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Innovative Solutions to Several Instrumentation Problems

Pressure, Differential Pressure, Level and Flow

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This article discusses innovative solutions that solved vexing instrumentation problems and enabled commissioning an ammonia urea and complex fertiliser units on schedule. Hopefully the readers would see from this article that thorough knowledge on the working principles of instruments is essential to troubleshoot and solve instrument problems. However, often the instruments themselves would be OK and the problems originate from overlooking some intricate vessel construction detail, and or processes details, which prevent correct process pressures reaching the instruments' ports. Identifying such problems require instrumentation engineers going beyond instrumentation and gaining knowledge on the process and engineering details of process vessels. The case studies of this article illustrate these points.

The liquid ammonia Level (L) readings across the five stages of a multistage flash drum of an ammonia plant were erratic. This posed difficulties in cooling the liquid by flashing to nearly -28° C for storing in atmospheric pressure storage tank. Repeated calibration of the High Pressure side seal type DP transmitters confirmed they were OK. The exasperated section instrument engineer sought help.

Trusting the Section Instrument Engineer; the vessel diagram and liquid NH_3 inlet system and instrument High Pressure (HP) and Low Pressure (LP) taps were reviewed **(Figure 1)**. This approach paid richly. He found that the liquid ammonia entered the vessel via the tangentially welded liquid inlet nozzle (TIN) at the top of each stage. A process engineer confirmed the author's guess that, the tangential entry of liquid NH_3 swirls it within the annulus between the vessel wall and the skirt S welded to the previous stage extending into the stage. This way the centrifugal force of spinning throws the liquid against the vessel wall and from there it collects at the vessel bottom. Unfortunately due to the swirling the pressure in the annulus fluctuates widely. Hence, the Low Pressure Tap (LPT) of the High-pressure side Seal Type Differential Pressure Transmitter (HSDPT), the level measuring transmitter, does not get representative pressure at the low

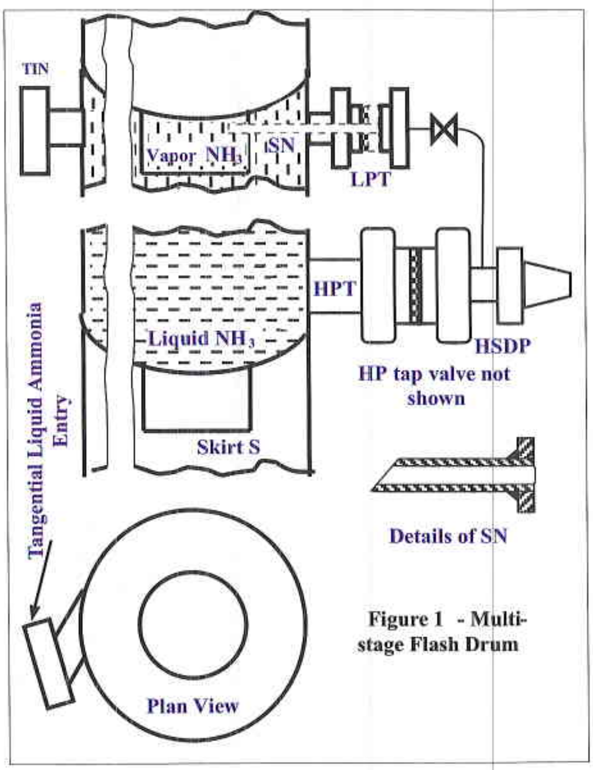

Figure 1 - Multi-stage Flash Drum

pressure port (LP). So, the readings were erratic.

A solution was also provided. The mechanical crew was asked to drill a 30 mm dia hole in the skirt concentric to the LP tap bore. The pipefitter crew was made to fabricate and install a Supplementary Nozzle (SN) – shown dotted in **Figure 1** - popularly called Dutch Man – penetrating into the skirt at LPT of all the five stages as in **Figure 1**. Since swirls are absent at this zone, LP tap of HSDPT also gets representative pressure signals and hence readings are no more erratic.

Correct level readings through innovative troubleshooting and problem solving enabled the plant to successfully commission the ammonia plant as scheduled.

Another level measuring problem solved: The ammonia flash vessel of an ammonia plant came with the following instruments on taps taken off a 3" Sch 120 pipe connecting the vessel Top Nozzle Flange TNF and Bottom Nozzle Flange BNF as in **Figure 2**; **Figure 2** shows just two instruments to avoid figure clutter.

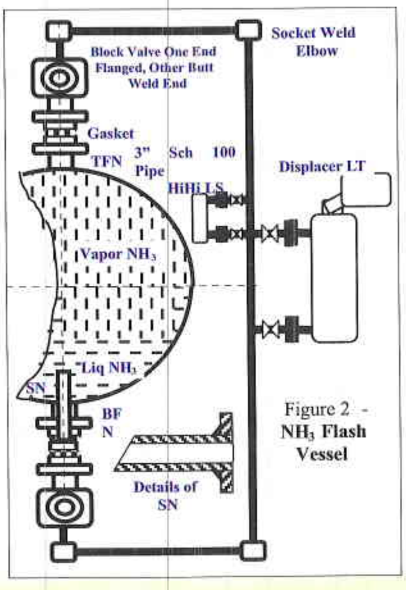

Figure 2 - NH_3 Flash Vessel

1. One Displacer level transmitter (DLT)
2. One high range level gauge glass (HLG)
3. One hi level switch (HLS)
4. One hi hi level switch (HHLS)
5. One low range level gauge glass (LLG)
6. One Lo level switch (LLS)
7. One Lo Lo level switch (LLLS)

This avoided numerous welds on the vessel fabricated under very strict fabrication codes and saved considerable costs.

The successful instrument system behaved erratically after three months of commissioning. The section engineer traced the problems to carry over oil of density 860 kg/m^3 settling below liquid NH_3 of density 640 kg/m^3. The oil NH_3 mixture formed an extremely viscous near solid product and blocked the bottom tap.

Oil draining by the operators was hazardous as even ppm of ammonia dissolved in oil flashing at atmospheric pressure rendered the entire area very pungent.

The section engineer installed a supplementary nozzle SN at the Bottom Flanged Nozzle (BFN) to extend about 200 mm above vessel bore as done for the Multi Stage Flash Drum and solved the problem. Since the volume of a horizontal tank increases drastically with increasing height from the bottom the collected oil level never reached the tip of the SN and hence, instrument problems vanished. Draining the oil at each turnaround at 18-24 months intervals was all that was necessary.

Level Problem-3: Process and Production engineers would often complain that the displacer level transmitters in the first flash separator of NH_3 read above zero before plant start up and made the instrument technicians to zero the DLT. The section engineer brought this to the seniors attention. He was told that zeroing that DLT under no pressure conditions is a serious mistake and asked him to explain! The perplexed engineer sheepishly told that he does not know and asked for explaination.

Refresher on Gas Laws and Displacer Level Transmitter (DLT) Working Principles

Gas Laws: According to Boyle's and Charle's Laws known as gas laws the below given formula gives the relation between the volume of a gas v_{pt} at pressure p bars and temp t^0 C and that v_n at 1.03 bars and 0^0 C known as Normal Pressure and temp NTP conditions.
$v_{pt} = v_n 1.03(273+t)/(p+1.03)(273)$. Hence the Density $\gamma_{PT} = \gamma_N(p+1.03)(273)/1.03(273+t)$.

DLT: The DLT's transmitting head H senses lesser and lesser weight of the displacer it carries and immersed in tank of liquid as the tank level rises. This is due to the upward force equal to the weight of the displaced liquid, i.e. buoyancy effect. H develops 3-15 psi air pressure, 4-20 mA current or digital signals according to its type for remote level reading and control. Density of gases at high pressures is considerable and hence considering the loss of weight on account gas immersion also, while calibrating DLT is must.

It was explained, "that the DLT working pressure of 220-bars the density of synthesis gas is not negligible compared to that of liquid NH_3 of density 640 kg/m^3. Normal Density of syn gas is 0.38 kg/Nm^3. Therefore it is (0.38*220*273)/(273+40) =73 kg/m^3, at the vessel pressure of 220 bars and temp of 40^{0}C i.e. 11.4% of the density of liquid NH_3 under the gas in the vessel. The displacer of the DLT looses less weight at zero vessel pressure than it would at 220 bars. No wonder it reads above zero." He was instructed to put a suitable board on high pressure DLTs to avoid zeroing these wrongly at zero vessel pressures.

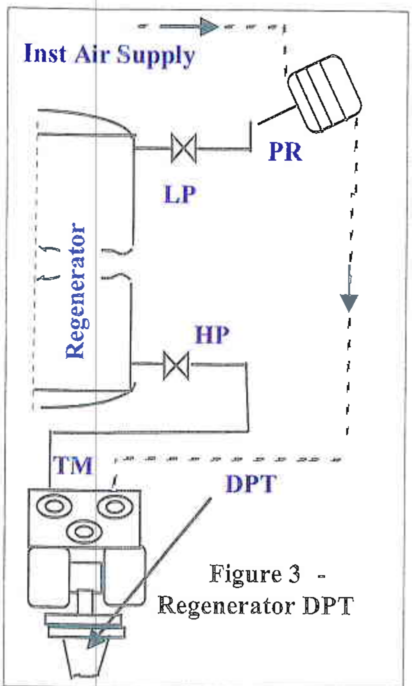

Figure 3 - Regenerator DPT

A tough DP problem solved: The DPT across the top and first bed of a 20-m tall CO_2 regenerator never read correctly. The problem was traced to the water form water saturated CO_2 collecting in the LP leg of the DPT (**Figure 3**). A large capacity cylinder connected LP leg bottom did not solve the problem as this and LP process lead filled within an hour. Since the zero elevation required for LP leg full of water is beyond the capabilities of any DPT, the plant had to run blind, and faced the associated risks.

Installation of 1:1 pneumatic relay PR at LP tap (**Figure 3**) solved the problems elegantly and economically: air pressure output equal to LP tap pressure fills the LP leg and not carry over water. So no zero elevation is necessary. Shop made SS-316 process wetted parts of PR in place of the original brass parts and a 0.8-mm thick PTFE disk to avoid process wetting the PR diaphragm assures trouble free service forever. Reliable DPT readings enabled operating and process engineers to monitor regenerator performance and make necessary adjustments to maximise CO_2 stripping from the absorbing solution to save costs from minimized make ups.

Tough Seal Type Pressure Instrument Problems Solved

A urea plant came with several seal type instruments: 60 pressure gauges, 12 Pressure Transmitters, 12 pressure switches and 12 Differential Pressure Transmitters for level, besides numerous seal type pressure switches for alarm and safety shutdowns. The 15-20 micron thick diaphragms of the seals wetted by the process fluid developed pinholes within a week; even a drop seal fill oil leak renders the instrument useless. Since due to their construction block valves are not possible, no online replacement of failed instruments is possible forcing the plant to run blind till a suitable opportunity facing serious risk to personnel and plant.

Sustained efforts of the crew led to successfully welding the thin replacement diaphragm to the seal, oil vacuum filling and restoration of failed instruments, a feat thought off as impossible field tasks by vendors and other instrument engineers.

However, since the purchased or local repaired seal instruments lasted for a week or even less only posing risks as above, the group developed No Seal instruments which last forever, saving crores of rupees annually and above all rendering plant operation reliable and safe with all readings, alarms, safety shutdowns, and controls working reliably.

Tough Flow Meter Problems Solved

Problem – 1; Erratic Liquid NH_3 Flow Meter: Erratic readings of 6 liquid ammonia flow meters – orifice + Pneumatic DPT, line pressure 3-bars – led to problems of poor product quality, and questionable specific ammonia consumption figures, which delayed the guarantee tests of three complex fertiliser streams and withheld contractor final payments.

Contractor's many correction attempts of shortening process leads as short as possible and repeated calibration checks failed; he finally admitted grudgingly that evaporation of liquid ammonia in the process leads is the cause of erratic readings and the quickest and least expensive solution would be installing Target Flow Transmitters in place of the existing orifice and DPT.

Figure 4 shows a wafer body style TM meter bolted between a pair of line flanges. The force beam F carries the target T forming an annular orifice. Flow caused differential pressure acting on the target produces force F which is proportional to flow square. The force beam passes through seal in the meter body not shown to the transmitting head H bolted on to on the meter body. The 3-15 psi output, in case of pneumatic or 4-20 mA current output in case of electronic head balances the force on the target through appropriate systems. Thus TFT produces output proportional DP i.e. flow square in case of pneumatic transmitters and 4-20 mA current output proportional to DP or proportional to square root of DP in case of electronic heads. TFT's main feature is it is an online meter requiring no external process leads. Hence, it is best suited for measuring flow of liquids congealing at ambient temp e.g. furnace fuel oil tar etc. and liquids that evaporate at ambient temp e.g. liquid NH_3 at pressures < 5 bars. In fact it is best for even steam flow metering in subzero ambient as the failed flow reading due to condensate freezing etc. are absent. Meter readings are as accurate as or even better than orifice and DP combination. TFTs

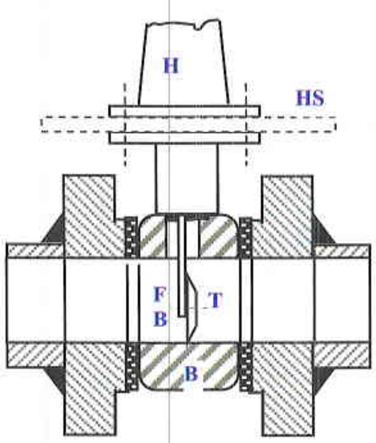

Figure 4 - Target Flow Transmitter

for pipe sizes ½" to 100" pressures 250 bars and temp 300° C are available.

TM body subzero temperature from expansion of liquid ammonia across the annular orifice froze the atmospheric moisture on the pneumatic head H and readings failed.

The problem was solved by using an innovative approach: a heat sink HS sandwiched between the head and meter body prevented ice formation and hence instrument failures vanished. HS is an aluminium sheet 300x300x6 mm thick with a hole cut to pass the parts of the head assembly.

Accurate and **reliable** readings from the TFT installed on each of the liquid ammonia lines eliminated all the problems listed in first paragraph, enabled conducting the guarantee test, and identified high specific NH_3 consumption. This prompted an investigation, and elimination of the root causes, which profited the contractor by way of guarantee test runs and final payment after rectification of the causes of high specific consumption. Reducing NH_3 specific consumption to better than industry standards, benefitted the plant also by way savings of over a crore of rupees annually besides reducing atmospheric pollution as the excess ammonia used eventually found its way into the atmosphere.

Problem 2; Camouflaged High Naphtha Specific Consumption: An ammonia plant did not come with a flow meter for measuring the daily total ammonia production. They calculated daily ammonia production from the formula $T_A = (A+B)$; T_A is daily ammonia production, 'A' is the turbine flow meter (TM) reading of urea plant, the major consumer and 'B' that of the complex fertiliser unit. TMs are custody transfer meters of accuracy 0.5% or even 0.25% on special order. Hence, urea plant ammonia consumption figures are accurate. They calculated B from the formula $B=C*D$; 'C' is daily complex fertiliser production and D specific NH_3 consumption per tonne of complex fertilisers. As the plant has no bulk silo, they bag all products immediately as 50 kg bags; hence daily complex fertiliser production data is acceptable. It was felt that assuming arbitrary specific ammonia consumption per tonne of complex fertilisers led to wrong value of B and hence the total daily NH_3 production, and in turn wrong specific naphtha consumption per tonne of NH_3. Hence, he proposed a TM to measure the daily ammonia production. The management rejected as import was necessary.

A 3" Turbine Meter (TM) declared unnecessary in a certain location was located. Fortunately a cooperative process engineer showed a 3" pipe through which estimated 99% of ammonia flowed as liquid and a 1½" vapour line handling the balance. The pipeline rating requires 300 # rated flanged meter, but the available meter body was 3"150# flanged. Meter body thickness measurements assured its rating as 600#.

An innovative idea flashed and the following modifications was effected to use the 150 # flanged

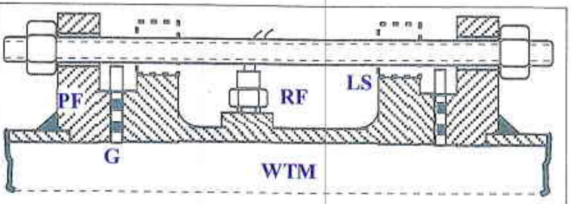

Figure 5 - Wafer Body Turbine Flow Meter between Pipeline Flanges (WTM internals removed)

meter fitted between 300 # rated line flanges:

1.Instrument Technicians removed the TM internals and the radio frequency pick up coil RF and saved them carefully
2. The machine shop reduced the flange OD till the bottom of the bolt holes. - the dashed lines rectangle in **Figure 5** show final flange dia.
3. Instrument technicians assembled back the internals and RF pick up coil into the meter body. Presto, wafer body style Turbine Meter (WTM) boltable between 300 # line flanges is ready! WTM too has raised face as in the pipeline flange (PF).
4. Pipefitter crew installed the meter between a pair of pipeline flanges using long studs – SCL in fig represents stud centreline.

Manufacturers test TM and assure accuracy within ±0.5 or ±0.25% as specified. As long as visible injuries or wear and tear are absent – as in this instance - TM maintain their specified accuracy.

Still production and process engineers insisted on demonstrating the meter accuracy though it is never done in the field and not necessary. The plant personnel demonstrated the accuracy using the procedure given below:

1. Install the meter in a temporary 3" pipeline ensuring min 30" (10D) upstream and downstream straight pipe runs. Weld a downward facing bend at inlet to connect fire hose kink free and at outlet to let water discharge into a tanker placed beneath it without loss.
2. Connect the inlet to a fire hydrant – with proper permission of course – using a fire hose
3. Connect the outlet to a truck mounted tank; we used our phosphoric acid tanker of about 15 m^3 capacity after thoroughly cleaning it
4. Calibrate the plant's 100 T weigh bridge
5. Weigh the empty tanker in the weigh bridge
6. Open the fire hydrant valve and let water flow.
7. Set TM least count as low as practical; it was set at 20 kg
8. Note TM initial reading
9. Start water flow and collect in the tanker
10. After about 15 T flow, stop water collection and note down TM final reading
11. The difference between the two is water collected; in this case it was 14.660 T
12. Weigh the tanker again; make sure of the same truck driver and no added or removed weights!
13. The difference between tare and net weight was 14.650 T. It was found weighbridge error in this reading zone was +10 kg. Hence, actual weight of water collected is 14.640 T.
14. TM error is therefore (14660-14640) =20 kg i.e. 0.07% much better than the TM vendor guaranteed accuracy of ±0.5%.

It was realised through TM that NH_3 production was far lower than the figure calculated from the formula T_A= (A+B); hence calculated Naphtha specific consumption is also too low i.e. wrong.

This led to a serious study and identification of the reasons for the low production and too high specific consumption and their rectification. The debottlenecked plant produced 5 to 10% more than the rated capacity and specific naphtha consumption also dropped 5% below vendor guaranteed figures saving several crores of rupees annually.

Problem 3: Wasteful Capital Expenditure of nearly Rs 2 crores for a New Pump Avoided

Flow meter readings of cooling water circulation rate were unreliable due to the very long pitot tubes bending and plugged pressure sensing holes from water borne algae and debris.

Based on the unreliable flow readings and much lower than design flow rates estimated from the poor performance of most heat exchangers despite their water inlet valves fully open. The process engineers were about to order a new 2500 HP 10,000 m^3/H cooling water circulation pump at an estimated installation cost of Rs two crores. On receiving the proposal it was reviewed to make sure the pump is OK. The header pressure gauge showed 3.5 bars the design pressure. To be sure; the block valve was closed and the gauge was drained to get zero reading. Still the gauge read 3.5 bars. That means that was a stuck gauge! A new gauge showed the header pressure was 4.5 bars. The estimated flow rate roughly matched with that of the pump characteristic curve. Hence, the too low flow is due to excess head and not due to the pump. He told them that the excess head could be due to fouled heat exchangers. They were advised to drop the new pump proposal.

However, the process and

production engineers requested for reliable water flow meter to assess pump and heat exchanger performance accurately in future.

A segment orifice plate was selected due to the following given advantages:

a. Failed and unreliable readings of pitot tube would be absent
b. Just a 16-mm thick plate P_1 of size 1730x1020-mm inserted in a 17-mm wide x 990 – mm deep slot cut in the pipe and welded to it (fig-4) serves as segment orifice – a very low cost device indeed!
c. Absence of 2 Nos. of 66 x 150 # raised face flanges, much less circumferential welding W of P_1 to P and much less digging below P than needed for flanges installed orifice saves still more.
d. Weld heat damage to the inner rubber lining is the least and so are the restoration costs.
e. Total installation time and costs is just 15% of flange installed orifice assembly.
f. Selected D and $^D/_2$ taps of very liberal tolerances makes field tasks easy and tap hole dia of 25-mm never chokes offering never failing reliable readings.
g. Permits using the existing DPT recalibrated to suit differential pressure produced by the segment orifice.

As surmised on opening during the next TA, the crew found all the heat exchangers badly fouled. Hydrojet cleaning metal cleaned them. On plant restart, the pump discharge pressure was 2.9 bars only and the flow reading roughly matched with pump characteristic curve. Operators had to throttle CW flow of all exchangers to get required performance. Header pressure settled at 3.35 bars.

These case studies clearly show that instrument engineers can contribute immensely by having thorough instrumentation knowledge and working knowledge of process and equipments the instruments serve.■