A Laboratory Flash Furnace for Strand Annealing Simulation

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The economic production of CRML steels depends on the use of continuous annealing. Successful development of improved CRML steels, the compositions of which have moved to lower carbon contents, is critically dependent on the rate of heating and its effect on transformation characteristics. As a result, accurate simulation of annealing conditions, particularly the heating rate, is essential. With this in mind, European Electrical Steels set criteria for a laboratory annealing facility that would, as far as was practicable, reproduce day-to-day continuous furnace operation. This paper outlines the design criteria, construction, and operation of the resulting annealing facility.

Keywords

furnace facility, magnetism

1. Introduction

THE ECONOMIC production, combined with consistent quality, of CRML (cold rolled motor lamination) steels depends on the use of continuous or strand annealing, which is characterized by a rapid heating rate, a short dwell time at temperature, and generally a rapid cool to a temperature at or near ambient. While batch or box annealing also can be employed, usage of it is now limited, particularly in Europe and Japan.

Successful development of improved CRML steels, which for some time has been moving into the area of lower carbon contents, is critically dependent on the rate of heating and its effect on the transformation characteristics of this type of steel. As a result, accurate simulation of annealing conditions, particularly the heating rate, which exceeds 700 °C/min, is essential. Conventional laboratory furnaces with their slow heating rates (typically 50 to 60 °C/min for sufficient material to produce an epstein test pack) and small sample size (frequently no larger than 30 mm, or 12 in., by 50 to 75 mm, or 2 to 3 in.) are no longer reliable vehicles for the design of new low carbon, rapidly annealed steels.

With this in mind, European Electrical Steels set criteria for a laboratory annealing facility that would, as far as was practicable, reproduce day-to-day continuous furnace operation. At an early stage, they decided not to use a continuous furnace for experimental annealing because of cost and manning requirements, coupled with problems of producing suitable feedstock. Therefore, a batch furnace with continuous furnace characteristics was called for with the following sample and operating criteria. The furnace was capable of:

- Accepting up to 20 samples of sufficient size such that a 12 strip epstein pack could be produced from one sample "panel," the final sample size being standardized at 540 × 320 mm. Figure 1 shows a sample panel and epstein cutting pattern
- Annealing these samples either singly or in groups of up to 20
- Annealing in a nitrogen or hydrogen atmosphere
- Hydrogen atmospheres capable of being "dry" or at a controlled dew point
- Heating a 0.65 mm thick sample (540 × 320 mm overall) from ambient temperature to 800 °C in 60 s
- Once the annealing temperature has been reached, the sample can be moved immediately to the cooling section or held for a maximum of 40 s at 800 °C
- The cooling rate from 800 to 100 °C should be achieved in 20 s

A number of U.K. equipment manufacturers were approached, and from the outline ideas initially presented, European Electrical Steels commenced cooperation with one of them. The outcome of that cooperation forms the basis of this article.

2. The Resulting Concept

The concept of the furnace was:

- Loading and unloading, which is pneumatically operated, would be at one end of the furnace. Thus the sample would travel through the heating, soaking, and cooling sections and then return to its starting point.
- The method of heating would be by infrared lamps, twenty banks total, ten on each side of the sample.
- The method of soaking would also be by the same infrared lamps used for heating. The sample would remain stationary in this section, and the power to the lamps would be adjusted accordingly.
- The method of cooling would be by water-cooled platens bearing on the strip and oscillating to increase heat extraction and avoid surface damage.

The furnace is capable, therefore, of being divided into a number of modules: (1) a loading and unloading station; (2) an infrared lamp furnace; (3) cooling platens and radiation shield, together with a preheater; and atmosphere control.

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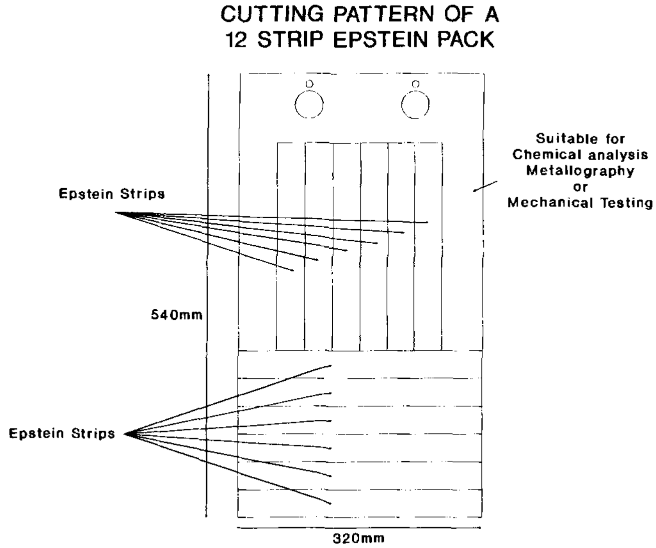

Fig. 1 Cutting pattern of a 12 strip epstein pack

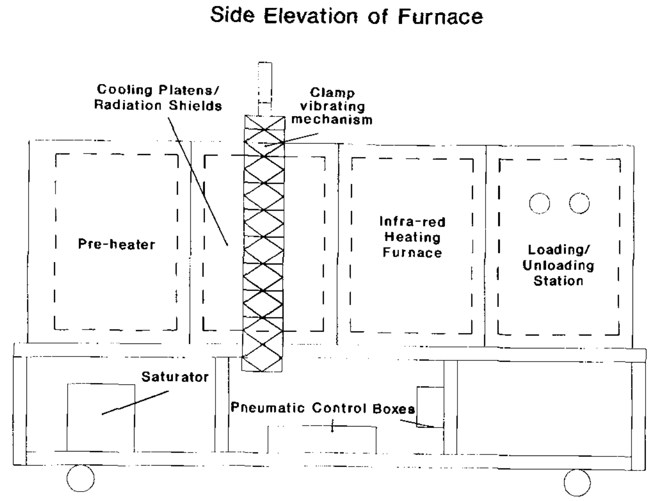

Fig. 2 Side elevation of furnace

3. The Furnace

The complete furnace, which is shown schematically in Fig. 2, is built as a sealed box, of which the above modules are an integral part. Access is through the loading and unloading end. Operation is by loading the sample or samples, sealing the unit, filling with atmosphere gas, and running a cycle or cycles. The unit is capable of operating the same cycle twenty times, or twenty different cycles on twenty preloaded individual samples.

3.1 *Loading and Unloading*

Each 540 × 320 mm sample (Fig. 1) has two 24 mm and two 6 mm prepositioned holes drilled along one of the shorter edges. These holes are to locate the samples on suspension arms. The larger ones are used to locate samples on support tubes, or rods, either in the load or unload stations prior to or following annealing. The smaller ones are to suspend the sample from the hanger as it travels through the furnace.

After the perspex panel at the end of the furnace is removed, individual samples are loaded onto the loading rack. The samples locate in grooves cut into the two support tubes on the load side of the unit. Not all samples are completely flat, however, and experience has taught that nonflat samples should be hung first, concave side to the center of the unit. If necessary, the samples can be "double" spaced, although this reduces the number of samples that can be annealed at a time. When "Load" is called for by the activation of the button on the control unit, the whole rack and all specimens move to a position beneath the specimen hanger. The hanger lifts the sample off the loading rack, and the rack returns to its original position. The hanger frame and sample then move into the furnace section thus completing the "Load" operation.

The unloading station, situated opposite the loading station, advances forward when the hanger has returned after the annealing cycle and pushes the sample off the two (small) pins on the hanger. The sample then drops onto the unload station, which then retracts to its original position. Thus the sample is removed from the hanger, which is now ready to accept a new sample.

Figure 3 illustrates the loading and unloading station as viewed by the operator.

3.2 *Infrared Heating Unit*

The furnace consists essentially of a water-cooled aluminum box with silica glass reflectors mounted on the internal surfaces. On either side are 10 rows of lamps with 8 lamps per row. In front of each set of lamps is a window shielding the lamps from the sample to avoid damage or contamination. The sample hangs from the sample hanger, which is moved to the central section of the furnace. This section is separate from the box halves and mounted on a slide to transport the sample to the load and unload stations and the cooling station. Two thermocouples are mounted on the sample hanger: the furnace control thermocouple and an over temperature alarm thermocouple. The unit is shown in Fig. 4.

3.3 *Cooling Platens, Radiation Shields, Preheater*

The cooling platens are basically large metal blocks maintained at the dew point of the unit by the water control circuit. They are both mounted on bearings and are pneumatically moved in order to clamp and thus cool the sample.

In addition to the pneumatic clamping, oil is present in the interspace between the platens and the outer silicone rubber gasket; this is pressurized by the electric motor through pistons. The action of the motor as it rotates clamps and releases the pressure on a sample between the platens, cooling it by conduction as it clamps, and allowing it to contract or relax the thermal strains on release. The clamping pressure is approximately 5 psi, which gives an overall clamping force of about 1000 lb, or half a ton.

Between the platens and the sample are two radiation shields. These are preheated prior to clamping against the sample; they cool it gradually and, in effect, avoid quenching the sample. When heated by the preheater, which normally resides

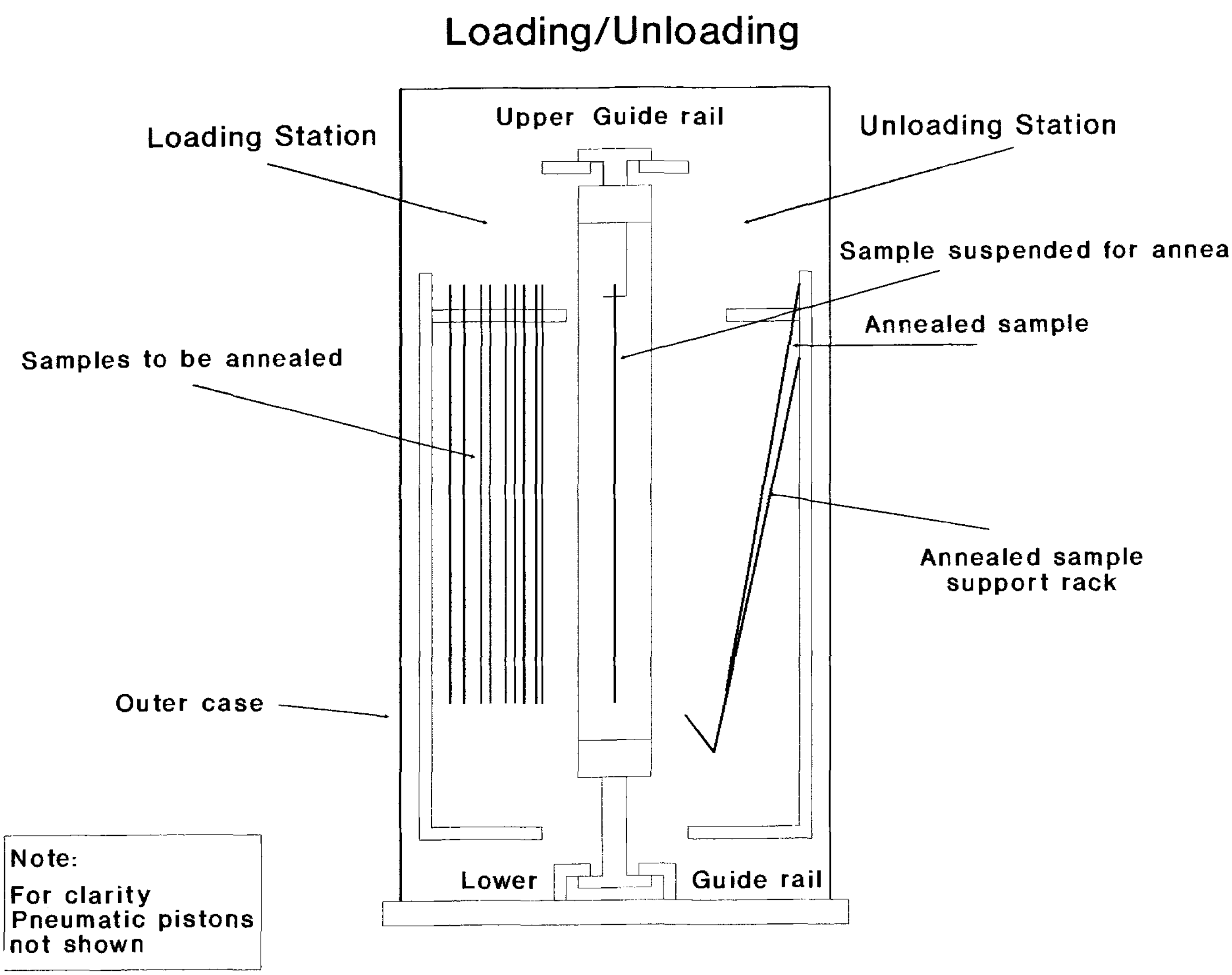

Fig. 3 Loading and unloading station

here and is automatically withdrawn when a sample enters the cooling section, they will bow and will therefore clamp the sample centrally first and then flatten under pressure between the platens to the edges of the sample. This minimizes distortion of the sample on cooling. Ideally these shields should be preheated to the annealing temperature so that when clamped to the sample the minimum of quenching is observed.

The preheater mentioned above preheats the radiation shields to a set temperature prior to clamping as described and consists of six carbide heating elements mounted horizontally within a stainless steel frame.

3.4 *Atmosphere Control*

The furnace may be used with either nitrogen or hydrogen. Nitrogen is used "dry." Hydrogen may be used "dry" or saturated with water at a dew point normally in the range of 45 to 55 °C.

Nitrogen is supplied directly from the works supply through pressure-reducing valves. Hydrogen is supplied in the same manner. It is used directly if a "dry" atmosphere is required or diverted through an electrically heated, water-filled saturator situated beneath the furnace if a moist hydrogen atmosphere is needed.

4. Operation

Operation of the furnace is quite straightforward. A typical sequence, which is illustrated in Fig. 5 to 8, follows:

1. Switch on main power.
2. Press heater "On" button to start the water heater. (The water is circulated around the various cooling circuits within the equipment at a minimum temperature of 60 °C to avoid condensation and possible corrosion.)
3. Load samples as required and replace outer perspex viewing panel. The samples must be thoroughly cleaned and degreased before loading into the furnace in order to avoid contamination of the reflective surfaces within the unit.
4. Start the nitrogen purge by setting the oxygen alarm trip on the oxygen analyzer instrument to the required setting,

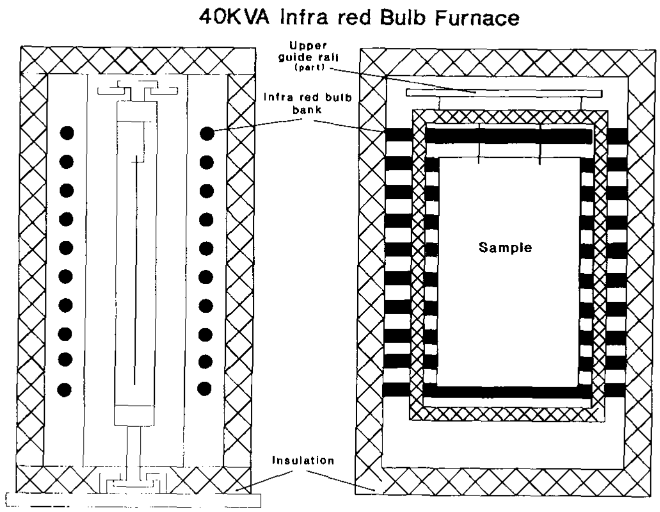

Fig. 4 40 kVA infrared bulb furnace

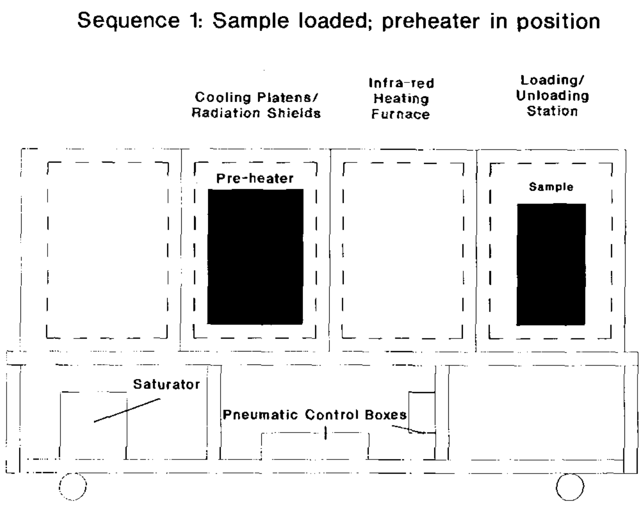

Fig. 5 Sequence 1: sample loaded; preheater in position

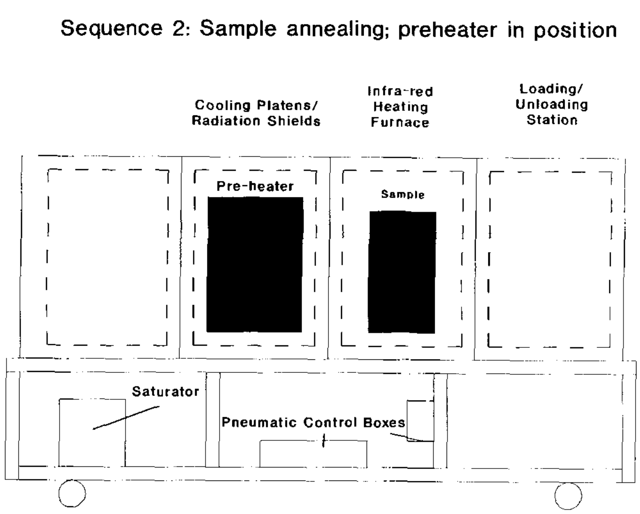

Fig. 6 Sequence 2: sample annealing; preheater in position

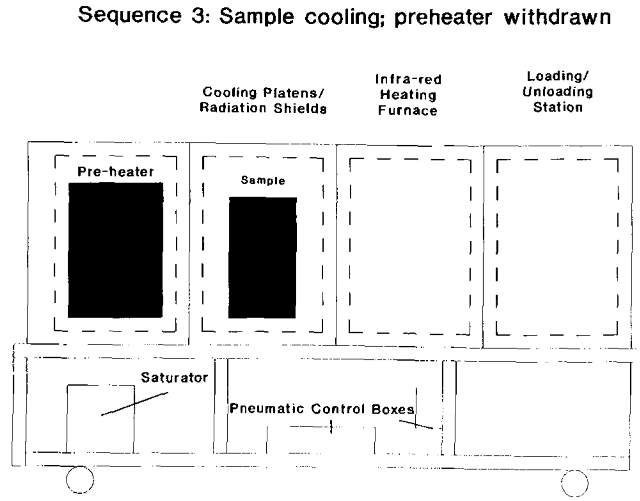

Fig. 7 Sequence 3: sample cooling; preheater withdrawn

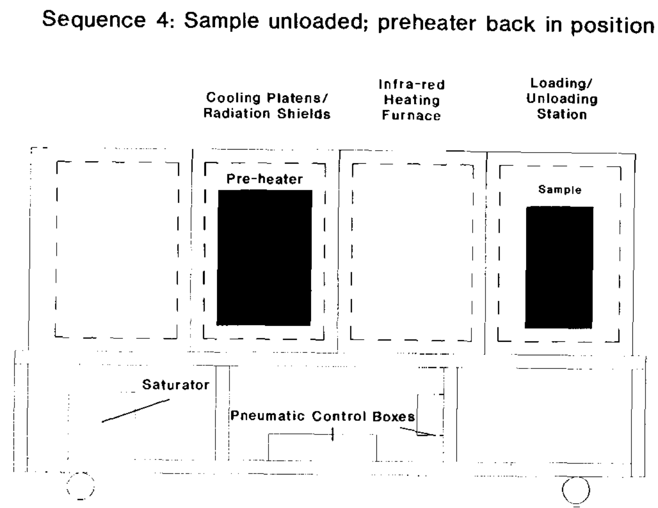

Fig. 8 Sequence 4: sample unloaded; preheater back in position

pressing the purge button, and setting the flow to no more than 120 L/min.

5. If the final atmosphere to be used is hydrogen, switch on the natural gas "burn off" flame. After attaining the required oxygen level, turn the nitrogen flow down to approximately 30 L/min.
6. At this point, turn over to hydrogen (wet or dry) if required, or continue with a nitrogen atmosphere.
7. Set the furnace controller to the heat and soak cycle required.
8. Press "Load" to transfer a sample to the traveling hanger frame.
9. Press "Heat" to send the sample through a complete cycle and return in to the load and unload station.
10. Press "Unload" to transfer the sample to the unloading carriage where it can remain until all other samples are completed.
11. Upon completion of all samples, the equipment may be opened up immediately if the furnace atmosphere was ni-

trogen, and following purging with this gas if the atmosphere was hydrogen.

5. Conclusions

The furnace has been in reliable operation for approximately two years. Few problems have been encountered, and the equipment has proved extremely beneficial in determining the continuous annealing characteristics of a number of CRML type steels.

Acknowledgment

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