1. INTRODUCTION

The basic task in the branch of pneumatic conveying of dry powder and finely granular materials is to supply the conveyed material continuously and in a sufficient amount into the conveying pipeline. Different kinds of feeders serve for the continuous and cyclic working cycle of conveying. Each type of feeders has its own advantages and disadvantages for the specific conveying material and conveying route.

This paper is intended to inform the professional public about a newly developed and in the long term operation proven system of pneumatic conveying of dry powder and finely granular material fed into the conveying pipeline through the continuous Flow-Feeder from silos, hoppers and from discharging hoppers and electrical precipitators. The possibility of its application is presented on specific cases of industrial and power plants.

2. PNEUMATIC CONVEYING BY FLOW FEEDER

2.1 Recent Methods of Material Feeding

There are several methods used at present for feeding materials into the conveying pipeline. For discontinuous way of pneumatic conveying they are pressure vessels (chamber feeders), for continuous way they are screw feeders, mixing rotary valve feeders or venturi feeders.

2.2 Principle of Pneumatic Conveying by Flow Feeder
The pneumatic conveying equipment has been developed in the effort to eliminate the negative features of the currently used conveying systems, for conveying powder material from silos, hoppers and from the discharging hoppers and electrical precipitators by system of Flow-Feeders. This equipment has been developed based on the Czech patent and original technical solution by RAYMAN Ltd. company Kladno.

The duty of each pneumatic conveying feeder is to feed conveyed material in required amount into the conveying pipeline at which beginning is the pressure given by resistance of conveying pipeline at conveying $p_{DP}$. To afford opportunity for conveying is necessary this pressure outwork by “pressure closure” which is in the case of using the chamber feeder its pressure vessel (resp. inlet closure part) - fig 1a, in case of screw feeder the resistance of material closure created by a screw - fig. 1b, in case of rotary valve feeder resistance of rotary valve - fig. 1c and in case of venturi feeder ejecting current intensity of conveying air - fig. 1d.

Flow-Feeder (fig. 2) is made up by high gravity chamber (often widened), pressure chamber with aerated bottom and mixer equipped by material orifice gauge.

The principle of conveying by Flow-Feeder is illustrated in scheme on fig. 3. “Pressure closure” in Flow-Feeder is made by hydrostatic pressure $p_{H}$ column of aerated material amassed in gravity chamber of feeder. Hydrostatic pressure $p_{H}$ is proportional roughly to highness $H_g$ column of aerated material.
Highness $H_g$ has to be so high so that generated hydrostatic pressure $p_f$ was in balance with pressure drop of conveying pipeline $p_{DP}$ given bore at conveying assigned capacity due to the conveying route.

As it is evident from given above, the necessary highness of high fluid bed of fluidized material and so the highness of gravity chamber is dependent on conveying capacity, process layout of conveying route, bulk weight of aerated material and on diameter of conveying pipeline. Conveying material qualities, conveying capacity and conveying route are mostly given in advance by technological and local conditions of operation and specification. According to highness of silo, hopper, precipitator or technological equipment outlet flange above the ground level or floor and it is necessary to determinate the optimal bore of conveying pipeline then.

### 2.3 Sources of Conveying Air

The building conditions at the most part of conveying material from silos, hoppers, filters and precipitators are of the kind that it is possible to draw pressure of high fluid lay in the range of $10^1$ kPa. It enable to use Roots blowers with a great advantage as a source of conveying air. Their discharge pressure can be up to 100 kPa. Neither Flow-Feeders nor conveying pipeline are restricted pressure equipment then and at equipment design with operating pressure up to 50 kPa are not pressure equipments in the sense of governing law at all. The next advantage of blowers as a sources of conveying air is their low investment exigency. That means not only the price of the only machines but even the costs for compressor plant purchase and equipment. The conveying air is not necessary to cool, dewatering and dry. Damping of conveying material by air dampness from conveying air can range $10^{-2}$ of per cent maximum.

If the substantial building highness is to disposal for making big hydrostatic pressure of aerating material over 0.1 MPa, the compressors with discharge pressures from 0.2 to 0.6 MPa can be used like the source of conveying air of course. Conveying air is necessary to cool to the environmental temperature and dewater well or eventually dry in this cases.

### 2.4 Energy Demand Factor of Pneumatic Conveying by Flow Feeder

Each type of the currently used feeders show a certain loss of energy which is necessary for making pressure closure which is necessary for exceeding of conveying pipeline resistance. In case of material feeding by pressure vessel is the part of energy loss at conveying process making by feeder vessel deaerating from full operating pressure at its discharging phase to atmospheric pressure at feeding phase. At screw feeder using the part of energy loss is making by energy necessary for screw drive. In case of rotary feeder using is this energy loss ensued both by energy necessary for rotor drive of feeder and by pressure air loss penetrating through leakage of feeder and at rotor deaerating. At venturi feeder using is energy loss ensued by low amount of usage of conveying air pressure potential to reach its ejecting effect.

The conveying by Flow-Feeder, against it, uses potential energy of material amassed in primary silo or hopper or also in filter or precipitator hopper for making pressure closure. The energy losses given above are omitted. That is why this kind of conveying is energetically more preferable in comparison with other pneumatic conveying systems.

To be able to reach given conveying capacity at lower operation air pressure it is necessary to choose larger bore of conveying pipeline than it used to be at design of high-pressure pneumatic conveying by chamber feeders.
There is a request for the higher flow rate of conveying air. But it is fully balanced with one rank lower necessary pressure otherwise high-pressure conveying need usually sources with discharging overpressure from 400 to 800 kPa thus clutch input of blower is lower than clutch input of compressor used for similar high-pressure pneumatic conveying.

Specific consumption of energy at Flow-Feeder conveying flows about from 0.9 kWh•t\(^{-1}\) (for conveying from silos, great conveying capacity and short and direct conveying route) till to 3.5 – 4.0 kWh•t\(^{-1}\) (for conveying from filters discharge hoppers with using of low building highness, less conveying capacity and long and rugged conveying route) of conveying material.

2.5 Operation of Pneumatic Conveying Equipment by Flow Feeder

Conveying by Flow-Feeder is continuous. In comparison with other conveying systems it comes here to less abrasion of conveying pipeline. Compared with conveying by pressure vessel expansion of dilute material phase into conveying pipeline at the end of conveying cycle is omitted. Because of conveying air expansion here comes to mass of air flowing through conveying pipeline in high velocity and to maximum pipeline abrasion because of it.

The next advantage of conveying by Flow-Feeders is their long service life and low maintenance costs. How you can see from scheme picture of Flow-Feeder on fig. 3 feeder does not bear any moveable parts coming into contact with conveying material. Their abrasion and maintenance are omitted then as it is at using of screw or rotary feeders. Above it moveable velocity of material in gravity chamber and in feeder body are very small. Mixer is the only part where comes to material flowing at higher velocity and the following tendency of abrasion. It is constructed in fortified anti-abrasive construction for conveying of abrasive material, like power plant flying ashes. The only moveable parts in pneumatic conveying system by Flow-Feeder are functional elements of closures in air distribution but they only move in clean air flow and do not suffer by abrasion.

As it is about continuous conveying the operation of equipment is fluent and stable. It enable select comparatively low conveying velocity of air (18 – 20 m/s at air state at the end of conveying pipeline) and mixing ratio approximately 15 - 25 kg/kg. Equipment has not tendency to plugging up on one side and to abrasion of conveying pipeline on the other side.

As it is about very simple equipment the process of putting into operation is also very simple. The precise design preparation has to overtake. Putting into operation represents only checking of function and right connection closure elements in aerated distributions and the right sitting of throttling nozzles. Adjusting of sole flow feeder means perhaps changing of material orifice gauge in mixer. The whole process of equipment starting takes usually only 1 day.

![Fig. 4: Scheme of conveying from silo by a Flow-Feeder](image-url)
2.6 Usage of Flow Feeder in Conveying from Silos and Hoppers

System of conveying of bulk material by Flow-Feeder is very convenient for conveying from silos and hoppers (fig. 4). By the principle of stocking the sufficient highness \( H_g \) is built up for generating of “hydrostatic pressure” which is necessary for conveying. What is more at sufficient aerating of material in silo the “hydrostatic” pressure \( p_s \) is built up and is transferred into gravity chamber of flow feeder. Proportional great material pressure is generated then in mixer given by total \( p_s + p_f \) and conveying is carried on economically in particular. Equipments have been realized for bulk material conveying for the distance over 200 m, with superelevation over 30 m at conveying capacities up to 100 t/hour.

2.7 Usage of Flow Feeder at Conveying of Dust from Filter Hoppers and Precipitators

Flow-Feeder is also used for economic removal of dusts from filter hoppers and precipitators (fig. 5). It is about combination of fluid conveying by fluid conveyors and conveying in air stream by Flow-Feeder. System is available to use where there is high highness of outgoing flanges of precipitator above floor. If there is not the sufficient highness under hoppers disposable, it is possible to use terrene irregularities or make a cofferdam under the level of floor or to suggest cascade conveying. Fly ash from hoppers is conveyed then through one Flow-Feeder on short distance into interstice bin of required highness and then by the next Flow-Feeder to requested distant place.

3. APPLICATION OF EQUIPMENT IN OPERATION

3.1 Limestone Pneumatic Transport from Silo

As an example of usage of Flow-Feeder for loose material conveying from silo is the equipment of pneumatic conveying of lime dusts from spare silo into expedition hopper in Lafarge cement works Cizkovice (CZ). Flow-Feeder with high gravity chamber is shown on fig. 6. Equipment has capacity 27 t.h\(^{-1}\) at conveying distance 238 m and superelevation 34 m. Specific energy consumption is 3,5 kWh.t\(^{-1}\) of conveyed material.

3.2 Fly-ash Pneumatic Transport from ESP Hoppers

As an example of equipment for pneumatic conveying of fly ash from electrical precipitator hoppers is the equipment mounted on four boilers in heating plant of Chemopetrol a.s. Litvinov since 2000. It serves for flow ash removal from electrical precipitators. Conveying is proportionate...
on min. 15 t.h\(^{-1}\) of capacity and conveying route is according to individual boilers distance about 100 m to 150 m with superelevation 35 m. Specific consumption of energy is 2.0 kWh.t\(^{-1}\) of conveyed material at maximal reached conveying capacity.

Equipment consists of the set of collecting fluid conveyors which transport fly ash from all filter hoppers into gravity chamber of common Flow-Feeder. The original system of fly ash wet shift-away was held by installation of diverters under the rotary feeders (fig 7). On this picture you can also see part of fluid conveyors system and on fig. 8 Flow-Feeder with a bottom part of spread gravity chamber and a former fly ash wet shift-away system on the left side. Its spreading is necessary because of the space creation for compensation of uneven material transport from electrical precipitator after electrodes cleaning.

4. CONCLUSION

Operating experience with operation of all hitherto realized equipments fulfilled expectation. It took an effect by high operational reliability and by very low maintenance demands of equipment. It in fact depends on care for blower – oil filler replacement, suction filters cleaning, and drive belts changing. The Flow-Feeders themselves are without any maintenance. Very simple and not liable to defects is also the control system of whole conveying system.

The next very pleasant character of this equipment is its very long lifetime. Also the spare parts, if you need any, are very inexpensive easy available and changeable easily.

Very favorable is the economy of investment and operation. Equipment as a whole including the conveying air source and dedusting equipment of conveying air needs noticeable less investment against pneumatic conveying system by pressure vessel and is suitable for installation both at new plants building and reconstruction of stable. Energetic exigency is also very kindly.

Described system of pneumatic conveying has already been realized in ca 25 applications for conveying of different powder material like cement, milled limestone, milled lime, plaster, foundry sand, clinker dusts, power plant fly ash and others. At development and bringing up to date of described pneumatic conveying system it was came up not only from experience at tests in test-room but from the knowledge gained by measuring carried out at realized plants in industrial operations which were adjusted above all.