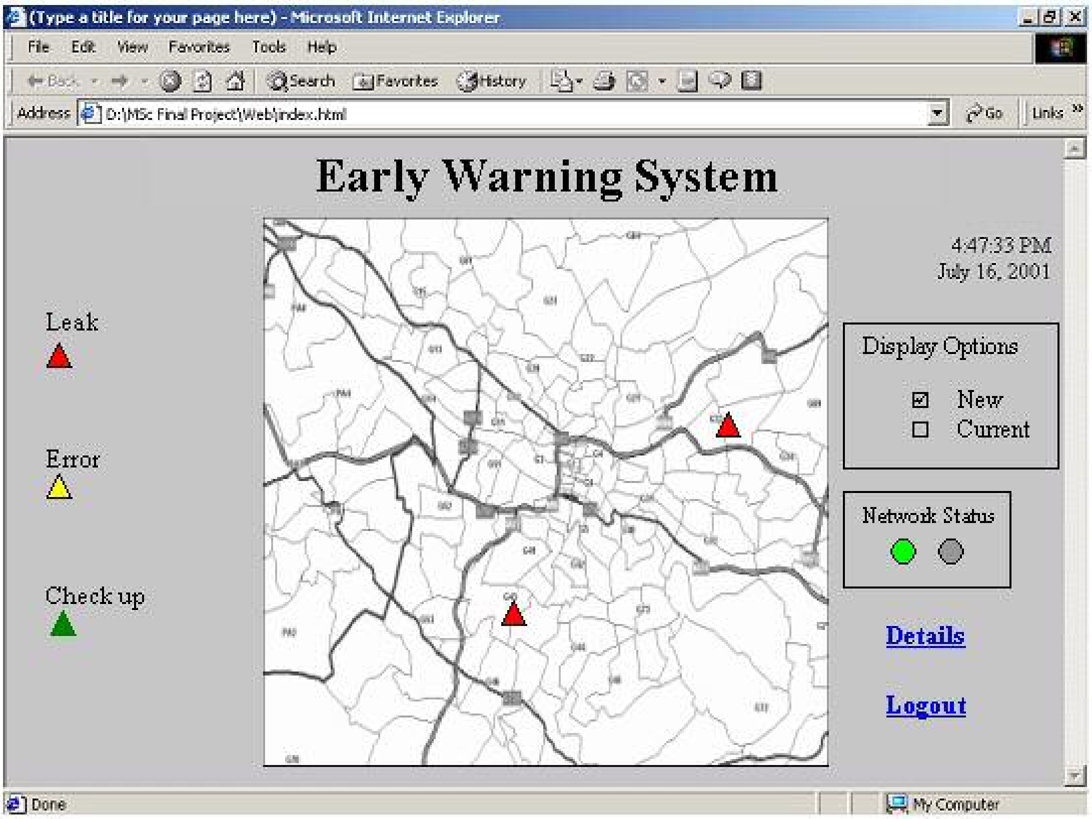


Figure 6.3.2.1, Local Level Warning Viewpoint - Interactive map with sub-postcode division of Glasgow.

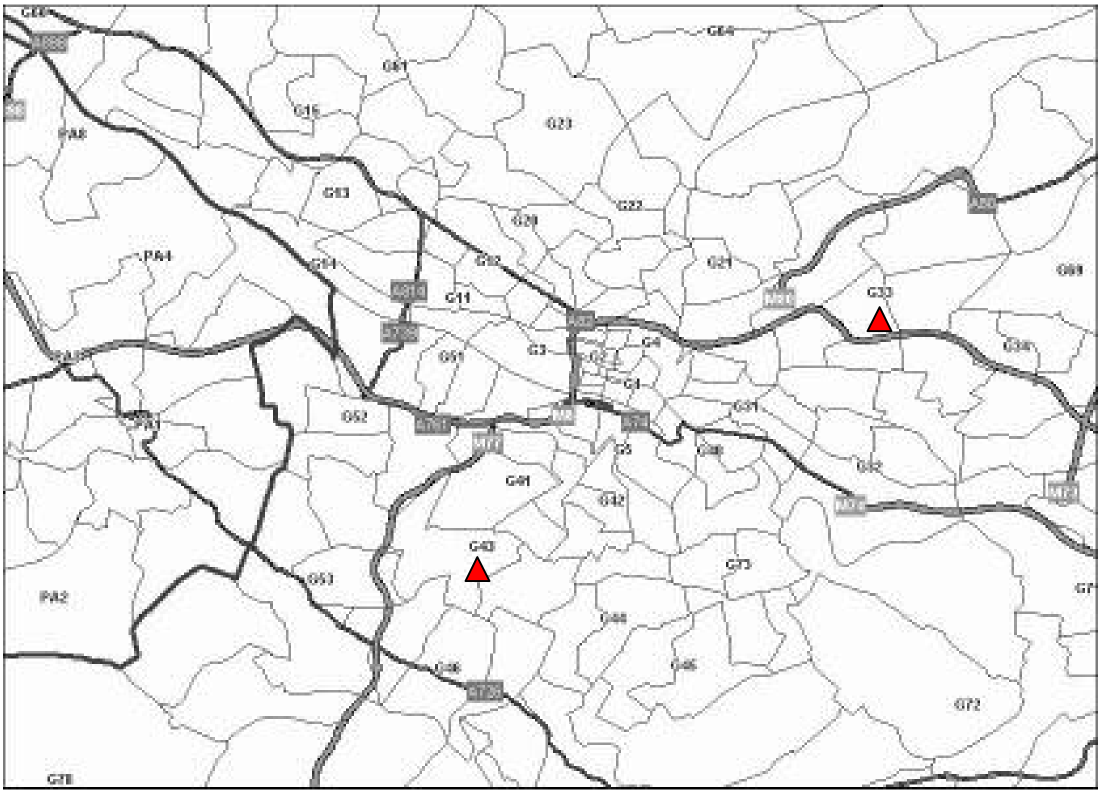


Figure 6.3.2.1a, Enlarged map of Glasgow

The above map Figure 6.3.2.1a indicates the locations where detections are received within the G postcode area. In this example, there are two detections, one in the G33 area and the other one in the G43 area. In this viewpoint, the operator could either click on the link named **Details** to review all the addresses that have gas problem within Glasgow or click on the specific postcode area (e.g. G33) that has flagged up gas problems on the map. This is in order to review only the addresses within that particular area (e.g. G33). The layout of the viewpoint for displaying these addresses would be identical except some sort of filter might be used to eliminate addresses that are not required.

Again, this viewpoint has another version for use with a narrowband connection link and it is shown in Figure 6.3.2.3.

The local level warning viewpoint for use with the narrowband computer is only accessible by clicking on the regional hypertext link on the narrowband version of the regional level warning viewpoint as shown in Figure 6.3.1.2. The information to be displayed in this viewpoint again would depend upon the action of the operator. If the operator clicked on the hypertext link named "**Glasgow - G**", information relating to the gas problem within Glasgow would be displayed. If the operator clicked on the hypertext link named "**Edinburgh – EH**", information relating to the gas problem within Edinburgh would be displayed instead. The design of the narrowband version local viewpoint is illustrated in Figure 6.3.2.3 below, the assumption being that the operator selected Glasgow.

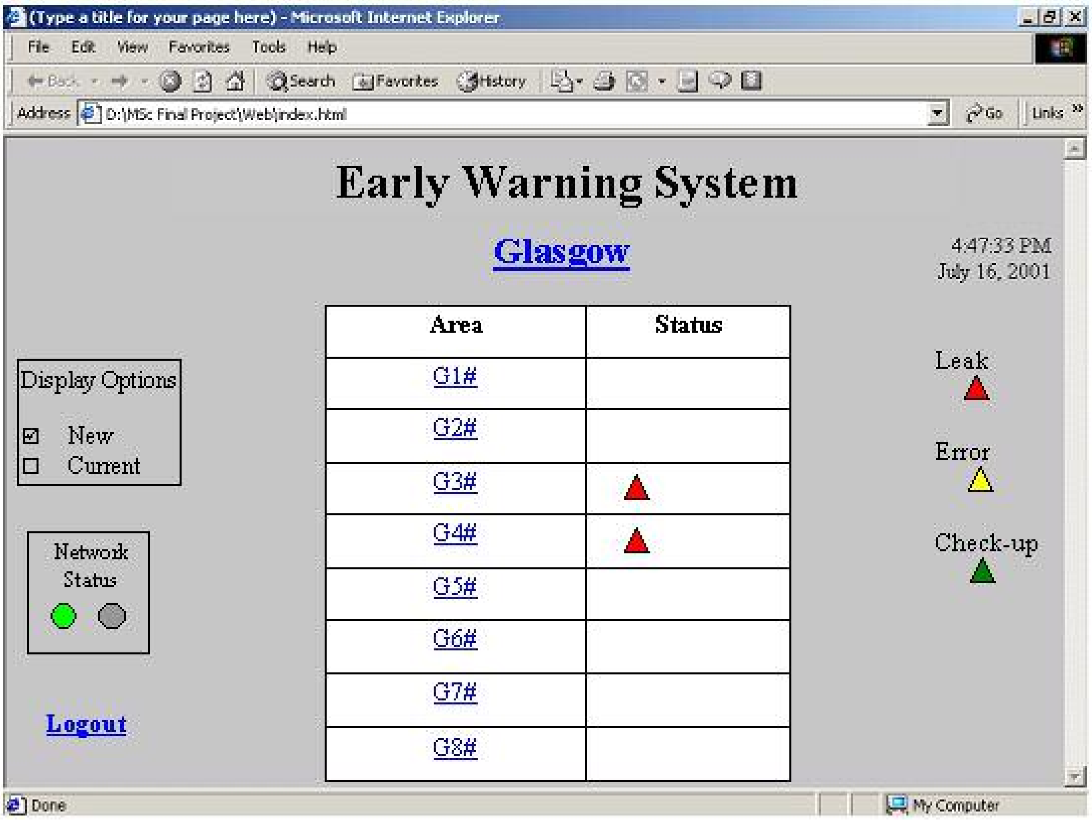


Figure 6.3.2.3, Local Level Warning Viewpoint for narrowband Internet connection - Interactive table with all postcode areas within Glasgow

As illustrated in Figure 6.3.2.3, all postcode areas within Glasgow are arranged into groups such as G1# for area G1 up to G19, G2# for area G2 up to G29 and so on. This design is to minimise the number of areas being displayed on the same page at the same time. In Glasgow, there are more than 80 sub-postcode areas. If each of them were to be displayed in this viewpoint individually that would make the screen overcrowded and make the information on the viewpoint window very difficult to read. The author believes it is more beneficial to the operator if all the areas were are arranged into small groups. This approach would also apply to other cities and towns such as Edinburgh, etc.

The operation of the local level viewpoint would again be very similar to the one designed for the broadband connection, except, this one would use a table instead of a map. The nature of the gas problem would be presented with the specified colour code appearing beside the postcode area (link) where there is a gas problem. Figure 6.3.2.3 shows that a gas problem has been detected within G33 and G43 areas. There are two ways to review the details. One is click on the link named "**Glasgow**" to review all the addresses within Glasgow (G area) where there is a gas problem, or click on the individual link (e.g. G3# or G4#) to review addresses only belonging to that particular area group. In such a case, a filter would be used to eliminate the addresses that are not required.

The viewpoint design for displaying the addresses for both broadband and narrowband are identical, and it is described on the next page.

6.3.3 Addresses Listing Viewpoint

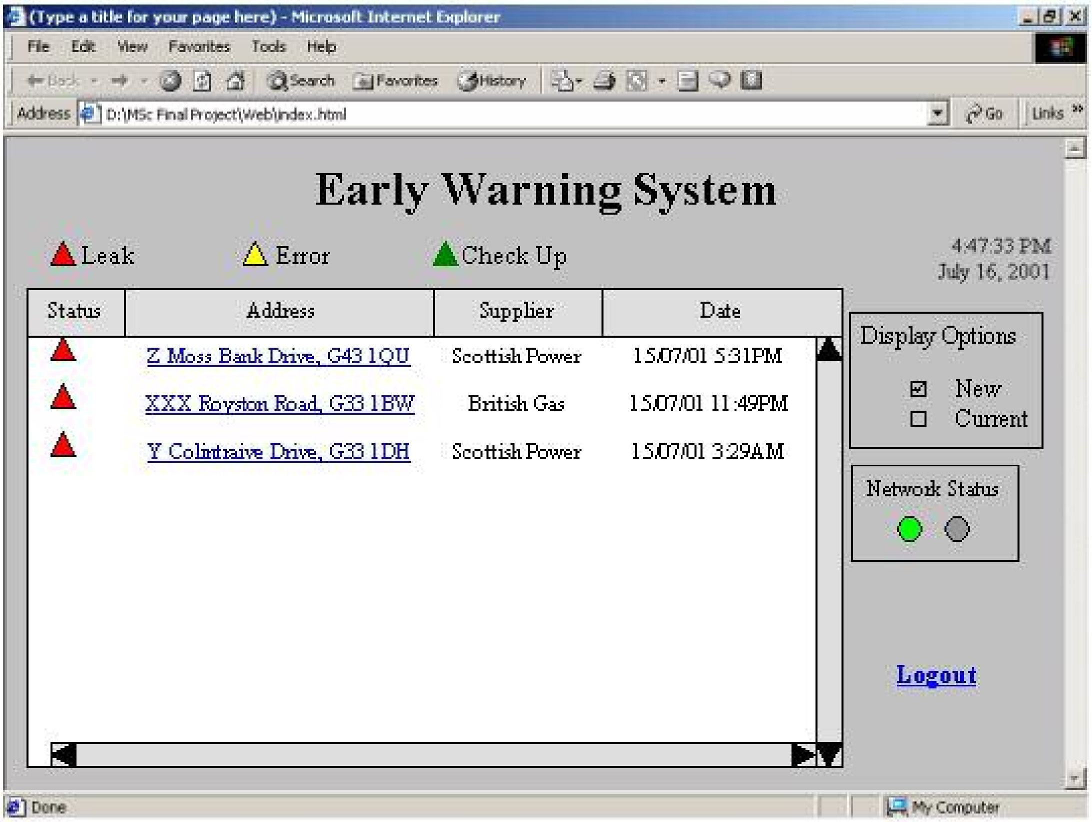


Figure 6.3.3.1, Addresses Listing Viewpoint - Showing all the addresses with suspected gas problem (access through the link **Detail** or **Glasgow** for narrowband version)

The above viewpoint has listed all the addresses within Glasgow (G area) where there is a gas problem. This page has to be accessed through the link named **Detail** or the link **Glasgow** for narrowband version on the local level warning viewpoint. Information such as status, exact address of the location of the detection, supplier, and the date and time when the detection is received are all displayed in this particular viewpoint.

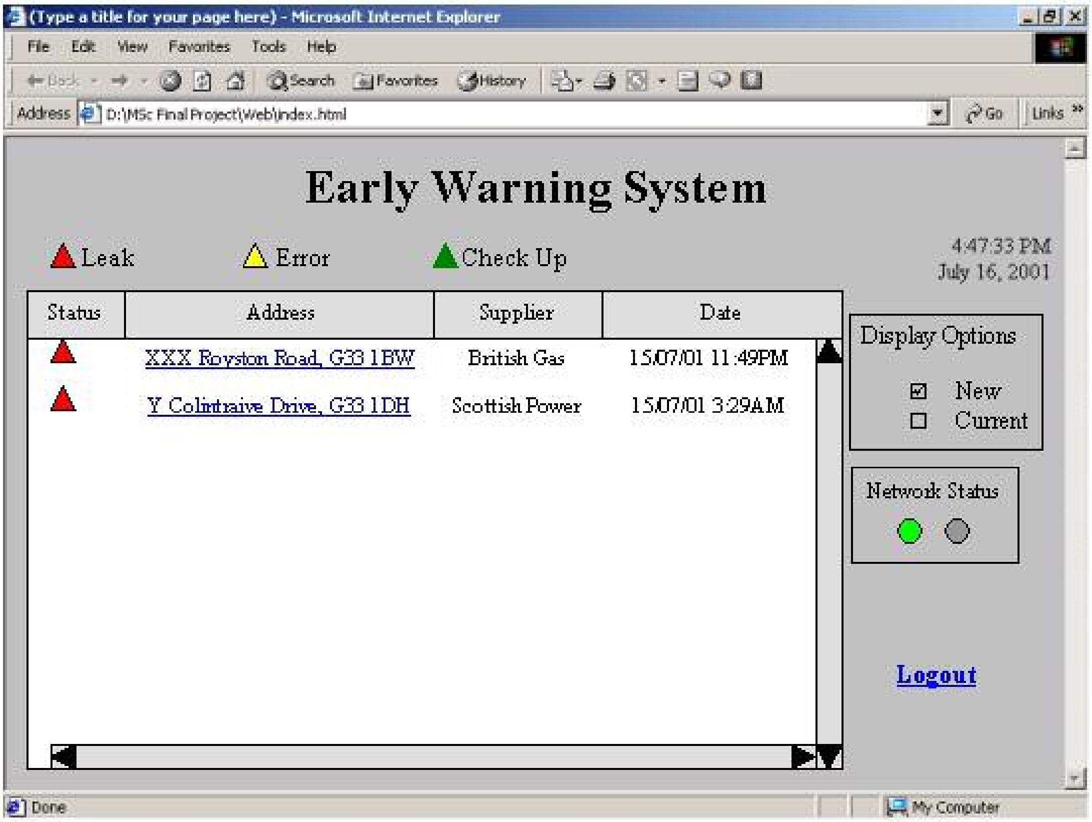


Figure 6.3.3.2, Address Listing Viewing - Showing the addresses only in a particular postcode area (access through interactive map on the local level viewpoint, e.g., G33)

All the functions in Figure 6.3.3.2 are identical to Figure 6.3.3.1 except this one only shows addresses within a particular area. This viewpoint has to be accessed through the interactive map on the local level viewpoint as shown in Figure 6.3.2.1, or the interactive table as shown in Figure 6.3.2.3 for the narrowband version. The address area to be displayed on this page depends on the area selected by the operator. For example, only addresses in the G33 area would be displayed if the operator clicked on the G33 area on the interactive map, or addresses within G3# group would be displayed if the operator click on the link **G3#** on the interactive table. Each address listed on this page is inserted with a hypertext link which would be used to direct the operator to the next viewpoint where detailed information on the house could be reviewed.

6.3.4 Individual Level Viewpoint

The individual level viewpoint is use to display detailed information of a house, e.g. the house interior structure, sensors location and gas analysis results. This viewpoint has to be accessed through the addresses links listed on the previous viewpoint such as Figure 6.3.3.1 or 6.3.3.2. The information to be displayed in this viewpoint would again be dependant on the action of the operator. If the operator clicked on the link, say, XXX Royston Road, G33 1BW, only information related to the house at that address would be displayed. However, if the operator clicked on the link, say, Z Moss Bank Drive, G43 1QU, information on the house at Z Moss Bank Drive, G43 1QU, would be displayed instead. The design of the individual level viewpoint is illustrated in Figure 6.3.4.1.

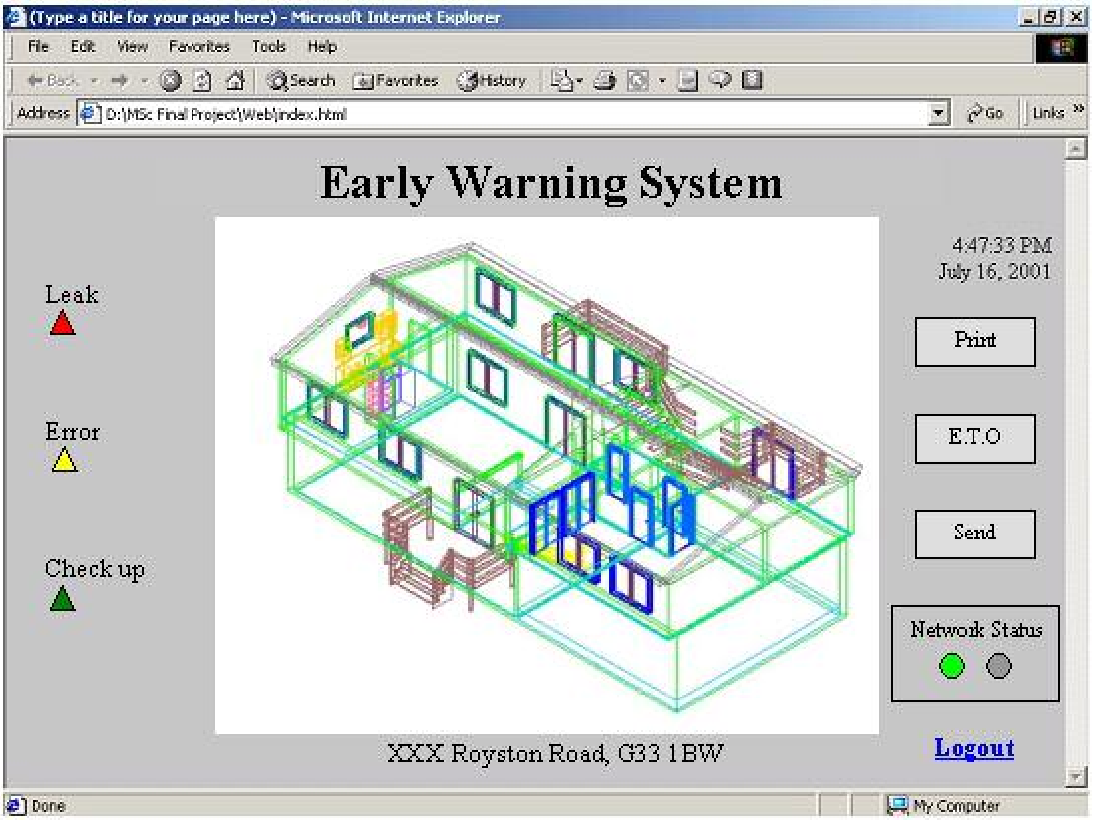


Figure 6.3.4.1, Individual Level Viewpoint - Showing detailed information on the house where there is a gas problem.

The 3-dimensional model of the house in Figure 6.3.4.1 has to be built interactively. The model should be able to be rotated 360 degree by using the mouse controlled by the operator such that he/she could review every single detail of the house at any angle they wish. Where a room within the house is identified as having, a gas problem, that particular room would be completely filled in with the colour specified at the left hand side of the viewpoint window. This would give an indication as to the operator the nature of the problem. For example, red for gas leak, yellow for system error and green for system check-up. By clicking the room that has a problem on the 3-D model the operator can review the detailed information on the room through a new viewpoint. The information to be displayed in the new viewpoint depends upon the nature of the problem such as gas leak, system error or system check-up. A set of different designs would be used for displaying the information on gas leak, system error and system check-up and they are illustrated in Figures 6.3.5.1, 6.3.5.2 and 6.3.5.3 respectively.

The *Print* function on the right hand side of the viewpoint in Figure 6.3.4.1 would allow the operator to print out the 3-D model of the house for reference. The S*end* function would allow the operator to send the model electronically to other cooperatives (such as the fire department) such that they could get hold of information on the interior layout of the house very quickly. That could help them to carry out safer rescue operations and locate problems quickly. The E.T.O (Emergency Turn Off) function would allow the operator to shut down the gas supply to the house remotely and quickly when there is a risk that the gas concentrations within the house could reaches a dangerous level. This assumes that the house has a network controllable gas supply switch installed.

This viewpoint also has another version for use with the narrowband computer. It is illustrated in Figure 6.3.4.2.

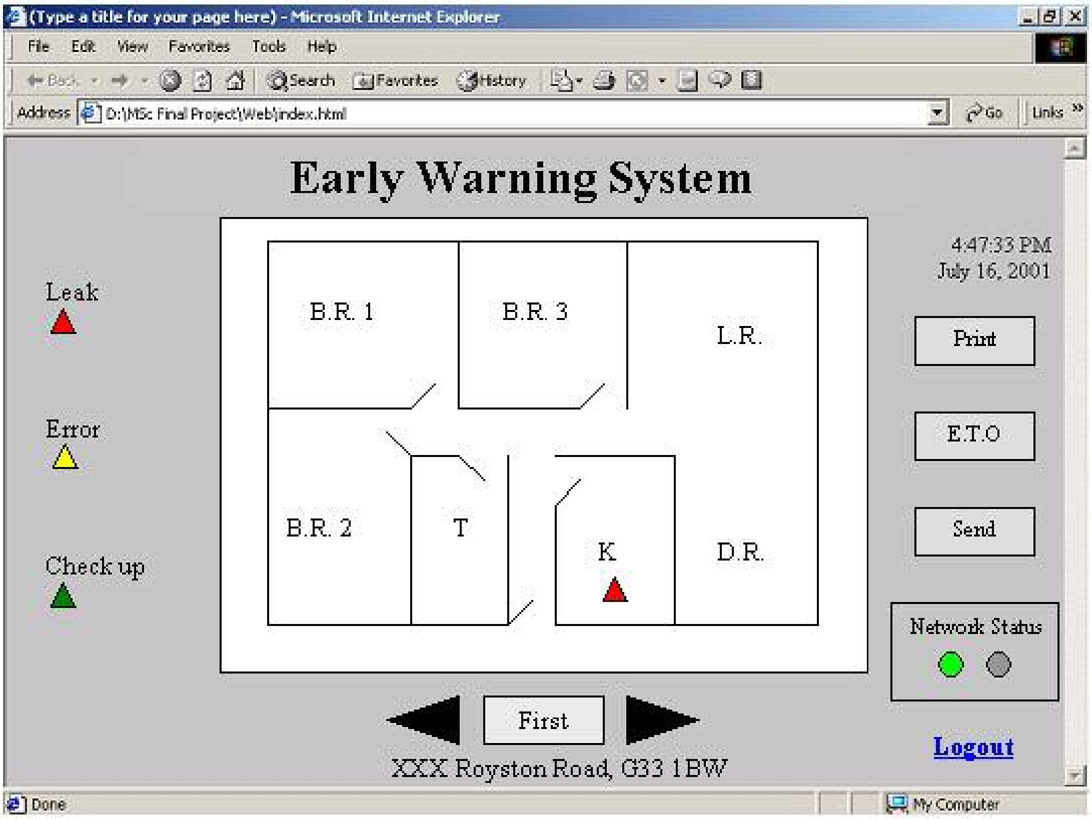


Figure 6.3.4.2, Individual Level Viewpoint for narrowband Internet connection - Showing detailed information of the house where there is a gas problem.

Unlike the individual level viewpoint for the broadband connection , the narrowband viewpoint would only use a 1-dimensional house model to display the house layout. However, the operator could use the arrow key pointing to the right to jump to the next floor if the house has more than one floor, and using the key pointing to the left to go back a level. The key named "First" is used to take the operator back to the beginning. All the other functions are identical to Figure 6.3.4.1, an equivalent viewpoint to that designed for broadband connection use.

In this narrow design, any gas problem within the house will be notified by appearing a warning symbol with a specified colour code (i.e. red for gas leak, yellow for system error and green for system check-up) at the location where the problem is detected. Figure 6.3.4.2 illustrates a gas leak occurring in the kitchen (K). By simply clicking on the room that has the gas problem (e.g. kitchen) operator could review the details of the room through a new viewpoint. The information to be displayed in the viewpoint would depend upon the nature of the problem. The window designs for gas leak, system error and system check-up are identical to the three designs used in the broadband connection, which are shown in Figure 6.3.5.1, 6.3.5.2 and 6.3.5.3 respectively.

6.3.5 Additional Viewpoint for Gas Leak, System Error and Check-Up

The gas leak viewpoint is for displaying the gas analysis result in a format as shown in Figure 6.3.5.1. Information such as the address of the building, sensors location within the building, gas type, concentration of the gas within the building, and the gas concentration value where the gas could become explosive, would all be displayed in this window. All this information can also be printed and transmitted by using the function keys on the left hand side of the viewpoint window. The operator could also turn off the gas supply if the gas concentration approached a dangerous level, assuming that the building would have a has network controllable gas supply switch installed. The concentration level when gas becomes explosive (also known as lower flammability limit) is dependent upon the gas type. The limit for natural gas is 5% v/v (see Figure 3.0.1 for details).

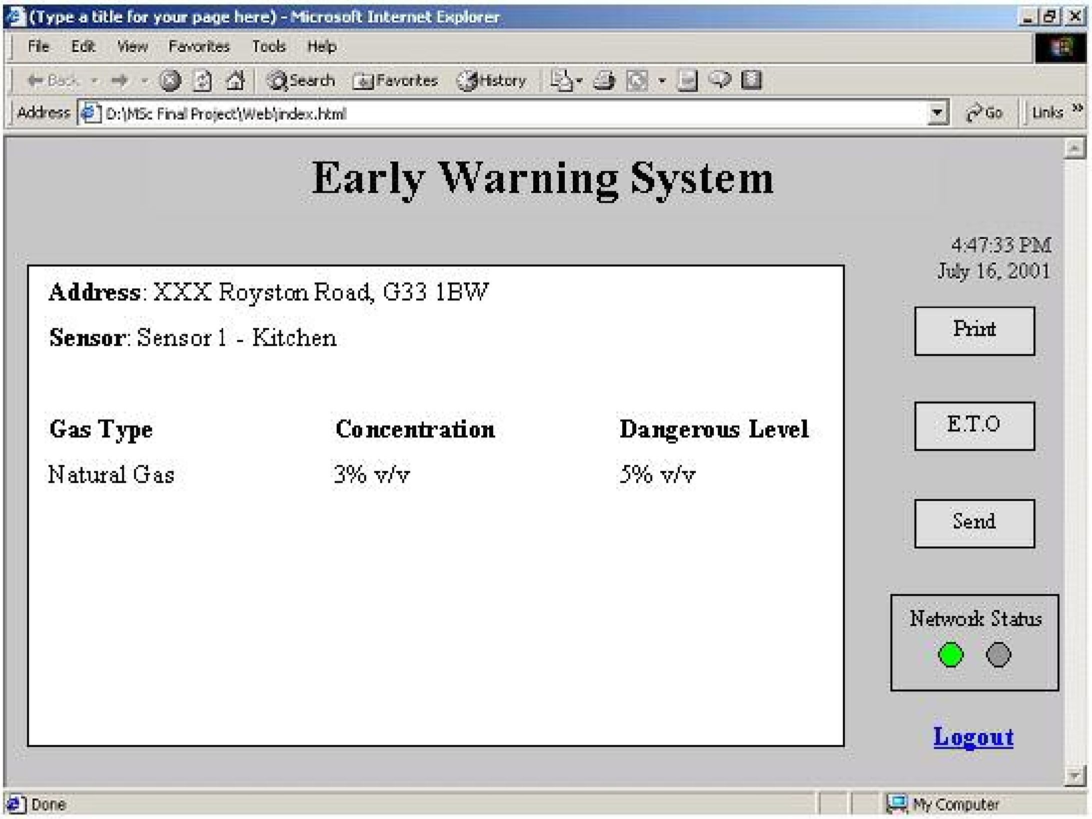


Figure 6.3.5.1, Viewpoint for displaying gas leak information

The system error viewpoint would display an error message should the gas leak detection system malfunction for any reason. For example, if a sensor within the building is not communicating with the main system, an error message such as the one shown in Figure 6.3.5.2 would be displayed. Being alerted to the system malfunction, the operator could then arrange for a technician or engineer to be sent to the scene as soon as possible in order to conduct a full system check-up. Such a warning function is crucial and provides a high level of security to the gas leak early warning system.

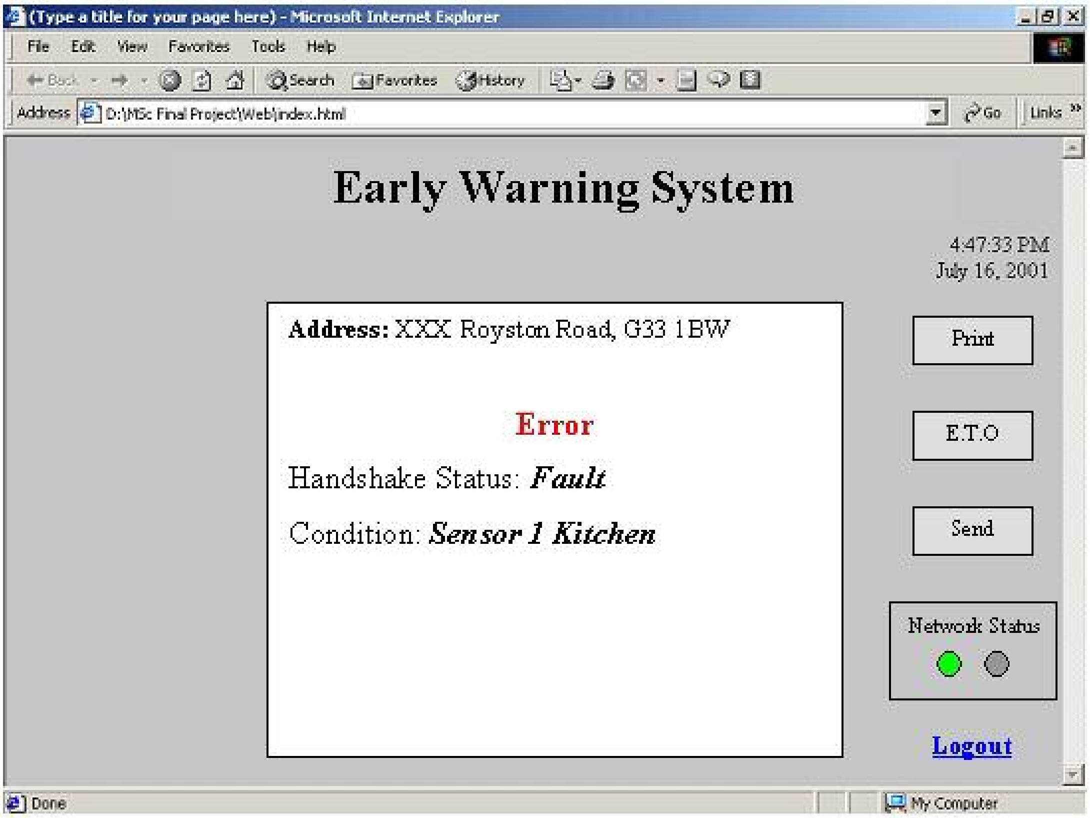


Figure 6.3.5.2, Viewpoint for displaying system error warning

It is important to ensure maximum reliability of the gas leak early warning system, particularly the gas detection sensors. To ensure that this is the case, regular system checks and maintenance would be required.

The objective of the "system check-up" warning as shown in Figure 6.3.5.3 is to act as a reminder to the operator to send out technicians or engineers to buildings to carry out the regular system check-up and maintenance works. Information that would be displayed in this viewpoint includes the date and time of the previous check-up, and the date and time for the next check-up. An automatic countdown of the days remaining would also be provided to remind the operator of the time left until the next check-up. Once again, all this information could be printed and transmitted electronically by using the function keys on the right hand side of the viewpoint window. The E.T.O function would not be available in this viewpoint because there is no perceived risk should this warning be instigated.

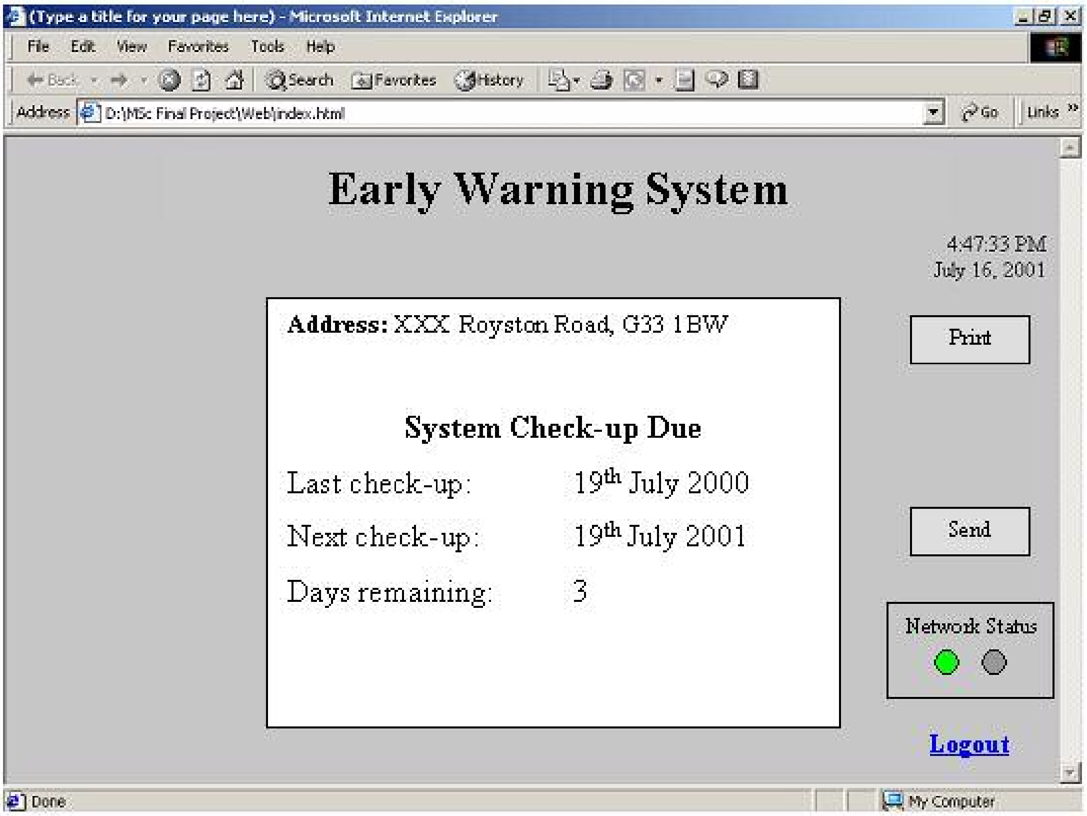


Figure 6.3.5.3, Viewpoint for displaying system check-up history

Currently, the proposed design would be for use only in Scotland. However, it would be perfectly feasible for the system to be adapted for use in other parts of the United Kingdom. It should be emphasised that there are distinct advantages in applying economies of scale to the deployment of such systems. Local area deployment is preferable to creating one single UK - wide system because of the massive amounts of information that would be generated. A devolved system would be a solution.

The proposed design would allow the operator(s) to zoom-in to any local postcode area which flagged-up a potential gas problem. This would be done in steps. The author believes that such an approach could effectively limit the amount of displayed information, while maintaining 100% system supervision at all times. Ideally, the area covered by such a system and the duties and responsibilities of the operator should be equally balanced. This would minimise mistakes in the system. The operator would be able to review his/her information domain more effectively.

The effect on hardware requirements and associated costs of deploying such devolved systems are:

- An increase in the amount of hardware required.
- An associated increase in capital and running costs.

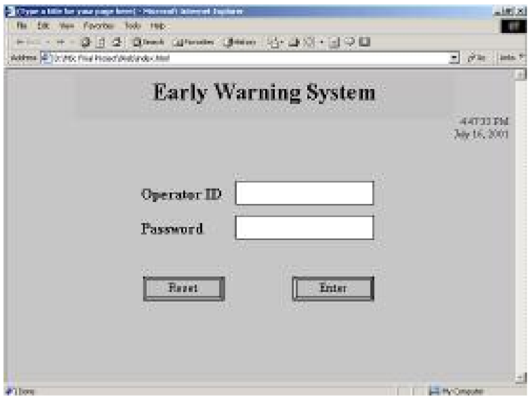
At the present time, it would probably not be cost effective to consider the installation of such system into every city or town. It must be said however that lives saved by detecting early gas build-up in buildings is a laudable objective in itself. This type of system would certainly save lives.

A suggested deployment strategy would involve dividing the UK into several divisions with proportional population densities. This would optimise the costs without affecting the system performance. Some possible geographical divisions that could be applied are shown in Appendix B.

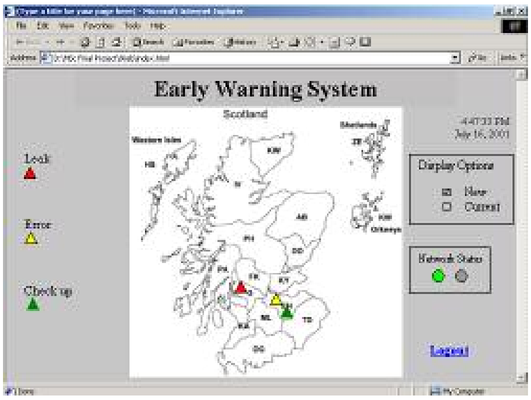
6.3.6 Operational Steps Remark (Broadband)

A summary of the operational steps of the system is illustrated below.

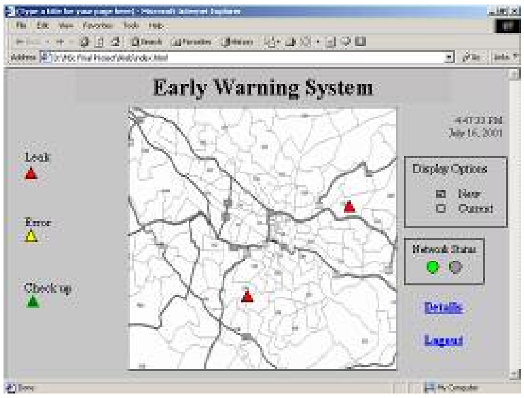
1st Selecting the connection type



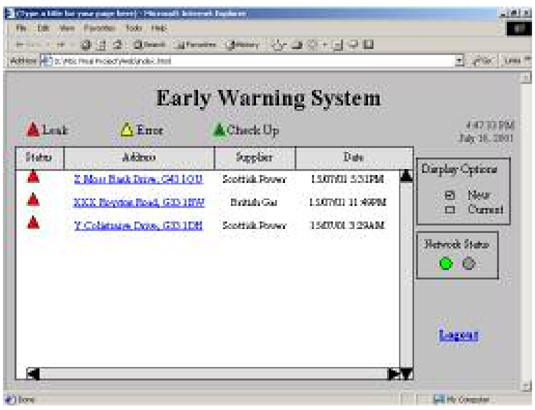
2nd Login to the early warning system



3rd Reviewing information in **regional** scale (e.g. within Scotland)

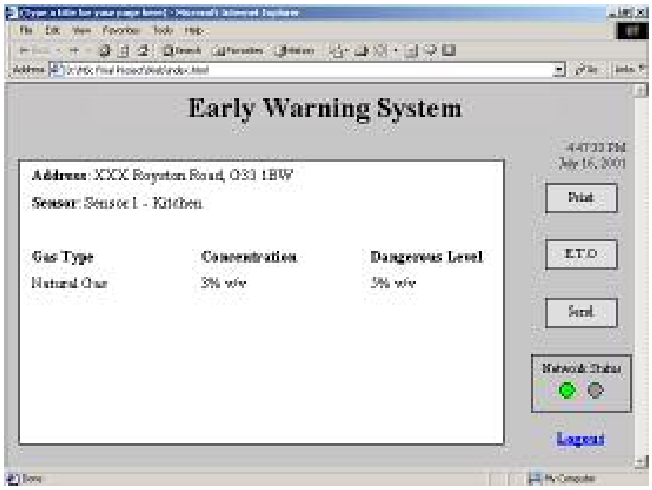


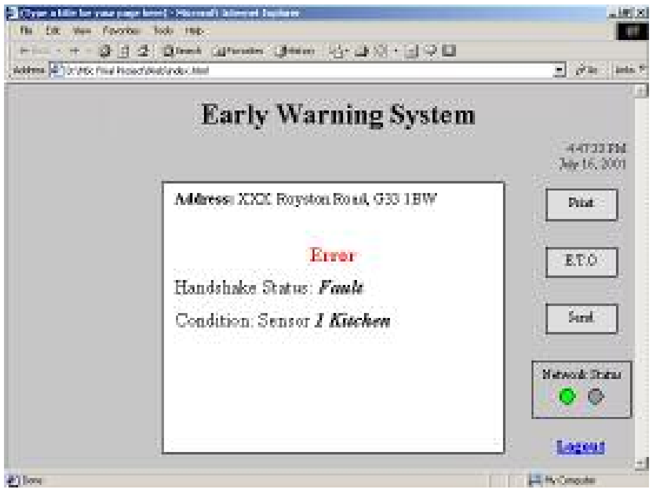
4th Reviewing information in **local** scale (e.g. within Glasgow)

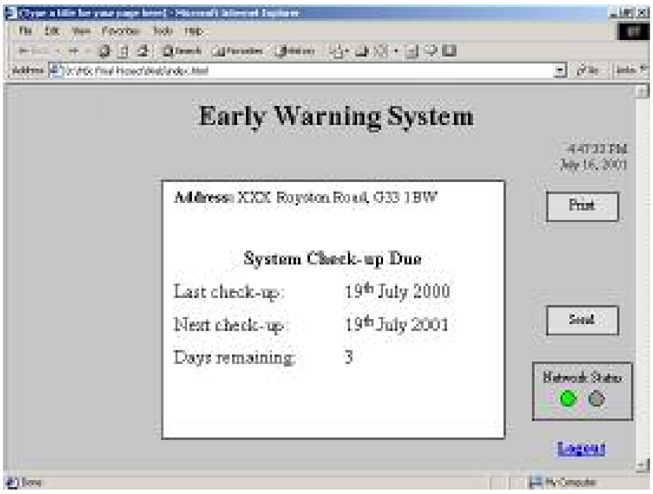


5th Reviewing addresses where there is a gas problem within the local area (e.g. Glasgow)

6th Reviewing information about the house at a particular address within the local area (e.g. Glasgow)





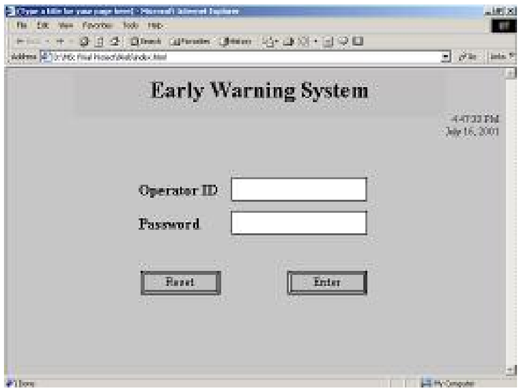


7th Reviewing information regarding the nature of the problem (e.g. gas leak analysis result, system error information or system check-up information respectively)

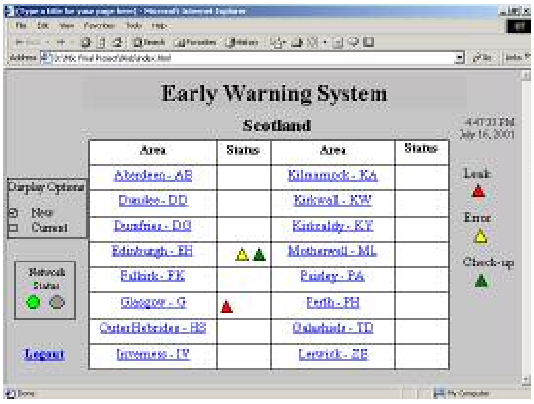
6.3.7 Operational Steps Remark (Narrowband)

A summary of the operational steps of the system is illustrated below.

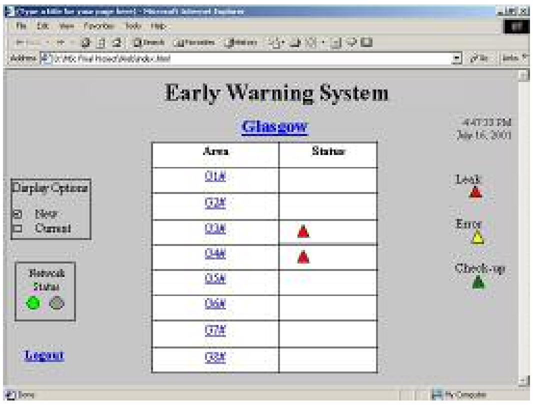
1st Selecting the connection type



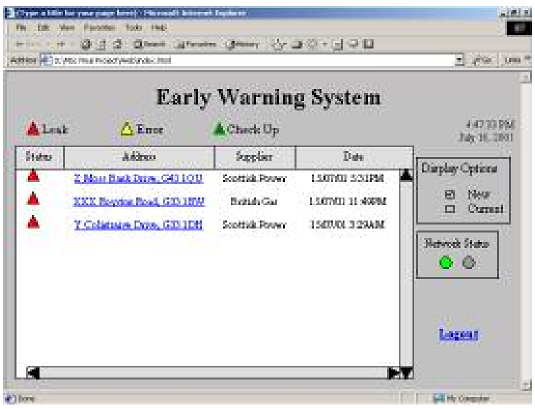
2nd Login to the early warning system



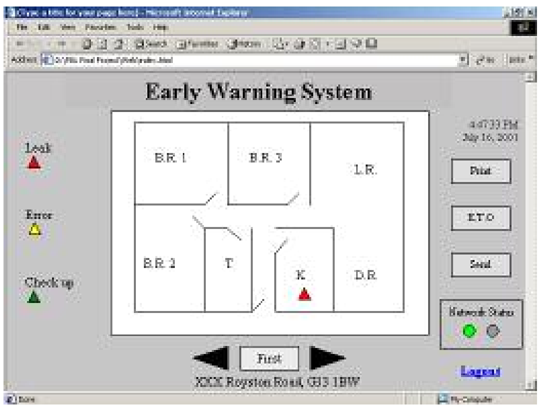
3rd Reviewing information in **regional** scale (e.g. within Scotland)



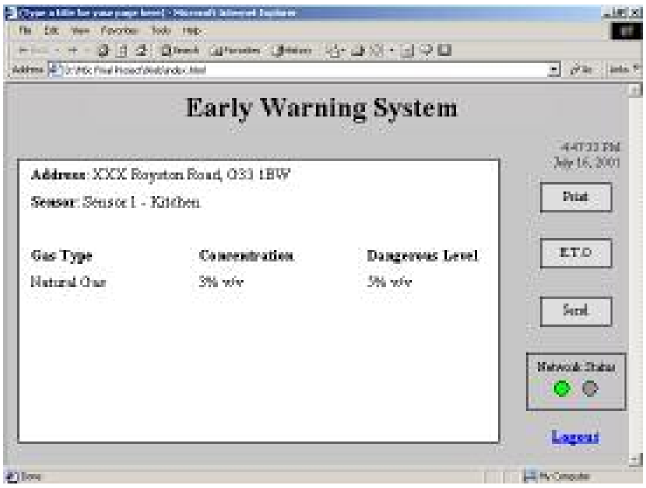
4th Reviewing information in **local** scale (e.g. within Glasgow)

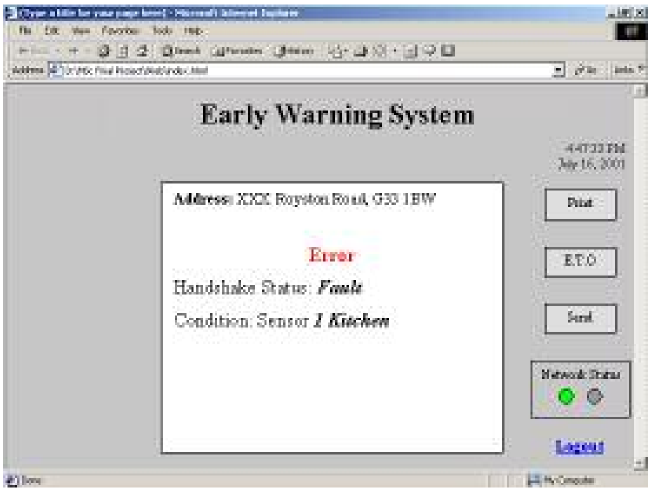


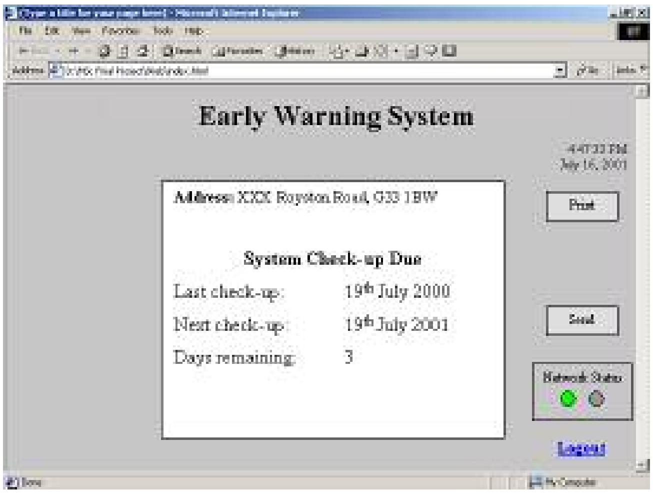
5th Reviewing addresses where there is a gas problem within the local area (e.g. Glasgow)



6th Reviewing information about the house at a particular address within the local area (e.g. Glasgow)







7th Reviewing information regarding the nature of the problem (e.g. gas leak analysis result, system error information or system check-up information respectively)

6.4 Data Requirement and Management

Each viewpoint used in the Early Warning System holds data which have to be collected. Real-time data would be achieved through the sensor, with subsequent interpretation by the DAHS. Certain local data would be prepared by the service provider and stored inside a database before it could be used by the Early Warning System. The data required by each viewpoint is described in this chapter. A conceptual data management model is also covered. It is important that data is organised in such a way that it can be processed efficiently by both humans and the system. This is particularly important as the collected data may required at a future date for investigation purposes, bearing in mind the increasingly litigious demands of society. The data management model is shown in Figure 6.4.1

Each viewpoint employed within the Early Warning System would have its own unique folder for storing data. This would prevent any mix up or corruption of data. Each folder would also be linked together in such a way that would allow different viewpoints to be communicated to each other.

The “Select” folder would only be used to store the viewpoint file that allows operator to select the connection type.

The “Security” folder would store the viewpoint file that allows authorised personnel access to the Early Warning System. In addition, a secured log file would also be stored in this folder, which would be used to record the date, time, operator ID, and the IP address of the computer that had been used to access the Early Warning System. This data would be recorded directly from the login page from such a time that anyone logs in to the system.

The “Regional” folder would store the viewpoint file that contain the interactive map or interactive table (for narrowband version) which is representative of a particular region such as shown in Figure 6.3.1.1 and 6.3.1.2. This folder would also receive a signal directly from the e-box, such that the nature of the problem would be presented on the interactive map or table using the specified colour code. The data that the e-box would send to this folder is the general postcode highlighting a potential gas problem (e.g. AB, G, EH, etc)

The “Local” folder would be used to store the viewpoint file that contains the interactive local area map or the table that has the entire local area postcode listed (such as Figure 6.3.21 and 6.3.2.3 respectively). Since there is more than one area within the region, say, in Scotland, a series of sub-folders would be used. For example, a folder named “Glasgow” would be used to store the interactive map or table of Glasgow, and a folder named “Edinburgh” would be used to store the interactive map or table of Edinburgh, and so on. The local folder would also receive a signal sent directly from the e-box, such that the nature of problem would be presented on the map or table with the specified colour code similar to Figure 6.3.2.1 and Figure 6.3.2.3. The data that the e-box would send to this folder is the postcode of a particular local area where a gas problem has been flagged (e.g. G43).

The “Address” folder would store the viewpoint file that display addresses where gas problems have been detected. This data would be sent directly from the e-box and would include the home addresses that have gas problems, their gas supplier’s name, and the date and time that the gas problems were detected.

The “House”, “Gas Leak”, “Error”, and “Check-Up” folders would be used to store data for any individual user who subscribed to the service.

The “House” folder would store the viewpoint file that contains the 3-D model of the house or the 1-D model of the house for the narrowband version. These models would require to be created in an appropriate format (e.g. jpeg) and be built into the viewpoint file for use by the system.

The "Gas Leak" folder would store the viewpoint file which is used to display real-time gas analysis results. The data included would be the address of the house, sensor location, gas type, real-time gas concentrations within the room, and the critical gas concentration figure when the gas becomes explosive. All the data could be built into the viewpoint file beforehand, except for the data for the sensor location and the real time gas concentration. This data would have to be sent from the e-box since it is not of a constant nature.

The "Error" folder would store the viewpoint file with sets of standard error messages enclosed, so that should an error occur within the system, an appropriate error message would be displayed accordingly, highlighting the nature of the problem.

The "Check-Up" folder would store the viewpoint file that displays the check-up history of the system. The information included would include the date of the last completed check-up and the date for next check-up.

Some data would not require to be updated frequently. This would apply to the data sets for the 3-D house model and the 1-D house model, as house structures rarely change. The other data streams, particularly those interpreted from the sensor would have to be updated ("refreshed") to an agreed protocol. This would be of necessity as gas build-up could occur very rapidly should a leak occur within a property. Time is of the essence and it would be desirable that the sensor communicates its status to the Early Warning System on a frequent and regular basis.

A “condition healthy” signal from the sensor(s) would not be recorded and displayed, in order to save on system memory space. It would however, be used as a constant check-up for the sensor in a “handshake arrangement” with the system. Based on industry standards relating to continuous monitoring system used for gas emissions, the optimums sample (“test and record”) period is between one and fifteen minutes.

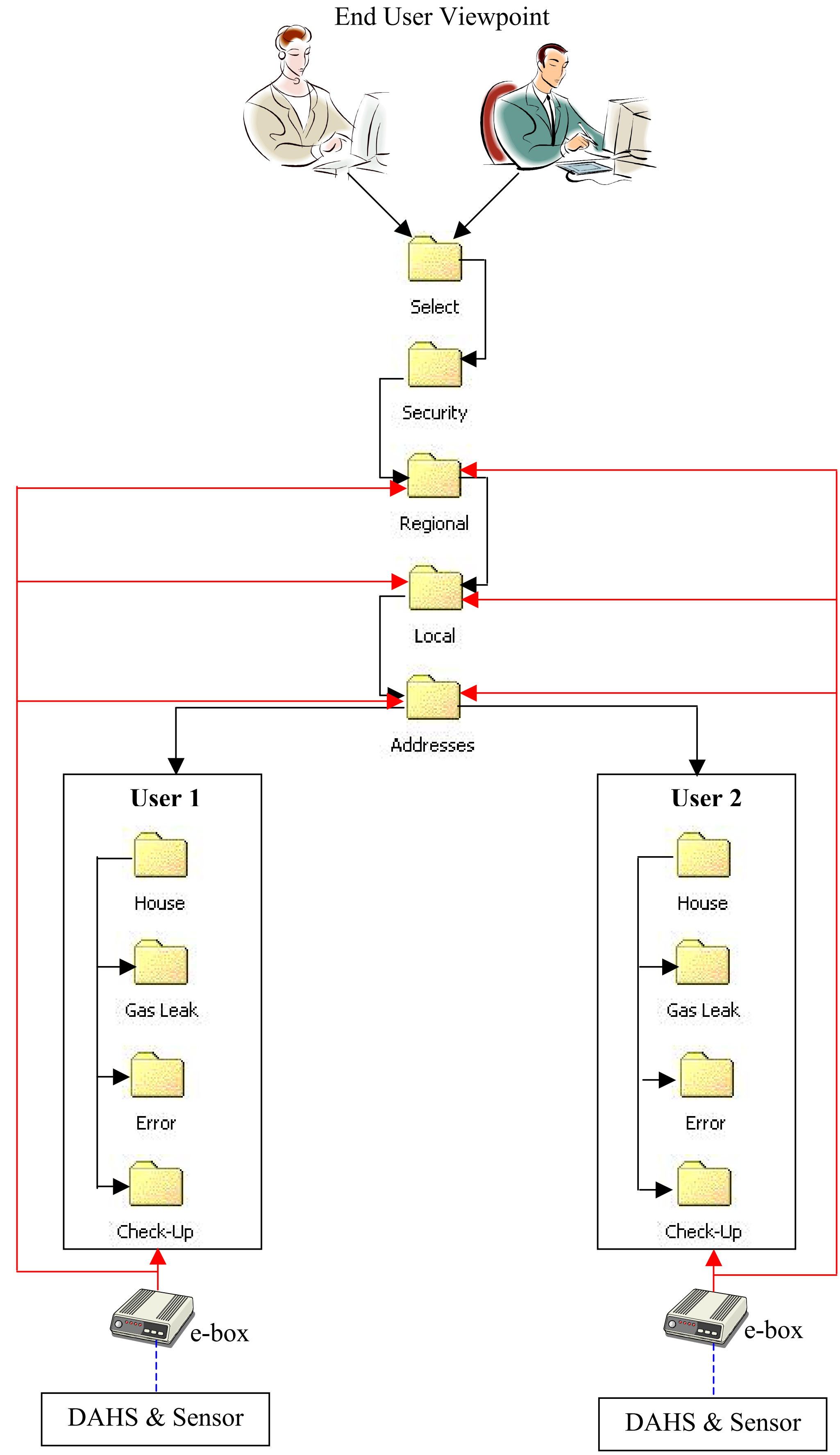


Figure 6.4.1 Data Management Model

Chapter Seven

7.0 Conclusion

Undoubtedly the e-service system has considerable potential for improving the quality and safety of people's lives. The e-service system has a very bright future indeed. Many large international companies e.g. Ericsson, Intel, Hewlett-Packard etc are already developing related systems. The author firmly believes that the benefits brought about by the application of the Early Warning System would be many. The adoption of such technology and its associated benefits would ensure its success. Indeed, the Early Warning System could well become a standard piece of "kit" in all future homes.

Like all great inventions and new concepts, barriers have to be surmounted and problems have to be solved. Tenacity leads to success! In this final section of the report, some problems that could delay the development of the Early Warning System are discussed, together with informed suggestions for future development and deployment of such a system.

At the present time, the limited availability of broadband technology is probably the biggest barrier to offering the Early Warning System to people in their homes. Only a small percentage of the UK population have broadband Internet access at present. According to a government report, it is forecast that by 2005 barely 30% of UK households will have high-speed Internet access. This situation could have a significant impact on the implementation strategy of the Early Warning System. Without a broadband connection, it is impossible to offer the service to people at home in an effective and economical manner. In balance however, this availability issue could be a temporary glitch as many telecommunication companies are already underway with ambitions plans to open up the UK to broadband Internet access. Also, the Early Warning System is at an embryonic stage in its development process and would not be commercially available for some time. Thus, if both broadband access facilities AND the Early Warning System technology develop in a concurrent mode, the delay impact could be minimised. Broadband technology is available now and is here to stay. Its application and use will be ubiquitous. It is merely a matter of time before the Early Warning System appears in every home.

Various development are still required within every aspect of the system. Most hardware technologies required by the Early Warning System are already available, which is an advantage. However, most of them are not custom designed for use within the residential sector. Their build quality is mostly based on industrial standards which would make them very expensive to implement directly in the Early Warning System for home use. It would be also be necessary for the manufacturers to redesign their hardware such that they are suitable for use within the domestic setting.

In this research, the author discovered that most currently available gas sensors are capable of detecting more than one type of gas. For instance, semiconductor gas sensor capable of detecting both combustible and toxic gases. Thus, it is possible to adjust the Early Warning System to provide more than one type of service to the end users to increase cost effectiveness. In fact, the Early Warning System could be built in such a way that it provided all the services mentioned earlier in the report e.g. the low temperature warning, high energy consumption warning and so on.

Designing the appropriate standard for use within the system would be another big development step. There are so many different kind of technologies which are capable of doing the same job but there is at present no agreement as to which technology could be adopted as the future standard. For example, both Bluetooth and wireless LAN are capable of connecting home appliances to computer systems but it is very unlikely that both technologies would share the same portion of the market. Identifying the one that best suits the system and provide better potential for the future is crucial for keeping the up to date and also profitable.

Further development of the system viewpoint is also necessary. This report has covered the conceptual design for the viewpoint system. For any system to function efficiently, data based on ergonomics must be at is core. Considerable time and effort would be required to identify and understand the human needs. It would therefore be necessary to devote much effort to this area to enable an optimum design of system to be engineered.

Using the Early Warning System infrastructure, another area that could benefit is that of core of the elderly and infirm. It would be feasible to design a “vital-signs” transducer arrangement in the form of a bracelet. This could be interfaced to the Early Warning System in order to monitor body temperature, pulse rate, etc. It could be tied in also to the home central heating system in order to prevent hypothermia.

References and Bibliography

[1] *The Investigation and Control of Gas Explosions in Buildings and Heating Plant*, R. J. Harris, ISBN 0-419-13220-1

[2] *Continuous Emission Monitoring Second Edition*, James A. Jahnke, ISBN 0-471-29227-3

[3] *Monitoring Methods for Ambient Air*, Technical Guidance M9, Environment Agency, ISBN 0-11-310176-7

[4] Manufacturer's literature, Ericsson, www.ericsson.com/wireless/products/e-box/

[5] Manufacturer's literature, Sierra Monitor Corporation, www.sierramonitor.com

[6] Manufacturer's literature, Emerald Fire Technology, www.emeraldfire.ie

[7] *Climate Change: the Case for Gas*, International Gas Union, www.igu.org/_X/environ/trans.htm

[8] *Global Warning*, Encyclopaedia of the Atmospheric Environment, www.doc.mmu.ac.uk/aric/eae/Global_Warming/Older/Fossil_Fuels.html

[9] *Dramatic Internet Growth Continues*, James Glave, www.wired.com/news/technology/0,1282,10323,00.html

[10] *Hypothermia*, BBC News on 10 Feb 1999, http://news.bbc.co.uk/hi/english/health/medical_notes/newsid_276000/276284.stm

[11] *Carbon Monoxide*, Health and Safety Executive, www.hse.gov.uk/gas/main.htm

[12] *Larkhall Blast*, BBC News on 23 Dec 1999, http://news.bbc.co.uk/hi/english/uk/scotland/newsid_574000/574946.stm

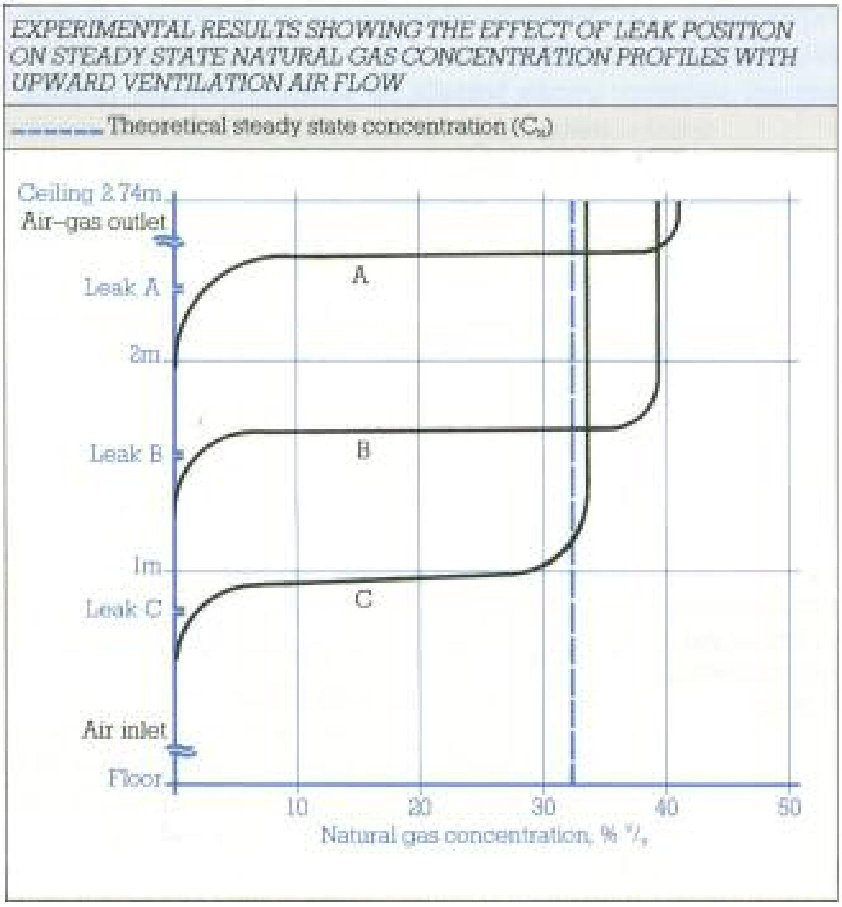
[13] *Gas leak caused explosion in Brazilian mall*, CNN World News on 12 June 1996, www.cnn.com/WORLD/9606/12/brazil.blast.update/

[14] *Networking Strategies for Information Technology*, Bruce R. Elbert, ISBN 0-89006-496-2

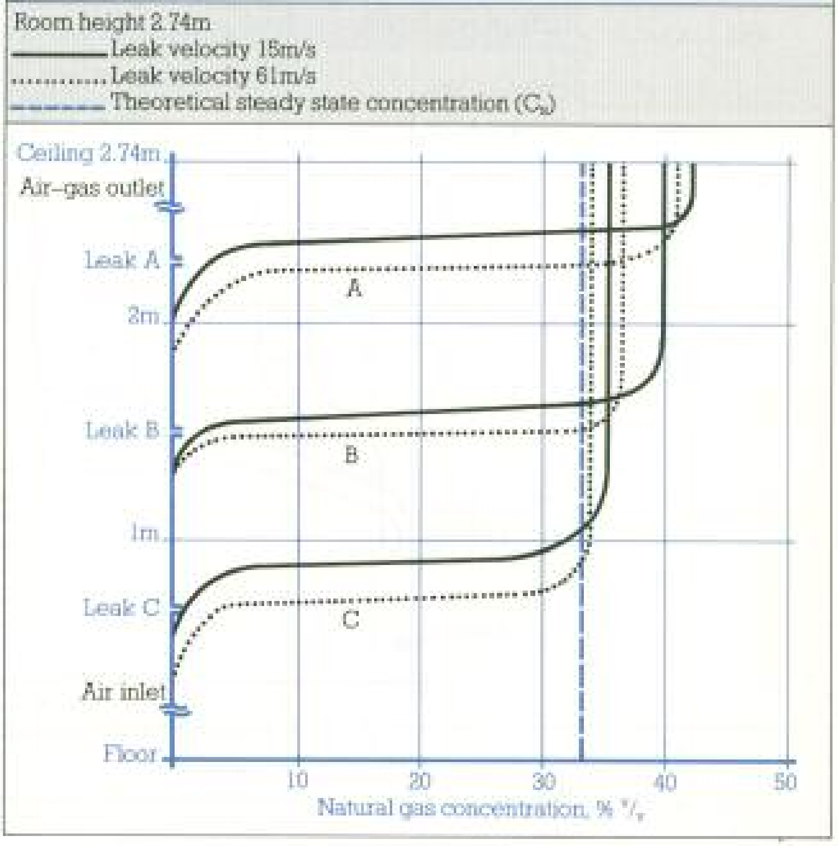
[15] *Introducing Information System Management*, Malcolm Peltu, ISBN 0-85012-672-X

Appendix A – Gas Concentration Profiles

* All Graphs in Appendix A are derived from [1]

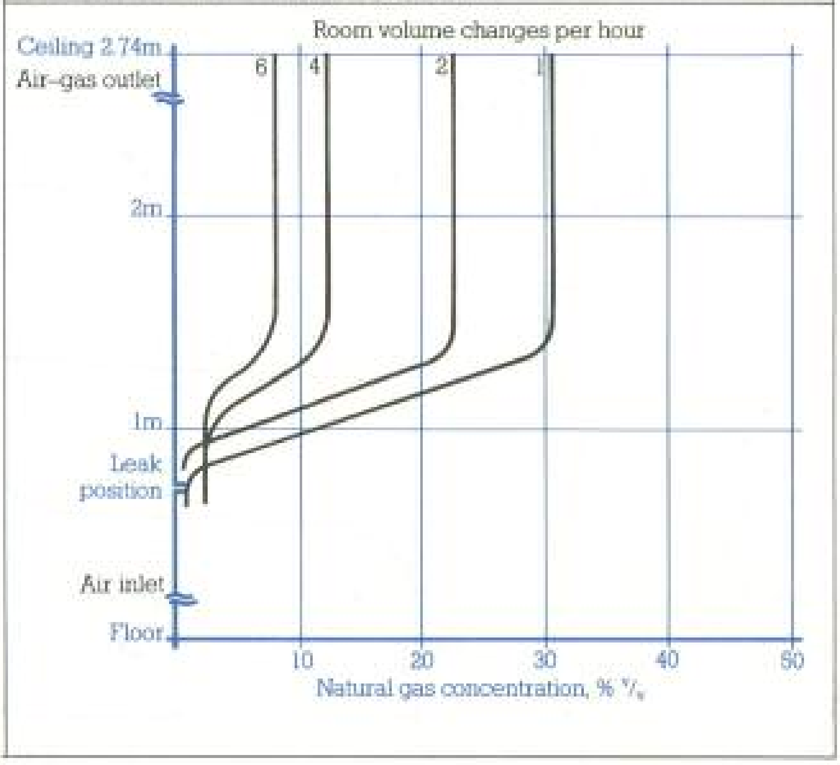


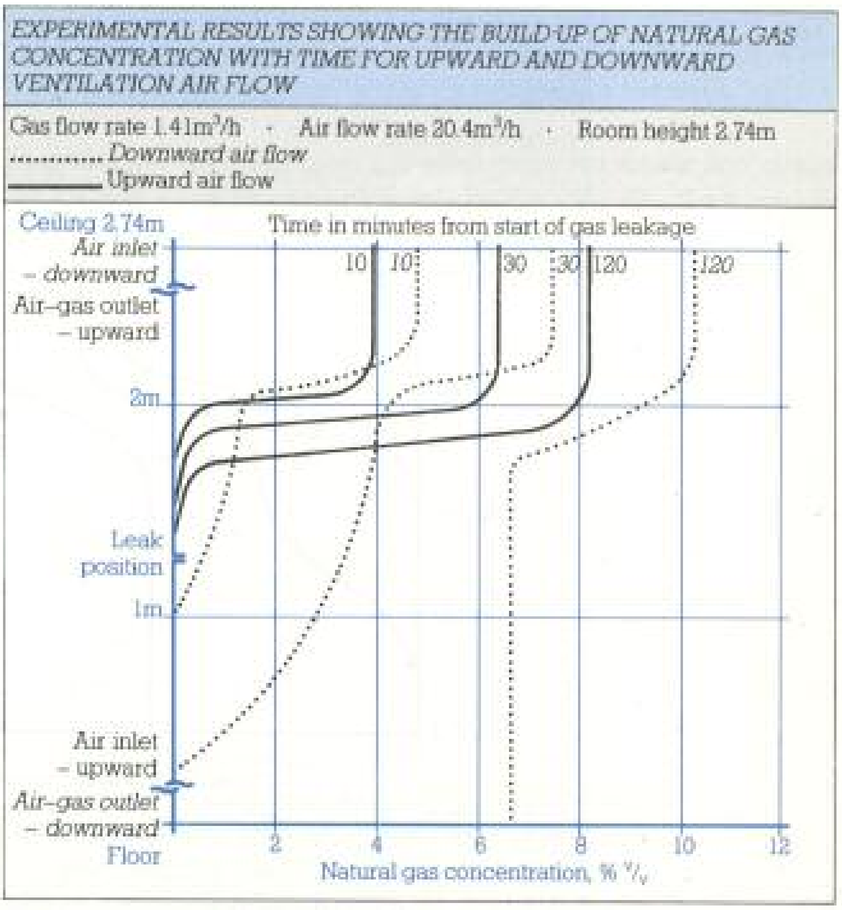
EXPERIMENTAL RESULTS SHOWING THE EFFECT OF LEAK VELOCITY AND LEAK POSITION ON STEADY STATE NATURAL GAS CONCENTRATION PROFILES FOR UPWARD VENTILATION AIR FLOW



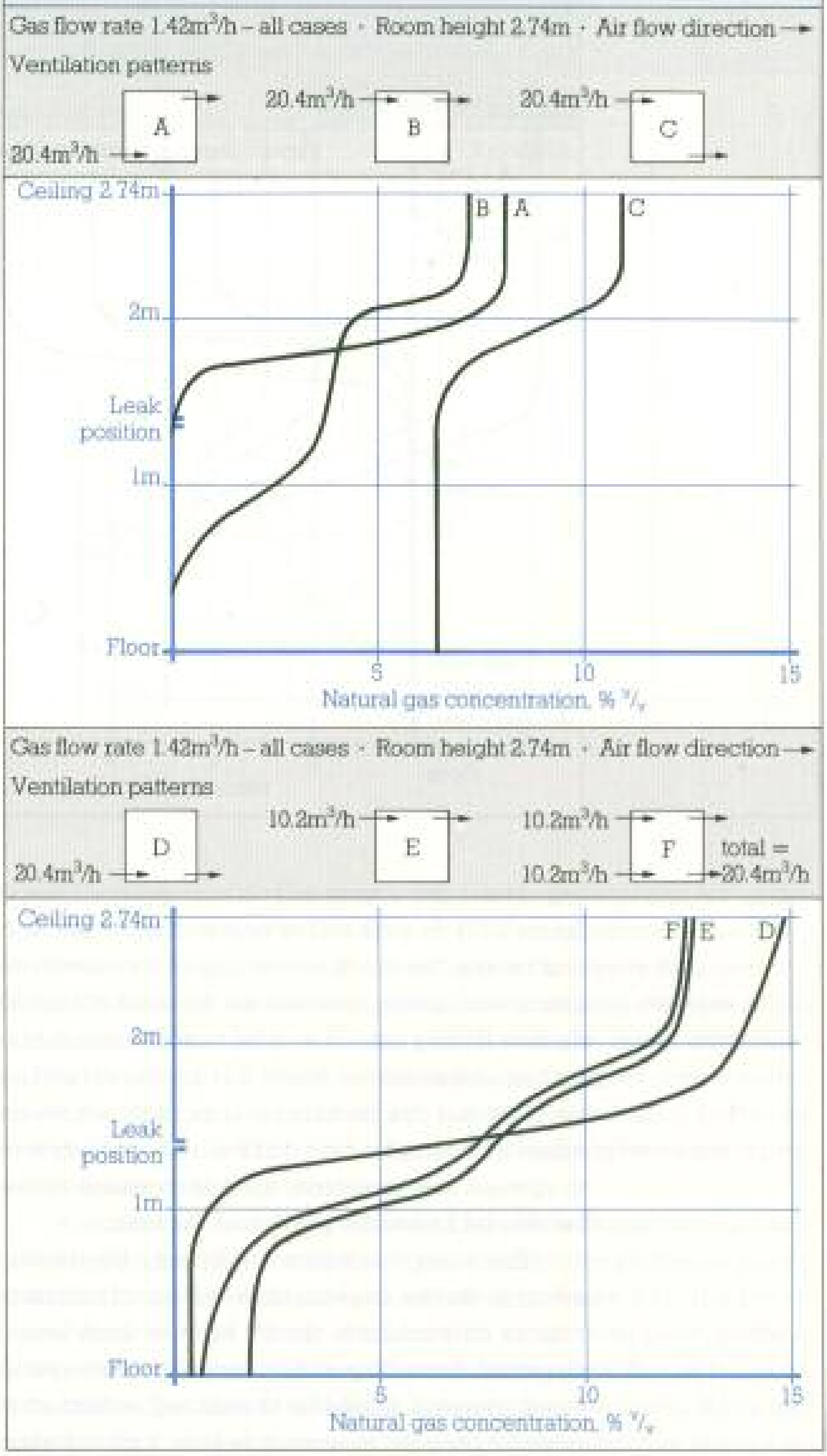
EXPERIMENTAL RESULTS SHOWING THE EFFECT OF VENTILATION RATE ON STEADY STATE NATURAL GAS CONCENTRATION FOR UPWARD VENTILATION AIR FLOW

Gas flow rate 9.7m³/h   Room height 2.74m

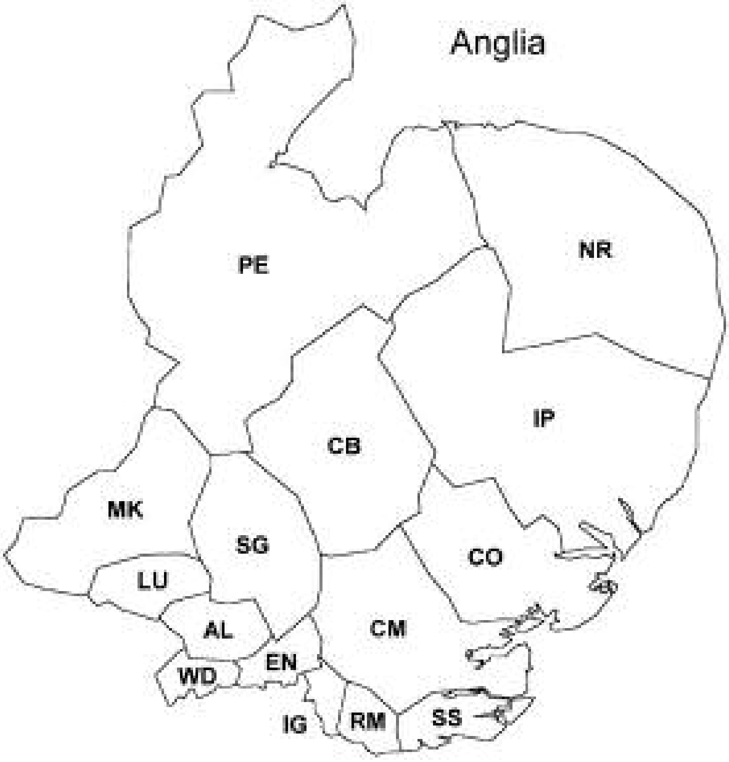


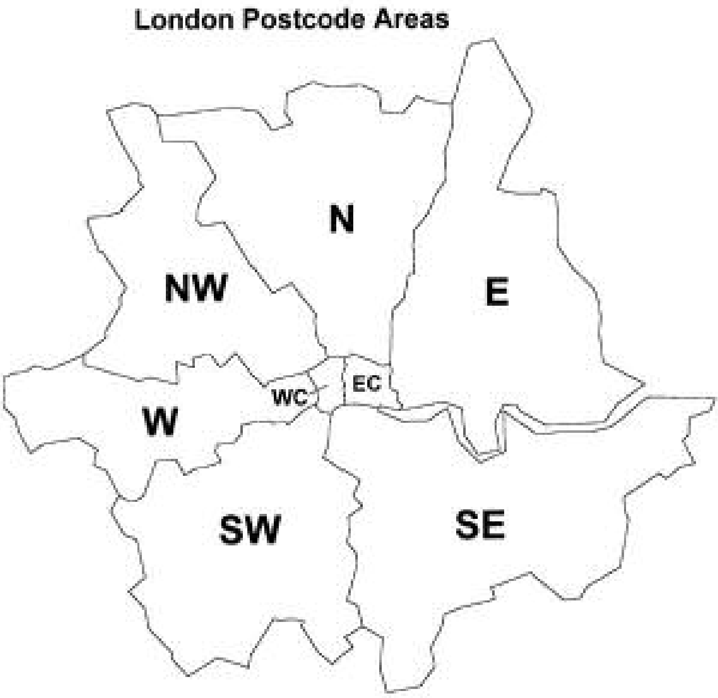

EXPERIMENTAL RESULTS SHOWING THE BUILD-UP OF NATURAL GAS CONCENTRATION WITH TIME FOR UPWARD AND DOWNWARD VENTILATION AIR FLOW
Gas flow rate 1.41m³/h · Air flow rate 20.4m³/h · Room height 2.74m
Downward air flow
Upward air flow
Ceiling 2.74m
Time in minutes from start of gas leakage
Air inlet – downward
Air–gas outlet – upward
2m
Leak position
1m
Air inlet – upward
Air–gas outlet – downward
Floor
10
10
30
30
120
120
2
4
6
8
10
12
Natural gas concentration, % v/v

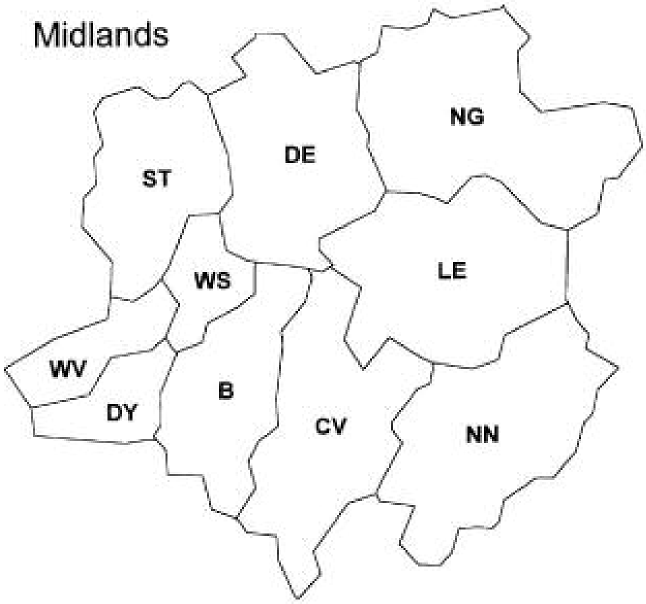
EXPERIMENTAL RESULTS SHOWING STEADY STATE NATURAL GAS CONCENTRATION PROFILES FOR DIFFERENT VENTILATION PATTERNS



Appendix B – Possible Divisions



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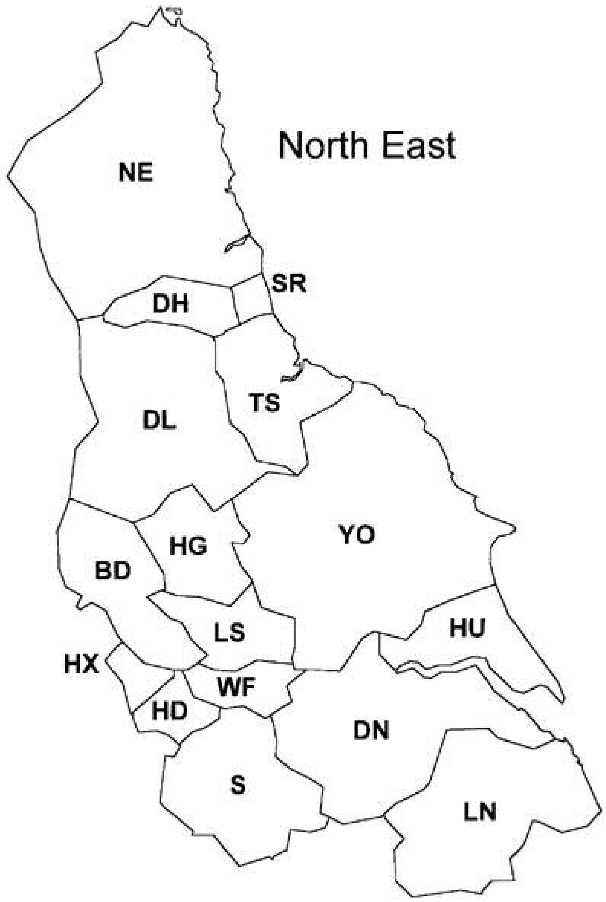
NG
WS
LE
WV
DY
B
CV
NN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DN
S
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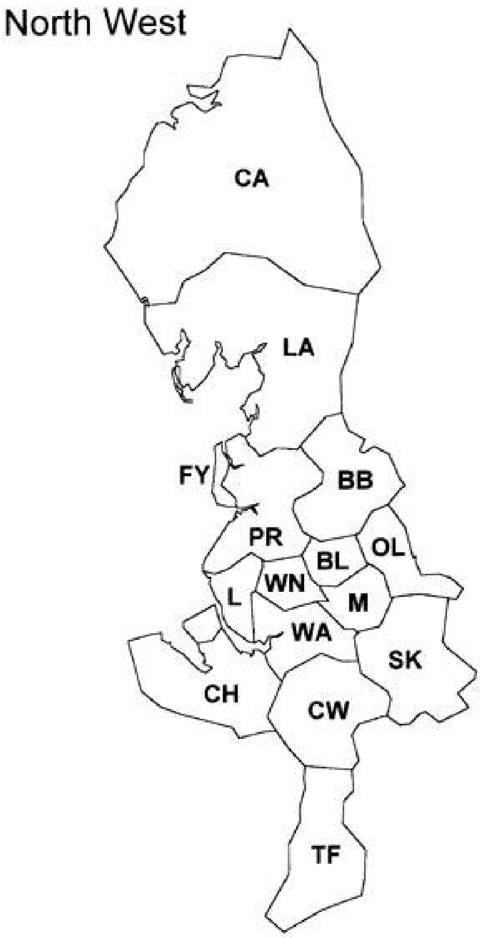
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PR
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WN
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M
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SK
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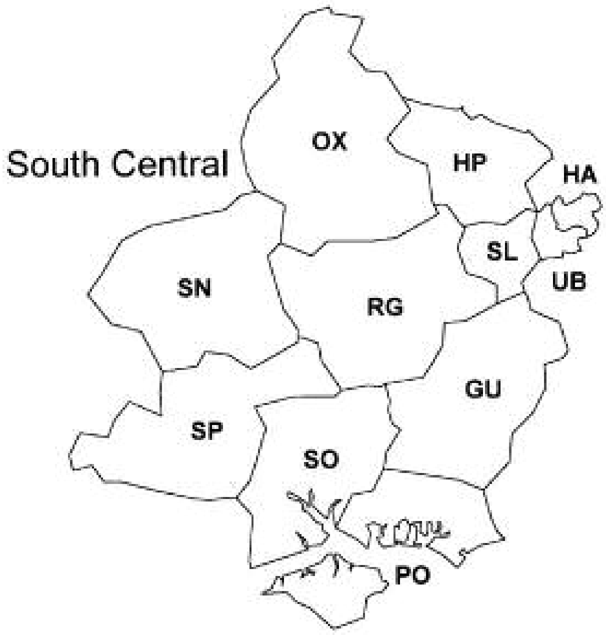
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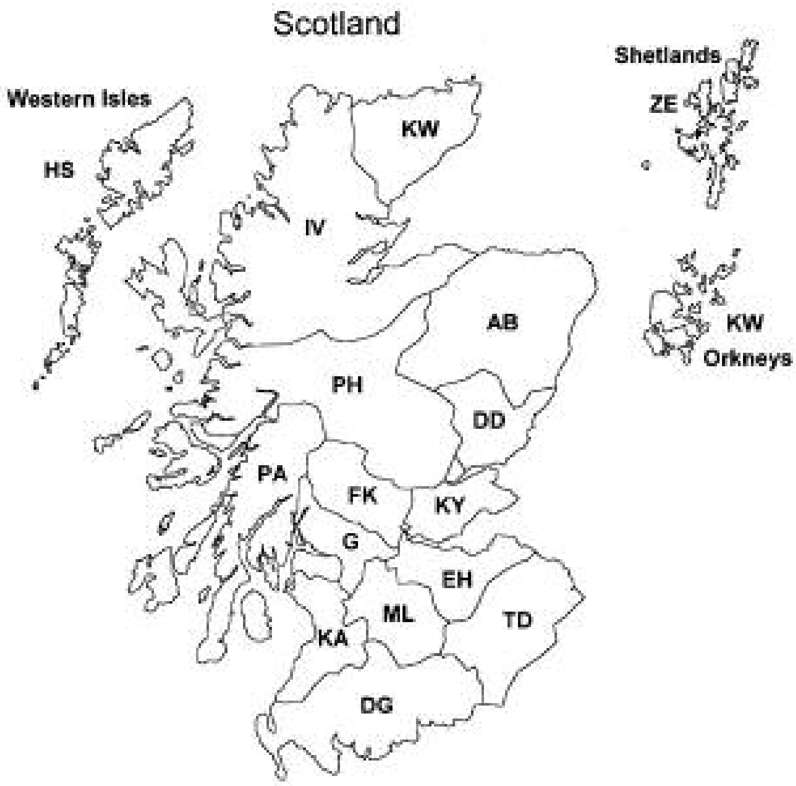
RG
GU
SP
SO
PO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Shetlands
ZE
Western Isles
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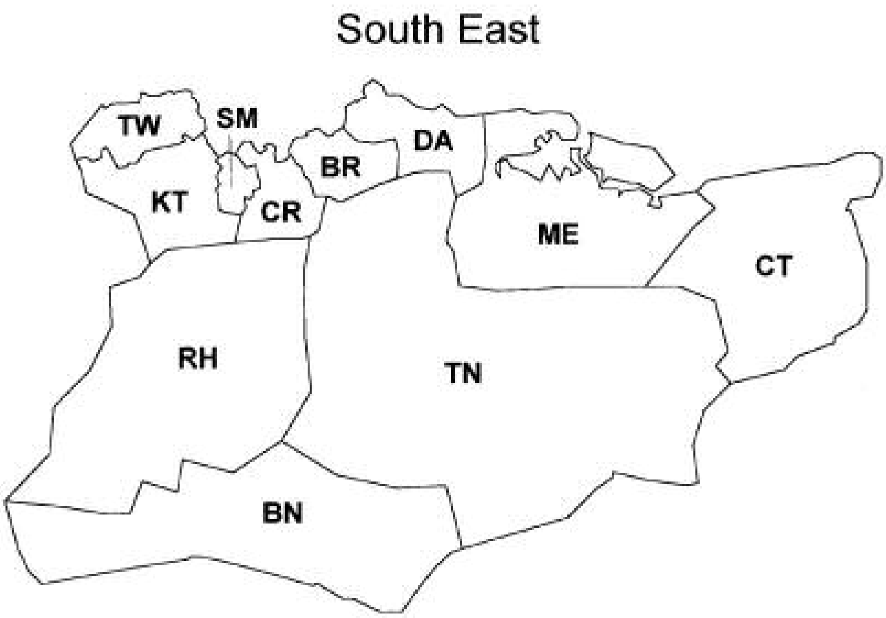
TD
KA
DG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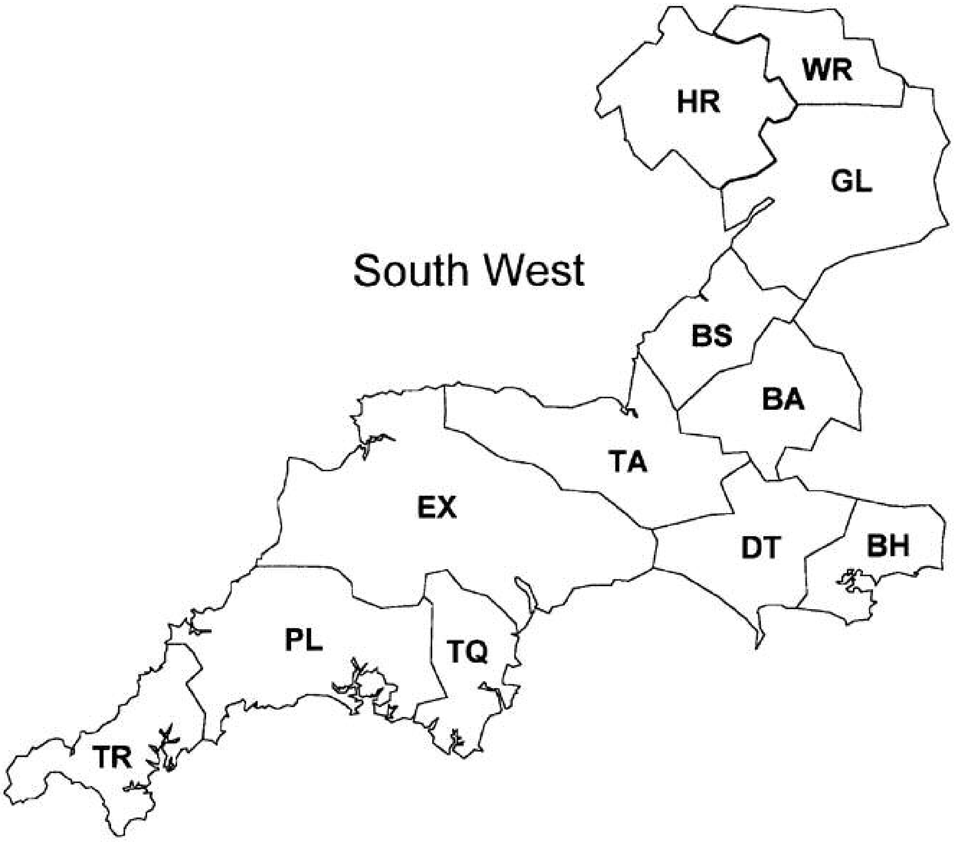
CT
RH
TN
BN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WR
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TA
EX
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PL
TQ
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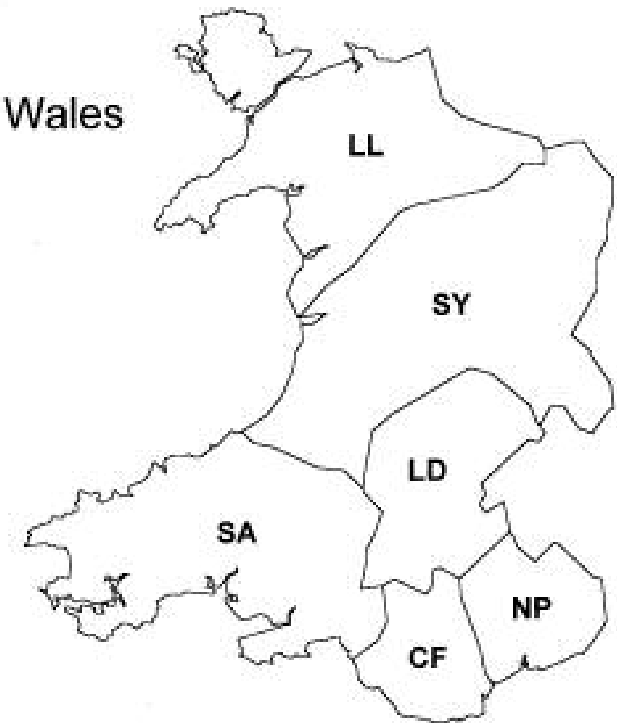
Wales
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SY
LD
SA
NP
CF