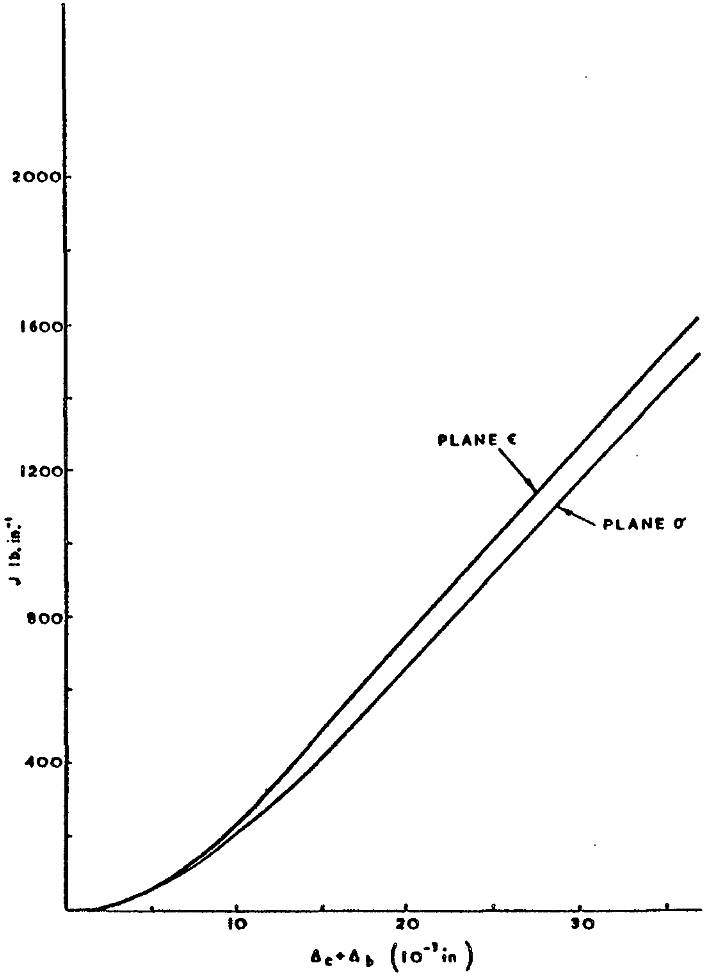

COMPUTER PREDICTION OF J VERSUS Δ RELATIONSHIP FOR A 29% PRESTRAINED SPECIMEN OF 0·394 in. THICKNESS

FIG. 15

UKAEA Mechanical Test Work in Sodium

D.S. Wood, UKAEA, RNPDL, Risley, Great Britain

INTRODUCTION

The main aim of the UKAEA work is to perform mechanical tests in high quality sodium, and on the basis of relatively long term tests to establish whether factors need to be applied to the air data for the design and assessment of components which will have to operate in sodium for up to 30 years. Most of the tests will be performed in sodium containing 5-10 ppm O_2 and ~ 1 ppm C with a flow rate over the specimen surface of 3m/sec. Some work is also planned to establish the effect of changes in oxygen level up to 30 ppm on the properties and carburisation studies will also be performed.

This work has been in progress on a limited scale for 2-3 years but is now increasing in magnitude to meet the programme requirements.

The materials under test include Type 316 steel and 9% Cr steel with most emphasis being placed on the austenitic steel.

EQUIPMENT

The extent of the equipment is shown in Table I. Four two-point loops are currently operational, an eight-point loop is expected to become available later this year and five four-point loops should be commissioned during 1978. As indicated in Table I various static facilities are also involved in this test work. All the equipment is capable of operating at temperatures of up to 650°C. Tensile, fatigue, crack growth or fracture specimens can be installed in the pre-exposure test stations. The fatigue machines can be utilised for endurance or fatigue crack growth testing.

SODIUM TEST PROGRAMME ON TYPE 316 STEEL

Stress rupture tests to 20,000h are planned at 625°C and 20,000h tests will also be performed at 575°C. Subsidiary tests will be carried out to 10,000h to study a number of variables. For example the effect of specimen size will be investigated and some tests will be repeated in static sodium to establish the relationship with dynamic sodium; specimens will also be tested which have been pre-fatigued prior to stress rupture testing. Additionally, welded specimens will be tested in both static and dynamic sodium. Some machines will be deployed on creep crack growth work using double edge notched specimens; this part of the programme has not yet been resolved but emphasis will be placed on the testing of weld metal because of its greater tendency towards embrittlement.

Strain controlled fatigue tests will be performed at a temperature of 625°C and a strain rate of 4%/min. The initial aim is to obtain data points to endurances of up to about 500,000 cycles. Tests to shorter endurances will be carried out on specimens which have previously been creep strained and also on weld metal specimens. Later, tests will be performed in which a hold time of up to 5h is introduced into the tension part of each cycle eventually extending testing times to about 6 months. The effects of pre-exposure to high quality and high carbon sodium on the subsequent fatigue behaviour will be studied.

Fatigue crack propagation tests will be performed on parent metal and weld metal using standard size compact tension specimens in high quality sodium at temperatures of 625° and 400°C. Tests in high carbon sodium are also planned. A basic frequency of 1cps will be employed but some tests will be carried out with square wave loading cycles, ie involving hold times of up to 5h. Some specimens will be pre-exposed in dynamic sodium prior to testing.

High cycle fatigue tests at a frequency of about 100 cps will be performed at 625°C on parent metal and weld metal to endurances of 1×10^9 cycles. Some specimens will be pre-strained by creep and others will be pre-exposed to dynamic sodium for 10,000h before testing.

Tensile specimens will be exposed to dynamic sodium at 625°C for times of up to 3 years. Both parent metal and weld metal will be studied. Tensile tests will subsequently be performed at RT and 625°C.

Examinations will be carried out on the various specimens after testing. This will include SEM work on the fracture face and studies of the surface and bulk microstructure.

Although some of the above tests will be carried out in 1977 and 1978 the majority of them will not be done until 1979-1981.

RESULTS

1. FATIGUE

a. Static Sodium - Bending Fatigue

The results obtained at 625°C are shown in Fig 1. Whilst sodium appears to have little effect on the endurance at strain ranges above 1.5% at lower strain ranges there is a distinct improvement in life. Two tests were performed in sodium with a ½h hold time in each cycle. This was found to reduce the endurance by a factor of two.

b. Static Sodium - Push-pull

Tests have been performed at 625°C. See Fig 2. In this case sodium was found to improve the life at all the strain ranges investigated (0.6 to 1.3%).

c. Dynamic Sodium - Push-pull

Four tests have been completed at 625°C. Some of the tests may be invalid as a result of the start up procedure which was modified after the second test. Nevertheless all the specimens showed an improved life relative to similar tests performed in air. Probably of greatest relevance is a test performed at a strain range of 0.4% which failed in 112,000 cycles; the corresponding air test failed in 30,000 cycles.

d. General Comments

Under rapid cycling conditions there is consistent evidence of an improvement of endurance by at least a factor of four in high quality sodium at strain ranges below 0.7%. Thus under cyclic conditions it may be possible to increase the allowable strain range as a result of this beneficial effect of sodium. It is not yet clear however that this improvement is carried over to the situation involving dwell periods. In future most emphasis will be placed on the evaluation of the effect of sodium under hold time conditions.

2. STRESS RUPTURE

Only two tests have been completed on Type 316 steel at 625°C in high purity dynamic sodium. Both tests were of about 3000h duration. (See Fig 3). Indications to date are that high quality sodium is not detrimental to either the strength or ductility of this steel. A test on the same case of steel performed at Interatom, Germany for the UKAEA for about 1000h at 550°C in static sodium confirms this view.

CONCLUSION

From the very limited fatigue and stress rupture tests so far performed on Type 316 steel there is no evidence to suggest that high purity sodium may be detrimental. Longer term tests are necessary however to confirm this finding which is based on results from relatively short term tests. Tests are also necessary in less pure sodium.

TABLE I: UKAEA – SODIUM MECHANICAL PROPERTIES TEST EQUIPMENT

	Number
I: EQUIPMENT CURRENTLY AVAILABLE:	
a. Dynamic Sodium	
2 point loops	4
Stress rupture machines	4
Fatigue machine	1
Pre-exposure points	2
b. Static Sodium	
Bend fatigue machine	1
Fatigue machine – endurance testing	1
Fatigue machine – crack growth work	1
II: ADDITIONAL EQUIPMENT AVAILABLE AT BABCOCK AND WILCOCK LATE 1977	
(Dynamic Sodium)	
Eight point loop	1
Stress rupture machines	8
III: ADDITIONAL EQUIPMENT AVAILABLE IN 1978	
a. Dynamic Sodium	
4 point loops	5
Stress rupture machines	10
Fatigue machines	4
High cycle fatigue machine	1
Pre-exposure points	4
b. Static Sodium	
Stress rupture machines	8

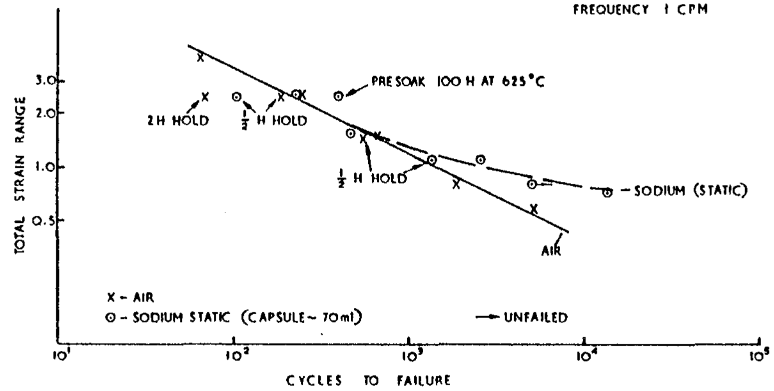

FIG. 1 EFFECT OF STATIC SODIUM ON BENDING FATIGUE OF TYPE 316 STEEL AT 625°C

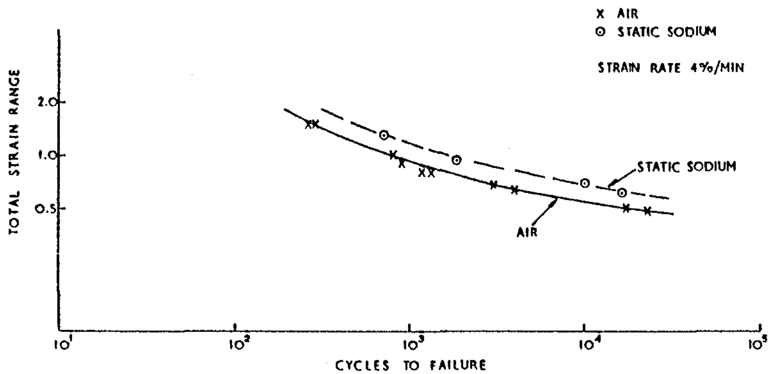

FIG. 2 EFFECT OF STATIC SODIUM ON THE PUSH-PULL FATIGUE BEHAVIOUR OF TYPE 316 STEEL AT 625°C

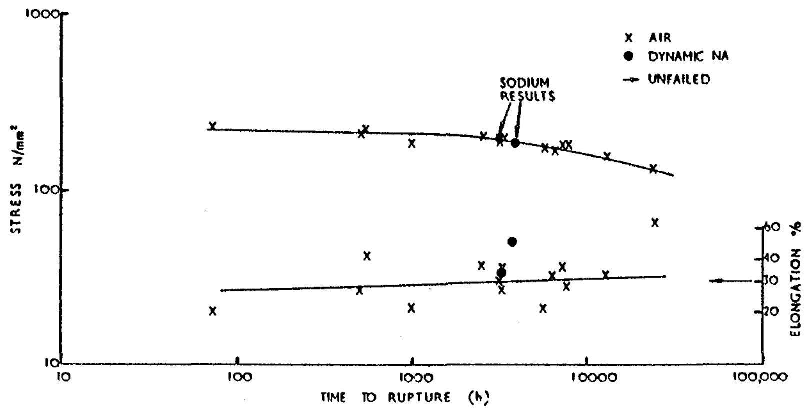

FIG. 3 STRESS RUPTURE TESTS ON TYPE 316 STEEL AT 625°C