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Rule-based intelligent monitoring and control of marc brandy stills

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Abstract

Galicia is the only Spanish region recognized by the EU as producing a region-specific spirit, "Galician marc brandy". For efficient maintenance of the corresponding quality requirements, it is preferable for the experience of stillmasters to be backed up by computer-assisted process control methods. This article describes a rule-based intelligent system for monitoring and control of one of the several different distillation processes that can be used to produce Galician marc brandy. This control and monitoring system improves the final quality of the product, since it helps to increase the efficiency and also to reduce the time needed for process completion. The system is currently in use at a commercial-distillery, and proved to be robust, improving the distillation times and correctly solving different anomalous situations.

Keywords: Artificial intelligence; Supervisory system; Distillation; Knowledge based system; Oenology

1. Introduction

Distillation consists in heating a solution, a mixture of liquids or, a mash or slurry, and condensing the resulting vapour into a different vessel; since the vapour and the original substrate will in general have different compositions, the distillate obtained at any given temperature contains a higher proportion of some of the original components and a lower proportion of others (Gay-Bellile, 1981; Hewitt, Quarini, & Morell, 1999; Pérez Sanchez, 1990). Thus distillation is a means of partial separation of the volatile components of a mixture. If the vapours produced by heating the original substrate for appropriate times at successively higher temperatures are condensed into different vessels, these different fractions will contain different major components.

Marc brandy is essentially (i.e. without regard to subsequent maturation processes) the ethanol-rich distillate fraction obtained by distilling fermented grape marc. More, specifically, it is the fraction obtained at temperatures between 78.4 and 100 °C, known as the "hearts" of the distillation run; together with ethanol, it contains minor alcohols (fusel oils), other aromatic substances, and water. The fraction obtained at lower temperatures is known as the "heads", and the fraction obtained at higher temperatures as the "tails" (Orriols, 1992).

The fundamental problem of still control is to maximize the yield in hearts while avoiding contamination by heads and tails, which reduce quality (Oreglia, 1978). Because of the variability of the raw material (the fermented marc) and other factors (Rhodes & Fletcher, 1969; Suárez & Iñigo, 1990), the times at which the distillate should be switched between the heads and hearts collector vessels, and between the hearts and tails vessels, vary from run to run. Traditionally, deciding these times and other aspects of distillation control has been the task of experienced stillmasters, whose decisions have been taken on the basis of, among other variables, the temperatures measured in various parts of the distillation system.

In the commercial context, the problem with traditional still control as described above is that it is uneconomic to assign personnel exclusively to still control, a task in which, in the absence of untoward incidents, most of their time would be spent in passively verifying the normal behaviour of the system and only a very short time in actually intervening in the system. Accordingly, stillmasters also have other duties to perform, and distraction by these other duties can lead to heads, hearts and tails being improperly separated, which means either loss of product quality or, if separation is severely amiss, the need to re-distill the

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whole distillate at extra cost. To avoid such incidents, stillmasters may tend to be over-conservative as regards the duration of the heart of the run, to the detriment of hearts yield.

Given the above circumstances, the introduction of automatic monitoring and alarm systems, with or without automatic control of effectors, is desirable for simultaneous optimization of both hearts yield and product quality. The best approach is to use expert system methods (Bardini & Gionelloni, 1990; Muratet & Bourseau, 1993), which in this context have two main advantages over conventional automatic control methods (Grenier, Fenilloley, & Sablayrolles, 1989). Firstly, building an expert system for still control is relatively simple in that it does not require the construction of a detailed model of the process, which in view of the complex nature of marc would be no trivial task; like the human stillmaster, an expert system responds to gross features of the behaviour of system variables by application of rules that can have either a theory-based or a purely empirical origin, and the appropriate rules can be elicited from the stillmaster in situ. Secondly, a well-designed expert system for process control is highly flexible in that its scope can readily be extended by incorporation of new sets of rules (Davis, Buchanan, & Shortliffe, 1977); this means that automatic control can often be introduced very gradually, which pleases both management (since there is no need for initial commitment to outlay on large amounts of control equipment) and staff (since modifications in the workforce and in working practices can be made equally gradually).

This article describes a rule-based expert system for monitoring and control of one of the several different distillation processes that can be used to produce Galician marc brandy. It has been developed and is currently in use at the distillery of Aguardientes de Galicia S.A., San Pedro de Sarandón, Spain.

2. Plant and process

The process to be controlled, known as the Portuguese process, takes place in copper distillation units of the kind illustrated schematically in Fig. 1 (Orriols, 1990). Each unit consists basically of two 200 or 300 l pots, a single water-cooled rectification plate, and a water-cooled condenser with a three-way outlet (for heads, hearts and tails). The two pots are used alternately, each being emptied and reloaded with about 200 kg of fermented marc while the load in the other is being distilled; this alternation allows continuous use of the other parts of the system even though each distillation run is essentially a batch process. The load in the working pot is heated by steam from a boiler that is fed in at the bottom of the pot. Water flow in the rectifier cooling circuit is continuous while the rectifier is in use, but the condenser cooling circuit is only opened intermittently to renew the water in the condenser jacket when it becomes too hot.

At the beginning of a run the temperature of the fresh load rises steadily. When it reaches roughly the boiling point of the major volatile head compounds the supply of steam to the pot is reduced, the cooling circuits of the rectifier and condenser are opened, and the condenser outlet is switched to the heads collector. The rectifier serves to return higher-boiling compounds to the pot; while the heads are boiled off, its temperature remains stable or increases only very slowly. When the heads have been

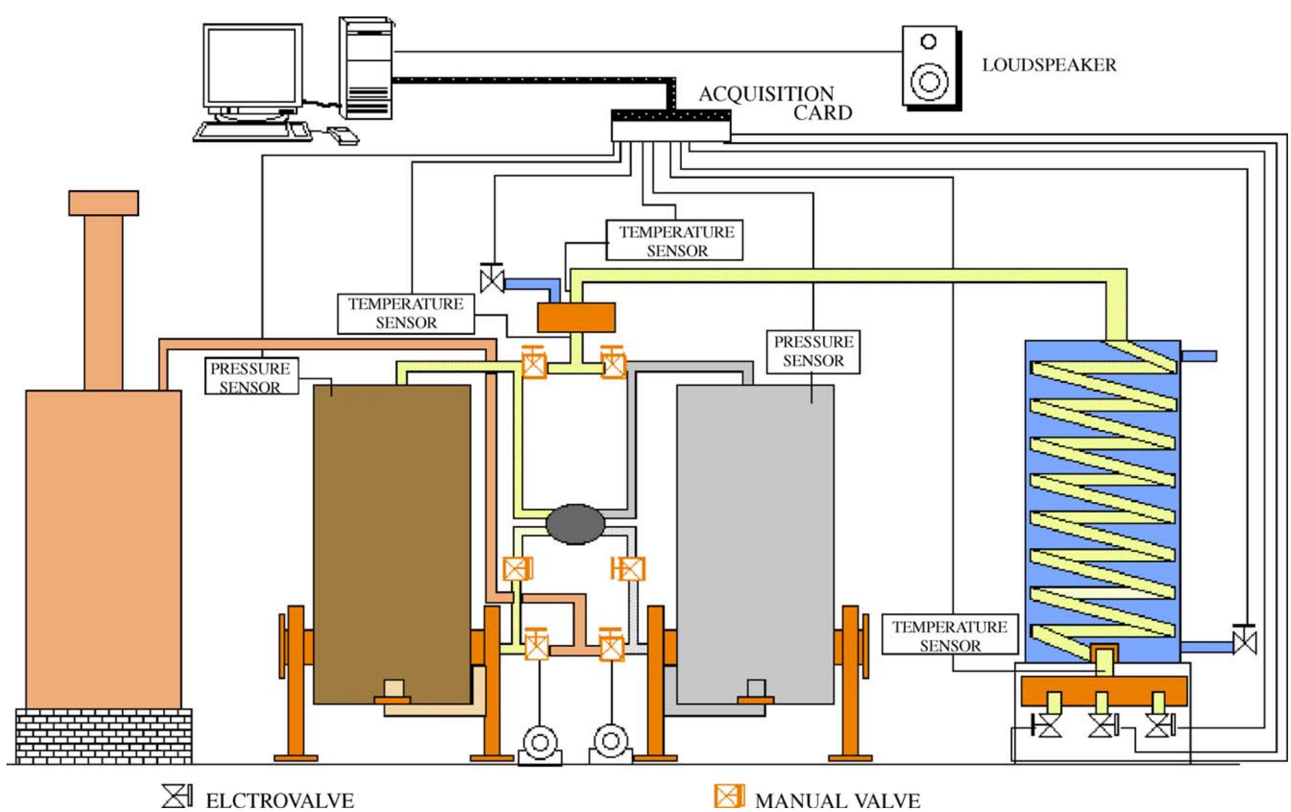

Fig. 1. System representation of alcoholic distillation and the sensors and effectors of the control system.