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Economy, Universality and Flexibility of Automatic Filler "NIVELA 12JC"

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ABSTRACT

The paper describes a technical solution for an automatic filler for filling liquids of different viscosities "NIVELA 12JC". The solution has been done for the NIS Petrol Company, Novi Sad Oil Refinery - the plant for blending oil. Given solution of an automatic filler for filling liquids of different viscosities "NIVELA 12JC" is an original approach to the processes of filling fluids and the way of managing filling process. The technical solution is being exploited for more than two years and during that period it has shown excellent results: simple preparation of filling process, high reliability in working process, flexible adjustment to different liquid viscosities and different shapes of bottles from 0.5 to 1 l, precise filling and good ratio between prices and quality. The main characteristic of the filler is very precise control of leveling of filled bottles from ± 0.02 to 0.5%. The capacity of the filler can be designed to meet different needs of users.

The objective of this study is to evaluate the universality, flexibility and economic justification of an automatic filler "NIVEA 12JC" that works in semiautomatic mode.

Keywords: *Universality, flexibility, economic justification, automatic filler, liquid, fluid, leveling, viscosity*

1. INTRODUCTION

Work safety, high capacity, universality and flexibility are important features for successful work of an automatic filler "NIVELA12JC". Technical and technological requirements for designing machines for filling liquids are high, and as a result of that innovative, reliable and environmentally friendly solution are offered to the market.

Large number of machines for filling liquids in various industries can be found on the market. Customers are focused on the equipment reliability, quality management, productivity and reasonable price. An important feature of these systems is reliable work in aggressive chemical environments, in order to increase the lifetime of system's components and reduce maintenance costs (Ašonja, A. 2006, page 106-110).

Filling conveyor belts for liquids use a weight or volumetric measurement for quantity of liquid that is poured into the packaging unit. Packaging filling with the required amount of liquid is based on the measurement of volume. Most frequently it performs indirectly by filling calibrated cylindrical vessels that have the possibility of fill settings. Second way for precise filling is based on the application of flow meters. Third way of filling and leveling is based on the principle of communicating vessels, but it is used rarely, because of low-speed filling and requirements for precise measurement of liquid level (Krunić, V, Ašonja, A, Krunić, M, 2010).

The technical solution for the filler "Nivela 12JC" is based on the thirdly mentioned principle, but problems of low-speed and imprecise filling are eliminated.

2. AUTOMATIC CONVEYOR BELT FOR LIQUID FILLING - "NIVELA 12JC"

1. The technical solution for automatic conveyor for liquid filling "Nivela 12JC" (Picture 1) uses system of filling and leveling based on the principle of communicating vessels. The main idea is that the problem of slow filling becomes outdated by biphase filling cycle, with the usage of a micro-computing management system (PLC-Programmable Logical Controller). The phase Fast Filling means simultaneous filling of the set of packaging units to the certain level (about 95% of required level), while the Leveling phase involves refilling of given set of packaging units to the required level. The required level in packaging units is achieved by balancing a level set in the benchmark-level container. The level set depends on the required quantity of filling per filling unit, as well as on the shape of packaging (Krunic, V., Asonja, A., Krunic, M., 2010, page 47-53).

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The Fast Filling phase (BP) and the Leveling phase (N) are controlled by defined times t_{BP} i t_N, respectively. t_{BP} time is dependable on a fluid pressure in a system, density and viscosity of filled liquid, as well as on resistance of a pipeline. The time of the Leveling phase - t_N depends on the fill level of containers reached in the Fast Filling phase, as well as on the density and viscosity of filled liquid, then on the resistance of pipeline from the level container to packaging units and on a speed control of comparable level. Time settings of t_{BP} and t_N are performed experimentally in a initial cycle, using a microcomputer system that "remembers" times given in the first filling cycle. The first cycle can be repeated, if it has not been performed well, and then previous values of the time parameters t_{BP} and t_N are being reset.

Fig 1: Filler "NIVELA 12JC"

The picture no. 1 shows filler for antifreeze filling "Nivela 12JC" that has been made on the demand of NIS Petrol Company – Novi Sad Oil Refinery, the plant for blending oil.

2. Whole construction of the filler is made of stainless steel (capacity 1,430 liters), while the pipelines and the level-container are made of acid-resistant stainless steel (capacity 1,430 liters). The filler is powered by a network voltage at 220V. Air under the pressure of 0.2÷0.6 bars is needed for fluid distribution, as well as for starting mobile parts of the filler. Two pneumatic stainless spherical valves with two-way actuators, stainless solenoid valve and additional handheld stainless spherical valve have been used for the distribution of fluids. Pneumatic cylinders have been used for starting mobile parts of the filler (Krunić, V., Ašonja, A., Krunić, M. 2010, page 47-53).

The filler "Nivela 12JC" (picture 2) consists of: 1- pneumatic distributor, 2- filler base, 3- liquid collector, 4- level-container, 5- conveyor, 6- pneumatic cylinders, 7- channel for collecting and returning surplus fluids, 8- guides of drawbridge, 9- energetic box, 10- entrance port for the fluid that is being filled, 11- main manual valve, 12- command board, 13- flexible hoses for fluid distribution, 14- drawbridge of filler, 15- system for fine adjustment of the fill level in bottles (Krunić,V.,2009).

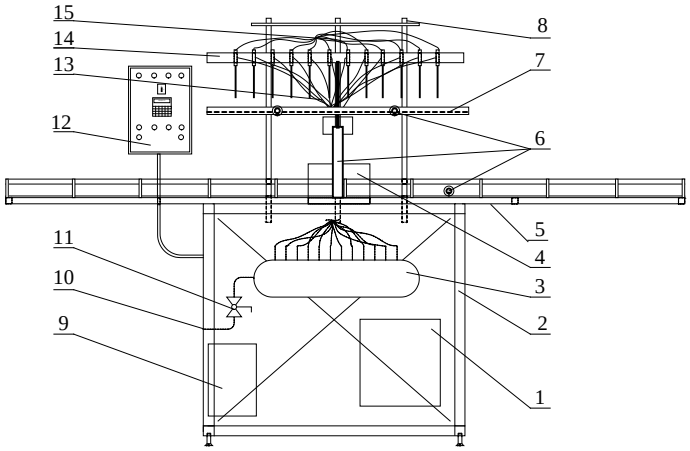

Fig 2: Schematic view of the filler "Nivela 12JC"

3. WORKING PRINCIPLE OF THE FILLER "NIVELA 12JC"

The filler "Nivela 12JC" has 3 working regimes [5], which can be selected by a switch on the control box. The switch has 4 positions:

- position 0 (neutral state),
- position 1 (manual working regime),
- position 2 (automatic working regime) and
- position 3 (drainage).

In the position 0, a machine is in neutral state. In that state, the machine is not under working regime, so manual or automatic filling is not possible. On the control box except the switch, there are: PLC Unitronics M-90, push buttons and indicator lamps that give information about working regime and a state of a process (Picture 3).

The working process in the filler is performed in several phases [4, 5]:

1. Filling of the system,
2. Manual working regime,
3. Automatic working regime and
4. Drainage of the system.

Fig 3: Control box

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Filling of the system is very important phase in which all preparatory activities, for the process of filling liquids, have been done. Valves are open in this phase.

Manual working regime is needed to be chosen every time after the filling of the system, while it is necessary to do manual filling at least in two cycles. The process is necessary in order to properly adjust the machine to operate in the automatic mode. The air will go out from the system in the first cycle, while the times of Fast Filling and Leveling will be set in the second cycle.

The times that are memorized by buttons - Fast Filling and Leveling are used in the automatic working regime as the times for fast filling and leveling. When first two cycles in the manual working regime finish, the automatic working regime can start. The Fast Filling cycle should last until approximately 95% of fill level is not reached.

Automatic working regime excludes the presence of an operator at the filler, due to the usage of a micro-computing management system. It is used in the systems in which manipulations of packaging before and after filling are fully automatized. In the cases of small, individual needs for filling, the filler can be handled by one operator. PLC, Unitronics M-90 (Picture 3) is used for a control of the automatic working regime of the filler.

Drainage of the system means emptying the pipeline, in order to enable flow of fluids from the distributor to the filler, as well as emptying the filler. When the pipeline is going to be emptied, first the valve on the distributor (part 11 on Picture 2) should be closed, and then a drainage tap, on the entrance of a fluid in the filler, is being opened. The pipeline and machine emptying could perform simultaneously.

4. ECONOMIC JUSTIFICATION OF USAGE OF AN AUTOMATIC FILLER "NIVELA 12JC"

The task of each organized function of production on technical systems for filling liquids, is to achieve lower costs. Inadequate technical solutions of fillers are today underlined as main reasons for uneconomical process of filling. Selection of adequate way of filling by implementation of an automatic filler "NIVELA 12JC", achieves the maximum efficiency in the exploitation.

The paper analyses economic justification of the automatic filler "NIVELA 12JC", that operates in semiautomatic mode and includes work of an operator. There are various types of fillers on the market that differ according to the different viscosity of filled liquids, various capacities of filling and number of operators handling the filler.

Total costs that occurred during the work of such systems, can be expressed by formula 1:

$$C_p = c_a + c_r + c_{te} + c_{am} + c_o \quad (€), \quad (1)$$

Where they are as follows:

c_a – depreciation costs,
c_r - costs of handling the filler,
c_{te} – energy costs,
c_{am} – costs of packaging,
c_o – maintenance costs.

In order to show the economic justification of usage of an automatic filler "NIVELA 12JC", it will be compared to other relevant fillers of the same type, with capacity of 2,000 l/h and working in semiautomatic mode. Total work costs of fillers - C_p will be analyzed. In the analysis of costs, a starting point is that: c_a – depreciation costs, c_{te} – energy costs, c_{am} – costs of packaging and c_o – maintenance costs are all fixed costs, while c_r - costs of handling the filler are variable costs.

The costs of handling the filler - c_r are working costs that depend on a number of operators. Analysis will include a research and comparisons of economic justification of fillers. On one side, there will be a filler "NIVELA 12JC" and on the other one standard, average filler by which work two operators. First operator stacks empty packaging on the conveyor, while the other prepares filled bottles for shipment, by putting them in appropriate cardboard or other storage boxes. If this filler works 24 hours a day and 6 days in a week, a spent time for two workers who work by this filler will be 13,824 hours per year. Same time needed for handling the filler "NIVELA 12JC", at which works one operator, will be 6,912 hours per year. If an average lowest price for work per hour of an operator is paid € 8, minimum savings generated on annual level due to the usage of the filler "NIVELA 12JC" can reach € 55,296.

Total work time for one defined cycle, needed for handling filler, can be expressed by formula 2:

$$T = t_p + t_z + t_{pb} + t_o + t_k \quad (h), \quad (2)$$

Where they are as follows:

t_p – preparatory time – before filling for one defined cycle (often for the period of 24 hours),
t_z – end time – finishing actions of a filling process for one defined cycle (often for the period of 24 hours),
t_{pb} – fill time,
t_o - provisional time – time for operator's rest and
t_k – additional time - downtime in the case of unpredictable failure.

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From the aspect of economic analysis done for future users who are uncertain in selecting a type of a filler, it is important to emphasis that the lowest price of an automatic filler "NIVELA 12JC" is around € 6,500, while a price of other similar fillers of a same type is around € 15,000. It shows that our filler is cheaper approximately around 2.3 times than other fillers in the same class. Also, it should be emphasized that these savings have been realized due to: significantly reduced unnecessary hardware, reduced dimensions (adequate dimensioning of filler), simplification of some processes and elimination of certain elements of the technical systems that are not directly relevant to the filling process.

5. RELIABILITY OF FILLING LIQUIDS PROCESS

Practice showed that technical systems for filling liquids usually come to state of failure due to defects on electronic equipment. The main part of the filler and subject of the paper are its electronic components and this is a reason as well to continue analysis of its reliability. For the presentation of reliability of a filling process, that can be applied on the filler "NIVELA 12JC", AGREE model (Advisor Group on Reliability of Electronic Equipment) will be used. Mentioned acronym refers to the so-called advisory group for the reliability of electronic equipment. This model is one of the most suitable models that can be implemented. Its main advantages are: respect for relative importance of certain elements in the system, from the aspect of their influence on successful work of the system and recognition of certain elements complexity, in particular their inner structure (in the case of subsystems, components and the like) [6]. Importance of elements is expressed by the so-called significance factor - E_{li}, which can range from:

$$0 \leq E_i \leq 1 \qquad (3)$$

If the significance factor $E_i=1$, it means that the failure of elements will directly cause a system failure. On the contrary, if $E_i=1$, it means that a system can work whether there is a failure of observed elements or not. Except the significance factor - E_i, that can be interpreted in different ways, most often through some subjective evaluations (like load of elements, work time, etc.), this method takes into account the total number of components - n_i, where $t_i \leq t_s$ and it can be expressed by following formula 4:

$$\lambda_i = \frac{n_i \cdot \left[\ln R_s(t_s)\right]}{N \cdot E_i \cdot t_i}, \qquad (4)$$

and the reliability in the following form:

$$R_i(t_i) = \frac{1 - \left[R_s(t_s)\right]^{\frac{n_i}{N}}}{E_i}, \qquad (5)$$

Where they are as follows:

λ_i - failure intensity of the i^{th} element,
$R_s(t_s)$ – specified system reliability for the period t_s and
N – total number of calls for inclusion in the work until the time t.

6. MAINTENANCE AND MAINTAINABILITY OF THE FILLER

Maintenance and maintainability on technical systems for filling liquids have different meanings. The maintenance is related to activities that are done by a system (filler) user, in order to keep the system operating or to repair it in order to bring it in such a state. The maintainability refers to activities that are done by the system constructor during a development phase, in order to implement such construction elements that will increase easiness of the maintenance. The function of maintainability is to ensure that the system (after production, implementation and setting up) can be maintained with lowest maintenance costs during the life cycle and with minimum downtime [7].

The maintainability depends on many factors and they can be internal (constructional), as well as external (logistic support). External factors are examined by logistics and a theory of maintenance. The theory of maintenance points out ways of optimization of inner factors that come from construction of a system [8]:

- easy accessibility to system elements,
- standardization and unification of installed system components,
- sequence of technologies in a maintenance process,
- possibility of replacement of an integral part of the system with the spare part of the same type,
- easy access to adjustment sites,
- transport possibility,
- usage of standard tools and equipment,
- easy stopping (shutdown),
- easy setting up, etc.

The maintainability of fillers means that there is possibility that a failure of a system or part of a system will be removed in a certain time.

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7. ANALYSIS OF RESEARCH RESULTS

Economic aspects of usage justification of the filler "Nivela 12JC" are:

- the filler is 2.3 times cheaper than other fillers of a same type and
- on annual level, only on the savings for handling filler can be saved more than € 55,000.

After two-year exploitation of the filler "Nivela 12JC" in the production process, have been noticed following advantages:

- very precise control of leveling of filled bottles from ±0.02 to 0.5%,
- there are not splashes and spills,
- suitable for filling liquids of different viscosity profile,
- suitable for both fully automatic and in semiautomatic processes,
- suitable for exploitation in the food, pharmaceutical and petrochemical industry,
- savings in economic sense (very cheap solution in comparisons to standard fillers),
- possible implementation of the solution on both individual fillers for small filling series and closed systems for mass-production,
- very easy management of filling process, from the aspect of an operator who serves a filler,
- very simple possibility for changing fill parameters,
- adjustable for all shapes of packaging from 0.5 to 1 liter,
- small dimensions,
- low weight makes it very manipulative and
- low energy needs (electricity and air).

Basic technical and technological characteristics of the technical solution applied on a filler "Nivela 12JC" are showed in Table 1:

Table 1: Basic technical and technological characteristics of automatic filler "Nivela 12JC"

Parameter and unit	Values
Max. capacity of filling (l per h)	1,440÷2,200
Max. number of bottles for filling (piece)	12
Min. number of bottles for filling (piece)	1
Filler weight (kilos)	147
Filler height (mm)	1,700
Filler width (mm)	1,200
Filler width with conveyor belt (mm)	3,000
Filler length (mm)	800

8. CONCLUSION

The technical solution implemented on a conveyor belt for filling liquids of different viscosity "Nivela 12JC", is based on an original idea of biphasic filling cycle with the usage of micro-computing system (PLC). The filling system is very efficient and economical solution that is much cheaper than standard ones, widely used systems with indirect filling of cylindrical vessels.

In several analyzed cases of economic justification of spent effective working hours needed for handling the filler "Nivela 12JC" and comparison to fillers of the same type, it can be concluded that minimal annual savings that can be achieved are over € 55,200, while the tested filler is 2.3 times less expensive than other fillers of the same type. It is very important for the development of this filler model that a capacity of the filler does not have much influence on the filler price.

The main characteristic of the filler "Nivela 12JC", which performed very well in two years period, is very precise control of leveling of filled bottles from ±0.02 to 0.5%. The filler can work without an operator in fully automatic systems.

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