CHIMIA 2000, 54, No. 12

Chimia 54 (2000) 721–723

ISSN 0009–4293

Productivity Improvement
From a Multipurpose to a Single-Product Unit and from Batch to Continuous Production

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Abstract: Ciba Specialty Chemicals has been manufacturing the Ciba® IRGAFOS® 168 Process Stabilizer for 25 years. Two fundamental changes in the design concept of the production equipment and in the process have been implemented:

• Firstly from a multipurpose unit to a single-product unit, both running with a batch-wise manufacturing process.

• Secondly from a batch-wise process to a continuous one, both running in dedicated single-product units.

Remarkable improvements in productivity have been achieved over the years, due to the extension of know-how about the product itself and its manufacturing process and to revisions in the design concept of the equipment and the production strategy.

Keywords: Dedicated production unit · Multipurpose plants · Productivity improvement

1. Introduction

Productivity improvement is probably the most outstanding challenge in the manufacture of chemical specialties. Normally the gain in productivity is achieved by an improved understanding of the properties of the product itself and by optimizing the manufacturing process. In addition fundamental differences exist between multipurpose production units and single-product units or even clearly designed dedicated units. This design concept of the equipment has a significant influence on the productivity as well. Furthermore carrying out the manufacturing batch-wise or continuously can also be important for productivity.

Using the example of the manufacture of a solid organic phosphite at Ciba Specialty Chemicals, remarkable improvements of productivity can be reported. All the above-mentioned differences in developing and optimizing the process, in the concept of the plant design and in the manufacturing strategy have contributed to this success.

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2. Fundamentals of the Ciba® IRGAFOS® 168 Process Stabilizer

2.1. *Chemistry and Properties*

Tris(2,4-di-*tert.*-butylphenyl)phosphite, trade name Ciba® IRGAFOS® 168 Process Stabilizer, is made by reacting 2,4-di-*tert.*-butylphenol and phosphorous trichloride (Fig. 1). It is a solid organic phosphite of low volatility and a high melting point (186 °C), and it is particularly resistant to hydrolysis.

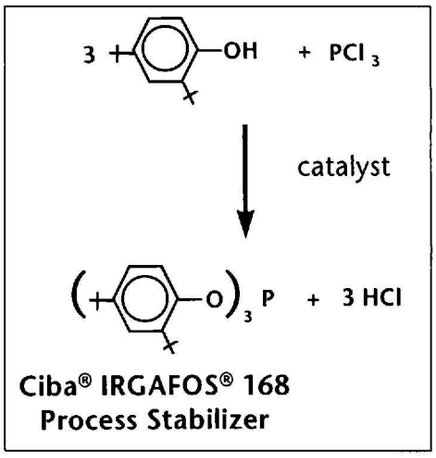

Fig. 1. Chemical reaction.

2.2. *Application*

The application range of Ciba® IRGAFOS® 168 Process Stabilizer – synergistically combined with other antioxidants – comprises polyolefins and polyolefin-copolymers as well as polycarbonates and polyamides and many other polymers.

As a secondary antioxidant it reacts during processing with hydroperoxides formed by autoxidation of polymers preventing degradation during the process and extending the performance of primary antioxidants. Those blends of Ciba® IRGAFOS® 168 Process Stabilizer with primary antioxidants give the polymer long-term protection against thermo-oxidative degradation.

2.3. *Manufacturing Process*

In principle the manufacturing process as shown in Fig. 2 is the same as it had been at the production start-up of the Ciba® IRGAFOS® 168 Process Stabilizer in 1975.

The raw materials 2,4-di-*tert.*-butylphenol and phosphorous trichloride and a catalyst are charged into the reaction vessel. One chloride of the phosphorous trichloride after the other is substituted by the alkylated phenol. Hydrogen chloride is generated as a byproduct. It is absorbed in water to produce a hydrochloric acid of a technical grade that can be used for other processes.

The product is crystallized from the reaction mass by adding a solvent, separated, *e.g.* by filtration or centrifuging, and finally dried. The solvent is recovered by distillation of mother and wash liquors and is re-used.

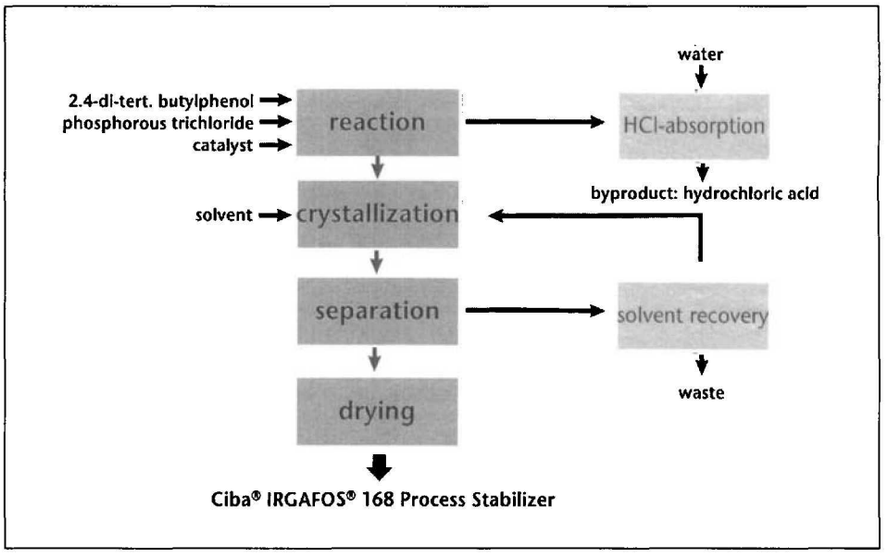

Fig. 2. Simple flow chart of the manufacturing process of Ciba® IRGAFOS® 168 Process Stabilizer

2.4. *Production: Growth and Concept*

Production of Ciba® IRGAFOS® 168 Process Stabilizer started in the Lampertheim Plant of Ciba Specialty Chemicals (former Ciba-Geigy) in 1975 with a batch process in a multipurpose unit.

According to the growing demand the multipurpose unit was restructured into a single-product unit in 1980, which has been extended several times, still working with a batch process. In 1996 a continuous manufacturing process was started in a dedicated production unit. The growth of the Ciba® IRGAFOS® 168 Process Stabilizer production in the Lampertheim Plant of Ciba Specialty Chemicals is shown in Fig. 3.

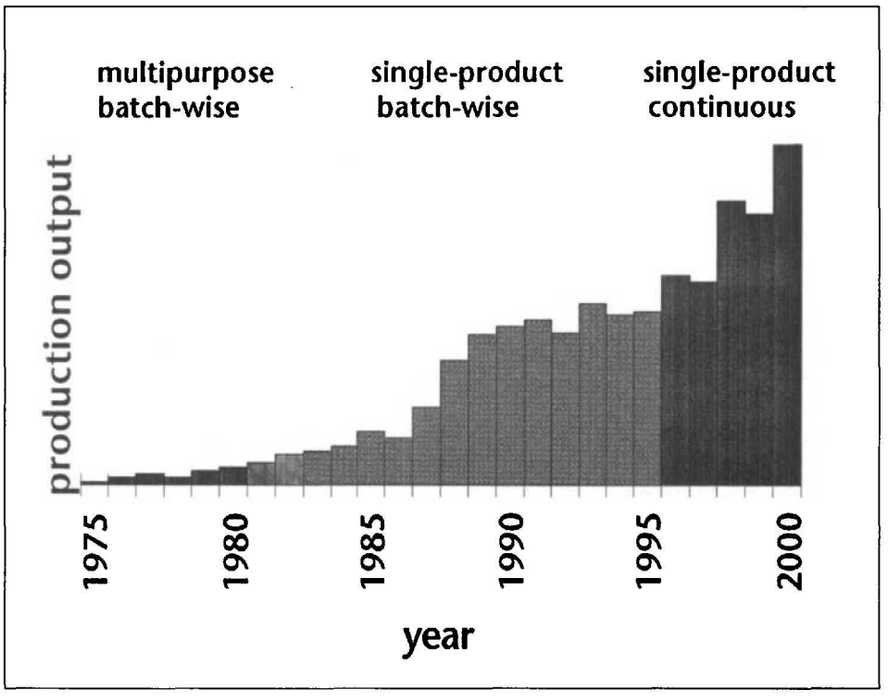

Fig. 3. Production output of Ciba® IRGAFOS® 168 Process Stabilizer in the Lampertheim plant of Ciba Specialty Chemicals

3. Improvements in Productivity

During 25 years of manufacturing the Ciba® IRGAFOS® 168 Process Stabilizer remarkable improvements in productivity have been achieved. On the one hand these improvements are related to an increased understanding of the product and its properties and of the production process. On the other hand they attribute to the fact that the production strategy and the design concept of the production unit and the process have been adapted to the growing demand in due course of time. Some important results in productivity improvement are shown in Fig. 4.

3.1. *Increase of the Yield*

Constant optimization of the process and the equipment led to the increase of the yield as shown in Fig. 4a. With the batch-wise production concept the yield could be raised by more than 15%. A jump of further 5–6% has been obtained by the switch to a continuous production process and its further optimization.

3.2. *Decrease of Consumption Numbers*

It is quite obvious that the increase of the yield is directly connected to a decrease of the consumption of raw materials. Furthermore the consumption of solvents has been decreased dramatically to 20% of the primary number as shown in Fig. 4b.

The reduction of the energy consumption (*e.g.* steam, electricity, cooling water, nitrogen, compressed air *etc.*) over the years was just as significant. The results are shown in Fig. 4c exemplary for the steam consumption which has been reduced by *ca.* 80%!

3.3. *Reduction of Waste*

The waste reduction is shown in Fig. 4d. Of course this development is

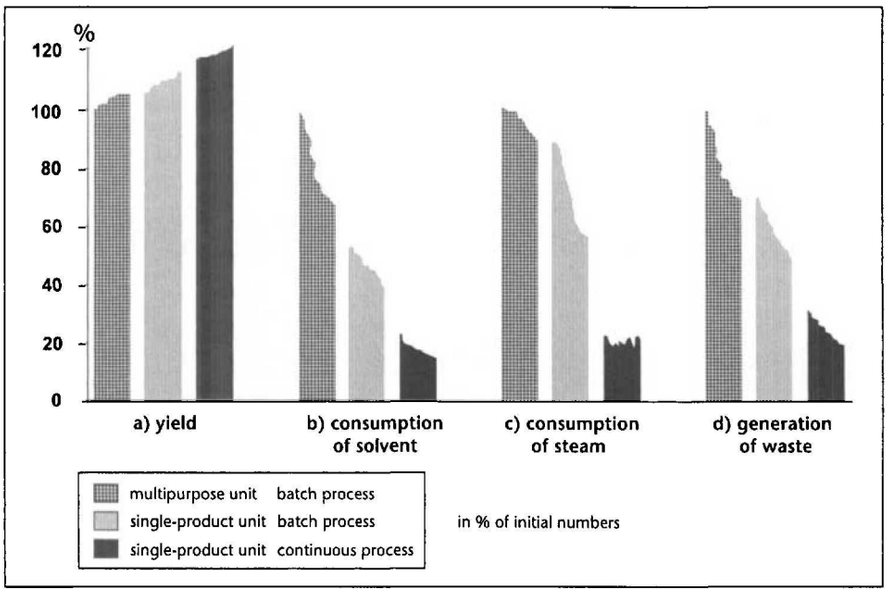

Fig. 4. Productivity improvements in manufacturing of the Ciba® IRGAFOS® 168 Process Stabilizer

closely connected to yield increase and decrease of raw material consumption respectively and to the development of solvent consumption. The result is a decrease in waste generation of more than 70%.

3.4. *Improvements in Process Labor*

The productivity of the work force has been improved by a factor of 4 to 5 of the primary product output per operator.

3.5. *Improvements in Quality*

All parameters concerning the quality of the product have been substantially improved over the years, *e.g.*

- assay
- color of solution
- volatiles
- resistance to hydrolysis
- *etc.*

The average has been improved as well as the standard deviation and all other statistical parameters.

3.6. *Availability of the Equipment*

The availability of the production equipment could be raised substantially with the change-over from multipurpose to monopurpose. Downtime due to product change-over is a necessity in multipurpose/multiproduct units. This could be abolished of course, resulting in a higher availability of the equipment and hence in a higher production output. Moreover preventive maintenance is easier to plan and execute in a single-product unit.

3.7. *Further Aspects*

Many other aspects had to be challenged with the switch from a multipurpose to a single-product unit and from batch-wise to continuous production. For example the concepts of safety and security, of automation and of quality assurance have been permanently adapted to these changes in the design concept of the equipment and of the process.

4. Conclusions

Improving the productivity of manufacturing Chemical Specialties is the daily challenge to survive in the business life. This target requires a permanent improvement of the manufacturing process. Furthermore the design concept of the manufacturing equipment and the fundamentals of the manufacturing process itself must be reviewed periodically.

The example of the Ciba® IRGAFOS ® 168 Process Stabilizer clearly documents to what extent all these aspects may contribute to the gain in productivity.

Received: October 12, 2000