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# Multifunctional High Precision Pneumatic Loading System (HIPS) for Creep-Fatigue Testing

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**Abstract**

The first successful application of the high precision pneumatic loading system for advanced material testing was developed at VTT in 1995. The pneumatic servo-controlled loading system is capable of operating in a range of extreme conditions such as high temperature, pressurised water or steam, Super Critical Water (SCW) and irradiation environments. The main benefit of the pneumatic loading system is that there is no moving parts (loading lead-throughs) required for loading a specimen inside a pressure vessel or otherwise demanding containment (water, gas, radioactive), only pressure lines and electrical feedback connections together with the pneumatic loading unit, bellows are required. Also, the pneumatically powered testing device itself can be far away from the control units and regulating servo valves. The HIPS, previously used for tensile testing, stress corrosion cracking, fatigue, in-pile creep fatigue (copper), and other test variants with combined environmental impact, has now been modified to perform load and strain controlled testing at temperatures in the creep range for steels. For the high temperature applications where creep is an active damage mechanism, the HIPS technology opens new applications for creep and fatigue related testing types such as standard creep-fatigue (with and without hold time), relaxation and slow strain rate tensile testing. The main focus of this paper is to present the current status of the development work of the HIPS technology for high temperature applications, presently conducted in air atmosphere. Also some initial creep-fatigue results and creep-fatigue behavior comparisons are presented for some austenitic stainless steels (316L, 347H, 321).


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*Keywords:* Creep-fatigue testing; high precision pneumatic loading system (HIPS); austenitic stainless steels

## 1. Introduction

Conventional hydraulic material testing systems produce the load on the specimen by using a pull rod. Pull rod penetrates the pressure boundary through a sealing element, which causes an additional friction force. In the high precision pneumatic loading system (HIPS) the operation principle of the material testing system is pneumatic instead of classical servo-hydraulic systems in order to produce highly accurate control and ensure that the testing environment cannot be contaminated with the pressurisation medium [1].

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Typically, the HIPS concept consists of the pneumatic servo controlled pressure adjusting loop with programmable servo controllers, pneumatic loading unit, bellows, together with the loading frame, test specimen and measurement sensors as shown in Fig.1. The system can therefore be used for testing of small size specimens in demanding and sensitive test environments, which is a significant advantage in in-reactor tests.

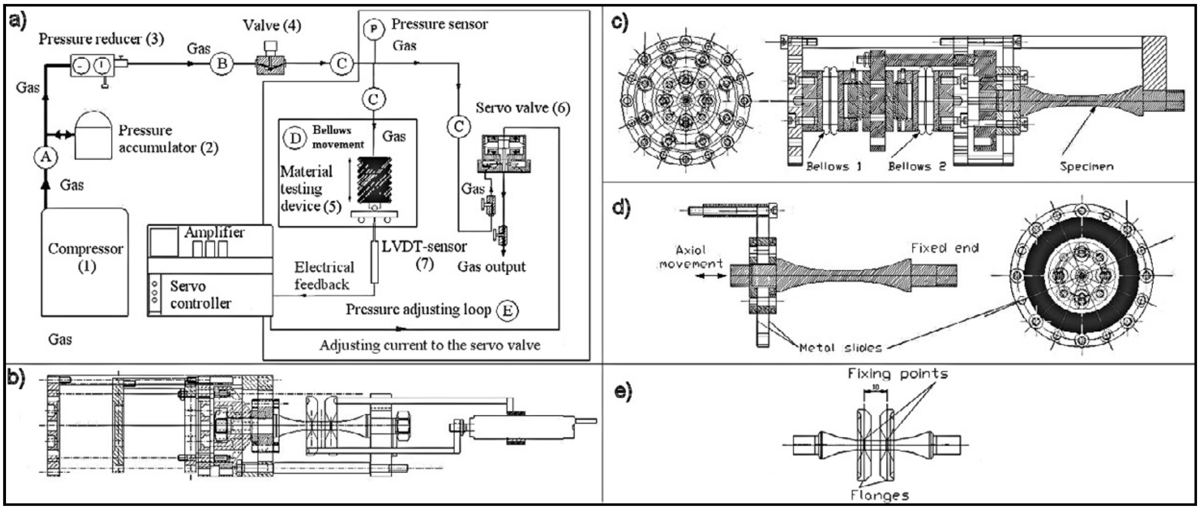


Fig. 1. (a) The main components of the HIPS system, (b) the main parts of the displacement measurement system, (c) the loading frame, (d) the specimen fixing parts and (e) LVDT fixing flanges.

## 2. HIPS applications

The HIPS concept is capable of operating in a number of different challenging environments such as at high temperature, pressurised water and steam, SCW and radiation environments. The wide spectrum of tests enabled by the flexible pneumatic bellows based loading unit concept includes tensile testing, stress corrosion cracking, fatigue, creep fatigue, tensile and fatigue under radiation and many variants with combined environmental impact. The system has also been successfully used as a high accuracy mover in a contact electrode resistance (CER) measurement system. Detailed description about the various HIPS applications and testing environments described above are presented in references [1-7].

## 3. HIPS application for creep-fatigue testing

Creep-fatigue testing is typically performed at elevated temperatures and involves the sequential or simultaneous application of the loading conditions necessary to generate cyclic deformation/damage enhanced by creep deformation/damage or vice versa [8]. The latest version of the HIPS creep-fatigue testing device includes components that enable the testing at temperatures up to 800°C in air atmosphere.

The pneumatic servo controlled pressure adjusting loop based control setup of HIPS is patented and it is basically the same for all the applications, with a few small modifications demanded by the selected environments. The main components of the HIPS creep-fatigue pressure control system are schematically presented in Fig.1(a). The pneumatic servo controlled pressure adjusting loop system consists of four separate pressure boundaries (A), (B), (C), and (D), as shown in Fig.1(a). The gas flow needed for the servo valve (6) is provided by the compressor (1). From the flow valve (4) the gas is led to the bellows (5) and to the servo valve (6) by using gas tubing. The suitable pressure for bellows is adjusted by letting the gas out from the pressure boundary (C) via the servo valve. In the current HIPS creep-fatigue application the pressure boundary (D) is at atmospheric pressure. During the tests, the pressure of the pressure boundary (C), and therefore also the