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Development of a shielded IASCC facility in AEAT

A Paper Presented to the European Working Group
"Hot Laboratories and Remote Handling"

21 - 23 September 1998

Low Wood Hotel, Windermere

Title	Development of a shielded IASCC facility in AEAT
Customer	European Working Group - Hot Labs.
Customer reference	
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File reference	
Reference number	

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Executive Summary

This paper describes the development of a facility in AEA Technology to undertake Corrosion-assisted mechanical properties tests on irradiated materials. The design philosophy applied to the facility is discussed, and the components of the system described.

1 Introduction

AEA Technology has established a potential requirement for a facility capable of undertaking mechanical properties tests on irradiated materials in the presence of aqueous environments simulating those in operating power reactor circuits. The types of test required would generally simulate service loading with in many cases, the additional requirement for collecting information on crack growth rates.

The materials to be tested might be removed from actual operating plant, or have been subjected to equivalent irradiation doses in Test Reactor or surveillance programmes. Such materials may have been subjected to fluxes of $> 10^{23}$ n/cm^2, and depending on their chemical composition, could have high specific activity. The environments applied during the tests would be typical of LWR primary or secondary circuits.

It is clear that the development of a facility capable of testing irradiated materials under representative environmental conditions would prove a key extension of AEA Technology's existing, substantial capability in environmentally-assisted testing on unirradiated materials, and would allow maximum advantage to be derived from the world-class expertise already existing within the Company in this area.

These conclusions led to a programme to design, fund, build and commission a facility based on an existing shielded test capability within Fuel Performance Group at AEA Technology's Windscale site.

2 Development Process

The steps to be undertaken in the development of a capability are:

- establish a fundamental requirement or opportunity
- establish the bounding parameters of the capability
- undertake initial safety assessments and hazard analysis
- undertake sufficiently detailed design to allow costing to typically +/- 10%
- undertake market research to establish market
- present business case to obtain funding

And following approval:

- undertake detailed design and safety submissions
- construction
- commissioning

The following sections describe how a number of these steps were undertaken. The existence of a fundamental requirement is assumed.

3 Bounding Parameters

The facility has been developed to undertake tests within the following bounding parameters:

(i) specimen activity from trace active to activities representative of substantial samples removed from reactor core, requiring up to 300mm steel shielding
(ii) specimen size from sub-miniature charpy (4mm x 4mm x 20mm) to 50mm thick CTS
(iii) full servo-controlled (load or displacement control) cyclic, constant rate or combination test histories
(iv) PWR or BWR water environments with full chemistry control and monitoring instrumentation.
(v) crack growth monitoring
(vi) once-through low flow refreshed environment (high flow rate recirculated in a future phase)

4 Initial safety assessment

An initial safety and Hazard assessment has shown that there were no overwhelming difficulties with the construction of a pressurised facility, and the operating procedures proposed. The major additional requirement was for the modification of the ventilation plant of the shielded cell housing the testing machine to be used, to accommodate the possible rapid release of quantities of contaminated steam into the cell environment.

5 Facility Design

5.1 Design philosophy

It is recognised that not all materials likely to be tested in the proposed facility will be highly activated, although some, containing particular alloying elements, or from high fluence regions, will require heavy shielding. It was decided therefore to base the facility around an existing shielded testing machine, which could easily accommodate the most highly active samples likely to be encountered. The use of only one testing channel would however severely restrict the rate at which data could be obtained, and so to supplement the existing capacity, it was decided (initially) to assemble two further testing machines, fitted with local shielding. This shielding will be adequate enough to accommodate the majority of test specimens, particularly if size is restricted. The existing heavily shielded testing machine is shown in Figure 1 and one of the locally-shielded machines, during construction, in Figure 3

Maximum flexibility could be gained from the availability of multiple testing channels if water chemistry could also be varied. Two separate water treatment and control systems are therefore installed, both nominally identical and constructed as modules, so that additional systems could be added at a later stage if necessary.

A summary specification of the facility is given in Appendix A.

In all aspects of the facility design, maximum advantage has been taken of experience gained in the operation of non-active facilities within AEA Technology at its Risley site.

5.2 Water chemistry

The environmental water makeup, pressurisation, chemistry control and instrumentation packages are almost identical to those in use at Risley, with only minor changes incorporated to suit the specific installation at Windscale, and updating of certain instrumentation to take advantage of the latest developments. In particular, the intent to allow operating temperatures up to 360°C has necessitated the use of a Zirconia reference electrode in place of the Ag/AgCl electrode normally used. Basing the water loop design on the tried and tested Risley system means that this part of the equipment will have high reliability and availability.

A schematic arrangement of a single water circuit is shown in Figure 3.

5.3 Autoclave vessels

The design of the large autoclave vessels has also been an incremental evolution of the system used at Risley. A general design of autoclave vessel and CTS specimen grips has been developed for a nominal 38mm thick specimen. This general design was used for costing and safety assessment, but it is anticipated that a family of designs for different specimen sizes will be developed. Not all variants will be constructed immediately. The design is based heavily on equipment already in use at AEA Technology Risley, particularly in the area instrumentation feedthroughs, pressure connections and gripping clevis features. The specimen clevises are replaceable to accommodate different specimen geometries, and when used for Compact Tension Specimens, the clevises are fitted with oxidised-zirconium insulating bushes to allow the use of DC-pd crack growth monitoring. The seal design currently in use at Risley has been modified to incorporate the latest developments in sealing materials, and to allow an increase of operating temperature to 360°C. The autoclave vessel material has been upgraded to Type 321 Stainless Steel.

The new vessel design has double-ended loading to accommodate the twin-screw, moving crosshead arrangement of the existing Schenck RM 280 testing machine at Windscale, with the external load cell fitted below the vessel bottom plate to minimise heat pickup. Vessel flange bolting has been redesigned to allow remote operation. Lifting devices have been incorporated to allow remote separation of critical joints. The general design of autoclave to be used is shown in Figure 4.

The majority of design effort has been concentrated on the development of an autoclave to be fitted to the existing shielded testing machine, although it is recognised that for small-scale tests, particularly those on tensile-type specimens, or tubing, that small sleeve autoclaves may be required. Current designs in use at Risley will be useable with virtually no modification.

5.4 Testing machine modifications

The existing shielded Schenck servoelectric testing machine required no modifications to enable it to undertake the tests proposed. As described above, modifications were required to the ventilation system of the cell to prevent steam wetting of the primary HEPA filter bank which is fitted at the cell ventilation outlet, and possible transient pressurisation of the cell. Steam dump valves and additional filters have been fitted.

Spot welding jigs are installed within the shielded cells for use in fixing crack growth monitoring probes.

6 Specimen preparation

Specimens to be tested in the new facility may either be pre-machined and irradiated specially in test reactors or as surveillance specimens, or be prepared from materials removed from operating plant. In the latter case, facilities are already available for machining specimens from low and high-active materials, to the precision and tolerances required in the relevant testing standards.

7 Use of the Facility

The new facility is designed to integrate fully with other active facilities within AEA Technology, and is seen as a logical extension of these. It is also intended to operate as a fully-compatible extension of the existing inactive corrosion test facilities at AEA Technology's Risley site.

AEA Technology adopts a Team approach in responding to project needs, and is able to bring together staff and facility resources appropriate to the problem. In the context of Environmentally-Assisted Cracking of Nuclear plant materials, such a team would involve materials and water chemistry experts and inactive test facilities from our Risley site, materials and electron microscopy experts from AEA Technology Harwell, and active materials testing experts and the active testing facilities at Windscale.

8 Advantages of the new facility

The new facility constructed by AEA Technology has been designed to bring together best practice and experience in operating pressurised corrosion testing rigs and active specimen testing. The resultant facility represents a state-of-the-art capability in this field, with a performance that exceeds that available in other installations. Some specific advantages leading to this performance are:

- fully shielded systems allowing use of highly activated specimens
- state of the art water chemistry control
- flexible water chemistries and operating envelope
- extended operating temperature (360°C)
- multiple testing channels
- high-force testing machines allowing use of large specimens if required
- technical backup through experience with non-active testing and sophisticated analysis/characterisation
- supporting activities in handling active materials:
  - *on-plant sampling,*
  - *transport,*
  - *machining of active materials*
  - *disposal*

Appendix 1
Specification of the facility

Testing Machine Capacity:	1 off 280KN servoelectric 1 off 250KN servoelectric 1 off 100KN servoelectric
Testing Machine control parameters	Load, Displacement, Strain. Microprocessor programmable histories
Maximum cycling frequency	1 Hz
Maximum Shielding	300 mm Steel
Maximum Autoclave Bore	200 mm
Water environment	PWR, BWR, Boric acid or LiOH doped, Hydrogen cover gas.
Maximum operating temperature	360°C
Maximum operating pressure	200 bar
Water refresh rate	1 - 5 litres/day
Water chemistry control	< 5 ppb Cl^- < 2 ppb dissolved oxygen
Instrumentation	Temperature Pressure Flow rate pH Zirconia reference electrode conductivity (inlet and outlet water) dissolved O_2 (inlet and outlet water) DC potential drop crack growth monitoring

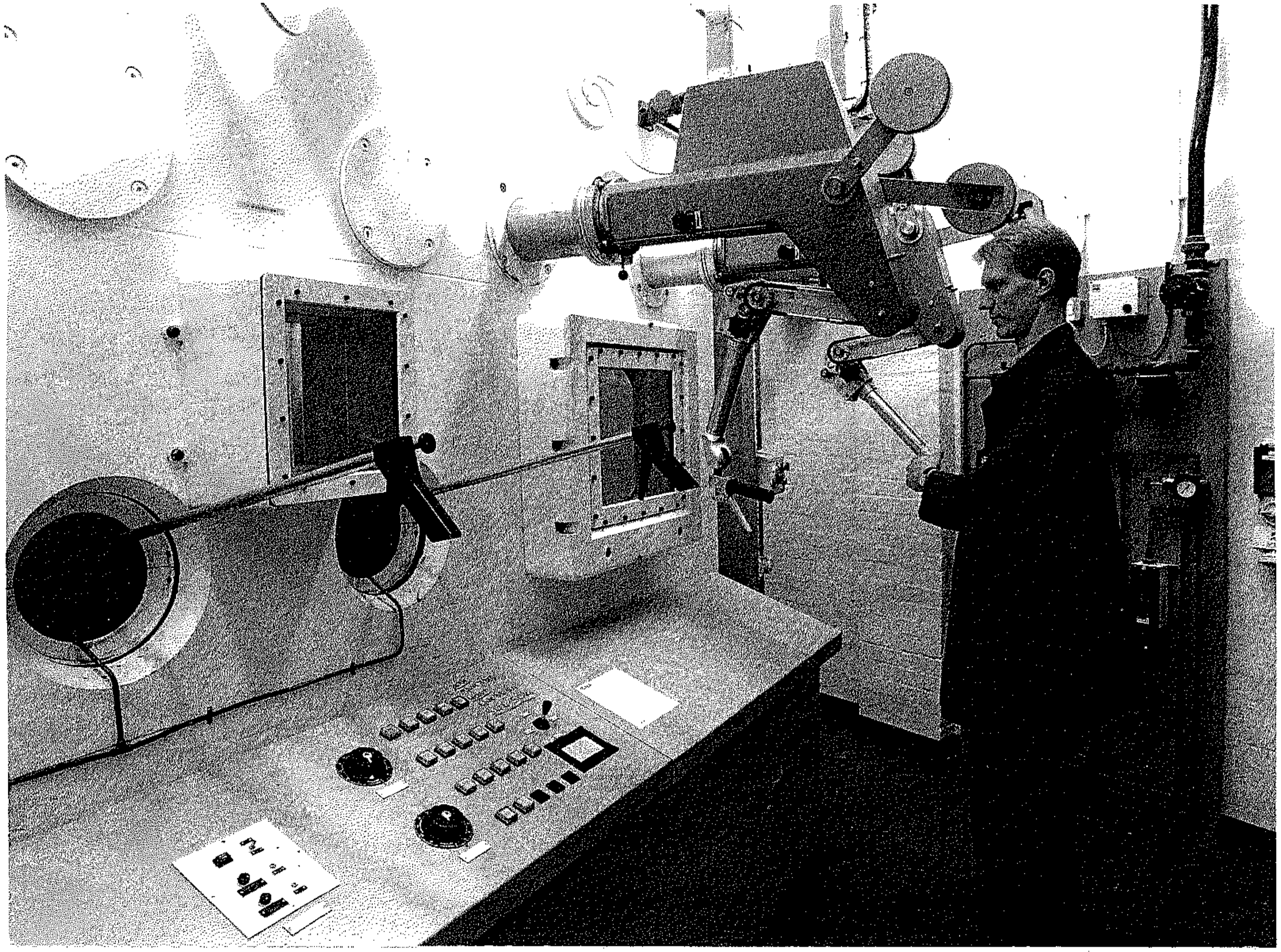


Fig 1: Working face of shielded 280KN Testing Machine.

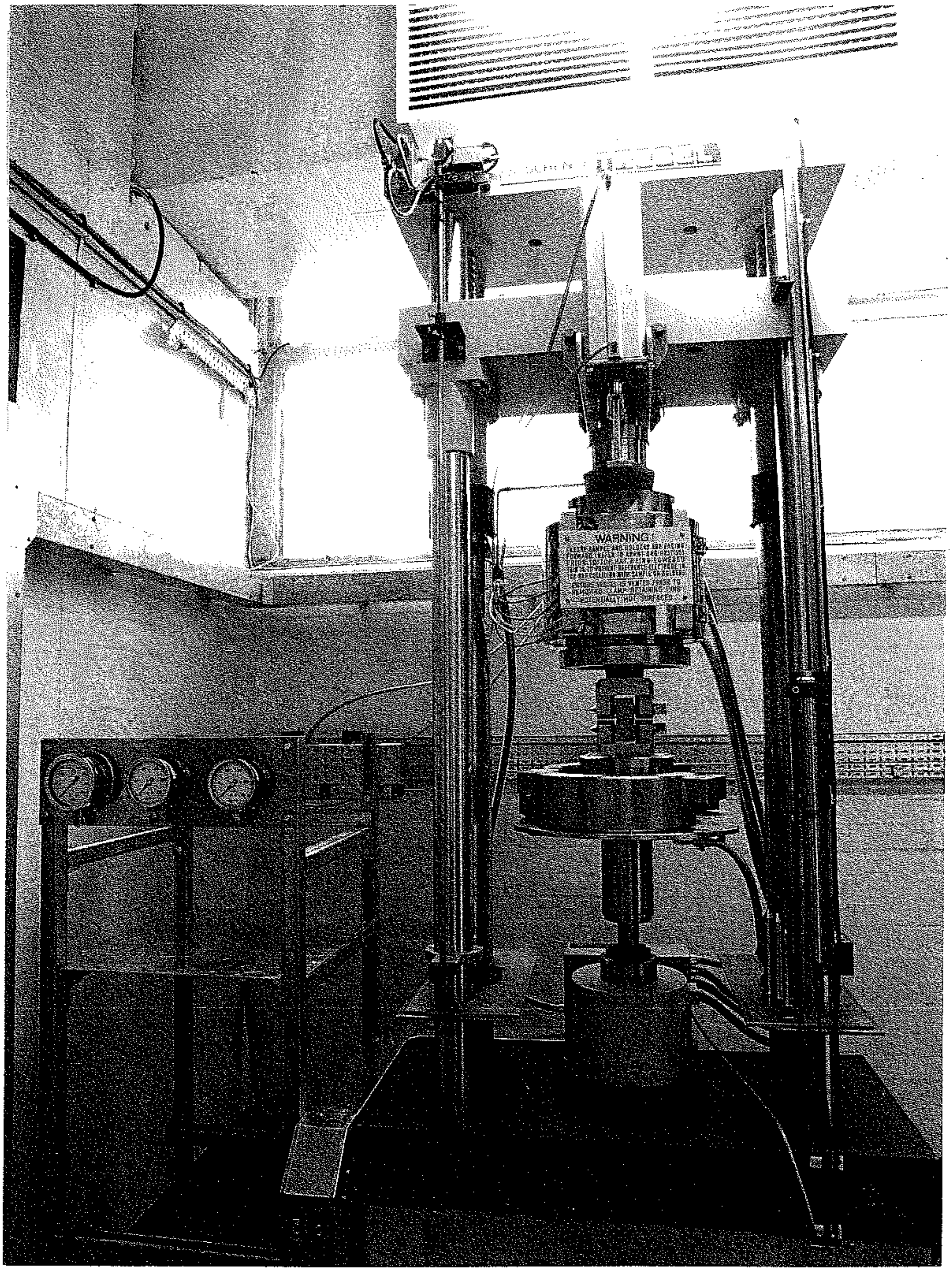
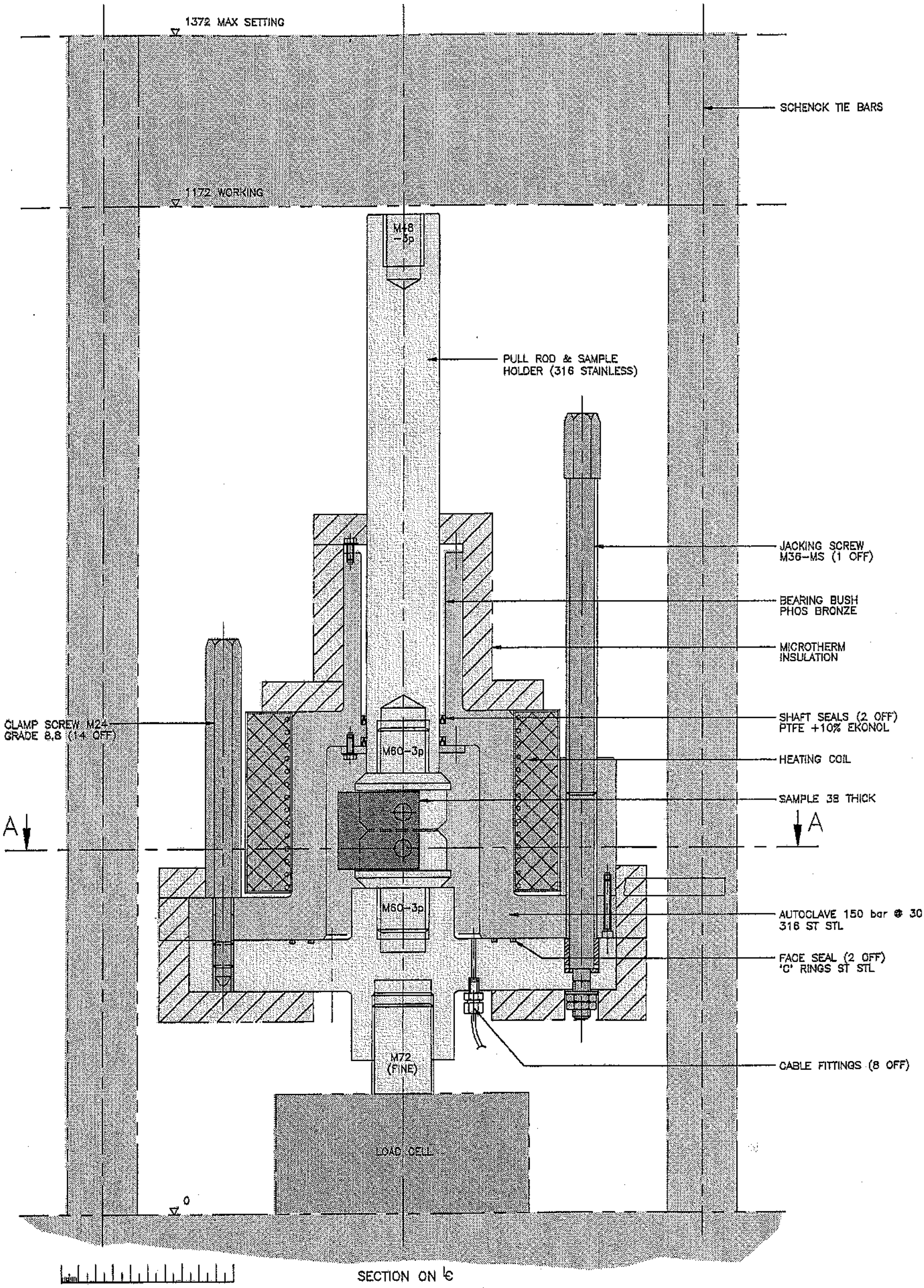
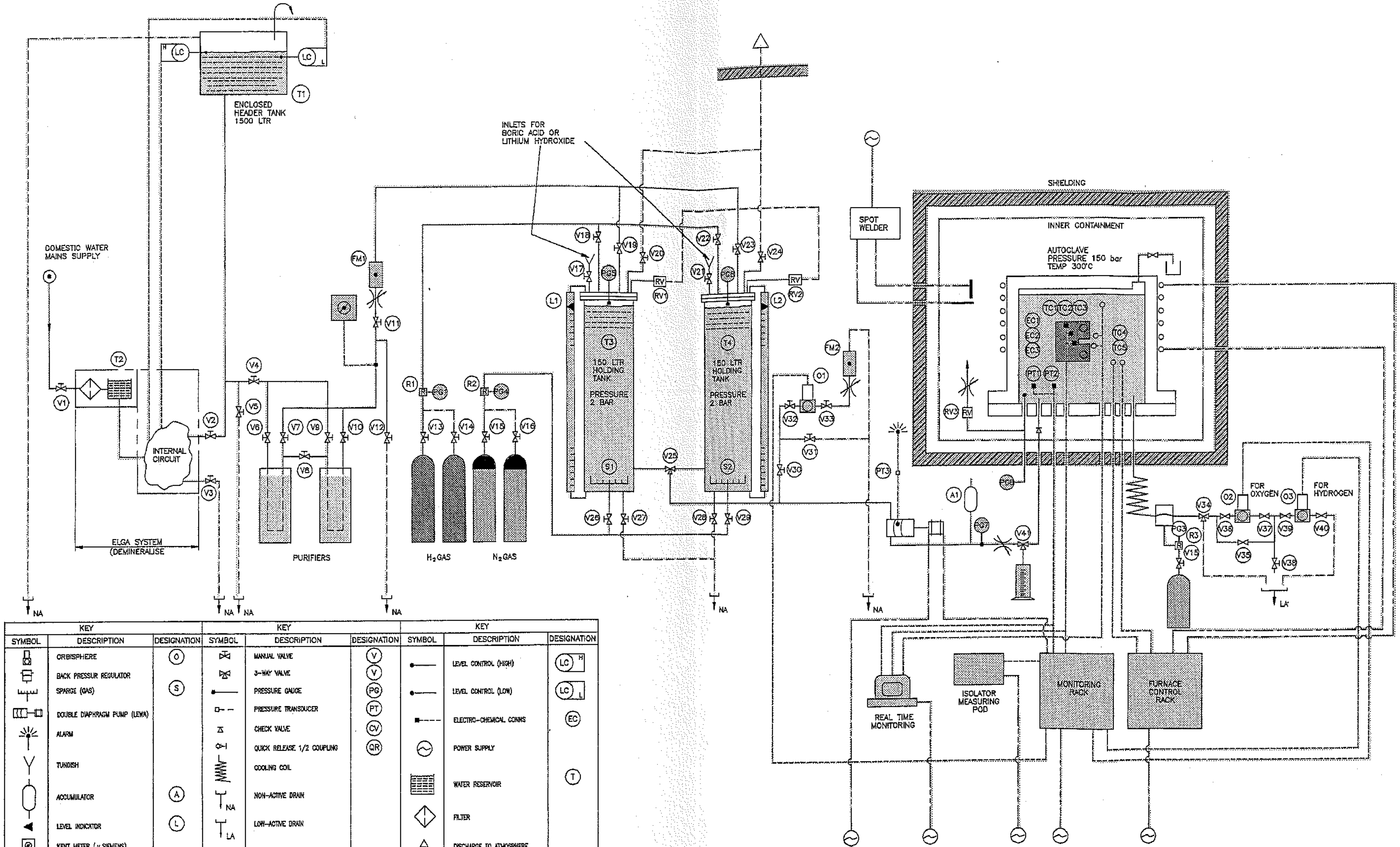


Fig 2: 100KN Testing Machine fitted with autoclave and clevises for CTS specimens.



Autoclave Stress Corrosion Testing Facility



KEY			KEY			KEY		
SYMBOL	DESCRIPTION	DESIGNATION	SYMBOL	DESCRIPTION	DESIGNATION	SYMBOL	DESCRIPTION	DESIGNATION
	ORBISPHERE	O		MANUAL VALVE	V		LEVEL CONTROL (HIGH)	LC H
	BACK PRESSURE REGULATOR			3-WAY VALVE	V		LEVEL CONTROL (LOW)	LC L
	SPARGE (GAS)	S		PRESSURE GAUGE	PG		ELECTRO-CHEMICAL CONNS	EC
	DOUBLE DIAPHRAGM PUMP (LEWA)			PRESSURE TRANSDUCER	PT		POWER SUPPLY	
	ALARM			CHECK VALVE	CV		WATER RESERVOIR	T
	TUNDISH			QUICK RELEASE 1/2 COUPLING	QR		FILTER	
	ACCUMULATOR	A		COOLING COIL			DISCHARGE TO ATMOSPHERE	
	LEVEL INDICATOR	L		NON-ACTIVE DRAIN				
	KENT METER (μ SIEMENS)			LOW-ACTIVE DRAIN				
	PRESSURE REGULATOR	R		HARD PIPE				
	RELIEF VALVE	RV		DRAIN LINE				
	FLOWMETER	F		CONTROL LINE				
	THROTTLE VALVE			ELECTRIC SUPPLIES				
	RESTRICTOR			THERMOCOUPLE	TC			

Process Flow Diagram Corrosion Testing Facility