ADVANCED HIGH CHROMIUM FERRITIC STEELS FOR BOILER COMPONENTS OPERATING AT HIGH TEMPERATURE

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***Abstract* - In the last 15 years Dalmine and Centro Sviluppo Materiali (CSM) have worked together to develop the high Chromium ferritic steels for tubes and pipes to manufacture high temperature boiler components used in new high efficiency power plants.**
The activities started in 1985 with the development of P/T91 process and metallurgy, in the frame of ECSC project, followed, in 1994, by the evolution of P/T91 with the addition of 1% W. This new European steel called E911 was introduced during the COST 501 European Programme to improve the high temperature mechanical properties.
This paper describes the process routes and compares the mechanical and creep behavior of the two grades as well as the evolution of microstructure and precipitates after aging.

***Keywords* - high chromium ferritic steel, creep, microstructure evolution, boiler material.**

I. INTRODUCTION

The development of the family of 9-12%Cr martensitic steels for power generation components has been a significant feature in the 1980s. However, the basic compositions of 9Cr1Mo have been widely used for many years. The driving force for new developments has been the need to increase the temperature and pressure of the steam circuit.

The Steel Grade P91, which has the base composition of 9%Cr 1%Mo with additions of niobium, vanadium and nitrogen, developed in the ORNL Research Laboratories, has provided a platform for further developments in Japan (Naoi *et al.*,1995; Sawarahi *et al.*, 1995). In Europe, a new steel called E911 derived from the Grade 91 (9Cr1MoNbVN) with the addition of 1% W was developed in the frame of the programme COST 501 Round III WP11.

The aim of this paper is to present the work carried out by Dalmine and CSM to develop and qualify P91 and E911 in terms of mechanical properties and microstructure evolutions (Di Gianfrancesco *et al.*, 1996).

II. MATERIALS

External qualified suppliers manufactured ingots of the two grades: Cogne for P91, UES (United Engineering Steel, UK) for E911.

The chemical compositions are shown in Table I.
Dalmine has manufactured the pipes with the following process route:

- ingot heating at 1300°C;
- partially boring on a horizontal press;
- piercing;
- rolling at the pilger mill;
- heat treatment (Grade E911 = normalizing 1060°C/air + tempering 760°C; Grade 91 = normalizing 1040°C/air + tempering 740°C);
- finishing operations;
- machining.

A. Characterization of the as treated material

The E911 transformation temperatures have been evaluated by dilatometer. As shown in Table II they are higher than for steel P91.

Grade	C	Si	Mn	P	S	Cr	Mo
P91	0.10	0.45	0.50	0.019	0.002	9.12	0.96
E911	0.11	0.20	0.35	0.007	0.003	9.16	1.10
	Ni	**Nb**	**V**	**Al**	**W**	**N**	
P91	0.05	0.060	0.21	0.004	-	0.040	
E911	0.23	0.068	0.23	0.007	1.0	0.072	

Table I: Chemical composition of steels (wt %).

Material	A_{c1} (°C)	A_{c3} (°C)
P91	815	865
E911	841	948

Table II: Transformation temperature.