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by Alan Arias

Lewis Research Center
Cleveland, Ohio 44135

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16. Abstract

The construction and operation of a versatile, simplified bend tester is described. The tester is usable at temperatures from -192° to 650° C in air. Novel features of the tester include a single test chamber for cryogenic or elevated temperatures, specimen alining support rollers, and either manual or motorized operation.

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A SIMPLIFIED DUCTILE-BRITTLE TRANSITION TEMPERATURE TESTER

by Alan Arias

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SUMMARY

A bend tester to determine the ductile-brittle transition temperature (DBTT) of body-centered-cubic metals and alloys has been designed, built, and satisfactorily operated. The tester features a novel single test chamber for cooling or heating the test specimens. Tests can be carried out at temperatures from -192° to 650° C. The tester can be easily modified for use to temperatures up to about 1000° C. Additional features of the tester include specimen alining support rollers and the choice of either motorized or manual operation.

The following components of the tester are described in detail: specimen holder, test chamber, loading system, framework, cooling system, heating system, and electrical circuits.

Procedures for determining DBTT's with a small number of specimens are explained. Typical bend angle-test temperature plots are included in this report.

INTRODUCTION

Most body-centered-cubic metals and alloys change from a very ductile to a glass-like, brittle behavior as the temperature at which they are strained is lowered. The ductile to brittle change for these materials usually occurs within a narrow temperature range. Within this range is the so-called ductile-brittle transition temperature (DBTT). The DBTT is determined by bending sheet specimens of the material and correlating the bend angle with the test temperature. In reference 1 the DBTT is defined as "the lowest temperature for a given bend radius, at which a sound, 90° to 105° bend can be produced and the highest temperature in which specimen failure occurs." Reference 1 also specifies the recommended test procedure, specimen sizes, and test fixture geometry.

The DBTT equipment used heretofore normally includes a furnace for heating and a separate container for cooling the test specimens. Usually, a tensile machine is used for bending the specimens, mainly because it has selectable crosshead speeds. In addition to using expensive equipment to carry out relatively simple DBTT tests, most tensile testers require specialized operators.

This report describes the construction and operation of a DBTT tester that overcomes these disadvantages. The tester features a single chamber for heating or cooling the test specimens. The specimen is loaded by means of a simple lever system driven by a variable speed motor. In addition, the tester is relatively small, inexpensive to build, versatile, and easy to operate.

GENERAL DESCRIPTION OF THE BEND TESTER

The assembly of the DBTT tester is shown in figure 1. The overall dimensions of the tester are 48.3 centimeters (19 in.) wide by 56 centimeters (22 in.) high by 53.5 centimeters (21 in.) deep. The tester can operate in the temperature range of -192° to 650° C (-314° to 1200° F). Temperatures from -192° C (-314° F) to room temperature (RT) are obtained by cooling the test chamber with liquid nitrogen. Temperature control in this low-temperature range is obtained by means of a solenoid valve in the liquid-nitrogen supply line. This solenoid valve is actuated by a temperature controller. Temperatures in the RT to 650° C (1200° F) range are obtained by resistance heating the test chamber. Temperature control in this high-temperature range is obtained by means of a power relay operated by a temperature controller.

For description purposes the tester will be regarded as made up of the following components:

(1) A specimen holder
(2) A test chamber for housing the specimen holder and for heating or cooling the test specimen
(3) A system for applying a bending load to the specimen
(4) An alining framework
(5) A test-chamber cooling system
(6) A test-chamber heating system
(7) Electrical circuits.

These various components will now be described in more detail.

Specimen Holder

An enlarged view of the specimen holder is shown in figure 2. In this holder the test specimen is bent as a simple beam in three-point loading. Yokes or notches are machined in the front and back of the holder for the support rollers. These rollers have a 0.254-centimeter (0.100-in.) outside diameter in the load bearing section. A novel feature of these rollers is that the back one third of the roller has an enlarged diameter to provide a shoulder for accurate positioning of the specimens.

The design of the holder follows the recommendations of reference 1. The holder shown in figure 2 provides spans of 2.54 centimeters (1 in.) and 3.81 centimeters (1.5 in.). However, there is room in the test chamber for specimen holders with spans up to 7.62 centimeters (3 in.). The holder and rollers are made from Inconel.

Test Chamber

The test chamber is shown as part of the assembly in figure 1. This chamber has a 14.9-centimeter $\left(5\frac{7}{8}\text{-in.}\right)$ inside diameter and is 15.2 centimeters (6 in.) long. Top and bottom plates are bolted to a shell to form a rigid chamber. This chamber slides up and down the base column thereby allowing easy access to the specimen holder for insertion or removal of test specimens. A removable holding pin inserted into a hole in the column holds the chamber in the raised (or testing) position. When the chamber is lowered, the lid is retained by a stud in the slide.

In addition to the specimen holder, the chamber houses a heater and a perforated baffle (to be described later). All the parts of the test chamber are made from type 304 stainless steel.

Loading System

The force required to bend the specimen is applied to its midsection by means of a roller located at the lower end of the slide. As shown in figure 2, this roller is held in position by means of roller holders fastened to the slide with screws. As recommended in reference 1, the roller should have a radius equal to four times the thickness of the test specimen. Rollers are easily replaced by loosening the screws of the front roller holder.

In its up and down motion the slide is guided in a slot accurately machined in the frame. The slide is moved through a lever, link, and cable by means of a geared down, reversible, adjustable speed motor (see fig. 1). Although the motor could have been geared directly to the slide, this arrangement was preferred because it allows manual bending of the specimens by means of the lever.

The cable is thin enough to snap should the operator forget to stop the motor at the end of a test. In addition, the controller has motor overload protection. However, if so desired, it is relatively easy to install limit switches actuated either by the slide or by the lever.

An adjustable counterweight at the back end of the lever lifts the slide when the rotation of the motor is reversed.

Fiducial lines on the front of the slide indicate the degree of bending of the specimen; they are also used to calibrate the slide speed.

Alining Framework

The alining framework is made up of the frame proper, the base column, and the guide slot cover. These three parts should be accurately machined. The slide should be able to move in the guide slot without binding, and its roller should act on the specimen at the midsection of the span. This also requires that the base column be accurately machined and positioned. The framework is rigidly fastened to the base and to the control panel.

Cooling System

As already stated, for operation below room temperature the test chamber is cooled with liquid nitrogen. The liquid nitrogen enters the chamber tangentially through a side opening. A perforated baffle (shown in fig. 1) deflects the incoming liquid-nitrogen stream and helps distribute it uniformly around the chamber. The liquid-nitrogen inlet is connected to a dewar flask reservoir (not shown) through a flexible metal hose and a solenoid valve. The metal hose also grounds the chamber electrically. The solenoid valve is a normally closed, cryogenic type valve. This valve is actuated by the temperature controller in response to signals from a copper/constantan thermocouple in contact with the specimen. The cooling system has been satisfactorily operated to temperatures down to -192° C (-314° F).

Heating System

The test chamber is heated by means of an Inconel sheathed, Calrod type heater. This heater enters the chamber through the top plate and is wound into a helix (see fig. 1). Unwound, the heater is 203 centimeters (80 in.) long with a 0.32-centimeter (1/8-in.) outside diameter. It has a nominal resistance of 25 ohms. The power consumption is about 575 watts at 120 volts input. This power is just sufficient to hold the specimen at 650° C (1200° F). However, there is enough room in the chamber for additional heaters or for a bigger and more powerful heater. Hence, higher operating temperatures or faster heating rates are possible. Since all the heated parts of the tester are either Inconel or stainless steel, temperatures up to about 1000° C (1832° F) should be easily obtainable.

Temperature control in the high-temperature range is obtained by means of a power relay actuated by a temperature controller in response to signals from a chromel/alumel thermocouple in contact with the specimen.

Electrical Circuits

The electrical circuit for the tester is shown in figure 3(a). The circuit features two separate temperature controllers: one for temperatures below room temperature and one for temperatures above room temperature. The temperature range is selected by means of a double pole double throw, center off switch.

An alternate, simpler electrical circuit is shown in figure 3(b). In this arrangement the single temperature controller could be used with an iron/constantan thermocouple. This thermocouple covers the temperature range from -195° to 870° C (-319° to 1600° F). This alternate circuit has the advantage that only one thermocouple and one controller are used. However, for a given size controller the temperature resolution is lower.

TEST PROCEDURES

The DBTT of a material is determined by bending specimens at successively higher (or lower) temperatures and measuring the bend angles after removing the specimens from the tester. Reference 1 recommends making the tests at 55° C (100° F) intervals in order to bracket the DBTT range.

With the tester described herein, the number of specimens required to determine the DBTT of a material can be substantially reduced by using a preliminary test. Starting at a temperature well above the estimated DBTT, a specimen is bent slightly by moving the lever down by hand and observing the position of the fiducial marks on the slide. The temperature is then lowered about 55° C (100° F), and the specimen bent slightly again. The procedure is continued until the specimen breaks in a brittle manner. This can be easily determined by feel. Once the DBTT is bracketed, data points for the bend-angle against test temperature plot are obtained by using a single specimen per test. Some of the curves so obtained illustrating the range capabilities of the tester are shown in figure 4.

The tester can also be used for determining the minimum bend radius of sheet materials at a fixed temperature. For this type of test a large number of rollers of different radii are needed.

CONCLUSIONS

A simplified ductile-brittle transition temperature (DBTT) tester has been designed, built, and successfully operated. With this tester, DBTT's from -192° to 650° C can be readily determined. The successful application of this tester to the determination of the DBTT of chromium and molybdenum has been demonstrated. This tester should be of value in any program that requires a large number of DBTT tests, since it can be used without tying up a tensile machine. The value of this tester is enhanced by its relatively small size, ease of operation, and inexpensive manufacture.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 23, 1973,
501-21.

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1. Anon.: Evaluation of Test Methods for Refractory Metal Sheet Materials. Rep. MAB-216-M, National Academy of Sciences, National Research Council (AD-625606), Nov. 1965.

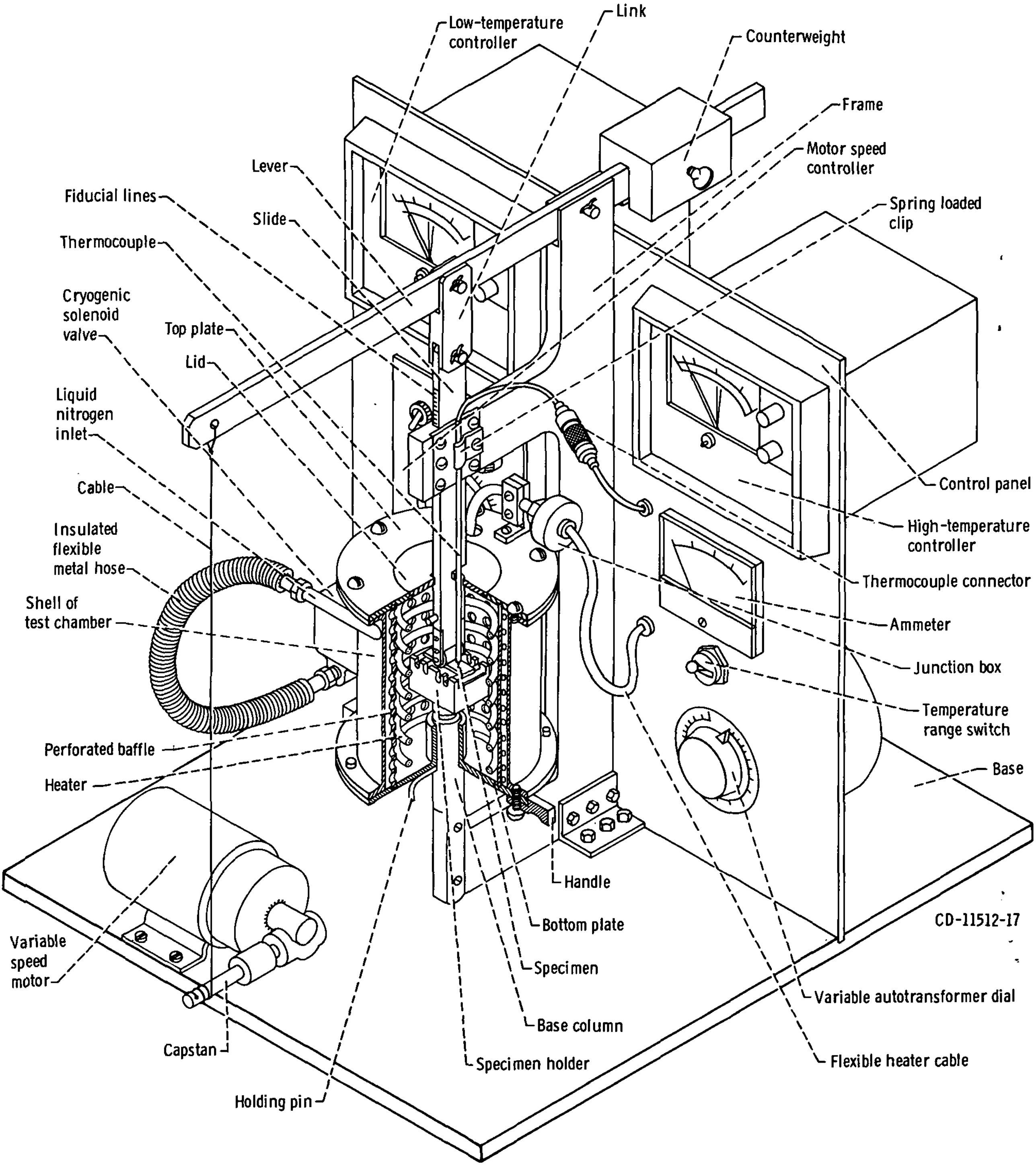


Figure 1. - Ductile-to-brittle transition temperature tester assembly.

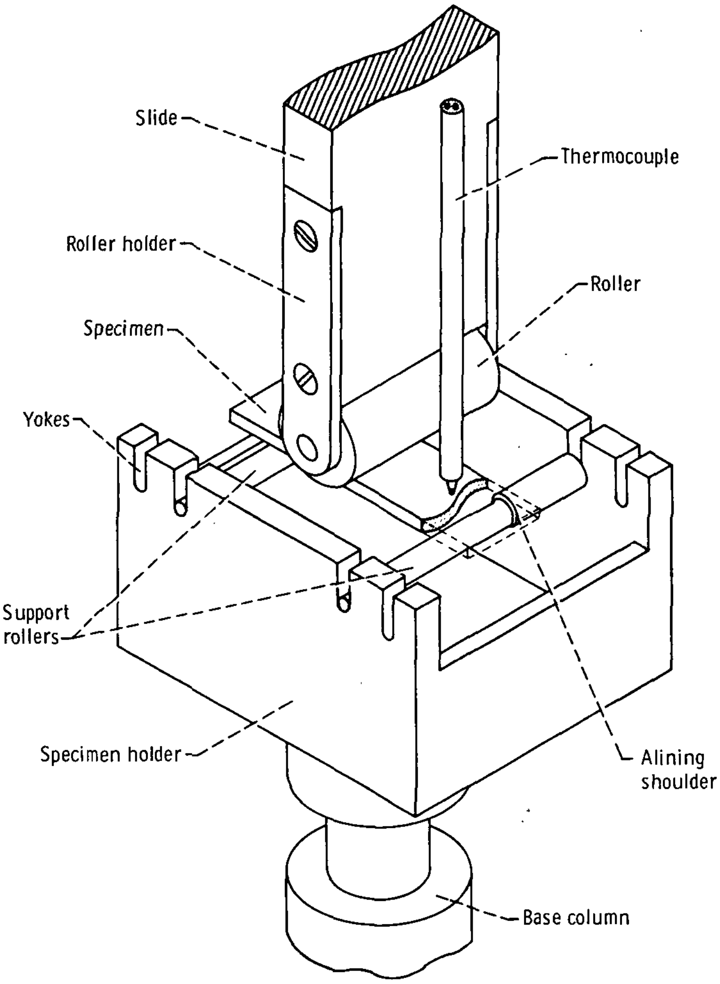
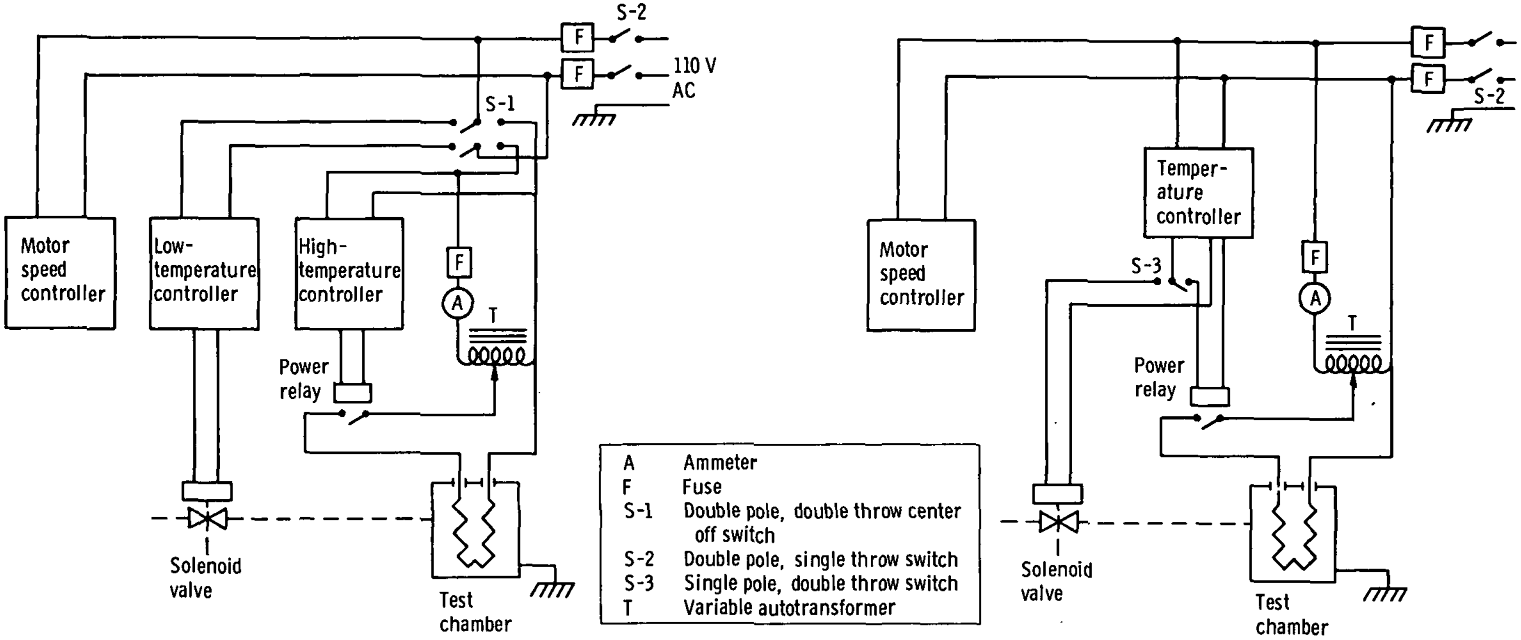


Figure 2. - Specimen holder detail.



(a) Two-controller bend tester.

(b) Single-controller bend tester.

Figure 3. - Two electrical circuits for bend tester.

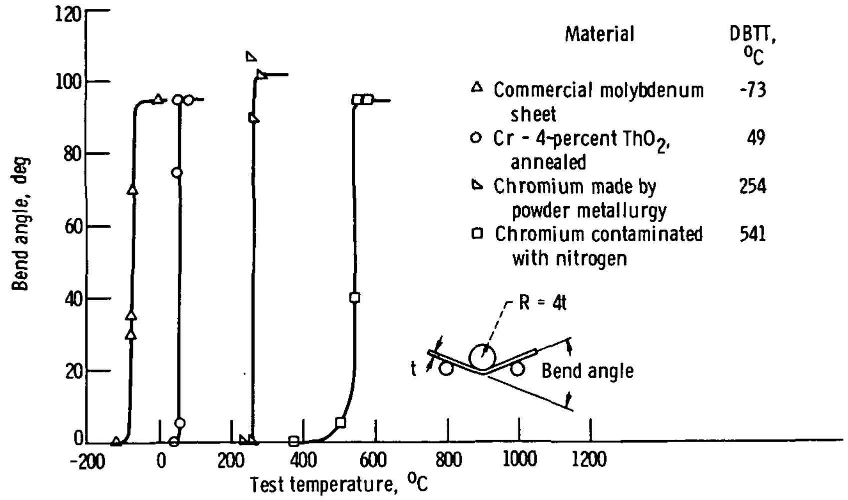


Figure 4. - Typical bend angle temperature plots.

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