Economic

- A significant reduction in the cost of inspection of storage tanks due to the elimination of the need for emptying and cleaning the tank before inspection. The objective is to create a Europe wide saving of 640 million Euros per year,
- The environmental clean up costs for leakage of oil into the ground is 100 million Euros per year Worldwide.

Social

- Elimination of hazard due to extensive exposure of workers to hazardous vapour during inspection. Fatalities in contract workers are 5 times those in process staff workers [4].
- Elimination of hazard due to working in confined spaces inside large oil and chemical storage tanks.
- Elimination of labour intensive and monotonous inspection tasks.
- Reduction in operator stress and error caused by the need for great attention to detail and inspection process variability.

Environmental - elimination/reduction of spillages of hazardous fluids from large storage tanks and contamination of water supplies and pollution of natural habitats.

Elimination/reduction of spillages of hazardous fluids from large storage tanks and contamination of water supplies and pollution of natural habitats. Present inspection procedures themselves cause pollution and residues that have to be transferred and processed. Tanks have to be emptied and cleaned and these operations allow vast amounts of hyrdocarbons and other stored product vapour to be carried by fine sprays directed upward into the atmosphere and the surrounding environment eg water vapour, carbon dioxide, methane, ethane and reactive organic compounds (Source: Government-Industry Partnership focuses on Air Pollution from Oil Storage Tanks. Chen 1997 www.lbl.gov). This causes breathing problem for workers and citizens living and working near the oil tanks.The environmental clean up costs for leakage of oil into the ground is 100 million Euros per year Worldwide.

Leakage from corroded storage tanks, especially their floors, is a major environmental, economic and safety hazard. External inspection of these storage tanks is inadequate. Thus the current inspection methods for the inspection of these tanks have the following major limitations: (1) Require the tank to be emptied and cleaned before internal inspection can take place. A process, which takes up 80% of the costs of the inspection itself. (2) The hazardous liquids have to be transported and stored in alternative tanks. This takes up expensive additional storage facilities so causing weeks of lost production. (3) Exposure of workers to chemicals and dangerous fumes during inspection and cleaning tasks. Also the process of emptying and cleaning releases large volumes of dangerous vapour into the surrounding atmosphere. (4) The huge expense involved in tank inspection and the older age of the storage tanks in Eastern European countries is causing huge leakages into the environment.

Large above ground oil storage tanks filled with hazardous liquids such as oil, oil derived products, chemicals and food processing liquids are in widespread use in Europe and indeed throughout the World. The following numbers of storage tanks exist in Europe:

- 40,000 large oil storage tanks. Each is approx. 100m in diameter and 20m tall. Each tank can carry about 1.6 million gallons of oil and oil products. Worldwide these tanks carry 400 billion gallons of oil [1].
- 120,000 large chemical storage tanks. Each is approx. 50m in diameter and 20m tall. Each tank can carry 1 million gallons of over 150 different chemicals, including solvents, caustics, acids, corrosives and combustibles [2].
- 80,000 large storage tanks carrying wood pulp and food products. Each is approx. 15m in diameter and 10m tall. Each tank can carry 100,000 gallons of wood pulp and food products [15].

The Problem

Leakage from corroded storage tanks, especially their floors, is a major environmental, economic and safety hazard. This is why each year the European owners and operators of storage tanks spend a total of 800 million Euros per annum on inspection of these storage tanks (see table 4, pg 33). External inspection of these storage tanks is inadequate [12] because current methods can only inspect up to 1m into the tank [15]. Thus the current inspection methods for the inspection of these tanks have the following major limitations:

- Require the tank to be emptied and cleaned before internal inspection can take place. A process, which takes up 80% of the costs of the inspection itself.
- The hazardous liquids have to be transported and stored in alternative tanks. This takes up expensive additional storage facilities so causing weeks of lost production.
- Exposure of workers to chemicals and dangerous fumes during inspection and cleaning tasks. Also the process of emptying and cleaning releases large volumes of dangerous vapour into the surrounding atmosphere.
- The huge expense involved in tank inspection and the older age of the storage tanks in Eastern European countries is

causing huge leakages into the environment [3].

There are several Eu Council Directives, which this proposal supports, for example Article 16 (1) 80/68/EEC on the protection of groundwater against pollution caused by certain dangerous substances, and Article 13 (1) 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment. and Article 18 on the major accident hazards of certain industrial activities, which was last amended by Directive 86/610/EEC. Latest directive 2003/605/EC is concerning a questionnaire relating to Council Directive 96/82/EC on the control of major accidents involving dangerous substances. And lastly an amended proposal for Directive of the European Parliament and the Council on the protection of workers regarding the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16 (1) of Council Directive 89/391/EEC).

State-of- the-art

The maintenance of storage tanks in process plant is moving away from scheduled and breakdown maintenance towards predictive maintenance. In predictive maintenance an accurate knowledge of the condition of storage tanks is required so that leaks can be prevented through scheduled repairs, renovation and replacement.

Predictive maintenance uses risk based inspection strategies to monitor condition [11]. Included in the inspection are non-destructive test (NDT) methods for detecting and measuring corrosion in storage tanks.

Tank shells are easily accessible for regular surveys of wall thickness using ultrasonics. The technique is applied manually, measurements taken with an ultrasonic gauge at spot locations over a grid. Although trends in general corrosion can be monitored over time, the technique will miss isolated corrosion pits [12] and [13]. To detect these mechanised continuous scans with the ultrasonic probe are required with computers to collect the ultrasonic data and combine them with probe position information to create corrosion maps [14].

Tank floors are a much more difficult problem for inspection [15] and it is corrosion in the tank floors that is responsible for toxic fluid leakages. Currently before inspection; the tank must be emptied of its product, leaving a heavy deposit that has to be removed and the surface cleaned to allow access for inspection. Before operators can enter, the tank must be purged of noxious and toxic gases. The operators must receive specific training about avoiding the hazards associated with working in confined spaces and in dangerous fumes.

The commonly used NDT method for inspecting tank floors is magnetic flux leakage (MFL) [16]. Where a detailed assessment of a particular area is required, this is supplemented with ultrasound C-scanning [17]. In the particular case of the annular ring that forms the tank floor's circumference and which supports the tank shell an ultrasonic technique that uses 'Creeping' waves can be employed [18].

As an alternative to NDT, condition monitoring using Acoustic Emission (AE) has been tried on tank and leak detection [19], but with only limited success. AE is an accepted method for inspecting fibre reinforced plastic pressure vessels [20]. The acoustic emissions are stress waves emitted from cracks as the wall of the pressure vessel is strained under a load. The acoustic emissions can also be created where liquid is leaking from a vessel. If the acoustic emissions from the leak can be detected at three dispersed sensors, then triangulation can be used to pin-point the source of emissions and therefore the leak.

Guided waves, a more general term that is applied to any wave propagated according to the boundary conditions set by the object, have already been successful in detecting corrosion in pipe [22]. However the use of such waves on plate has up until now been restricted to testing at short range [23]. In the case of tank floors, the inspection area is not only very large, perhaps in excess of 100m across, but also the floors are split up by plates joined with welds.

Limitations of current NDT methods.

The principal limitation of all current NDT methods mentioned above is that the tank has to be emptied, cleaned and purged before manual inspection.

Limitations of manual ultrasonic thickness measurement

Digital ultrasonic thickness gauges are simple to use, but errors come into the measurement when the gauge has not been calibrated properly, the surface is rough and couplant thickness becomes a factor, or there are laminations in the plate that give false readings. In addition, operator error is a prominent factor. The taking of ultrasonic measurements is laborious and is hazardous in confined spaces. Lack of a permanent record can be overcome to some degree by using instruments with automatic data logging, but the exact position of the reading is not known.

Limitations of ultrasonic C-scan mapping

The ultrasonic probe is held in a mechanical scanner in order to create C-scan images. The C-scan image can contain useful information about the spatial extent of the corrosion as well as the ligament left between the corrosion and the test surface. C-scans will reveal the presence of corrosion pits that would be missed in point ultrasonic thickness measurements.

The equipment is expensive and the scanning rate slow. It is not economic to use ultrasonic C-scanning in any but very local inspections, perhaps as back-up to a more global technique. There are technical limitations also. The surfaces must be very clean and the presence of the many weld lap-joints between floor plates disrupts the scans. As with ultrasonic thickness measurements, the presence of plate laminations, a common occurrence in tank plates, can create false images of corrosion.

Limitations of magnetic flux leakage scanning

The technique relies on the leakage of magnetic flux from a dense magnetic field induced in the tank plate, created when its cross-sectional area is reduced by corrosion. The magnetic field is produced between two very strong magnets that are moved over the test surface in a wheeled carriage, pushed by the test operator. Hall Effect transducers placed above the plate between the magnets sense the leaking magnetic flux. The transducer creates electronic signals for collection and processing by the instrument.

The technique is not sensitive to plate laminations, as is the case with ultrasonics. However the signal is proportional to area of metal loss rather than remaining wall thickness. Serious deep isolated pits may therefore produce a smaller response than benign shallow areas of general corrosion. Although a faster rate of inspection than ultrasonics, one tank floor may take several hours to scan, the operation of the test is laborious and therefore operator mistakes common.

Limitations of Acoustic Emission (AE) Leak testing

Noise is the main problem of AE testing. Noise can even be created from drops of rain falling on the test object. The corrosion must be severe enough to cause the leak, this may not be an acceptable test condition.

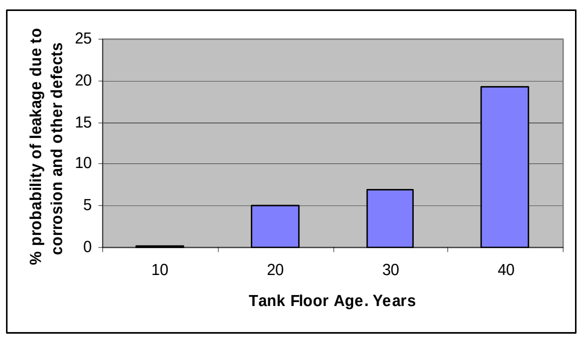
In summary all the above inspection techniques require the tank to be emptied, cleaned, manually inspected and then the product reinstated..

IMPACT

- **The increase in inspection requirements** have grown considerably due to environmental concerns by the following legislation: (1) EC Directive on dangerous substances (76/464/EEC) leaking into the ground water and (2) Directive 98/34/EC, legislating for a 50% reduction in pollution in ground water by leaking tanks. Both Directives are strictly being enforced by heavy fines and even jail sentences. The owners and operators of large oil tanks have now increased their inspection requirement drastically. The increase in storage tanks and their inspection requirements for inspection means that the requirement for inspection instrumentation and services is also increasing at this high rate [4].
- **The ageing population of oil storage tanks** will require an increasing numbers of detailed inspections per annum as the probability of leakage rises with age. The average age of large storage tanks carrying hazardous liquids is greater than 20 years [1]. Figure 14 shows that these older storage tanks have about 5-20% chance of leakage and thus are in urgent need of inspection. This leakage probability means that EC owners and operators of storage tanks carrying hazardous fluids such as oil, oil products, wood pulp, ammonia and other chemicals are now spending more on inspection of storage tanks [1]. These factors will generate in excess of 15% per annum increase in spending on inspection.

.

Figure 14. <u>% chance of leakage "vs" age of storage tanks</u>.



Average inspection costs for a typical large oil, oil product, wood pulp or other chemical storage tank.	No of large storage tanks	Total cost of inspection in Europe per annum based on inspection per 5 year period	80% saving generated in Europe by “Tank-Inspect” system by eliminating emptying, cleaning and other tasks.
100,000 Euros per large tank. Includes costs involved in (1) Emptying, (2) Storing hazardous fluids in other tanks. (3) Cleaning the tank to be inspected. (4) Making tank suitable for worker entry (removing explosive gases). (5) Refilling with original hazardous fluid afterwards and (6) Loss of tank facility for 6 week period of inspection.	**40,000** in Europe.	**800 million Euros per annum**	**640 million Euros per annum**

The manufacture, inspection and the need for in-service inspection of large storage tanks carrying hazardous liquids are EU wide requirements. Applications in the following EU industries include:

- **Large oil storage tanks**. All EU countries have substantial numbers of land based tanks, the oil industry alone having 40,000 (150,000 worldwide) [16] very large tanks, some of diameter 100m.
- **Large chemical storage tanks**. The EU chemical industry alone has 120,000 (900,000 worldwide) large tanks.
- **Large storage tanks carrying wood pulp and other hazardous fluids**. There are 80,000 large storage tanks carrying wood pulp, other chemicals and food products in Europe.