International Fertilizer Industry Association

IFA Technical Conference

Johannesburg, South Africa
30 September-4 October 1996

International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
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Date of Receipt: 29 April 1996

REVAMP OF UREA PLANT TO IMPROVE EFFICIENCY

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RESUME

PT Pupuk Sriwidjaja (Pusri) avec quatre unités de production est l'un des plus grands producteurs d'urée dans le monde avec une capacité annuelle de 2,28 millions t. L'unité d'urée Pusri II, démarrée en 1974, fonctionne suivant le procédé Toyo Engineering Corporation (TEC) utilisant son procédé de recyclage total amélioré (TR'C'I) consommateur d'énergie. Pour résoudre les problèmes fréquents du réacteur d'urée et pour améliorer le rendement, l'unité a été réhabilitée. A ce sujet, Pusri a contacté des partenaires sélectionnés sur le procédé d'urée et la décision finale a été d'utiliser le nouveau procédé ACES (Procédé avancé pour les économies de coût et d'énergie) de TEC.

La réhabilitation a été envisagée pour améliorer le rendement de l'unité comme ci-dessous :

1. *Accroissement de la production de 1150 à 1725 t/j (50 % de plus)*
2. *Réduction de 25 % de la consommation d'énergie*

TEC fournit l'ensemble licence et conception d'engineering du procédé. L'engineering de base a été réalisé par Pusri sous la supervision de TEC. L'engineering de détail, la fourniture et la construction ont incombé à Pusri. Des essais de démarrage et de performance ont été effectués par Pusri sous la supervision de EC. La réhabilitation a été financée par la Banque Mondiale et la participation des actionnaires. La réhabilitation a été un succès complet, l'essentiel de la construction ayant eu lieu pendant l'opération normale, impliquant le remplacement de la section de synthèse, y compris le réacteur d'urée, les compresseurs de CO_2, la pompe à carbamate, l'équipement modifié et supplémentaire dans la section purification et récupération. Le travail d'ajustage a été effectué durant l'interruption annuelle.

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I. INTRODUCTION

PT Pupuk Sriwidjaja ("PUSRI"), a state-owned company, is one of the largest urea producers in the world with an annual production capacity of 2.28 million tons per year. The four (4) production plants of PUSRI are located in one single location at Palembang, South Sumatra, Indonesia and all use natural gas as raw material. Each plant consists of an ammonia unit, an urea unit and utility & off-site facilities which supply potable water, cooling water, demineralized water, electric power, steam, plant air, instrument air along with bagging and shipping facilities to support the operation of the ammonia and urea units.

PUSRI-I was commissioned in the year 1963 with the ammonia unit of a production capacity of 180 MTPD of liquid ammonia in two (2) trains using Girdler process and the urea unit of a production capacity of 300 MTPD of prilled urea in two (2) trains using Mitsui Toatsu Chemical Corporation's (MTC) Total Recycle B (TR'B') process. Due to the aging and inefficiency of the plant, the plant was closed down and has been replaced with a new one, namely PUSRI-IB in 1994. The ammonia unit in Pusri-IB uses Kellogg's latest low energy process, and has a production capacity of 1,350 MTPD of liquid ammonia. The urea unit uses Toyo Engineering Corporation's (TEC) ACES process (Advance process for Cost and Energy Savings) and has a production capacity of 1,725 MTPD of prilled urea.

The second plant, PUSRI-II was commissioned in the year 1974. The ammonia unit uses Kellogg process and has a production capacity of 660 MTPD of liquid ammonia and the urea unit uses the Toyo Total Recycle C Improved (TR « C » I) process and has a production capacity of 1,150 MTPD of prilled urea. With the steady increase in the country's population and rice being the staple food of the Indonesian population, a large amount of urea was needed to increase the rice production. With this in mind, PUSRI was asked by the Government to increase its production capacity.

To increase the urea production PUSRI-III and PUSRI-IV units were built and commissioned in the years 1976 and 1977 respectively. Both the units used Kellogg's ammonia process and TEC's TR C-I process. The plants are identical, each with an ammonia capacity of 1,000 MTPD and urea capacity of 1,725 MTPD.

Prior to Pusri-II Urea Revamp, Pusri II, III & IV ammonia plants were revamped to increase the ammonia production capacity by 20% and reduce energy consumption by 10%. This revamp project was completed in the year 1993.

II. THE REVAMP BACKGROUND

Starting from the year 1984, serious problems developed in the titanium lining of the urea reactor of Pusri II plant, namely bulging and cracking especially around the nozzles. A number of shut-downs in PUSRI II urea unit were necessitated for inspection and repairs apart from annual shut-downs for turnaround. Repairs to the titanium lining were carried out by Kobe Steel Co.'s experts and they were assisted by PUSRI engineers. Each time 2-3 weeks were lost and these repairs turned out to be costly. The equipment vendor suggested the replacement of the urea reactor. After a thorough study based on technical and financial aspects, PUSRI management, in view of the long term benefits, decided that the best solution would be to revamp the plant by utilizing low energy process which will increase the plant efficiency by increasing production capacity on one hand and reducing energy consumption on the other.

Technical factors which support the plant revamp are as follows:

1. By utilizing low energy process, conversion in the synthesis unit will increase in comparison with the existing process. Most of the equipment in the purification and recovery section will have sufficient capacity to accommodate the increased production capacity, requiring only minor modifications. The additional main equipment required are: one (1) unit recycle solution feed pump and one (1) unit ammonia recovery absorber.

2. Construction can be carried-out while the plant is still in operation, except for the tie-in work to be carried out during the plant shutdown. The right time to carry-out the tie-in work is during annual turnaround to minimize production loss.

III. PROCESS SELECTION AND PROJECT IMPLEMENTATION SCHEME

For plant revamping, PUSRI contacted three (3) selected urea process owners/licensers. The process to be used for revamping the plant was selected from the preliminary proposals submitted by the process owners/licensers. Based on the technical and commercial evaluation results of the proposals, the final decision was made to use TEC's low energy ACES process to replace the existing process.

Considerations for the selection of TEC's ACES process are:

1. The process of the existing plant is TEC's TR' C' I process. Hence utilizing ACES process to replace the existing process will be easier to implement without major changes or modifications of the equipment compared with the other processes.

2. None of the urea plants in the world that are using TR' C' I process have been revamped by any other process licenser except TEC itself. However using the TEC ACES process would give more technical advantages in view of TEC's familiarity with its own process.

During the preliminary proposal stage, the technical evaluation indicated the following benefits:

1. Increase in production capacity to 150% of the original production capacity.

2. Decrease in energy consumption per ton of urea by 25% compared to current energy consumption. It was decided to carry out detailed calculations of plant efficiency during the « Evaluation Study Stage » for setting-up final objectives.

In line with Government of Indonesia's guidelines, the project was implemented following Self Management Concept to maximize the local content.

Split of Work between PUSRI and TEC are:

1. Evaluation Study and Process Engineering Design Package were carried-out by TEC and PUSRI. TEC to be responsible for the work.

2. Basic Engineering was carried-out by PUSRI under the supervision of TEC.

3. Detail Engineering was carried-out by PUSRI. TEC provided supervision based on PUSRI's request.

4. Procurement, Construction and Commissioning were carried-out by PUSRI.

5. Start-up and Performance test were carried-out by PUSRI under the supervision of TEC. TEC to be responsible for process guarantee.

IV. BUDGET FOR REVAMP AND SOURCE OF FUNDS

The revamp of the project was financed by The World Bank (The International Bank for Reconstruction and Development-IBRD) and PUSRI equity.

The Project budget:

PUSRI equity		= US \$ 14,050,000.0*
IBRD loan		= US \$ 22,260,000.0
Total		**= US \$ 36,310,000.0**

The Realized Cost:

PUSRI equity		= US \$ 10,991,528.0*
IBRD loan		= US \$ 22,015,818.0
Total		**= US \$ 33,007,346.0**
	or	**= 90.9% of the project budget**

* *Including IDC (Interest During Construction)*

V. THE PROJECT

The project consisted of mainly seven (7) activities:

A. Evaluation Study
B. Process Engineering Design Package (PEDP)
C. Basic Engineering
D. Detail Engineering
E. Procurement
F. Construction
G. Commissioning, Start-up and Performance test

A. Evaluation study, PEDP and basic engineering

The first step in a plant revamp project is the evaluation study of the existing plant. The purpose of the evaluation study is to check the capability of the existing equipment and devise alternatives for equipment bottle-necks. The evaluation study results are used to establish final revamp objectives.

The evaluation study was carried-out by TEC and PUSRI at Toyo Engineering Center, Japan. Utilization of the low energy ACES process to increase production capacity to 150% of original capacity required the following replacements and additions:

1. The existing urea reactor in the synthesis section to be replaced with an ACES urea reactor with the capacity required to produce 1,725 MTPD of urea. Replacement of the existing urea reactor will directly solve the reactor problems.

2. One (1) unit urea stripper, two (2) units carbamate condensers, one (1) unit scrubber, one (1) unit steam drum and one (1) unit steam saturation drum to be added in the ACES synthesis section.

3. Addition of one (1) unit recycle solution feed pump to handle increased carbamate solution and the existing unit to function as a stand-by.

4. Replacement of the existing two (2) units CO_2 reciprocating feed compressors with one(1) new unit of all turbo compressor which shall have enough capacity to handle the increased production capacity. The above change will support the revamp as below:
   - Maximum utilization of the steam which is generated in the ACES process as admision steam for the turbine of CO_2 compressor.
   - Utilization of the 22 kg/cm^2 extraction steam produced by the turbine of CO_2 compressor in the ACES process as required.
   - Modification of the existing compressors or replacement with new centrifugal compressor has no cost impact as either of the modification costs will be the same.
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- Replacement with new compressor will save the revamp time as the same can be installed during the plants normal operation.

5. Minor modifications to perforated plate holes and demister of HP decomposer.

6. Installation of two (2) units of additional urea solution pumps for transferring excess urea solution to other plants.

7. Modification of the existing high pressure absorber cooler to accommodate increased heat duty.

8. Installation of one (1) additional heat exchanger vessel in the ammonia recovery unit. The existing unit consisted of three (3) vessels.

9. Installation of one (1) set of Foxboro Distributed Control System (DCS) for operation control of the new ACES synthesis section and the new equipment.

The finishing section was not modified, based on the considerations below:

1. To increase the capacity of the finishing section to 1,725 MTPD, the required change of equipment will take a much longer time than shut-down time for turnaround, resulting in a big production loss.

2. Urea solution equivalent to 200 MTPD of prilled urea had to be sent to Melamine Plant as raw material.

3. The existing finishing section, especially the prilling tower had a maximum capacity to prill 1,300 MTPD.

4. Other existing urea plants (PUSRI-III, PUSRI-IV and PUSRI-IB) have enough capability to receive and process the remaining 225 MTPD excess urea solution from PUSRI-II.

As per the detailed energy consumption calculations, steam consumption will be 77.58 tons/hr and electric power consumption will be 3,090 KWH for the revamped plant. Based on the performance of relevant steam boiler and electric power generator, to generate 1 ton of steam (42.0 kg/cm^{2}g, 400^{o}C) the energy required is 2.82 MMBTU (based on delta enthalpy) and to generate 1 KWH of electric power the energy required is 0.0098 MMBTU.

Energy consumption for 1,725 MTPD of urea will be:

- Steam	= 77,58 x 2.82	= 218.776 MMBTU/hr.
- Electric power	= 3,090 x 0.0098	= 30.282 MMBTU/hr.
Total		**= 249.058 MMBTU/hr.**
		= 3.465 MMBTU/ton of urea
Energy Savings		= (4.62-3.465)/4.62 x 100 %
		= 25% per ton of urea

Final revamp objectives are as follows:

1. Increase in production capacity to 150% of the original capacity.
2. Reduction in energy consumption per ton of urea by 25% of current consumption.

Process Engineering Design Package (PEDP) and Basic Engineering (BE) were also carried-out at TEC's Engineering Center, Japan. PEDP and BE results were used to perform Detail Engineering and Inquiry package documents.

B. Detail engineering

Detail Engineering (DE) was carried-out at PUSRI's engineering office in Palembang, Indonesia. All documents compiled during DE work were used for construction activities and to complete the inquiry documents for procuring equipment and materials.

C. Procurement

Procurement of local and foreign materials and equipment were carried-out by PUSRI following the Government of Indonesia (GOI) regulations for funds from PUSRI equity and the World Bank guidelines forfunds from IBRD loan. The World Bank advised PUSRI to use IBRD loan for procurement of imported materials and equipment and not for services.

D. Construction

PUSRI was totally responsible for construction activities. To achieve maximum productivity and minimize construction cost, some of the construction work was sub-contracted to the local companies. However, work was carried-out under the supervision and direction of PUSRI. Most of the construction work was done during the plant's normal operation, except the tie-in work which was taken up during the annual plant turnaround.

E. Commissioning, start-up and performance test

Commissioning activities such as flushing and blowing of pipe lines, pressure tests, leak tests, running test for each rotating machinery, DCS and instrument loop tests, etc. began at the end of the construction stage before mechanical completion. During the start-up stage, some minor mechanical and instrumentation problems arose, but were solved as soon as possible after each problem occurred. After the plant was under continous operation for several days at 100% capacity, the plant performance test was conducted for 10 consecutive days.

The process/product guarantees of the licensors were achieved except the water content in the final product which was higher than the process guarantee; but was still within the industrial product specification of maximum 0.5% for prilled urea. Results of the performance guarantee test are shown in Attachment 1.

High water content in the product was caused by the steam injection into the bottom of the melter during the performance test to prevent choking of the outlet pipeline. Normally, injection of steam is not allowed and actual water content in the prilled urea should be maximum 0.3%.

F. Energy consumption

According to plant operational data prior to revamp, the energy consumption of PUSRI II urea plant, calculated based on steam and electric power, was 4.62 MMBTU/ton of urea. As shown in the performance test results data in Attachment 1, steam consumption is 1.078 ton/ton of urea and electric power consumption is 42 kwh/ton of urea.

Based on the performance of the relevant steam boiler and electric power generator, the energy consumption was calculated as follows:

- Steam	= 1.078 x 2.82	= 3.04 MMBTU/ton of urea
- Electric power	= 42.0 x 0.0098	= 0.41 MMBTU/ton of urea
Total		**= 3.45 MMBTU/ton of urea**

Total savings in energy consumption:

= (4.62 - 3.45) MMBTU/ton of urea
= 1.17 MMBTU/ton of urea
= (1.17/4.62) x 100%
= 25.3%

VI. PLANT PERFORMANCE AFTER REVAMP

After the completion of the Performance Test in June 1994, the plant went into commercial production; but the production capacity achieved during the second half of 1994 was not satisfactory due to insufficient raw material supply for 100% production. The additional raw materials were supplied by PUSRI-IB or other plants.

In 1995, performance of the plant was good without any major shutdown. In the period of October and November 1995, the plant was shut-down for four weeks for the first turnaround. During the plant turnaround the inspection of all major equipment revealed no abnormalities even after 20 months of operation.

The best performance was in April 1995. Almost optimal operation conditions were maintained to achieve the performance guarantees. Operational performance of the revamped plant is shown as Attachment 2.

VII. CONCLUSION

The revamp project was successfully implemented using d TEC's low energy ACES urea process. The project management was taken up by PUSRI and most of the activities were carried-out by PUSRI except the Evaluation Study and the Process Engineering Design Package which were performed by TEC along with PUSRI.

The project was financed by World Bank loan and PUSRI equity with a total budget of US $ 36,310,000 and the actual total project cost is US $ 33,007,000 or 91% of the project budget.

Performance test results show that the revamp objectives and TEC guarantees were achieved. Production capacity increased to 1,754.5 MTPD, more than the expected 1,725 MTPD or to 153% of original production capacity. Energy consumption reduced to 74.7% higher than the expected 75% of the previous energy consumption. The plant revamp resulted in the overall improvement in efficiency.

Attachment 1

RESULTS OF PERFORMANCE GUARANTEE TEST

NO	DESCRIPTION	UNIT	GUARANTEE FIGURES	PERFORMANCE TEST RESULTS
1.	Production	Mtpd	1,725	1,754.5
2.	Raw material consumption			
	a. Liquid ammonia	Ton/Ton	0.586, max	0.585
	b. CO_2 gas	Ton/Ton	0.765, max	0.753
3.	Energy consumption:			
	a. Steam, 42 kg/cm^{2}g	Ton/Ton	1.09, max	1.078
	b. Electric power	Kwh/Ton	44.0, max	42.0
4.	Product specification:			
	a. Nitrogen content	Wt %	46.0, min	46.0
	b. Water content	Wt %	0.3	0.48
	c. Biuret content	Wt %	0.7	0.43
	d. Ash content	ppm	15.0	4.025
	e. Iron (Fe) content	ppm	1.0	0.215
	f. Free ammonia	ppm	150.0	62.34
	g. Size distribution :			
	- 6 US Sieve	Wt %	99.5, min	99.92
	- 6 + 18 US Sieve	Wt %	95.0, min	99.09
	+ 25 US Sieve	Wt %	2.0, max	0.83

Attachment 2

OPERATIONAL PERFORMANCE OF THE REVAMPED PLANT

1. **PRODUCTION**

1994	PRODUCTION (Tons)	ON STREAM FACTOR, (%)	PRODUCTION RATE, (%)
June	33,360	98.55	65.41
July	37,847	100.00	73.13
August	38,283	100.00	71.59
September	39,381	100.00	76.10
October	42,798	100.00	80.03
November	48,140	100.00	93.02
December	39,186	80.89	75.72
Total	**278,995**		

1995	PRODUCTION (Tons)	ON STREAM FACTOR, (%)	PRODUCTION RATE, (%)
January	41,463	100.00	77.49
February	26,649	64.96	84.93
March	45,269	96.79	87.47
April	50,600	100.00	97.78
May	39,707	86.85	85.50
June	40,391	100.00	78.05
July	41,459	95.15	81.48
August	47,587	100.00	77.53
September	46,384	100.00	89.63
October*	13,096	8.30	91.45
November*	18,427	38.55	92.36
December	50,067	100.00	93.63
Total	**460,917**		

*Notes: *) Plant shut-down for turnaround from mid of October to mid of November*

2. OPERATION RECORDS

1994	DURATION	REMARKS
June	10 hours 237 hours	Plant shut-down (internal problems) Low production rate
July	218 hours	Low production rate
August	212 hours	Low production rate
September	173 hours	Low production rate
October	145 hours	Low production rate
November	54 hours	Low production rate
December	142 hours 70 hours	Plant shut-down (external problems) Low production rate

Remarks: Low production rate: 1,109 hours due to raw material shortage

1995	DURATION	REMARKS
January	168 hours	Low production rate
February	235 hours 67 hours	Plant shut-down (external problems) Low production rate
March	24 hours 102 hours	Plant shut-down (external problems) Low production rate
April	38 hours	Low production rate
May	98 hours 105 hours	Plant shut-down (external problems) Low production rate
June	156 hours	Low production rate
July	36 hours 147 hours	Plant shut down (internal problems) Low production rate
August	90 hours	Low production rate
September	100 hours	Low production rate
October	18 hours 545 hours	Low production rate Plant shut-down for turnaround
November	442 hours 28 hours	Plant shut-down for turnaround Low production rate
December	72 hours	Low production rate

Remarks:

Low production rate — *1,091 hours due to raw material shortage*

Plant shut-down — *- 36 hours due to internal problems*
- 987 hours for turnaround
- 357 hours due to external problems