UNITED
CONVEYOR
CORPORATION

PNEUMATIC CONVEYING SYSTEMS for COAL FLY ASH –

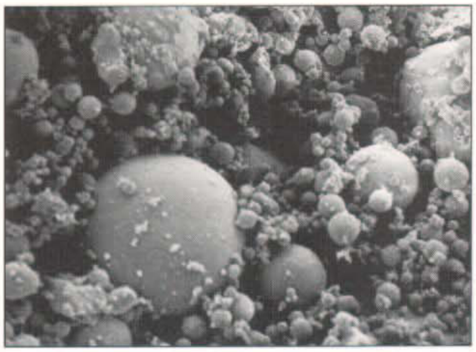
A DISCUSSION OF FLOW REGIMES

Which System Type Meets Your Specific Needs?

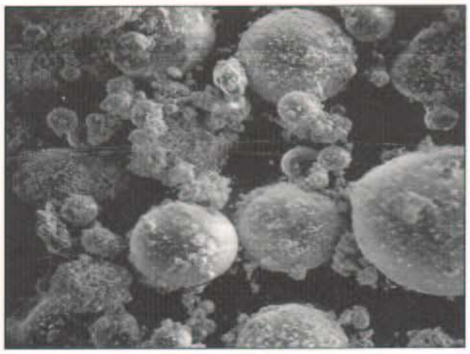
- Defining needs and understanding an application
- Types of pneumatic systems
- Progression of solids flow in a pneumatic horizontal conveying line
- System choices
- Selecting the right system for the application
- Range and performance specifications of UCC pneumatic systems
- How UCC can assist you

SELECTING AN ASH HANDLING SYSTEM

When selecting an ash handling system, it is important to consider the type of ash to be conveyed. Ash types vary as a result of different fuels, different combustion methods, different flue gas treatments, and various boiler designs. The chemical composition of ash varies – aluminum oxide, silica oxide, iron oxide, calcium oxide and other compounds are found in varying proportions. Particle size, particle density, particle shape and size distribution can also be very different.



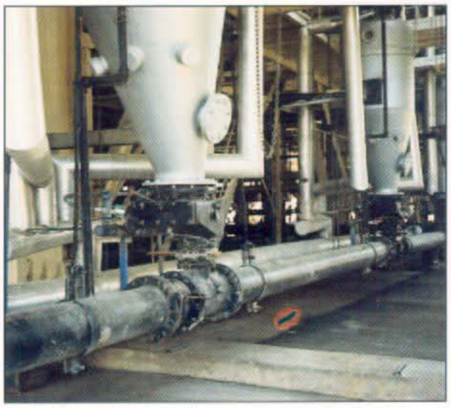
Fly ash (540x magnification) from a pulverized coal fired boiler; fuel–bituminous coal



Dry scrubber ash by-product (540x magnification); fuel–western USA bituminous coal

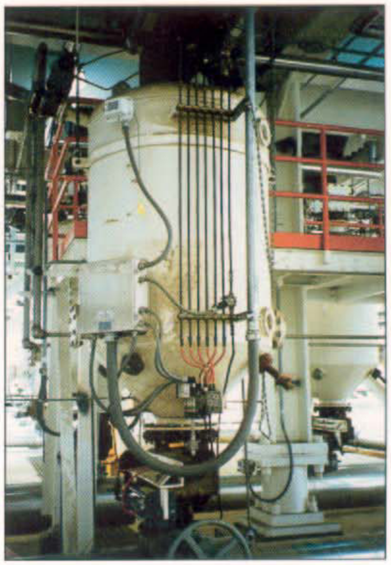
EACH POWER PLANT HAS UNIQUE NEEDS

Elevation and ambient conditions of power plants vary; therefore, each plant requires special considerations. Ash systems will vary from plant to plant to suit each set of capacity and conveying distance requirements.



Pressure fly ash system, installed in Japan

Long distance conveyor line, installed in China



High capacity pressure system, installed in the USA

UNDERSTANDING AN APPLICATION

System requirements vary from plant to plant due to the many varieties of ash. Therefore, the ash handling system must be designed specifically for a given plant location. To determine which type of pneumatic system is appropriate for a given application, consideration must be given to the physical characteristics of the material, the conveying requirements and several economic factors. First, however, it is important to understand how material flows through a conveying line under different conditions of pressure and velocity. The following discussion and graphic illustrations will help to provide an understanding of UCC's pneumatic systems, the flow regimes in a conveying line, and the various factors that affect the selection of the right system.

TYPES OF PNEUMATIC SYSTEMS

Negative pressure systems operate below atmospheric pressure to move material through the conveying line. Positive pressure systems operate above atmospheric pressure, and are generally referred to as either "dilute phase" or "dense phase" systems. However, use of these terms without a complete understanding of what they mean has led to much misinformation within the industry. Three conveying regimes commonly occur in positive pressure systems: slug flow, dune flow and suspended flow. More than one regime normally occurs within the same system – therefore, it is inappropriate to apply a singular "phase" definition to a system.

Air velocity in the system is the chief determinant of the conveying regime, but velocity may also be misapplied as a definition. System air and ash velocities vary within any system due to expansion of the air as pressure decreases; air and ash velocities increase along the length of the system. The higher the operating pressure, the larger the increase in system velocity.

Rather than using the terms dilute phase or dense phase, United Conveyor Corporation (UCC) uses trade names to differentiate between various types of negative and positive pressure systems. These trade names are:

- NUVEYOR® System
- NUVA FEEDER® System
- DAC™ System
- MultiDAC™ System.

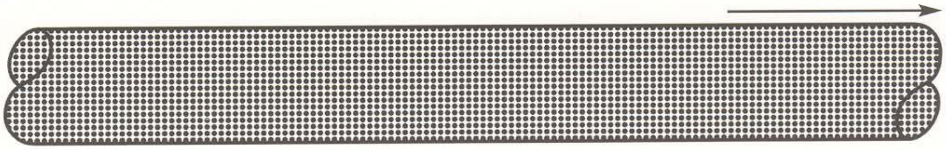
This approach – blending the most efficient flow regimes – offers advantages in reliability and reduced maintenance costs that can keep your system operating more efficiently and effectively.

PROGRESSION OF SOLIDS FLOW IN A PNEUMATIC HORIZONTAL CONVEYING LINE

Flow in a conveying line can vary on a continuum from full bore slug flow to full bore suspended flow of the material. Six typical flow regimes are illustrated within the continuum, and flow characteristics for each regime are listed below each illustration.

A Pneumatic Conveying State Diagram, as shown on the opposite page, is often used to illustrate the relationship between air velocity and pressure differential in a conveying line. The five flow curves (m1, m2, m3, m4, and m5) represent given capacities in the same size line; the mark at the lowest point on a curve is the minimum conveying pressure for that capacity.

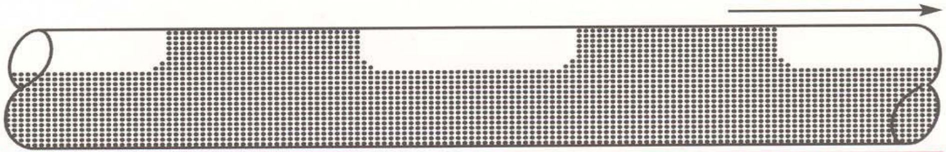
Note from the Pneumatic Conveying State Diagram that for a given capacity, as conveying air velocity increases, pressure differential decreases, reaching its lowest point at "full bore dune flow, suspended flow for fines" (IV). As the solids flow becomes more dilute, the pressure differential increases.



I

FULL BORE SLUG FLOW OR PIPE PLUGGED

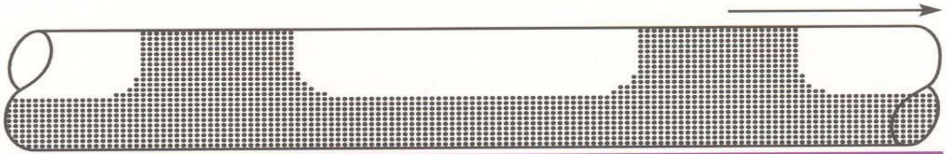
Characteristics:
- Unstable condition
- Very high pressure surges
- Particle to wall friction dominates
- Highest ΔP – very high material to air mass ratio



II

SHEARING SLUGS OVER STATIONARY BED OR DEGENERATE SLUG FLOW

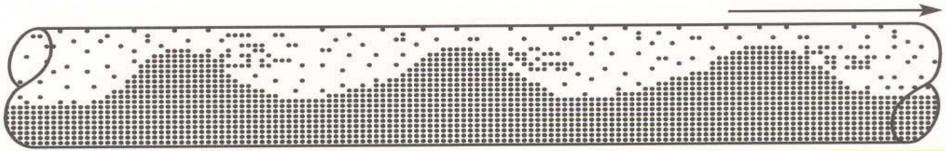
Characteristics:
- Transient condition
- High ΔP – high material to air mass ratio
- High pressure surges
- Particle to wall friction dominates with some particle to particle friction



III

DUNE FLOW OVER STATIONARY BED OR IMMATURE SLUG FLOW

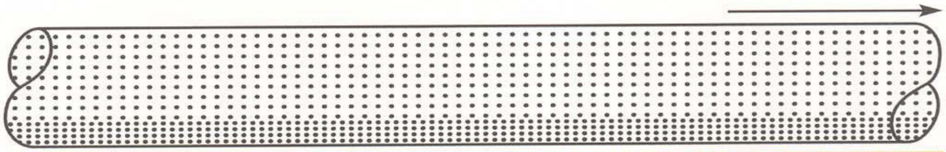
Characteristics:
- Stable system operation
- Moderate ΔP – moderate material to air mass ratio
- Moderate pressure surges
- Particle to particle friction dominates with some wall friction



IV

FULL BORE DUNE FLOW, SUSPENDED FLOW FOR FINES

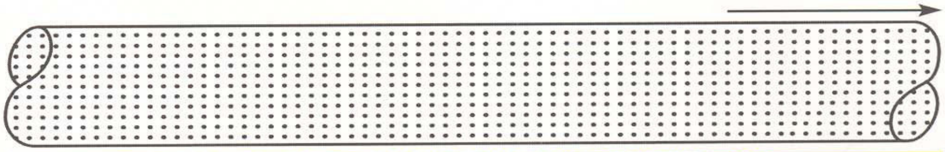
Characteristics:
- Stable condition
- Lowest ΔP – moderate material to air mass ratio
- Low pressure surges
- Particle to particle friction dominates with some particle to air friction



V

SUSPENDED FLOW OVER SLIDING BED OR DEGENERATE HOMOGENEOUS FLOW

Characteristics:
- Very stable condition
- Low ΔP – low material to air mass ratio
- Very low pressure surges
- Particle to air friction dominates with some particle to particle friction



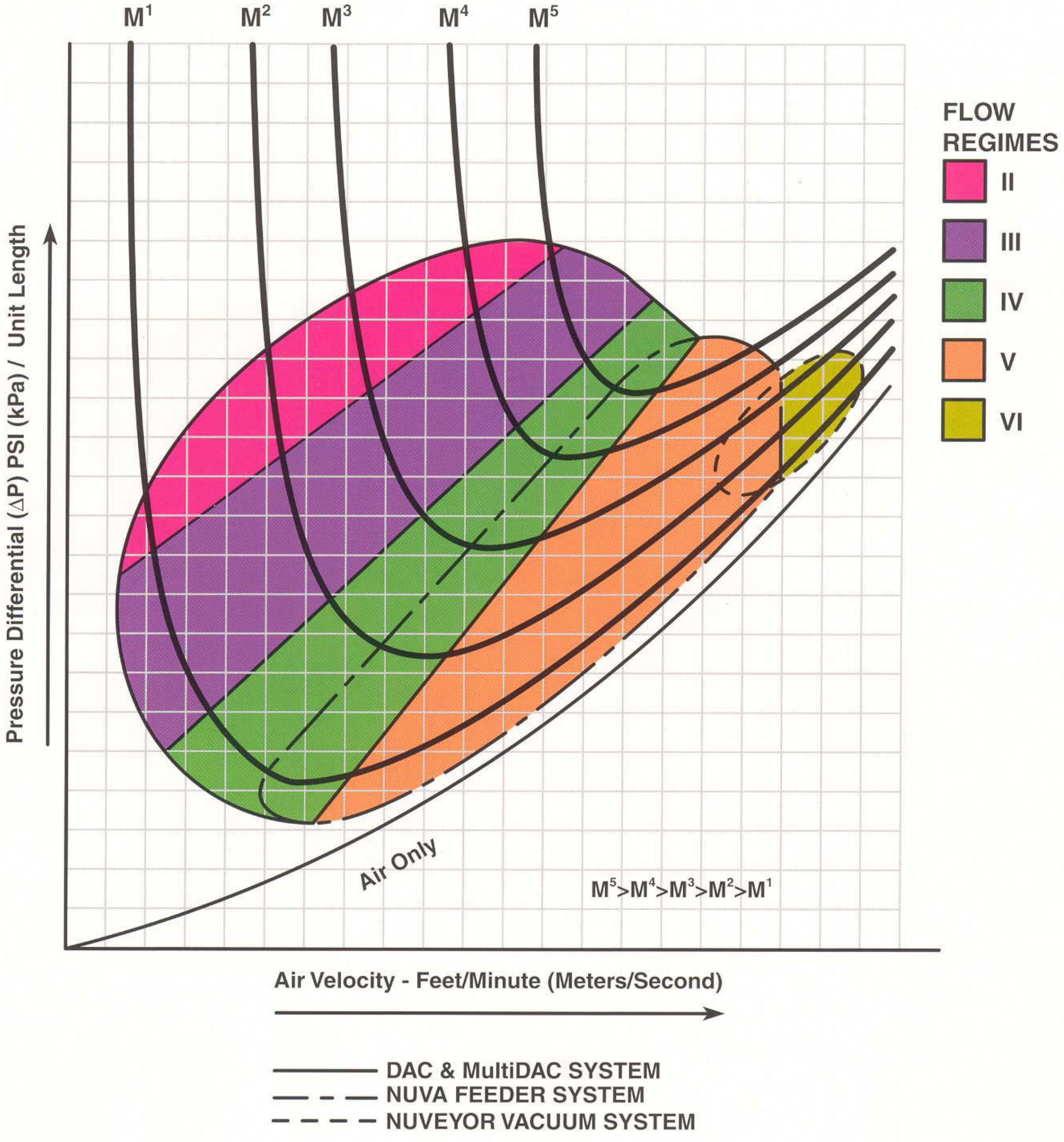
VI

FULL BORE SUSPENDED FLOW OR HOMOGENEOUS FLOW

Characteristics:
- Highly stable condition
- Moderate ΔP – very low material to air mass ratio
- No pressure surges
- Particle to air friction dominates

PNEUMATIC CONVEYING STATE DIAGRAM

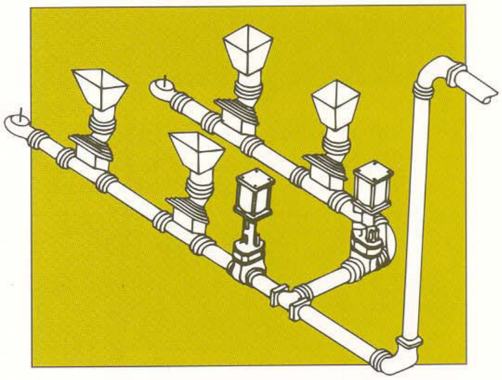
The diagram shown below has been simplified for purposes of illustration. Ranges indicated on the flow curves may vary; the ranges shown are typical for fly ash.



- **UCC DAC and MultiDAC systems generally operate in flow regimes II, III, and IV.**
- **UCC NUVA FEEDER systems generally operate in flow regimes IV and V.**
- **UCC NUVEYOR systems generally operate in flow regimes V and VI.**

SYSTEM CHOICES

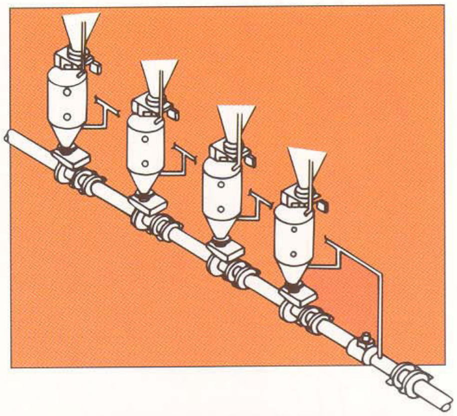
NUVEYOR Systems



- Operating vacuums (negative pressures) up to 20 inches (530mm) of mercury
- Ability to stop and restart due to low ash-to-air ratios
- Low headroom requirements below the fly ash collection hoppers
- Short conveying distances – up to 1500 feet (450 meters)
- Capable of handling a wide range of ash types

In a NUVEYOR system, ash intakes feed to the conveying line sequentially. Full load control maintains vacuum in the line until each row of hoppers is empty. When vacuum falls to the no load setting, the system moves to the next row.

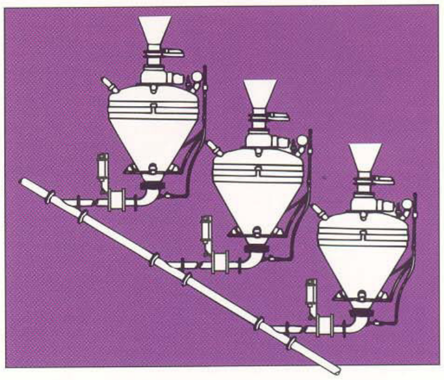
NUVA FEEDER Systems



- Operating pressures up to 40 psi (275 kPa); relatively low pressures allow for lower cost components
- Ability to stop and restart due to moderate ash-to-air ratios
- Low sensitivity to ash characteristics; capable of conveying larger and more dense particles
- Capable of conveying long distances; longest to date – 8000 feet (2400 meters)
- Relatively small vessels feeding to the line simultaneously

In a NUVA FEEDER system, multiple feeders allow the line to remain filled for long periods, resulting in high conveying efficiency. Full load control maintains pressure in the line until each row of hoppers is empty. When pressure drops to the no load setting, the system moves to the next row.

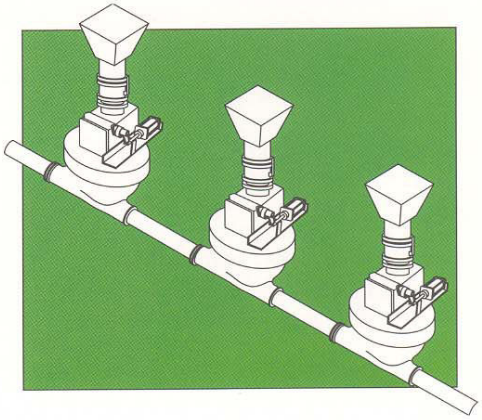
DAC Systems



- Operating pressures up to 60 psi (415 kPa); high capacity conveying line
- Ability to stop and restart due to injection of air at required points
- Smaller conveying lines; generally one or two pipe diameters smaller than a NUVA FEEDER system
- Conveying distances up to 5200 feet (1600 meters)
- Wide range of vessel sizes

In a DAC system, the pressurized vessels feed to the conveying line. The automated control system maintains a constant conveying air mass flow in the pipeline, which prevents plugging and optimizes compressor operating power.

MultiDAC Systems



- Operating pressures up to 60 psi (415 kPa)
- Smaller conveying lines
- No outlet gates required on the transfer vessel
- Short conveying distances – up to 1500 feet (450 meters)
- Vessel size matched to conveying line size

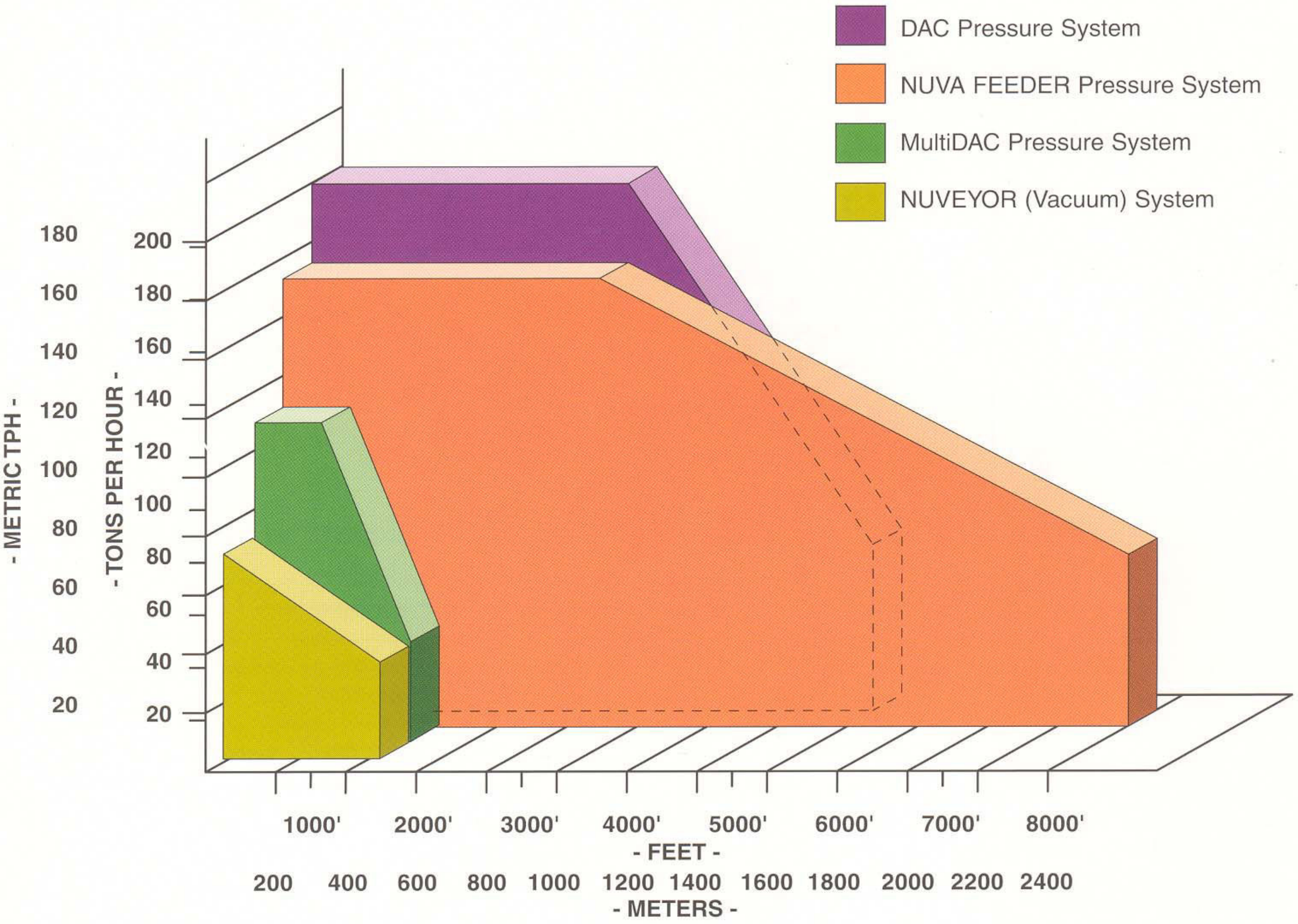
The MultiDAC system is similar to a NUVA FEEDER system in that multiple feeder units feed the line; however, in this system material flows into the conveying line before the line is pressurized. A MultiDAC system has a three-phase cycle: (1) material fills the line and the gate above the feeder closes; (2) the line is pressurized and the material is conveyed; (3) the line is purged and the cycle repeats. The MultiDAC system is a practical alternative for a vacuum system where head room is limited.

SELECTING THE RIGHT SYSTEM FOR THE APPLICATION

In selecting the optimum system for a given application, several factors should be considered.

1. Capacity vs. Distance

Various types of pneumatic systems have different capabilities for the combined requirements of conveying capacity and conveying distance. The graph below illustrates the general capabilities of pneumatic systems relative to capacity and distance requirements. These are **not absolute** limitations; they can be used as guidelines. UCC's engineers evaluate each system according to its unique requirements and recommend a design best suited to the application.



2. Material Characteristics

To differentiate between materials that can be conveyed effectively in a DAC system or a NUVA FEEDER system, two essential characteristics must be evaluated: Permeability and Deaeratability.

Permeability is a measure of how readily air will percolate through the material mass to assist its movement in the conveying line. If permeability is high, air will pass through the material without moving it. If permeability is low, air flow will tend to compact the material and plug the line.

Deaeratability is a measure of how rapidly air will escape from the material mass when air flow is stopped. Low deaeratability values are preferable for dune flow conveying. If deaeratability is too high, air will be lost readily and the material will tend to compact.

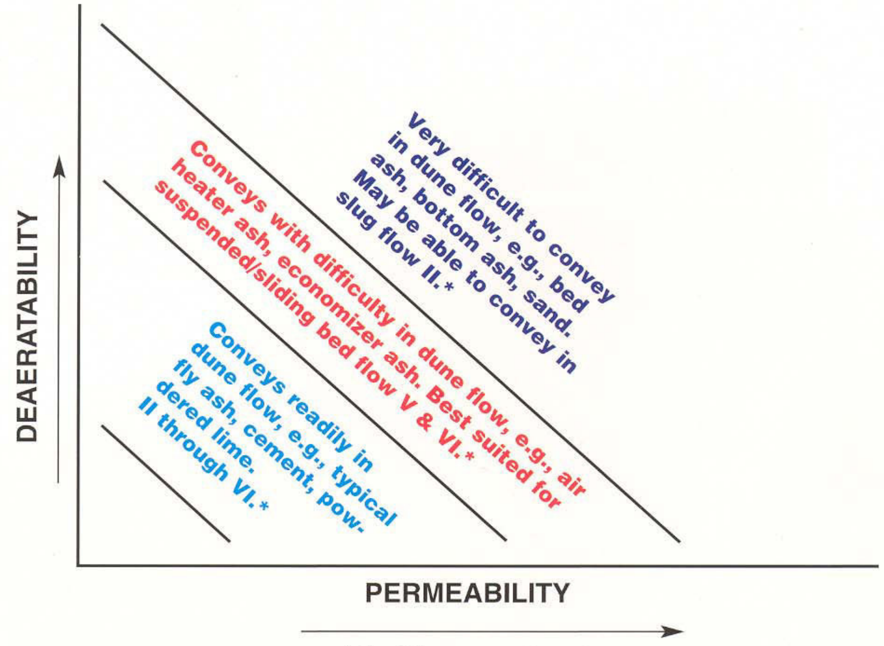
SELECTING THE RIGHT SYSTEM FOR THE APPLICATION

Permeability and deaeratability determine how readily material will fluidize, and remain fluidized when conveyed. These characteristics are influenced by the physical properties of the material, or "microproperties," including:

- Particle size
- Particle shape
- Particle size distribution
- Particle density or specific gravity

Permeability and deaeratability can be plotted as indicated in the graph, and ranges established within which a material will convey readily in a DAC system, convey with some difficulty, or will be better suited to a NUVA FEEDER system or a vacuum system. Various types of ash and other material are indicated in the ranges where they typically fall on the graph.

Permeability & Deaeratability of Conveyed Material



* See Diagram on Page 5

As indicated in the Conveying State Diagram (page 5), the vacuum system operates at relatively high velocities and, therefore is the most versatile – it will accommodate material that is highly permeable or has high deaeratability. Since most of the material is kept suspended, this type of system will carry particles that are difficult to convey in dune flow. For example, dry bottom ash received from a crusher is a mixture of large particles (1" to 2" diameter) and fines as small as fractions of a millimeter. In addition, the particles have rough, jagged shapes which promotes particle-to-particle interlocking. This type of material is conveyed most reliably in a vacuum system.

If the conveying distance or capacity requirements are greater than a vacuum system's capacity, then the choice is between a NUVA FEEDER system and a DAC or MultiDAC system. NUVA FEEDER systems are capable of handling material that will convey with some difficulty in dune flow; however, they are more sensitive to the microproperties of conveyed material than vacuum systems.

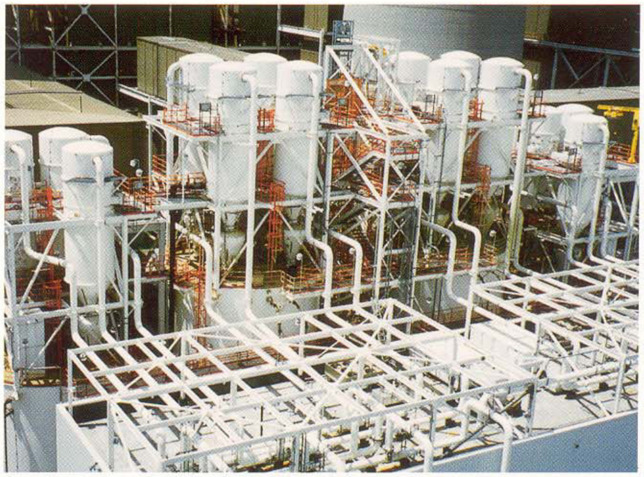
The DAC or MultiDAC system is the most sensitive to the microproperties of the material to be conveyed. These systems require material that has relatively low permeability and deaeratability. They are, for example, a good choice for handling fly ash or lime powder, both of which usually have the characteristics required for dune flow conveying.

3. Economics

If the requirements of the system permit a choice between several types of conveying equipment, then the decision may be primarily an economic one. For example, the simplest and least expensive system to install is usually a MultiDAC pressure system or a NUVEYOR vacuum system. These systems use fewer equipment components, reducing maintenance expense as well.

Power consumption is another major concern. DAC systems are practical for short to intermediate distances, because they minimize power consumption for conveying those distances. When conveying more than 3000 feet (900 meters), this may not be true. A NUVA FEEDER system will consume less power for the longer distances, and could be a better choice when operational costs are considered.

When there are a large number of ash hoppers, or space below the hoppers is limited, use of a pressure system alone may not be practical or economical. In this case, a combination vacuum/pressure system may be a better alternative. A short vacuum system can be used to minimize cost of the multiple pick-up points and bring the ash to an intermediate transfer point. From that point, a NUVA FEEDER or DAC system can be used to move the ash to storage facilities, depending on the conveying distance.



Vacuum to pressure transfer system at a new installation (1996) in the USA

Range and Performance Specifications of UCC Pneumatic Systems

	MultiDAC	NUVEYOR (vacuum)	DAC	NUVA FEEDER
Maximum Distance	1500 feet (450 meters)	1500 feet (450 meters)	5200 feet (1600 meters)	8000 feet (2400 meters)
Maximum Capacity	130 TPH (120 mTPH)	80 TPH (75 mTPH)	200 TPH (180 mTPH)	175 TPH (155 mTPH)
Mass Ratio ash : air	25–60	5–22	25–60	5–22
Air Velocity	900–2700 ft/min (5–15 m/sec)	3000–5200 ft/min (16–27 m/sec)	900–2700 ft/min (5–15 m/sec)	2400–4800 ft/min (12–25 m/sec)
Maximum Conveyor Line Pressure	60 psi (415 kPa)	20 inches Hg (530 mm Hg)	60 psi (415 kPa)	40 psi (275 kPa)
Maximum Prime Mover (blower or compressor) Pressure	100 psi (690 kPa)	22 inches Hg (560 mm Hg)	100 psi (690 kPa)	45 psi (300 kPa)

About UCC

Design and Development

United Conveyor Corporation's Waukegan, Illinois headquarters is both the management center of the company, and the center for design and development of every UCC ash handling system. This facility is the "one source" for all project phases . . . from initial pre-proposal planning through preliminary designs and contract completion.

The office building also includes a fully equipped laboratory where material samples can be tested for conveying characteristics and stored for future reference; products can be modified and new products can be developed.

Steel Fabrication

United Conveyor Supply Company, supplier of genuine UCC equipment and parts, owns and operates a steel fabricating plant in Melrose Park, Illinois, where many of UCC's specialized steel structures, including ash hoppers, crushers, separators, filters, ash storage bins, and unloaders are fabricated.

Warehousing and Assembly

United Conveyor Supply Company also maintains a 95,000 square foot warehouse and assembly plant in Mishawaka, Indiana. A complete inventory of more than 8,500 system component parts are kept in the automated warehouse for use in new systems and to serve replacement parts requirements. In emergency situations, parts can be shipped from available inventory the same day.

**UNITED
CONVEYOR
CORPORATION**

Printed in U.S.A.