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UNDERWATER INSPECTION AND NONDESTRUCTIVE TESTING OF OFFSHORE ST--ETC(U)

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*Liaison Technologist from Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA

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Regulations have been established by the governments of countries bordering the North Sea which require annual inspection of offshore structures. This has resulted in a much more intensive use of nondestructive testing (NDT) techniques for underwater inspection than currently exists in the United States. This report presents a review of the NDT techniques and equipment currently used in the North Sea area and discusses some of the research being conducted in the UK and Norway to improve the quality of over

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UNDERWATER INSPECTION AND NONDESTRUCTIVE
TESTING OF OFFSHORE STRUCTURES

INTRODUCTION

As manager of the Naval Facilities Engineering Command's (NAVFAC) exploratory development program for both shore facilities and ocean facility engineering, the Civil Engineering Laboratory (CEL) has recently become involved in the requirement to develop a capability to perform nondestructive testing (NDT) of waterfront structures. The primary structures requiring NDT inspection are piers, wharves, seawalls, and seafloor pipelines and cables. A major portion of these structures are under the surface of the water, and therefore the equipment used to conduct the NDT inspections must be compatible with the submarine environment. Also to be taken into account, when assessing the suitability of various NDT techniques for underwater inspections, is the type of material that will be encountered. The majority of structures to be inspected are constructed of either wood, steel, concrete, or a combination of these. To a lesser extent, cast iron and plastic or rubber compounds may be encountered, however, not usually as part of the main structural elements.

To date, underwater NDT techniques have been used infrequently on structures in US waters because of the high cost involved in both the inspection and possible *in situ* repair. The basic philosophy of companies operating offshore structures has been to so overdesign the structure that it can remain operational even with substantial damage to parts of it. This situation has not been the case in the North Sea, however, where government regulations require annual inspection of offshore structures in order to maintain certification for operation. These regulations combined with the severe environment that exists in the North Sea has spurred the development of underwater NDT equipment and techniques on a much larger scale than presently exists in the United States.

This report presents an assessment of the state-of-the-art (SOTA) of underwater NDT technology in the North Sea area of Europe and identifies those items currently under development that may lead to an advancement in the SOTA in the near future. It is based on the writer's observations made during a one-month temporary assignment with the Office of Naval Research Branch Office, London as a liaison technologist. (See ONRL Report R-9-77 for a brief description of the liaison technologist program.)

BACKGROUND

Numerous techniques have been developed for NDT of materials either in the laboratory or fabrication yards; however, only four have found application in underwater inspection. These methods are:

1) Radiography—in which gamma rays or x-rays are used to detect metal thickness variations by recording on photosensitive film the amount of radiation that passes through the test specimen.

2. Ultrasonics that use the transit time of high-frequency sound waves to detect metal thickness and internal defects.

3. Magnetic particle inspection (MPI) that uses the magnetic phenomenon of flux leakage to detect cracks and surface discontinuities in ferrous materials.

4. Eddy current testing in which information on the electrical conductivity, magnetic permeability, and dielectric properties of metallic materials are used to detect cracks and measure wall thickness.

Of these four techniques, the first two are not restricted by the type of material being tested while the latter two may be used for testing metallic structures only. MPI is further restricted to detection of surface cracks of ferrous materials. These techniques may also be divided according to the type of defect detection for which they are primarily used. Radiography and ultrasonics are most commonly used to detect internal defects and material thickness. Magnetic particle and eddy current techniques find their primary application in the detection of surface cracks.

An important requirement for all of these techniques is that the surface of the structure be cleaned of all marine growth, scale, rust, and coatings such as paint or concrete. Without direct contact of the test equipment on the surface to be tested, little chance exists of obtaining valid results. Surface cleaning is an important facet of visual inspections as well and often times becomes the critical path as far as time and cost of the inspection are concerned.

SURVEY APPROACH

A brief survey of capabilities within the US indicates that when NDT is used underwater, radiography and ultrasonic testing are the most common techniques employed. A preliminary review of report's prepared by companies conducting NDT in the North Sea, however, indicates very little use of radiography with the major emphasis being placed on magnetic particle testing for weld-defect inspection and ultrasonics for metal thickness measurements.

Because of the greater versatility of ultrasonic inspection in testing the varied materials encountered in waterfront structures, primary emphasis was placed on investigating the application of this technique in the North Sea Area. Magnetic particle testing was investigated because of its potential for inspecting the new ACMR (Aircraft Maneuvering Range) towers recently installed along the east coast of the United States. Since cleaning of structures has been important for all NDT techniques, recent developments in this area were of primary interest. The final major area of investigation was that of developing technology that might affect the state-of-the-art in NDT within the next few years.

Owing to the limited amount of time available for this technology assessment (about 3½ weeks), contact priority was established in the order of the foregoing list of major topic areas. Fortunately, several of these topics could usually be discussed during a single visit since they are all within the NDT technology area. Appendix I is a list of the organizations and personnel contacted during the course of this assignment. When new developments to NDT technology or personal opinions were expressed, reference is made in the text to the individual or organization involved. A large number of the statements presented in this report, however, were the result of common opinions received from a number of contacts, and no attempt has been made to credit any one individual.

TECHNOLOGY REVIEW

1. Ultrasonics.

The scattering and attenuation of ultrasonic signals in wood and concrete structures requires the use of low frequency (when compared to metal structure inspection) transducers. Reports had been received at CEL of underwater ultrasonic testing of wooden pile structures using transducers manufactured by CNS Instruments Ltd., London. To get a better feel for the entire operational capabilities of this equipment, I contacted Mr. Randall of the CNS plant. CNS manufactures several types of transducers for their PUNDIT (Portable Ultrasonic Nondestructive Digital Indicating Tester) system. These range from 24 kHz to 200 kHz with the lower frequency transducers being used on thicker concrete sections. With the 24-kHz transducer, transmission distances of about 40 ft are obtainable. The entire PUNDIT system, developed for testing concrete structural integrity, is a transmission system (as opposed to the reflected signal technique normally used for steel) and consequently requires both a transmitting and receiving transducer. The ultrasonic signal is pulsed at a rate of either 3 or 10 Hz with the lower repetition rate being used for penetration of thick concrete sections.

The transducer signal may be displayed as either a digital, analog (meter), or CRT (oscilloscope) readout. The digital display is the only one that is battery powered and truly portable. Alignment of the sending and receiving transducers is critical if accurate readings are to be obtained, and a jig or framework would be required to position the transducers on either side of the pile or structural member. When transmission cables greater than 30 ft long are required to reach the inspection site, an amplifier is fitted to the receiving transducer. This allows transmissions of at least 200 ft. The alternative to this procedure would be to enclose the readout equipment in a waterproof housing. This approach, however, would require the diver not only to position the transducers but interpret and record the data as well. To date, watertight housings have been built to protect the transmitting and receiving transducers but not for the signal processing equipment.

Use of this equipment on waterfront structures requires complete cleaning of all marine growth so that the transducer face can be placed in direct contact with the structure. A special tapered point transducer is available which reduces the size of the area to be cleaned.

Some concern has been expressed, however, about the applicability of ultrasonic transmission testing of concrete underwater. Several NDT specialists contacted on this trip indicated that their experience with testing wet concrete (on land) revealed the sound transmission velocity to be almost identical to that of water. On land, voids can be detected since they are filled with air and thus cause a difference in transmission time. When submerged, however, these voids are filled with water and therefore may not be detectable. Further testing should be conducted to verify this technique on submerged concrete structures.

The use of ultrasonics to inspect steel structures is usually divided into two categories: thickness measurements and flaw detection. By far, the most common application of underwater ultrasonics inspection encountered was for thickness measurement of pipelines and risers.

Det Norske Veritas (DnV) in Oslo, Norway, appears to be one of the leaders in developing NDT techniques for the inspection of offshore structures in the North Sea. They have used two types of Krautkramer Ultrasonic Instruments (the D meter and USM-2) in pressure housings for underwater inspections. With this arrangement, the diver must conduct the test and interpret the results. For this reason, their divers are quite highly trained in ultrasonic inspection and follow rigid procedures for conducting the test. Of the two meters, the USM-2 is preferred because it is more versatile, and although depth measurements are not as accurate as with the D meter, it is much less prone to produce erroneous results. On corroded (rough) surfaces, CRT display of ultrasonic signals appears to be the only feasible way of obtaining depth measurements. It is also important for the operator (diver) to see this CRT output.

When the back surface of the metal is severely pitted, it is usually necessary to use a 45° angled transducer to detect the depth of the pits. This causes internal reflection of the ultrasonic signal when the surface is smooth, and a reflection is received only when a pitted area is scanned. A technique has been developed by DnV with which the diver can produce a topographic type map of the pitted area. Although this map is distorted from the actual configuration of the corroded area since the transducer is not located directly-above the pit that reflects the signal, enough lab testing has been conducted to enable DnV surveyors to correlate the map to the actual damage. This technique was developed specifically for Phillips Petroleum and at present is proprietary.

The use of ultrasonics for weld inspection is very difficult, at best, owing to the requirement to correlate the ultrasonic signal precisely with both the position and orientation of the transducer. The USM-2 has been used once by DnV to inspect a 6-ft-long repair weld. This operation took over 3 hours and revealed no major defects. If problems with the weld quality had been detected, they would have had to be mapped, and the inspection would have required several more hours to complete. An automated procedure is essential if ultrasonic weld inspection is to become practical.

There was a consensus among the organizations contacted as to the importance of using an oscilloscope display of the ultrasonic signal, and the fact that underwater ultrasonic weld inspection will not become economically feasible until some type of automated equipment becomes available. There were two radically different philosophies, however, regarding the type and amount of training required of the diver/inspector and whether the monitoring equipment should be operated by the diver or remain on the surface to be observed and recorded by a topside technician.

The first underwater ultrasonic inspections were apparently conducted using Krautkramer instruments that had to be packaged in underwater housings since the electronics were not compatible with transmission of the ultrasonic signal through cables of more than a few meters in length. This resulted in the approach taken by DnV that requires the diver to be a highly trained ultrasonic technician and places the monitoring equipment underwater with the diver. The introduction of ultrasonic equipment manufactured by Sonic Instruments (Trenton, New Jersey) to the European market may in part be responsible for the development of the second school of thought. The inspection philosophy adopted by those using the Sonic's instruments is that the diver should only be required to clean the surface of the structure and manipulate the transducer.

The electronics in the Sonic oscillograph monitor have built-in automatic gain control (up to 120 dB) that allows accurate reading of metal thickness with 200 ft of cable between the transducer and monitor. An automatic distance-echo correction (DEC) circuit allows the transducer to be placed as much as 3 inches away from the surface of the structure and still obtain accurate thickness readings. This may greatly reduce the requirement for cleaning on mildly fouled structures. The topside monitor is capable of producing both digital and oscilloscope readings. If a permanent record is desired, an output plug is provided for connection to an oscillograph or strip-chart recorder.

Feedback to the diver of the type of signal being received on the surface appears to be important to the successful operation of this equipment, and verbal communications between the topside technician and diver/inspector seem to be adequate at this time (for metal thickness measurements).

The validity of this second approach appears to be supported by recent tests conducted by Brown and Root (UK) to determine the suitability of NDT techniques for underwater inspection. As a result of these preliminary tests it was concluded that: (1) None of the currently available NDT equipment is suitable for underwater crack detection, and (2) because of the level of skill required for accurate interpretation of the ultrasonic signal display and the general lack of training of commercial divers, it is desirable to have a system with a surface readout capability for thickness measurements. No decision has been made to date as to the requirement for the diver to view the CRT display simultaneously.

2. Magnetic Particle Inspection

MPI appears to be the most widely used NDT technique for inspection of offshore structures in the North Sea. Three basic types of hardware have been employed for underwater tests: permanent magnets, current producing prods, and a parallel conductor system. The prod system is by far the most commonly used to date, but the parallel conductor system promises to improve inspection quality by allowing a larger area to be inspected at one time thus reducing the chance that defects will go undetected owing to improper placement of the prods.

DnV again is among the leaders in developing MPI techniques for underwater use. The equipment developed by Veritas consists of a deck handling system (hydraulic hoist), a power supply, and the underwater inspection unit. The underwater unit contains the transformer for supplying current to the prods, the magnetic ink supply, and an ultraviolet-light source for observing the test results. The total package weighs about 1.5 tons and therefore requires a sizable surface support craft.

For the type of structures being inspected in the North Sea, the power source for the MPI test equipment must be able to produce an alternating current (50-60 cycles) of at least 1000 A to produce an acceptable magnetic flux field. The voltage is generally regulated at 10 V. The tips of the electrical prods must be covered with lead in order to prevent arcing damage to the steel structure being tested. DnV have found that permanent magnets are inadequate for producing acceptable MPI test results.

The major concern about accepting MPI test results for the certification of structures is that the shape of the prods and structural nodes may cause the magnetic flux to flow through-the seawater rather than through the structure thus making it impossible to detect a flaw or structural damage even if it is present in the area that is inspected. It is hoped that the "parallel conductor" system for MPI will eliminate the prod configuration problem. However, even with this equipment, a validity check is required. This would consist of a test coupon with a known defect which is attached to the structure to assure that the magnetic flux was flowing through the structure rather than shortcircuiting through the seawater. The requirement for a validity test procedure appears to be the major shortcoming of all underwater NDT techniques used to date.

3. Cleaning

High pressure water jets are by far the preferred method of cleaning offshore structures. Two companies that manufacture this type of equipment were contacted, and both appear to offer equipment with very similar capabilities. A relatively new development for the system sold by F.A. Hughes Ltd. is the ability to introduce abrasive particles into the high-pressure fluid stream. The abrasive particles are carried to the jetting gun through a separate pneumatic line and are introduced into the high-pressure water at the nozzle. The pneumatic carrier is apparently important in keeping the abrasive dry and flowing through the long delivery hose (200 ft long). The air bubbles caused by the pneumatic abrasive carrier does reduce visibility but not much more than cleaning without abrasives. The counter-balance nozzle has also been redesigned to incorporate an eductor system, which greatly reduces the pressure of the fluid flowing out of the back of the gun thus making the system much safer.

The size and weight of this equipment will present the biggest drawback to use by the Navy's Underwater Construction Teams (UCTs). the pumping unit, is a triplex plunger pump capable of producing pressures to 14,500 psi. The smallest of these, internal combustion-engine powered units is capable of a flow rate of 25 liters/minute at the maximum pressure and weighs almost 4000 lbs. If the abrasive cleaning module is attached, transportation of another 1500 lbs of equipment plus a low-pressure [100 psi) compressor is required. The equipment produced by Harben Systems Ltd. has approximately the same performance capabilities and is slightly smaller in size.

Some structures have been cleaned with needle guns (both pneumatic and hydraulic powered), grinders, wire brushes, and chisels. The potential for damaging the structure is much higher with any of these techniques than with high-pressure water jets. There is also some question as to whether or not these techniques might tend to disturb the surface of the test area sufficiently to make it impossible to detect small surface cracks.

DEVELOPING TECHNOLOGY

Several new developments were observed or discussed with personnel involved with NDT research. These are discussed in the following paragraphs. Information on other projects that might influence the state-of-the-art in the near future was obtained from secondhand sources, but because of scheduling conflicts, contact with the personnel actually involved in the work was not possible. Appendix II contains a brief description of the item under development and the principal contact.

1. EMI Electronics Ltd.

I met with Messrs. Andrews and Brown at the Central Research Laboratories of EMI Ltd. to observe a demonstration of the acoustic camera that is currently under development. The heart of this equipment is a quartz-faced cathode-ray tube called an ultrasonic image-converter tube (UICT) that is based on a design originally proposed by S. Sokolov in 1932. It was not until recently, however, that satisfactory techniques for bonding the quartz crystal to the face of the CRT were developed. After processing of the electrical output of the UICT, a visual image, similar to that produced by television, is displayed on a second CRT. At the current state of development the image does not have the resolution of the more highly developed vidicon tube; however, the image produced can resolve shapes to within a few millimeters. This accuracy is obviously not sufficient to determine material loss due to corrosion or to detect hairline cracks, but it should be sufficient for detecting voids in wood or concrete piles.

Two methods of "illuminating" objects with ultrasound have been used. Most of EMI's work has been done with reflected ultrasonic waves in which case a number of transducers are located around the perimeter of the camera, facing away from the lens. The sound is broadcast forward into the water, and the reflected signal is focused with a plastic lens before impinging on the face of the UICT. The second method places a single transducer behind the object. After passing though a columnating lens, some of the parallel waves are blocked by the object thus creating a shadowgraph.

The interesting application of the back lighting technique arises from the fact that objects containing a large percentage of water become semi-transparent to the ultrasonic signal, producing a fluoroscopic type of image. This technique therefore has the potential of "seeing" through some type of marine growth and water-saturated wood and concrete thus potentially revealing voids, reinforcing bars, and internal damage caused by marine organisms. Although this particular technique has not been tested on these materials, the developers feel it is feasible. As a demonstration Brown placed his hand between the transducer and the UICT. On the display screen appeared an x-ray type of image showing the bones, major blood vessels, and the outline of skin.

The transducers used for this application are in the 2 MHz range. This appears to be the best compromise between the conflicting frequency requirements for resolution and low transmission attenuation. Resolution is improved with higher frequencies; however, transmission lengths become very small. When multiple transducers are used for front illumination, the frequency is randomly varied in a 100-kHz band around the 2-MHz signal to eliminate interference fringe patterns. For the demonstration observed, four transducers were used with a total power output of 20 W.

The requirement to find defects in concrete may require application of shear-wave transducers directly to the surface of the concrete structure. As these waves pass through the structure, the acoustic impedence discontinuity caused by a defect produces a modal change in the ultrasound. This modal change results in the generation of longitudinal waves at the discontinuity which can then be detected by the UICT.

2. Jaker Instruments

Jaker Instruments is currently engaged in the development of ultrasonic testing equipment to be utilized on a remotely controlled submersible. This submersible is to have a depth capability of 20,000 ft which requires the development of pressure resistant transducers and electronic equipment capable of transmitting the ultrasonic data to the surface.

Once the vehicle has been maneuvered to the desired inspection site it will be able to grip the structure, clean the surface with high-pressure water jets, and then conduct both visual (television) and ultrasonic inspection. Since the remote submersible operator will not have the dexterity normally required for manipulating and orienting the transducer, a special gimbled transducer holder is also being developed to assure proper alignment between the face of the transducer and the surface of the structure.

Successful development of this vehicle and the associated inspection equipment will greatly extend the depth to which underwater NDT can be conducted. It also has the potential of reducing the cost of inspections that now require saturation-system divers to handle the inspection equipment.

3. Det Norske Veritas

Mr. Olav Førli is currently in charge of the section at Veritas that is conducting research and development on NDT techniques. Projects underway or planned for the near future center on improving NDT methods of inspecting concrete structures, ultrasonic weld-inspection techniques, and magnetic particle equipment.

Concrete inspection research will consider the development of both low-frequency ultrasonic and surface-impact testing of concrete. The ultrasonic work is being done with the PUNDIT transducers, and for surface-impact testing, DnV is attempting to waterproof a Schmidt hammer for underwater use. Both of these projects are in very early development, and no positive indication of their feasibility is available at this time. At present concrete structures are inspected only visually.

For improving ultrasonic-weld-inspection capabilities, Veritas plans later this year to begin working with a P-scan ultrasonic system currently under development by the Danish Welding Institute. This system consists of an angle transducer coupled to an articulated arm that automatically feeds the 6 degrees of freedom position of the transducer to a computer. The computer correlates transducer position, orientation, and signal, and it then prints out two orthogonal profiles of any defects in a weld. This unit is still in the prototype stage, but DnV expects to receive one in April or May for conversion to underwater use. If they are successful, this may provide the automated features required for underwater ultrasonic weld inspection.

In addition to reducing the size and weight of the currently used MPI equipment, a technique is also under development which would allow crack depth to be determined using magnetic particle inspection. This technique would involve measuring the potential drop across a crack once it has been detected using MPI. The same prods used for the crack detection would be used at a reduced power level to provide the current source, and an underwater voltmeter would be used to determine the potential drop.

CONCLUSIONS

Based on the contacts made with NDT equipment manufacturers and organizations engaged in underwater inspection, there appears to be no significant difference in equipment currently used for underwater inspection of structures in the North Sea and in the US. The techniques found to be most often employed are ultrasonic testing for metal thickness and magnetic particle inspection for surface crack detection. Radiography has not been employed to any significant extent in the North Sea to date. The major difference in underwater inspection in the North Sea and US is the extent to which NDT is employed. Regulations have been established, by the governments of countries bordering the North Sea, that require annual inspection of offshore structures. This in turn has resulted in a much greater effort to develop and standardize techniques of conducting NDT inspections.

There was a consensus regarding ultrasonic testing, that with currently available equipment, metal thickness measurement is the only type of testing that is practical at this time. The development of automated equipment or computer-assisted analysis of the ultrasonic signal and transducer position will be required if ultrasonics is to be employed for weld inspection. Digital display of metal thickness tests often results in erroneous readings when used on irregular (corroded) surfaces. Oscilloscope display of the ultrasonic signal is therefore essential for valid metal thickness measurement.

Opinions were much more divided on the question of the level of training required for the diver/inspector and whether or not the monitoring should be taken underwater with the diver or remain on the surface, to be interpreted by a highly trained technician.

The level of research in the area of underwater inspection and NDT is considerably higher in both the UK and Norway than in the United States. Developing technology is likely to result in significant changes in the type of equipment and techniques used for underwater NDT in the next three to five years.

APPENDIX I. List of Contacts on Underwater NDT Technology

ORGANIZATION NAME/LOCATION	TYPE OF ORGANIZATION	DATE OF VISIT	PERSON(S) CONTACTED	PHONE
1. Underwater Security Consultants, 50 Pall Mall London, SW1Y 5JQ	Engineering Consultants	28 February	Mr. David Hughes Mr. A. Louell-Smith	0445-43301 01-839-4489
2. CNS Instruments, 61-63 Holmes Rd. London NW5 3AN	NDT Instrument Manufacturer	2 March	Mr. Randall	01-485-1003
3. C&JB, 8 Harewood Row, London NW1 6SE	Underwater Engineering Consultants	2 March	Mr. Kevyn Allen Dr. Mike Haywood	01-724-0801
4. F.A. Hughes & Col. Ltd., Bienheim Rd., Longmead, Epsom, Surrey, England	Equipment Manufacturer (High Pressure Water Jet)	3 March	Mr. H.M. Peart Mr. Roy Chuter	EPSOM-25201
5. EMI Electronics Ltd., Central Research Lab, Blythe Road, Hayes, Middlesex, England	Electronic Instrument Development/Manufacturing	6 March	Mr. Bill Andrews Mr. Patrick Brown	WOKING-76123 01-573-3888 EXT 2830
6. Jaker Instruments Ltd., Baystrait House, 15 Station Rd., Biggleswade, Bedfordshire, England	NDT Equipment Distributor	7 March	J.S. Jamieson	0767-314199
7. Morgan Berkeley & Co. Ltd., Ember House, Moorside Rd., Winchester, Hampshire SO23 7SF	Cathodic Protection Equipment Manufacturer	8 March	Mr. R.L. Hiscop	WINCHESTER 69622

ORGANIZATION NAME/LOCATION	TYPE OF ORGANIZATION	DATE OF VISIT	PERSON(S) CONTACTED	PHONE
8. Oceaneering International, Riverside Rd., Gorleston-on-Sea, Great Yarmouth, Norfolk NR31 6QP	Underwater Engineering	9 March	Mr. Kingsley Ashford-Brown	GREAT YARMOUTH 64161
9. Det Norske Veritas Industrial & Offshore Div., N-1322 Høvik, Norway	Inspection & Certification of Offshore Structures	13-14 March	Mr. Rune Sletten Mr. Olav Førli	02-129955
10. Svenska Mekanister Riskförning Malmskillnadsgaten 48 Box 40207 10344 Stockholm 40, Sweden	Engineering Society	15 March	Mr. Gunnar von Feilitzen	
11. Brown & Root, Brown & Root House 125 High Street, Colliers Wood, London SW19	Offshore Services	20 March	John D. McKeown	01-540-8300

APPENDIX II. Developing Technology Requiring Additional Contact

ITEM UNDER DEVELOPMENT	CONTACT	ORGANIZATION/ ADDRESS	PHONE
1. Small A scan ultrasonic test instrument with minimal adjustment requirement (large CRT screen)	Mr. Ernie French	Merit Lowson & French Otterden Place Eastlang-near-Faversham, Kent, UK ME13 OBU	079589341
2. Ultrasonic Tourch; high resolution visual display of ultrasonic flaw detection. May be used remote from surface of structure. Hand held.	Dr. J.M. Pool	Atomic Energy Research Establishment, Harwell	0235-24141
3. P-scan ultrasonic weld inspection system	Mr. S.A. Lund	Svejse Centralen Park Alle 345 Glostrup, Denmark	
4. Pistol type digital ultrasonic testing instrument w/built in validity check mechanism	Mr. John McMillan	Panatron Systems Ltd. Fern St., Motherwell, Strathclyde, UK	0698-53411