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Opened Joint Stock company Research and Design Institute of Urea and Organic Synthesis Products JSC "NIIK"



# Efficiency enhancement of urea synthesis reactor

## Introduction

JSC NIIK Research and Design Institute of Urea has 55 years of experience in designing of new and revamping of old urea production units. Recently our company is ready to offer a number of client approved developments aimed at capacity increasing and energy saving.



Main office of JSC NIIK

One of the basic elements in the revamping concept developed by NIIK is modernization of synthesis unit. This unit is the most important part as its efficiency determines recycle ratio of unconverted feedstock and, thus, energy consumption of the production unit. Efficiency enhancement of synthesis unit would not only improve operation parameters, but also increases final product output.

## Description of revamping concept

This measure is aimed at increasing of urea synthesis process and improvement of conversion rate of CO<sub>2</sub> into urea. Consequently it increases efficiency of reacting volume due to optimal hydrodynamics of flows inside of the reactor. Moreover, the increased CO<sub>2</sub> conversion rate reduces amount of unconverted NH<sub>3</sub> and CO<sub>2</sub> in synthesis melt and this gives possibility to put more load on sections processing unconverted components.

The concept of revamping is sectioning of synthesis reactor. This concept applied for column type reactors is approved by numerous experimental trials. Sectioning is one of the most available for implementation and efficient way of generating hydrodynamic conditions close to ideal displacement mode.

Depending on the process synthesis reactor can be divided into three operation zones:

1. Mixing zones of original reagents.
2. Zone of the 1-st stage of urea synthesis.
3. Zone of the 2-nd stage of urea synthesis.

## Mixing zone of original reagents.

In the mixing zone, the initial dispersion of gas takes place as well as formation of liquid - gas mixture. This zone includes existing feeding nozzles and mixing device, design and configuration of which is determined by original designer and manufacturer.

It is necessary to note that design of the mixer is very significant because its efficiency is decisive for bounding of original feedstock into ammonia carbamate.

With this regard mixer should have the following features:

- to set conditions at the inlet of reactor for efficient contact of phases in the way as close as possible to ideal mixing excluding stagnant zones;
- to ensure intensive dispergation of gases in order to form homogenous small bubbles structure of liquid - gas flow and extended interphase surface.

The provided by our researchers simulated service tests of different internal mixers applied in urea synthesis reactors led us to the conclusion that all of them do not ensure the necessary mixing degree of reagents. The described conditions result in increased duration of the first stage of reaction and feedstock is dispersed in the reactor space amounting to longitudinal mixing effect. These processes are the reason of hydrodynamics failure in reactor and further reduced efficiency of the synthesis process.



High efficiency vortex mixer developed by JSC NIIK

## Zone of the first stage of urea synthesis reaction

Zone of the first stage of urea synthesis reaction is aimed at ensuring maximum reliable bounding of the original components into ammonia carbamate

While revamping this zone is equipped by longitudinal sectioning element of our own design. This element en-

ensures complete bounding of the feedstock into ammonia carbamate. High speed and rate of gaseous feedstock bounding into liquid phase ammonia carbamate ensure optimal hydrodynamics in the reactor.

Longitudinal sectioning element has already been applied at a number of urea units of different capacity. Recently we are glad to offer a modified sectioning element with the following advantages compared to the original one:

- more efficient contact of feedstock and consequently higher rate of local conversion;
- stable efficiency regardless of operating loads;
- reduced hydraulic resistance;
- possibility of fast drainage of the reactor.

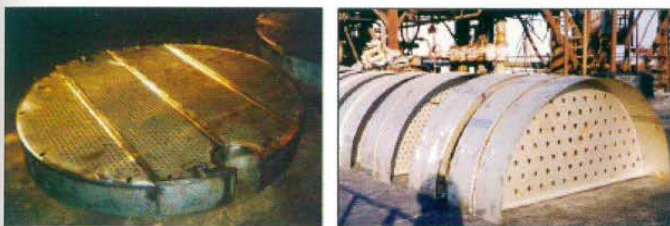


Longitudinal sectioning for reactor developed by JSC NIIK

### Zone of the 2nd stage of urea synthesis reaction.

This zone is aimed at ammonia carbamate dehydration with formation of urea. To achieve maximum efficiency of reactor this zone is equipped with sieve trays designed to eliminate longitudinal mixing, equalize velocity profiles of ascending movement of phases and to increase interphase surface.

In each particular case trays are calculated considering achievement of uniform velocity profiles in both longitudinal and horizontal sectioning of reactor because these measures ensure hydrodynamics in reactor close to optimal.



Mass exchange trays manufactured by JSC NIIK design

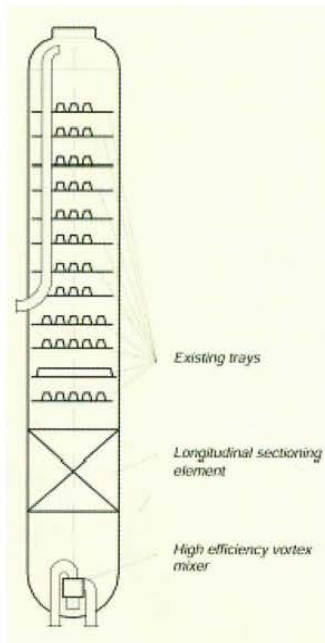
Installation of the mentioned internals into urea synthesis reactor ensures energy saving of 0,04-0,05 Gcal/t., conversion rate increase by 3-5% and gives possibility for increasing of load on reactor by 10-20%.

The main advantage of such internals is the possibility of application in any type of vertical urea synthesis reactor, including those supplied for Snamprogetti technology.

In 2007 a Snamprogetti urea synthesis reactor at JSC "Togliatti Azot" (Russia) was revamped by JSC NIIK con-

cept. Reactor (pos.R-1) was equipped with the set of internals including longitudinal sectioning element and high efficiency vortex mixer. These measures resulted in urea unit capacity increasing up to 1650 mtd. as per final product (original design capacity 1500 mtd).

Pay-back period of capital investments of the provided revamping for this particular case is less than one year.



Revamping of urea synthesis reactor pos. R-1.

### RESULTS OF SYNTHESIS REACTOR MODERNIZATION

#### Baseline testing.

Baseline testing of urea synthesis loop were provided in between 06 - 12 July 2007. The unit was put in stable operation mode. Load on the unit was in the range of 1250 - 1360 mtd. Low value of final product output was explained by the following factors:

- high temperature of direct circulation water (+42° to +53°) preventing from efficient operation of concentration units;

at night time with lower ambient temperatures unit load as per final product was increasing up to 1460 mtd. ;

- poor condition of heat exchanging equipment (needed thorough cleaning).

Basic capacity was accepted with design figure of 1500 mtd as per final product.

#### Guarantee testing.

Guarantee testing of urea synthesis loop were provided in the period of 06 - 15 December 2007. While such testing we managed to reach urea unit capacity 1640 - 1650 mtd as per final product.

Analysis of urea melt form the reactor pos. R-1 compared to baseline testing showed urea concentration increase by 0.8%. Also decrease of ammonia content by 3.5% was observed. These two important facts prove increase of urea synthesis reactor efficiency.

### CONCLUSION

All the mentioned types of internals are protected by patents and proved their efficiency in a number of industrial scale trials. By nowadays set of internals by JSC NIIK design are installed at more than twenty urea units in Russia and CIS.

We are glad our best price services for synthesis loop revamping and urea plant as whole with guaranteed efficiency enhancement, energy saving and final product quality improvement.

With hopes for fruitful cooperation.