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600 T/D UREA PLANT

COOPERATIVE FARM CHEMICALS ASSOCIATION

SCOPE

This technical proposal sets forth the design criteria and scope of work offered by C&I/Girdler Incorporated for a 600 short tons per day urea plant to be located on the Purchaser's site at Lawrence, Kansas. The work includes the necessary engineering and erection services as well as the procurement of equipment and materials.

The process techniques offered, consisting of Synthesis and SPHERODIZER® sections, are proprietary to C&I/Girdler. The plant is designed to receive carbon dioxide, liquid ammonia, steam, cooling water, instrument air, plant air, and electrical power and to return SPHERODIZER® granulated urea product, steam condensate, cooling water and drainage which includes process condensate containing approximately 200 ppm of ammonia. The design conforms to C&I/Girdler specifications and standards except as otherwise noted.

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PROCESS DESCRIPTION

Carbon dioxide containing less than one part per million of hydrogen sulfide is received at the battery limits of the urea plant at a temperature of 295°F and at a pressure of 3300 psig. A small quantity of air is added to the carbon dioxide to protect the reactor lining. Liquid anhydrous ammonia and recycled ammonium carbamate solution are pumped separately to 3250 psig in slow speed, heavy duty reciprocating pumps of a special design. In the reactor the ammonia and carbon dioxide react to form ammonium carbamate, a portion of which dehydrates to form urea and water. The reactions are as follows:

$$2NH_3 + CO_2 \rightleftharpoons NH_2COONH_4$$

$$NH_2COONH_4 \rightleftharpoons NH_2CONH_2 + H_2O$$

The first reaction occurs rapidly and goes to completion. The second reaction occurs slowly and controls the reactor volume. The fraction of ammonium carbamate that dehydrates is determined by the ratios of the various reactants, the operating temperature and the residence time in the reactor. The mol ratio of ammonia to carbon dioxide is around 4 to 1. The reactor temperature is maintained around 375°F by varying the ammonia preheat temperature. The conversion of carbon dioxide to urea under the conditions is approximately 67% per pass based on the total equivalent carbon dioxide present.

The reaction melt, which consists of urea, water, free ammonia and ammonium carbamate, flows through the let-down valve to the steam heated high pressure decomposer where essentially all the excess ammonia is flashed or boiled out and a large fraction of the ammonium carbamate is decomposed back to gaseous ammonia and carbon dioxide. These gases, after being separated from the solution, flow to the high pressure absorber for recovery. The solution flows to the steam heated low pressure decomposer where much of the remaining ammonium carbamate is decomposed. The overhead gases flow to the low pressure cooler and are recovered. The solution from the low pressure decomposer flows to the gas separator where most of the last remaining traces of ammonia and carbon dioxide are removed from the aqueous urea solution. The overhead vapors are recovered in the gas precondenser and gas condenser which are operated in series. The solution from the gas separator flows to the urea flash drum where the urea concentration of the solution is increased and the temperature of the solution is lowered. The urea flash drum operates under vacuum and the solution flows from the flash drum through a standpipe

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PROCESS DESCRIPTION, CONTINUED

to the urea surge tank. The urea solution is then pumped through the concentrator heater to the concentrator separator which operates under vacuum. The overhead vapors, along with those from the urea flash drum, are condensed in a water cooled surface condenser. The condensate flows to the stripper feed tank. The concentrated urea solution is then pumped through the evaporator heater to the evaporator separator which operates at a higher vacuum than the concentrator. The overhead vapors are condensed in a water cooled surface condenser. The condensate flows to the stripper feed tank.

The urea melt is pumped from the evaporator through each of the three SPHERODIZER® granulators through specially designed spray manifolds and sprayed onto the beds of recycled material which consists of undersize granules and crushed oversize granules. Counter-current flows of air (cooled before entering the SPHERODIZER® granulator when necessary due to high ambient temperature) serve to cool the granules in each unit, forming very hard, dense spherical granules.

The material discharged from each SPHERODIZER® granulator is conveyed to a bucket elevator which elevates the material for screening. The undersize granules and the crushed oversize granules are recycled to the SPHERODIZER granulator to form the bed in the SPHERODIZER granulator. The product size range is controlled by the size of the opening in the installed screens. This can be changed by changing the size of the openings in the screens. The product granules are weighed before being conveyed to the bulk warehouse.

The air streams exhausted from the SPHERODIZER granulators are scrubbed in impingement type wet scrubbers before being exhausted to the atmosphere. Hot condensate is used as feed to the scrubbers. The aqueous urea solution is pumped from each scrubber back to the urea surge tank where it mixes with the urea solution from the synthesis section. The resulting urea solution is pumped to the concentration and evaporation system.

The gases from the gas separator are condensed and recovered in the gas precondenser and gas condenser. Heat is removed by cooling water. The solution formed in these two units is pumped to the low pressure cooler where the gases from the low pressure decomposer and stripper are recovered. The heats of absorption and reaction are removed by cooling water. The solution from the low pressure absorber is then pumped to the high pressure absorber where the gases from the high pressure decomposer are absorbed and reacted. Here the heats of absorption and reaction are removed by cooling water. The overhead vapor from the high pressure absorber is essentially pure ammonia which is condensed is water-cooled condensers and recycled to the process as the excess ammonia required to obtain a high conversion to urea.

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PROCESS DESCRIPTION, CONTINUED

The solution from the high pressure absorber is the recovered aqueous ammonium carbamate solution which is recycled to the reactor as described earlier.

The condensate from the surface condensers is collected in the stripper feed tank. The mixture is pumped to the stripper where the solution is preheated by heat exchange with the bottoms. The ammonia and carbon dioxide are stripped from the solution and go overhead to the low pressure cooler for recovery. The stripper bottoms contain approximately 200 ppm of ammonia.

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PERFORMANCE GUARANTEES

A. Basis of Guarantees

C&I/Girdler Incorporated guarantees that the Urea Plant, when completed and operated in accordance with Girdler's instructions and under Girdler's technical advice will for a performance test period of 72 hours so operate at design rate without major interruption that the results set forth below will be realized, provided C.F.C.A. furnishes sufficient operating personnel, process material, utilities, and provided the characteristics of the process materials and utilities are no less favorable than the following:

Ammonia

Commercial grade liquid having the following specifications at the Urea Plant battery limits:

Composition:	NH_3	99.8% by Weight, Minimum
	H_2O	0.2% by Weight, Maximum
	Oil	2 ppm by Weight, Maximum
	Inerts	0.005 ml/Gram of Ammonia, Maximum
	Iron	Nil
	Color	Water clear
Pressure		300 psig, Minimum
Temperature		105°F, Maximum

Carbon Dioxide

Gaseous CO_2 having the following specifications at the Urea Plant battery limits:

Composition	CO_2	98.5 Mol Percent, Minimum
	Inerts	1.5 Mol Percent, Maximum
H_2S and other Sulfur Compounds		1 ppm by Volume, Maximum
MEA, Potassium Carbonate Sulfinol, etc.		Nil

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PERFORMANCE GUARANTEES, CONTINUED

Carbon Dioxide, Continued

Temperature	295°F, Maximum
Pressure	3300 psig, Minimum

Electrical Power

Voltage	4160	and 440
Phase	3	3
Cycles	60	60

Steam

Condition	Superheated to 650°F TT
Pressure at Battery Limits	550 psig

Ambient Air

Wet Bulb, Maximum	76°F
Dry Bulb, Maximum	102°F
Absolute Humidity, Maximum	0.0137 Pounds of Water Vapor Per pound of air

Instrument Air

Pressure at Battery Limits	80 psig, Minimum
Condition	Dry and Oil Free

High Pressure Air

Pressure at Battery Limits	300 psig
Condition	Oil Free

Cooling Water

Source	Cooling Tower
Temperature at Battery Limits	85°F, Maximum
Pressure at Battery Limits	50 psig, Minimum
Condition	Non Corrosive to Carbon Steel Free of sand, silt and suspended solids

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600 T/D UREA PLANT
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PERFORMANCE GUARANTEES, CONTINUED

B. Guarantees

1. The Urea Plant will be capable of producing 600 short tons of granulated urea per 24-hour day.

2. When the Urea Plant is operated at guaranteed capacity in accordance with Section A above, the granulated urea produced will conform to the following specifications:

Nitrogen, % wt	46.0 minimum	(typical 46.5)
Biuret, % wt	1.2 maximum	(typical 1.0)
Moisture, % wt	0.2 maximum	(typical 0.05)
Size Specification	(Tyler Sieve)	
On 5	1.0 maximum	
On 8	30.0 minimum	
On 10	80.0 minimum	
On 14	98.0 minimum	

3. When the Urea Plant is operated at guaranteed capacity in accordance with Section A above, the consumption of raw materials per short ton of granulated urea produced will not exceed the following:

Ammonia (100% NH_3 Basis)	0.580 Short Tons (1)
Carbon Dioxide (100% CO_2 Basis)	0.760 Short Tons (1)

4. When the Urea Plant is operated at guaranteed capacity in accordance with Section A above, the total cost of the utilities listed below per short ton of granulated urea produced will not exceed $3.51 when unit costs listed below are used to determine the total cost of these utilities:

Utility	Expected Usage	Unit Price
Electric Power (2)	71 KWH	0.9¢/KWH
Steam (3)	3325 LBS	60.0¢/M LBS
Cooling Water	27,040 GALS	2. ¢/M GALS

(1) These quantities are subject to a plus or minus 2% metering error.

(2) Does not include plant lighting or CO_2 compression.

(3) Does not include building heating and steam tracing.

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UTILITY CONSUMPTION SUMMARY

The SPHERODIZER® granulated urea plant, when supplied with the specified utilities and when operated at the design capacity, will require the following estimated utility requirements:

Steam	
550 psig, 650°F TT	83,100 lbs/hr.
Cooling Water	
50 psig, 85°F	11,600 U.S. GPM
Electrical Power	
4160V/3 ph/60 Hz and 440V/3ph/60 Hz	1775 KW
Instrument Air	
80 psig	200 SCFM
Process Air	
300 psig	5 SCFM
Condensate Returned	
50 psig, 210°F	68,400 lbs/hr.

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EQUIPMENT LIST

The following list of equipment is generally inclusive, but not necessarily exact and the details may be modified by C&I/Girdler as the design of the plant develops.

B-1A Exhausters
B-1B

Type	Centrifugal
Drive	Electric motor
Material - Casing	Aluminum
Impeller	Stainless steel

C-2 Refrigeration System

Type	Package unit
Refrigerant	Ammonia
Drive	Electric motor
Auxiliaries	Inlet surge drum, aftercooler with carbon steel tubes, refrigerant surge drum, capacity control by unloading and by-passing

D-1 Reactor

Type	Vertical cylinder
Design Pressure	3600 psig
Design Temperature	400°F
Material - Shell	Carbon steel
Liner	316L stainless steel
Internals	316L stainless steel (removable)

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EQUIPMENT LIST, CONTINUED

D-3 High Pressure Condensate Tank

Type	Horizontal cylinder
Design Pressure	200 psig
Design Temperature	450°F
Material	Carbon steel

D-4 Gas Separator

Type	Vertical drum
Design Pressure	35 psig
Design Temperature	300°F
Material	316 stainless steel

D-5 Urea Flash Drum

Type	Vertical cylinder
Design Pressure	Full vacuum
Design Temperature	300°F
Material	304L stainless steel

D-6 Urea Surge Tank

Type	Cylindrical tank - flat bottom, cone roof
Design Pressure	Atmospheric
Design Temperature	275°F
Material	Aluminum
Auxiliaries	Stainless steel steam coil

D-7 Concentrator Separator

Type	Vertical cylinder
Design Pressure	Full vacuum
Design Temperature	300°F
Material	304L stainless steel

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EQUIPMENT LIST, CONTINUED

D-8 Evaporator Separator

Type	Vertical cylinder
Design Pressure	Full vacuum
Design Temperature	325°F
Material	304L stainless steel

D-9 Stripper Feed Tank

Type	Cylindrical tank - Flat bottom, cone roof
Design Pressure	Atmospheric
Design Temperature	250°F
Material	Carbon steel

D-10 Ammonia Receiver

Type	Horizontal cylinder
Design Pressure	300 psig
Design Temperature	450°F
Material	Carbon steel

D-11 L.P. Decomposer Condensate Tank

Type	Horizontal drum
Design Pressure	300 psig
Design Temperature	400°F
Material	Carbon steel

D-14A and D-14B SPHERODIZER® Granulator

Type	Rotary drum
Drive	Electric motor
Material	Carbon steel
Internals	Lifters, dams, breeching, feed and discharge chutes

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EQUIPMENT LIST, CONTINUED

D-15A and D-15B Scrubbers

Type	Impingement
Design Pressure	25" of water vacuum
Design Temperature	250°F
Material	304 stainless steel

D-16 Urea Rundown Tank

Type	Cylindrical tank - Flat bottom, cone roof
Design Pressure	Atmospheric
Design Temperature	200°F
Material	Aluminum

E-1 Ammonia Preheater

Type	Shell and tube	
	Shell	Tubes
Design Pressure	200 psig	3600 psig
Design Temperature	450°F	450°F
Material	Carbon steel	Carbon steel

E-2 High Pressure Decomposer

Type	Vertical thermosyphon - shell and tube with entrainment separator	
Reboiler Section:		
	Shell	Tubes
Design Pressure	200 psig	300 psig
Design Temperature	450°F	350°F
Material	Carbon steel	316L stainless steel clad

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EQUIPMENT LIST, CONTINUED

E-2 High Pressure Decomposer, Continued

Entrainment Section:

Type	Tray
Design Pressure	300 psig
Design Temperature	350°F
Material, Shell	316L stainless steel clad carbon steel
Trays	316L stainless steel

E-3 Low Pressure Decomposer

Type	Shell and tube heater with entrainment separator

Heater Section:

	Shell	Tubes
Design Pressure	200 psig	75 psig
Design Temperature	450°F	350°F
Material	Carbon steel	316 stainless steel

Entrainment Section:

Type	Vertical cylinder
Design Pressure	75 psig
Design Temperature	300°F
Material	316 stainless steel

E-4 Gas Separator Heater

Type	Shell and tube

	Shell	Tubes
Design Pressure	200 psig	35 psig
Design Temperature	350°F	300°F
Material	Carbon steel	316 stainless steel

E-5 Concentrator Heater

Type	Shell and tube

	Shell	Tubes
Design Pressure	200 psig	Full vacuum
Design Temperature	350°F	300°F
Material	Carbon steel	304L stainless steel

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EQUIPMENT LIST, CONTINUED

E-6 Concentrator Overhead Condenser

Type	Surface condenser with steam jet ejector	
	Shell	Tubes
Design Pressure	Full vacuum	75 psig
Design Temperature	200°F	200°F
Material	Carbon steel	304 stainless steel

E-7 Evaporator Heater

Type	Shell and tube	
	Shell	Tubes
Design Pressure	200 psig	Full vacuum
Design Temperature	360°F	350°F
Material	Carbon steel	316 stainless steel

E-8 Evaporator Overhead Condenser

Type	Surface condenser with steam jet ejector	
	Shell	Tubes
Design Pressure	Full vacuum	75 psig
Design Temperature	200°F	200°F
Material	Carbon steel	304 stainless steel

E-9 Stripper Feed Heater

Type	Shell and tube	
	Shell	Tubes
Design Pressure	150 psig	150 psig
Design Temperature	400°F	400°F
Material	Carbon steel	Carbon steel

E-10 Gas Precondenser

Type	Shell and tube	
	Shell	Tubes
Design Pressure	150 psig	150 psig
Design Temperature	300°F	300°F
Material	Carbon steel	304L stainless steel

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EQUIPMENT LIST, CONTINUED

E-11 Gas Condenser

Type	Shell and tube	
	Shell	Tubes
Design Pressure	35 psig	75 psig
Design Temperature	300°F	200°F
Material	304L stainless steel	304L stainless steel

E-12 Low Pressure Cooler

Type	Shell and tube	
	Shell	Tubes
Design Pressure	70 psig	75 psig
Design Temperature	200°F	200°F
Material	304L stainless steel	304L stainless steel

E-13 High Pressure Cooler

Type	Shell and tube	
	Shell	Tubes
Design Pressure	300 psig	75 psig
Design Temperature	300°F	300°F
Material	316L stainless steel clad carbon steel	316 stainless steel

E-14A, E-14B Ammonia Condensers

Type	Shell and tube	
	Shell	Tubes
Design Pressure	300 psig	75 psig
Design Temperature	450°F	150°F
Material	Carbon steel	Carbon steel

E-15A, E-15B, E-15C Aqua Ammonia Solution Coolers

Type	Kettle Reboiler	
	Shell	Tubes
Design Pressure	300 psig	75 psig
Design Temperature	450°F	150°F
Material	Carbon steel	Carbon steel

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EQUIPMENT LIST, CONTINUED

P-4A, P-4B Aqua Ammonia Solution Pump and Spare

Type	Centrifugal
Suction Pressure	235 psig
Suction Temperature	105°F
Discharge Pressure	300 psig
Drive	Electric motor
Material	All iron

P-5A, P-5B Recovered Solution Pumps

Type	Reciprocating
Suction Pressure	275 psig
Suction Temperature	205°F
Discharge Pressure	3275 psig
Drive	Back pressure steam turbine
Material	Forged stainless steel

P-6A, P-6B Carbamate Circulating Pump and Spare

Type	Centrifugal
Suction Pressure	240 psig
Suction Temperature	215°F
Discharge Pressure	300 psig
Drive	Electric motor
Material	316 stainless steel

P-7A, P-7B High Pressure Absorbent Pump and Spare

Type	Centrifugal
Suction Pressure	35 psig
Suction Temperature	100°F
Discharge Pressure	305 psig
Drive	Electric motor
Material	316 stainless steel

P-8A, P-8B Low Pressure Absorbent Pump and Spare

Type	Centrifugal
Suction Pressure	0 psig
Suction Temperature	140°F
Discharge Pressure	75 psig
Drive	Electric motor
Material	316 stainless steel

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EQUIPMENT LIST, CONTINUED

X-1 Product Conveyor

Type	Rubber Belt
Capacity	50 ST/hr.
Drive	Electric motor

X-2A, X-2B, X-2C Product Scales

Type	Automatic Weigher
Capacity	15 ST/hr.

X-3A, X-3B, X-3C Screen (Oversize and Undersize)

Type	Rotex
Capacity	50 ST/hr. (each)
Drive	Electric motor
Screen Material	316 stainless steel

X-4A, X-4B, X-4C Bucket Elevator to Screens

Type	Continuous bucket on chain
Capacity	50 ST/hr.
Drive	Electric motor
Material	Carbon steel, vinyl buckets

X-5A, X-5B, X-5C Recycle Conveyor

Type	Rubber belt
Capacity	50 ST/hr.
Drive	Electric motor

X-6A, X-6B, X-6C Recycle Bucket Elevator

Type	Continuous bucket on chain
Capacity	50 tons/hr.
Drive	Electric motor

X-7A, X-7B, X-7C SPHERODIZER® Outlet Conveyor

Type	Rubber belt
Drive	Electric motor

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EQUIPMENT LIST, CONTINUED

X-8A, X-8B, X-8C Oversize Crusher

Type	Fixed arm hammer mill
Drive	Electric motor

X-9A, X-9B, X-9C Recycle Scale

Type	Belt
Capacity	50 tons/hr.