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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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# SAFE DESIGN AND OPERATION OF AMMONIA PLANTS[1/]

by

M. Vos*
A. C. Ludbrook**

* Kellogg International Corporation, London, United Kingdom
** Manager, Operating Division, Kellogg International Corporation, London, United Kingdom

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## INTRODUCTION

This paper is presented to highlight the safety aspects which are either incorporated in the design or in the procedures used during the operation of an ammonia plant. The paper is purposely brief and is intended to form the basis for an open discussion.

### Design Stage

All plants are designed to internationally accepted codes and standards and materials are selected to cater for the most severe conditions anticipated during the operation of the plant. These may occur during startup, shutdown or normal operating conditions. Where it is not practical to design for an emergency condition, such as after burning, high temperature alarms are installed to alert the operators to take remedial action immediately. Instrumentation is used to prevent temperature runaways on vessels which cannot be designed to withstand the maximum temperature to which the vessel could be subjected. Provision is made for the injection of ammonia into the syn loop circulating gas during the reduction of the ammonia synthesis catalyst to prevent freezing of any residual water. On large compressors which may be shut down by a variety of failures, lube oil, seal oil, etc., often a "first out" indication feature is provided to enable the operator to determine which fault tripped the machine.

Reacceleration features are often specified for critical motor drives in the event of voltage dips for short periods. Emergency power systems for motor drives and instruments are incorporated which invariably involve the

installation of an instantaneous battery supply system for critical instrumentation to cater for the period between the power failure and the run up time of the emergency power generator. The sizing of the emergency power source can be (a) to continue the unit operations or (b) to enable the safe shutdown of the unit. All instrumentation is designed to fail safe which may be for the valve to open, close, or stay put in its exact position prior to the failure.

Vent systems form a critical part of the safe design of an ammonia plant since during startup atmospheric venting via silencers is a normal procedure. To avoid the production of carbamate in these vent lines, vent systems containing ammonia are segregated from systems containing carbon oxides.

The designer's personnel checks that all features are incorporated in the plant design to safely start or stop the plant. In addition an operating manual is written to serve as a guideline for client's personnel, explaining startup, normal operation, normal and emergency shutdowns and special safety precautions.

## Construction Stage

Identification of materials is one of the most important items during field construction. This ensures that the correct specification piping, fittings, valves etc are in fact installed in the correct location. Pipe is identified by coloured bands running the whole length of the pipe. Valves are identified by a code stamped on the vendors plate which itself is rivetted to the valve bonnet.

Preservation procedures are exercised in the field prior to the actual startup of the plant and whilst in some cases preservation is necessary for example compressor and turbine rotors, the preserving medium has to be removed by the vendor prior to actual startup. For less critical equipment this preservation may be desiccant bags inside sealed enclosures, oil bearing housings filled completely with oil, pump shafts rotated manually, rusted weekly by hand etc.

A frequent cause of plant emergencies is gasket failures. The use during construction of "temporary" gaskets where it is intended to eventually replace them with gaskets of the correct specification, is forbidden. In particular asbestos gaskets must be annular in form and not made up on site from sheet material.

Hydrostatic testing circuits are selected according to the required pressure level and each item of equipment is reviewed to ensure that:- (a) the design shell/tube differential pressure will not be exceeded, and (b) where an exchanger design incorporates bellows, tie-bars are fitted before testing and removed afterwards, (c) the hydro test water is of potable quality and hence does not contain chlorides which can cause stress corrosion cracking, in stainless steel components. Pressure tests, either hydraulic or pneumatic are governed by the minimum temperature/maximum pressure relationship for the material to be tested.

Pre commissioning Stage

Contractor's operating personnel are assigned to the job at this stage, and they work in close cooperation with the client's operators. This allows preliminary on the job training which may include classroom lectures

by contractor's operating personnel using the plant operating manual as a basis, and direct involvement in or advice on all of the precommissioning activities carried out prior to startup.

Typical precommissioning activities include checking the entire unit for conformity with the engineering drawings, catalyst loading, water flushing or air blowing of piping, scrupulous cleaning of compressor suction piping, chemical cleaning of steam generation and $CO_2$ removal systems, leak testing of piping and equipment, checking of overspeed and instrumentation trip systems, checking correct control valve actions, checking alarm settings by simulation as required.

Startup

Vessels designed for high temperature/pressure or cryogenic service require specific commissioning procedures to ensure that the pressure/temperature relationship and/or the maximum permitted temperature differential throughout the vessel, is not exceeded. These procedures are developed to minimise vessel material stresses during the commissioning phase and are followed at each subsequent startup.

The margin for errors during the initial startup of the plant is greater than at any other time since all equipment has yet to be tested operationally. Despite all the care that has been put into simulating trips, testing equipment prior to the initial operation, etc, it is a fact that all equipment as yet is untried under operating conditions, and therefore elaborate planning is required to ensure that complete co-ordination of the startup operation is achieved and all operating personnel assigned to the plant for the initial startup should have a very clear definition of their area of involvement and of what is going on simultaneously in other areas of the plant.

Normal Operation

There is no safer feeling in the plant's life than when it is operating normally but operation and maintenance staff should not be lulled into a state of false security. Operators and indeed all personnel actively engaged on the plant should bring to the attention of the shift supervisor any item which is in need of repair. Those repairs which can be made with the plant in operation should be promptly carried out, others which require a plant shutdown should be listed so that these can be planned for the next scheduled shutdown. In particular the need for temporary repairs made during plant operation. Equipment which is gradually deteriorating in performance should be closely monitored, so that a timely decision for an intermediate shutdown can be taken. Standby equipment and associated instrumentation should be checked on a regular basis for serviceability. Normally de energised trip circuits should be checked for continuity.

Testing of trip mechanisms with the plant on line is becoming increasingly common. The procedures involved, especially simulated trip testing of large compressors with the machine on line, guaranteeing that the machine in fact will not trip are very sophisticated and have to be individually developed for the specific item of equipment. Certain turbine vendors are now building in an "unclamp" device which does prove that the hydraulic steam trip valve is free to move.

Plant Shutdowns

A potentially hazardous situation exists at any shutdown due to the number of people present on the plant who individually are not familiar with either the plant or the process. The responsibility rests upon the operating personnel to ensure that any item of equipment, or piping system to be handed over to maintenance for repair or inspection is in fact gas free and ready for maintenance.

The specified safety procedures and issuance of isolation and gas free certificates must be meticulously followed. Entry into nitrogen filled vessels, one of the most common causes of shutdown fatalities, has to be carefully controlled and all safety precautions fully explained to the personnel involved. Temporary maintenance personnel engaged for the period of an overhaul must be particularly closely supervised by the client's personnel.

## Catalyst Unloading

Catalysts are normally unloaded in their reduced state and hosed down to prevent undesirable pyrophoric rise in temperature. Catalysts are removed from the plant in a wet state and dumped in a safe location to undergo atmospheric oxidation prior to final disposal.

## Special Precautions

At all planned or emergency shutdowns involving the methanator the residual carbon oxides must be immediately purged with nitrogen to prevent the formation of highly toxic nickel carbonyl, or material damage caused by runaway temperatures due to uncontrolled oxidation.

Any vessels containing catalysts where inspection is not required are kept under a positive nitrogen pressure throughout the period of the shutdown. Temporary gauges should be fitted as necessary to indicate that this positive pressure does in fact exist at all times.

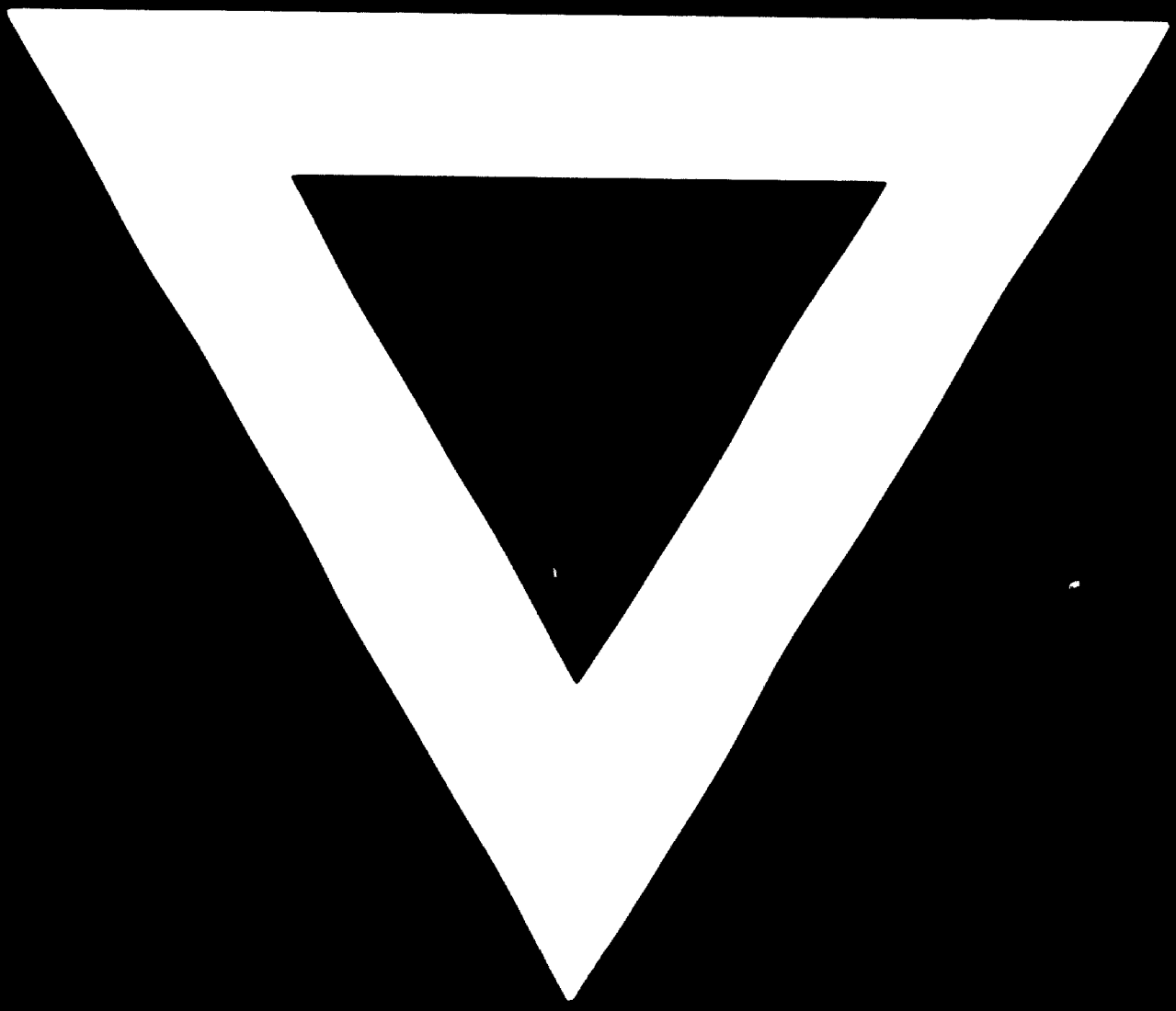
## Conclusion

Plant safety is a function of adequate design, correct construction and safe operation. Maximum on-stream production efficiency and minimum incidents which may lead to hazardous situations are the prime

responsibilities of operating personnel. The ability immediately to identify change in plant conditions and to correctly diagnose the cause of this change, so that the correct remedial action can be taken requires considerable training and experience.

UNIDO Assistance

A major problem when formulating training schemes for clients' personnel is obtaining access to similar operating plants where clients' trainees can discuss and observe the procedures used by the host operating company. Any influence that UNIDO can exert to facilitate such visits would be of great value.



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