Low Cost High Efficiency Design for Emptying the Cold Box

Authors:

Mr. Shahram Hashemi
E: shahramhashemi@yahoo.com

Mr. Mark Brouwer
E: mark.brouwer@ureaknowhow.com

Shiraz Petrochemical Complex (S.P.C) is first petrochemical plant and fertilizer industry of I.R. Iran over than 60 years' experience. Today its production are Ammonia, Urea (both prills and granules grade), Ammonium Nitrate, Nitric Acid, Methanol, UAN, Argon/Nitrogen. Last decade the company also produced STPP, NPK, Soda Ash, Baking soda, HCl, Cl_2, Bleach, Calcium hypochlorite, but today these production units stopped because of environmental considerations.

After 27 years continuous operation of Ar/N_2 plant with capacity of 5500tpy, process condition shown small internal leakage in Cold Box. It started some 18 months ago, but operation was continued until 15/4/2020 and the unit stopped for overhaul.

The first decision after reporting of the small leakage was unloading the Perlite insulation. Perlite insulation is a kind of very low density material that is used for very low temperature service (less than -200°C). For the protection of equipment's in the Cold Box of Ar/N_2 plant, the space around equipment and wall of the Cold Box is filled by perlite material. Composition and mechanical property of perlite is provided in Table 1.

Table 1: Composition and mechanical property of perlite

Component	Mass fraction %	Mechanical properties
SiO_2	74	Density=48Kg/m^3
Al_2O_3	15.4	Moisture content=0.5% max.
K_2O	4.2	Softening point=870~1100°C
Na_2O	3.5	Fusion point=1280~1350°C
CaO	1.5	Thermal conductivity
Fe_2O_3	1	@-126°C = 0.025~0.029w/m.k
MgO	0.3	
TiO_2	0.1	

Table 1.Perlite insulation composition and property.

The low density and small particle diameter of the perlite insulation make it very difficult in unloading from Cold Box because particles fly and float in air by very slow air movement or air streamline around devices. The particle size distribution is shown in Table 2.

Table 2: Particle Size Distribution of perlite

Particle size diameter , x	Distribution percentage
800μm	10%
125μm < x <800μm	80%
x≤100μm	20%

Table 2 Particle size distribution,PSD

Typically vacuum cleaners are using for unloading perlite. The vacuum cleaner is equipped with bag filters and constraint volume. When the bag filter is filled by perlite, the user needs to open the bag house and clean the filters. This procedure takes time and the device also needs electrical motor and fans.

These problems forced me to design and construct the following device for unloading perlite without any electric motor and fans against a lower cost. The system consists of small Ejector, Main cyclone filter, a secondary cyclone filter and pipes and fittings.

Figure 1 shown the details of equipment and Figure 2 shown details as 3D model.

Figure 1. Main and secondary cyclone filters. Ejector not shown. for ejector see figure 2.

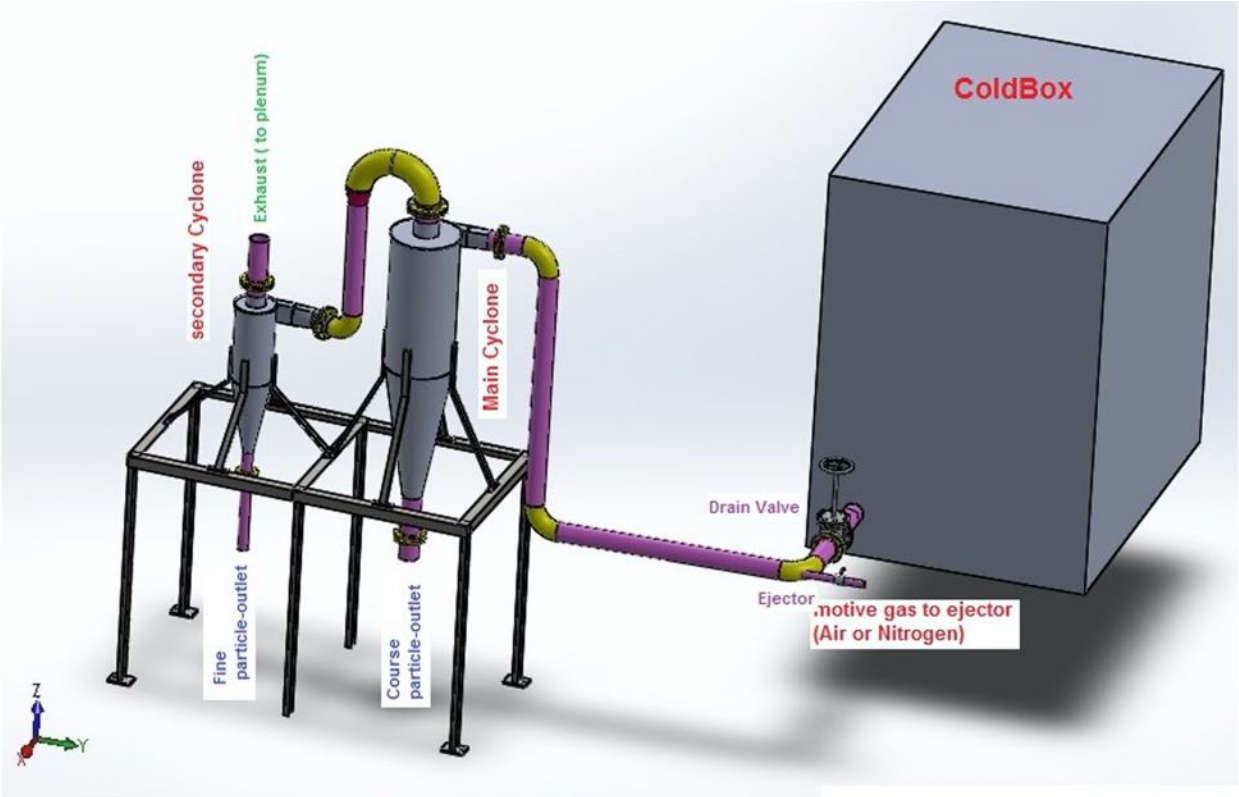

Figure 2. Shematic 3D of system.

The Ejector provides vacuum to pull out the perlite from drain nozzle of Cold Box and the main cyclone separates 86% of particle size between 100µm to 800µm.The secondary cyclone, separates 80% of less than 100µm particle size. The efficiency of system depends on relative humidity and temperature of plenum and pressure of motive gas of ejector (motive streams are Air or N_2).

Figure 3 shows the efficiency versus motive pressure. The positive pressure of Cold Box is affected but it effects is less than 5%. For more consideration refer to Ejectors and Cyclone design handbooks.

In the bottom of the Cold Box a 6 inch drain nozzle and valve is present. After installing small Ejector on first 90 degree long radius

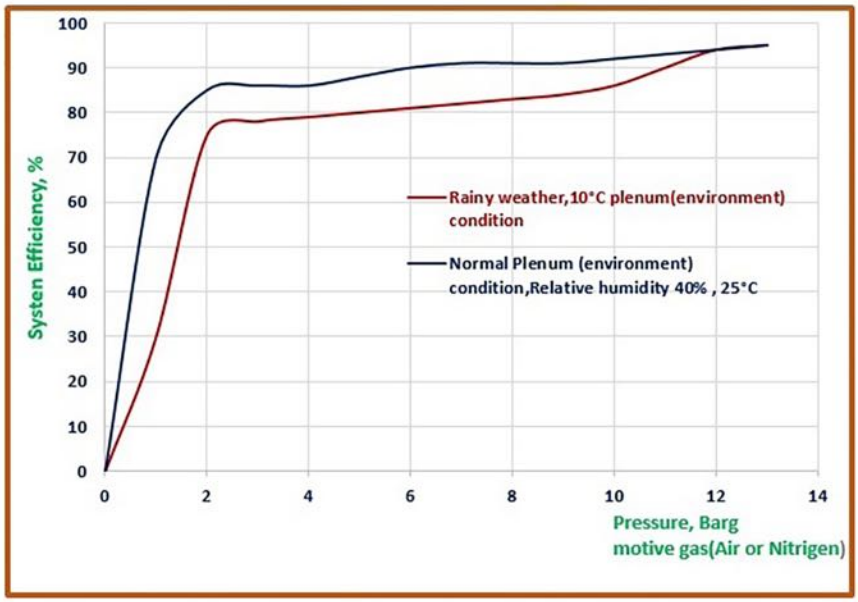

Figure 3. System Efficiency and Environment effect

elbow, it produced -14mmH_2O to -40mmH_2O vacuum pressure in the Cold Box by 1/2" motive Air/N_2 pipeline with a back pressure of 2 barg to 13 barg.
The calculated back pressure was 1 barg and 2 barg but it become 4.5 barg during the test and it reached to 13 barg during operation. The conditions during real operation were partially different from test and design condition because of raining weather (humidity and low plenum temperature). Total efficiency of system was 86% to 95% in dry air and relative humidity less than 40%.

The 320m^3 Cold Box was emptied in 8 hours and approximately 208m^3 wet perlite (about 10t) was drained. As leakage occurred at the Cold Box, the perlite was humid and it was ruined and these effected the gas residence time and particle drift velocity. Efficiency of cyclones depends on back pressure, environmental relative humidity and temperature. Also the main cyclone has 95% efficiency for particle size diameter between 125µm to 800µm and the secondary cyclone is efficient for particles less than 100µm.

This experimental and analytical investigation help us in industry and modeled by Aspen/Hysys program. The calculations and operating results, endorsed the program.