National ENGINEERING Month

Engineering Idol

# UNVEIL PACKAGE

## ENGINEERING IDOL 2011

# FLUIDIZED BED

fluidize to energize

Presented By: Professional Engineers Ontario
Etobicoke Chapter

Sponsored by:

RYERSON UNIVERSITY

KINECTRICS

NORTHLAND POWER

Kingsway Chapter of PEO

OACETT

Professional Engineers Ontario

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## Introduction

The purpose of this document is to describe to you the elements of Engineering Idol. Do not be frustrated when you see a lack of specifics around how you should build your device or put your presentation together. If the answers were always known – there would not be a need for Engineers. Engineers tend to excel at projects when they get to define both what the solution will be and how it will be arrived at.

It is our hope that this exercise will give you an opportunity to experience the profession of Engineering.

## Your Role

Congratulations! You are a member of a talented, ambitious and innovative Engineering Team. You and the members of your team all work for an international Engineering Firm hoping to win the contract from a group of rich, but shrewd investors hoping to build a world class *Fluidized Bed* for use in specialty metals manufacturing.

The investors are holding a Trade Show at *York University* on Saturday, March 5$^{th}$, 2011 and have invited 8 Engineering Firms such as yours to present their proposals. It is at the Trade Show that they will pick their Engineering firm for this project and award $400 to the first place team, $300 for second place and $200 for third place.

Your team realizes that successful Engineers in this field are innovative, communicate well, remain professional, even when under pressure, are highly skilled and prioritize well. You have already figured out that you need to convince the investors that your team has what it takes to design and implement the best project. Although you will have the opportunity to present and test one of your prototypes at the competition day, it is the team that will win the competition, rather than the prototype itself.

## The Project

The project is designed to give you the opportunity to see how disciplines of Engineering often overlap. As you learn about “Fluidized Beds” you will learn that Chemical Engineering is more than just Chemistry and Mechanical Engineers often play an important role in developing process units for industry.

Your team needs to research and learn the technical aspects of Fluidized Beds – fluidization of solid particles in Gas. The investors need a bed that will operate fully fluidized. The ideal prototype would fully fluidize the solids within the supply limitations of the Testing Equipment specified in this document. You need to consider the trade-offs associated with the different variables and build a prototype representing your view of the best technology available.

You need to consider more than the Fluidized Bed itself. Consider who will be investing in your proposal and how you will make your design interesting to them. The investors will be spending a lot of money on this project and understandably they have many concerns about the project, the timeline and the budget. Consider how your presentation can be used to put their fears at ease.

## Fluidized Beds

You may not be familiar with Fluidized Beds – or perhaps even heard of them before. You are probably wondering why this was chosen as an Engineering Idol topic!

Fluidized Beds are well known in Industry. Billions and billions of dollars worth of annual Industrial products would not be possible without the use of Fluidized Beds in North American Industries. Those of you future Electrical, Mechanical, Chemical, Environmental, Nanotechnology Engineers choosing to work in Industry will likely become much more familiar with this technology in years to come.

In fact, all the gas used to run our cars and gas to heat our houses, at one time was processed through a circulating style fluidized bed called a Catalytic Cracker (Cat-Cracker for short). Many specialized metal components used in wiring, pipes and to build buses and trains were at one time treated in a stationary style fluidized bed like we are going to design in Engineering Idol. The commercialization of future Carbon tubes – the foundation of the new Nanotechnology – will include the use of fluidized beds. Those of you interested in the Environment and the conversion of waste into BioFuels will be interested in the fluidized beds designs to make this possible. Engineers working in the medical field and in particular with Pharmaceutical companies are familiar with the use of Fluidized beds in the manufacture of some medicines. The crystallization of chemicals used to whiten paper is done through fluidized bed technology.

There are many styles of Fluidized Beds including Circulating and Fixed style. Some Fluidized Beds are used for Chemical Reactions, others for heat transfer. The mechanisms for handling the material portion of Fluidized Beds differ depending on whether they are batch or continuous processes. When you are researching your project, make sure you are clear that the investors are looking for you to design a Fluidized Bed with the following characteristics and do not let the other styles of beds you will encounter confuse you:

- Solid/gas (rather than liquid/solid or even liquid/gas)
- Fixed ("Bubble") style Fluidized Bed – if it looks like a 'Popcorn Popper', you're on the wrong track
- Batch Process (the solid stays in the bed permanently until it is too old in which case it is replaced) – the solids don't leave the top of the vessel

Engineering is more than just math and science. In some instances, success requires intuition, design innovation and even trial and error. The Fluidized Bed exemplifies these aspects of Engineering and is one of the main reasons we chose it for an Engineering Idol project.

## Fluidized Beds for Metal Treating

In physics, you have learned equations that describe the transfer of heat between materials and how resulting temperatures can be calculated. In Industry, Engineers need to address HOW the heat actually gets transferred and design processes to do this efficiently. In physics class, the heat transfers 'perfectly', however, in real life, there is no such magic.

Engineers and Scientist have found that solids fluidized in hot gas provide thermal properties that improve the efficiency in which heat is transferred to metals requiring treatment. It is not your job to understand or consider this as part of your project. You need only understand that an evenly bubbling fluidized bed will meet the thermal requirements of the Investor's project. It also explains, why the quality of fluidization is one of the factors that will be judged on competition day.

After manufacturing, metals are often heat treated to enhance the final properties of the metal. Baths of liquid lead are excellent means to transfer heat to newly cast pipes, wires or small parts that are submerged below their surfaces. Lead, however, is an extremely toxic substance to both the environment and workers. Fluidized Beds offer an alternate way to transfer heat efficiently to newly cast metal objects and offer industry an opportunity to eliminate lead from their processes. In order for the Fluidized Beds to perform their function properly in this application, they need to be designed so the heat (in the incoming gas) is distributed evenly throughout the bed. A Fluidized Bed that bubbles on only one side or just up the middle, is not good enough. A Fluidized Bed that spews solid out the top like a Popcorn Popper is not acceptable for both technical and safety reasons.

The investors are hoping to supply to industry a Fluidized Bed with excellent heat distribution through the bed as well as one that requires minimum inlet pressures.

## Bare Bones Requirements

This quickly lists the "deliverables" required by your team just to make sure you do not forget anything!:

1. Wednesday, February 2, 2011, your *list of team members* submit their T-Shirt sizes and make sure they are ordered by sending the order form to Richard Weldon, P.Eng. at *Richard@CDWengineering.com*. Appendix 1 includes the order form for reference. Teams also receive the links for their packages which officially 'Unveils' the Engineering Idol project.

2. Wednesday, February 16, 2011, your team will submit a *Preliminary Report* to *Mrs. Linda Drisdelle P.Eng, 112 Princess Margaret Blvd., Etobicoke, ON M9B 2Z3* or *rotman789@yahoo.com*. Appendix 2 gives an outline of what this report should contain. The report includes a sketch of your proposed design that you will attempt to build on competition day. The Preliminary Report allows our Technical Expert to confirm that all the teams are on the right track ahead of the competition day. If problems are detected, it gives the teams time to work through the issue to ensure everyone has a successful day at the competition.

3. Monday, February 21, 2011, Teams receive final approval regarding their concept design package. This just means that the Engineering Idol team feels you have an excellent chance at being successful in building your prototype on Competition Day.

4. Arrive on time on Competition Day (Saturday, March 5, 2011) at York University with your notes, team, materials and Fluidized Bed design. Please see Appendix 4 to be sure you know how to get to the competition. Be prepared to talk to the judges about your project. There is no reason to get nervous about the Competition Day – it is our hope that everyone is looking forward to it! We are looking forward to meeting all of you and hearing about your projects. It is likely that each team will discover they approached the problem very differently from the other teams. This is the wonderful thing about Engineering – there are no wrong solutions – they are all innovations!

5. Each team is allowed to spend up to $100 on materials for their Prototype. Bring a complete list of materials, receipts along with the reimbursement form in Appendix 5 on competition day. You will be reimbursed during the day. One cheque will be issued; be sure you know to whom the cheque should be made out to. Your supervisor is required to sign off on the Materials and Cost Sheet to ensure it is accurate.

## The Investors

The investors, at first glance, appear to have more money than sense. Do not let this fool you. While the investors are not experts in Fluidized Beds, they are smart people and self-educate themselves ahead of investing large sums of money.

They have been successful in implementing other large-scale engineering projects around the world and are familiar with problems that can arise. For instance, they once picked the most impressive technical design for one of their projects that ended up costing too much. Another time, something went wrong and the project took twice as long to build as was expected! One of their projects was built on time and within budget, but the plant cost a ton of money every year in maintenance.

One thing they have learned well is that good engineering is more than the initial design. Constructability, maintenance – and other factors you may want to point out – are all important considerations when investing large sums of money in new and innovating Engineering projects.

As far as Fluidized Beds are concerned, they are becoming frustrated with how long it is taking to find Engineers who can effectively fluidize solid and gas. What's the big deal? Don't kindergarten kids fluidize sand all the time? Their previous attempts to pick an Engineering Team has taught them that scaling up small Fluidized Bed designs to larger units is difficult and in some cases does not work at all. They therefore understand that seeing a large surface area fully fluidized is more impressive than a fluidized smaller one. They are less clear why Engineers concern themselves about how the Fluidized Bed operates under 'upset conditions' and you will have to help them understand that. Why should they have to spend more money to make sure things operate under 'upset conditions'?

## The Judges

The investors have solicited the help of 3 technical experts with knowledge about Fluidized Beds to help evaluate the submissions of the teams. All three of these experts have built an impressive career in Industrial applications of various unit operations similar to Fluidized Beds. Being entrants into the field of Fluidized Bed technology, you and the members of your team are all very respectful of their accomplishments and realize the wealth of knowledge available through their acquaintance.

## The Judging Criteria

Each project will be evaluated by the panel of 3 judges according to the following criteria: scientific thought, originality, skill, team cohesiveness, written report and oral presentation. Greatest emphasis will be placed on scientific thought and an understanding rather than the attractiveness of the design itself. The judges will be assessing the planning and execution of the project as well as how well the student team worked together to achieve their goal. The testing of your Fluidized Bed prototype will form part of the evaluation under "skill".

We are allowing the judges the luxury of a jury-style deliberation. Their conversations and final deliberations will be left known only to themselves. Teams should not expect a detailed 'mark' for each element of the judging criteria.

We have asked the judges to appoint among themselves a commentator who will provide feedback for each team to be received at a later date. The feedback will be a summary of the judges' comments of the teams' strengths and weaknesses and will be forwarded to the schools after the event. It is our hope that each of the teams will find the feedback useful.

## Building Your Prototype Fluidized Bed

The building of your prototype gives you the opportunity to demonstrate what your team has learned about Fluidized Bed technology. On competition day, you will be required to assemble your Prototype at the Trade Fair. You are expected to bring your materials prepared for assembly along with your list of materials and receipts with the form in Appendix 5.

Basic hand tools and power tools will be available at the competition day. Please refer to Appendix 10 for details.

We will make test stations available on competition day for you to use ahead of the evaluation of your design.

### *Plant Specifications*

Your prototype should demonstrate the ability to fluidize solid with air as follows:

Solid – the solid to be fluidized for this project is Sifto Table Salt. Appendix 11 gives the particle size distribution of Sifto Table Salt that you can use for the calculations associated with your design. *We are currently evaluating an alternate solid in which case you will be notified and the updated specifications will be posted on our website. In any event, the alternate solid will be fairly close to Sifto Table Salt.*

Gas – the gas which will be used to fluidize the solid is just air. The air source is a 12 Gallon 4 (Peak) HP RIDGID Wet Dry Vac (Shop-Vac) run in reverse. The blower gives more flow when there is less back-pressure so make sure you design your vessel accordingly. For instance, if the design of your gas distributor causes a higher pressure drop, the blower will have less capacity available to fluidize. Therefore, you need to perhaps choose a vessel with less diameter. The flow characteristics of the gas source flow is given in Appendix 12 for your use and mimics a compressor curve common in industry.

Plant Requirements – The ideal Fluidized Bed would fully fluidize 6 inches of Solid evenly across the entire surface. Although 6” depth is the target, it is realized this may not be possible. See how close to 6” you can get your prototype to handle. Choose your vessel so that this is possible within the capabilities of the gas source detailed in Appendix 12. Teams capable of demonstrating full fluidization over a larger surface area will be favoured over those choosing to demonstrate fluidization over a smaller surface area.

Gas Dispersion – think about the way your gas is going to be dispersed through the solid and how are you going to pipe the inlet gas into your dispersion system. How are you going to prevent the solid from falling into the inlet gas pipe? What characteristics can you design into the Gas Dispersion to minimize the overall pressure drop? Knowing beds with bigger surface areas are favoured by the judges, what risks are you willing to take with your Gas Dispersion design to achieve this?

Inlet Gas Pipe Connection – you must design your inlet piping so that it connects to the discharge of the Testing Apparatus detailed in Appendix 9. Note that the air supply is low pressure and ‘duct taping’ is permitted in this portion of the design and others.

*Appendix 6 walks you through the Engineering Calculations associated with typical Fluidized Beds and are intended to help you determine whether the vessel size you choose is acceptable or not. For a given Solid and Gas combination, the Gas velocity required for fluidization can be calculated. Because the source of Gas is “FIXED” and defined in Appendix 12 teams need to be cognizant that the maximum Gas Flow supplied by the source cannot be exceeded. This mimics a typical Process Engineer designing a unit to “fit in” an existing plant with a defined capacity. With the Gas velocity calculated and the maximum available Gas Flow known, teams can then determine the maximum size their Fluidized Bed can be by considering various Areas – regardless of what shape that may be.*

*Appendix 6 includes the calculation required to determine the Gas Pressure required to fluidize the 6” bed of Solid. Again, Appendix 12 indicates the Gas Source has limitations to the amount of Pressure it can deliver. As with many pieces of equipment in industry, the discharge pressure from the Gas Source is related to the Gas Volume it is operating at. Think about this relationship to ensure your Gas Dispersion design does not impose so much ‘pressure loss’ in the system that the Gas Flow required for fluidization cannot pass through.*

## Physical Limitations

The plant can be any shape or size – as long as it meets the process requirements given above.

The prototype must be free standing (be able to stand on its own). We will have a testing table available at Competition Day and will facilitate prototypes having the inlet feed nozzle configured through the bottom of the vessel as well as the side.

The prototype must be fully open at the top so the surface of the bed can be video taped during testing.

There must be a way for the Solid to be loaded into the prototype. It is expected that most designs will be loadable from the fully open top of the vessel – but just in case.

## Testing Details of the Prototype

Teams are reminded that the testing of the Prototype is only one component of the overall Engineering Idol competition. The Prototype test is part of the 'skill' component of the overall judging criteria.

The performance of the Prototypes will be tested against the design parameters of the Fluidized Bed submitted in the interim report. Don't be alarmed if your Fluidized Beds deviate significantly from the design parameters. This is quite common for Fluidized Beds and is the reason why companies invest so much time and money into building prototypes ahead of bringing vessels into production. The fact that your bed deviates from design will be one of the big take-aways this competition will provide you.

*Testing Procedure: Minimum Fluidization Velocity*

With the use of the Rotameter in the testing apparatus, the air flowrate required to fully fluidize your Fluidized Bed will be compared against the design.

*Testing Procedure: Quality of Fluidization*

With the bed at the Minimum Fluidization Velocity, the quality of the Fluidization will be determined by visual means. The preferred Fluidized Bed will be fluidized evenly across the entire surface.

*Testing Procedure: Pressure Drop*

The backpressure on the testing apparatus will be measured at the Minimum Fluidization Velocity and compared with the design parameter

*Testing Procedure: Upset Condition*

With the use of the Rotameter in the testing apparatus, the air flowrate will be set at twice the Minimum Fluidization Velocity determined in the first part of the test. The Quality of the Fluidization will be measured under these conditions as well as whether the Solid remains within the upper limit of the vessel

## The Competition Day

The competition day will be from about 9:00 a.m. to 4:30 p.m. on Saturday, March 5, 2011 at York University (location given in Appendix 4). Members of PEO (Professional Engineers Ontario), many visitors to the University and local politicians will be in attendance. You are welcome to invite friends and family; however, they should realize you will be busy building your Prototype until about noon. You will be given a lunch voucher to buy your lunch at the University Cafeteria.

Parking and entrance to the University will be complimentary for participants, family and friends choosing to visit the competition

The judges will arrive after the competition day gets going. They will be interacting with the teams during the building of the prototype.

The details of the agenda may change between now and March 5th, however, the day will look similar to that listed in Appendix 8.

Schools are encouraged to create and bring a sign with them to identify the school they are from and/or the name of their engineering team.

## Presentations

There is only one rule with respect to the team presentations – all team members need to participate.

Please feel free to design your own 4 – 5 minute presentation in a form that best suits the personality of your team and demonstrates the robustness of its technical evaluation and prototype design. A laptop and data projector will be available at the competition day.

Be sure to bring a USB (memory stick) to transfer your final version of your presentation to the computer at the competition. Make sure there is only 1 file on the USB when it is given to us to ensure the correct version of your presentation is loaded.

## Safety

Your school's Supervising Teacher or Volunteer should be expected to help with keeping the building and testing of the Fluidized Beds safe during competition day.

Your adherence to all safety precautions implemented by the testing engineer is both appreciated and expected.

## Questions

We are extremely fortunate to have Dr. Jake Friedman from the Ryerson University as our Technical Expert. He specializes in Fluidized Bed research and is available to help with the Engineering Idol competition. **Please do not try contact Dr. Friedman for any reason during this competition**. It is important that questions be handled as follows:

Please forward questions to Linda Drisdelle, P.Eng. at rotman789@yahoo.com. If the Engineering Idol team cannot provide the answer, it will be forwarded to Dr. Friedman. All questions and answers will be summarized and posted on the www.engineeringidol.com website. If your question is specific to the design of your team, it will not be posted to ensure other teams do not learn about your design until competition day.

The header of your Email should start with **"EIdol – School Name –".**

Notice
PEO, its employees, contractors and volunteers shall not be responsible for, and all contestants hereby release and forever discharge PEO, its employees, contractors and volunteers from any and all claims, suits and demands for any loss, damages or injury howsoever arising except of caused by the gross negligence of PEO, its employees, contractors and volunteers.

# Appendix 1: Team T-Shirt Form
# Due February 2, 2011

School Name: ____________________________________

Supervising Teacher/Volunteer: ___________________________ Size ___________

Please indicate Size beside each name as S – M – L – XL – XXL

Names of Students (4 – 6 in total)

1. ____________________________________ Size ________
2. ____________________________________ Size ________
3. ____________________________________ Size ________
4. ____________________________________ Size ________
5. ____________________________________ Size ________
6. ____________________________________ Size ________

Please return (on or before the due date) to:

Richard Weldon, P.Eng.
4 Maydolph Road
Etobicoke, ON
M9B 1V8

OR

Richard@CDWEngineering.com

## Appendix 2: Preliminary Report Template

**Due Feb.16, 2011 (2 PAGES MAX plus sketch)**

SCHOOL: ______________________________________

PROJECT TITLE: _____________________________________________________

PROJECT TEAM MEMBERS: NAMES / GRADE LEVEL

SUPERVISING TEACHER OR VOLUNTEER: ____________________________

METHOD OF APPROACH: How team members were selected, how subject was researched, how responsibility was assigned, etc.

DESIGN MINIMUM FLUIDIZATION VELOCITY AND CALCULATION:

DESIGN PRESSURE DROP:

VESSEL VOLUME AND DIAMETER:

DO YOU THINK YOUR PROTOTYPE WILL FLUIDIZE THE FULL 6" BED OF SOLID? IF NOW HOW MUCH DO YOU THINK IT WILL HANDLE?:

SKETCH OF GAS DISTRIBUTOR SYSTEM:

COMMENTS / SUGGESTIONS:

** Attach a sketch showing your proposed Fluidized Bed along with a preliminary list of materials and their costs (Appendix 5 form) for the Prototype you plan to build on Competition Day.

SIGNATURE: ______________________________________
SUPERVISING TEACHER OR VOLUNTEER

DATE SUBMITTED: ________________________________

## Appendix 3: Presentation Format

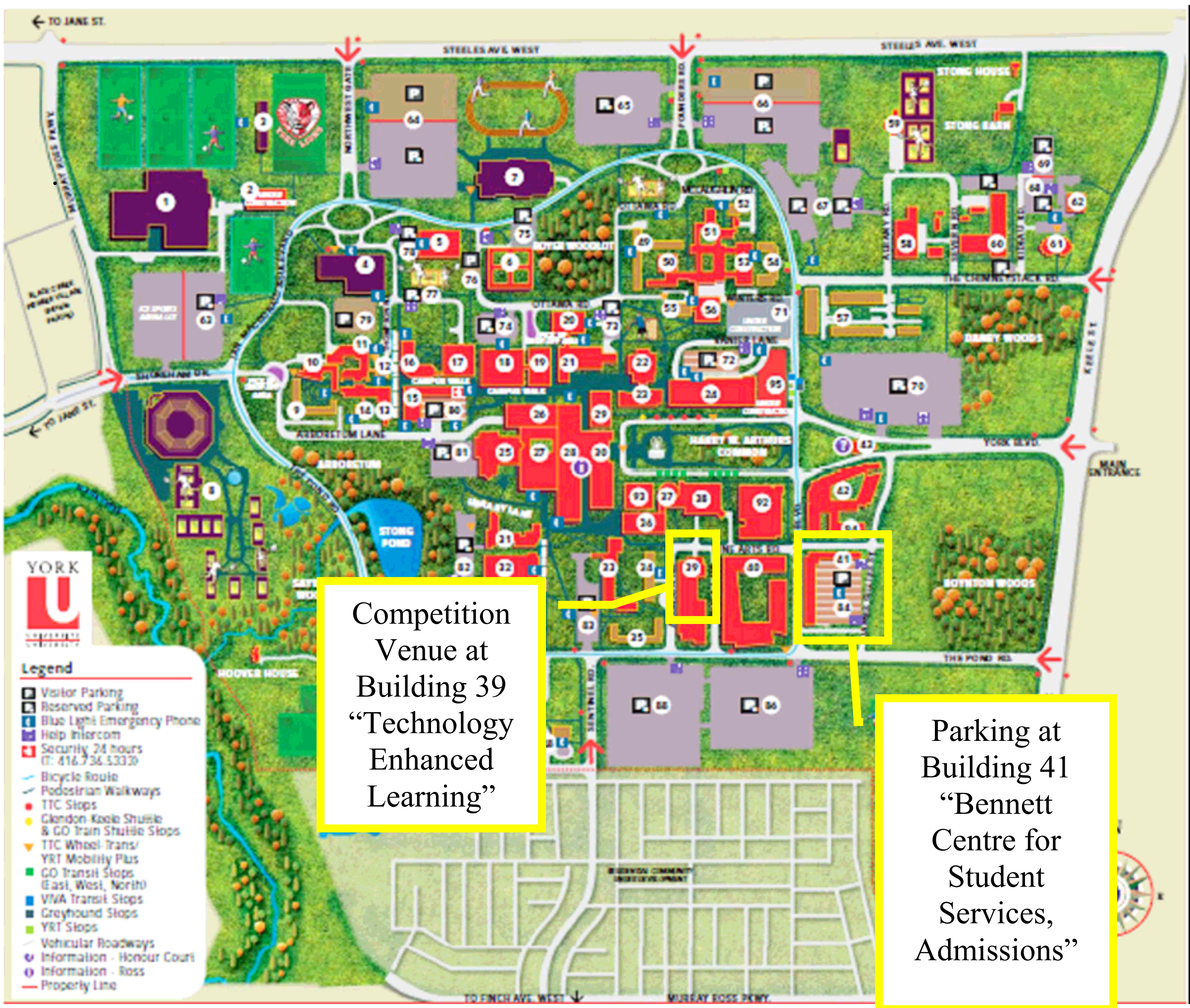
If making a Power Point presentation, presentations are to be submitted on USB Memory Sticks using MS PowerPoint 97 - 03.

You are also required to bring a backed up copy of the presentation on a Compact Disk.

Any inserted photographs in the presentation should be a minimum of 1.2 Megapixels, as the display screen is quite large.

Submit only one final version file on the USB to avoid the possibility of the incorrect version being used for the presentation.

# Appendix 4: The Location for Competition Day
## York University – Keele Campus




The Technology Enhanced Learning Centre, Building #39 at the corner of Fine Arts Rd and Atkinson Rd within the University has convenient access to drop off equipment, students prior to parking at the “Bennett Centre for Student Services, Admissions #41.

Level #2 is the ideal parking level at the Bennett Centre, however, there is an elevator which makes higher levels convenient as well.

You will need to take a parking ticket when you park at the Centre. At the competition, you will be given a special ticket so you will not have to pay parking when you leave.

## Appendix 5: List of Materials and Associated Costs (for reimbursement)

| Team Name: | |
|---|---|
| Component | Cost |
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| Total Cost: | |
| Teacher Verification/Signature: | |

# Appendix 6: Fluid Mechanics Calculations Associated with Fluidized Beds

In math and Physics class, we learn about forces and energy typically in frictionless environments and other perfect conditions. The Engineer needs to consider friction and other real-life conditions when they design their processes. Useful relationships have been developed by Engineers who study processes and these will be used in a simplified form as part of this project. Engineers using these relationships are highly trained and understand under what conditions the relationships hold.

To give you some experience in these calculations we are making the assumption that they all apply perfectly to all the prototypes and include them here:

Definition of Terms

$\rho g$ = fluidizing gas density (kg/m$^3$)

$\rho p$ = fluidizing particle density (kg/m$^3$) ie the density of one crystal of particle

$\rho_B$ = bulk density (kg/m$^3$) of solid ie the density of the solid and its air spaces

g = acceleration due to gravity (9.81 m/s$^2$)

$\mu$ = fluidizing gas viscosity (kg/m-s) ie 1.8 x 10$^{-5}$ kg/m-s for air

dp = mean particle size (m)

umf = miminum fluidization velocity of particles (m/s)

V = volume of the solid fluidized bed at rest (m$^3$)

A = area of the fluidized bed surface (m$^2$)

Archimedes Number

As a first step, the Archimedes Number describes a relationship that holds true for a range of Fluidized Solid Gas systems. The number itself is not that useful, however, it begins to describe the relationship between the relative densities between the gas and solid as well as the diameter of the particles.

$$A_r = \frac{\rho_g \, g \, (\rho_p - \rho_g) \, d^3}{\mu^2}$$

Reynolds Number

The Reynolds Number is widely used among engineers in their calculations related to fluid mechanics. It can firstly be determined from its relationship with the Archimedes Number.

$$R_e = \frac{A_r}{1400 + 5.22 \sqrt{A_r}}$$

The minimum fluidization velocity can now be calculated from the Reynolds number:

$$R_e = \frac{\rho_g \, u_{mf} \, d_p}{\mu}$$

Pressure Drop

The Pressure required by the bed to fluidize its mass is determined as follows:

$$\Delta P = \frac{\rho_B \, g \, V}{A}$$

## Appendix 7: Test Sheet – Preliminary

| Team | Minimum Fluidization Velocity (m/s) | Minimum Fluidization Volume (m3/h) | Minimum Fluidization Volume (scfh) Calculated | Minimum Fluidization Volume (scfh) Observed | Even Flow Distribution (yes/no) | Design Pressure Drop (psi) | Actual Pressure Drop at Design Conditions (psi) | Upset Condition Observations | Diameter (cm) |
|---|---|---|---|---|---|---|---|---|---|
| RCI | 0.3 | 87 | 3,131 | 3,000 | yes | 1 | 2 | controlled | 32 |
| XCI | 0.15 | 38 | 1,376 | 1,000 | no | 2 | 1.5 | overflows | 30 |
| MCI | 0.2 | 35 | 1,274 | 2,000 | yes | 3 | 3.5 | controlled | 25 |

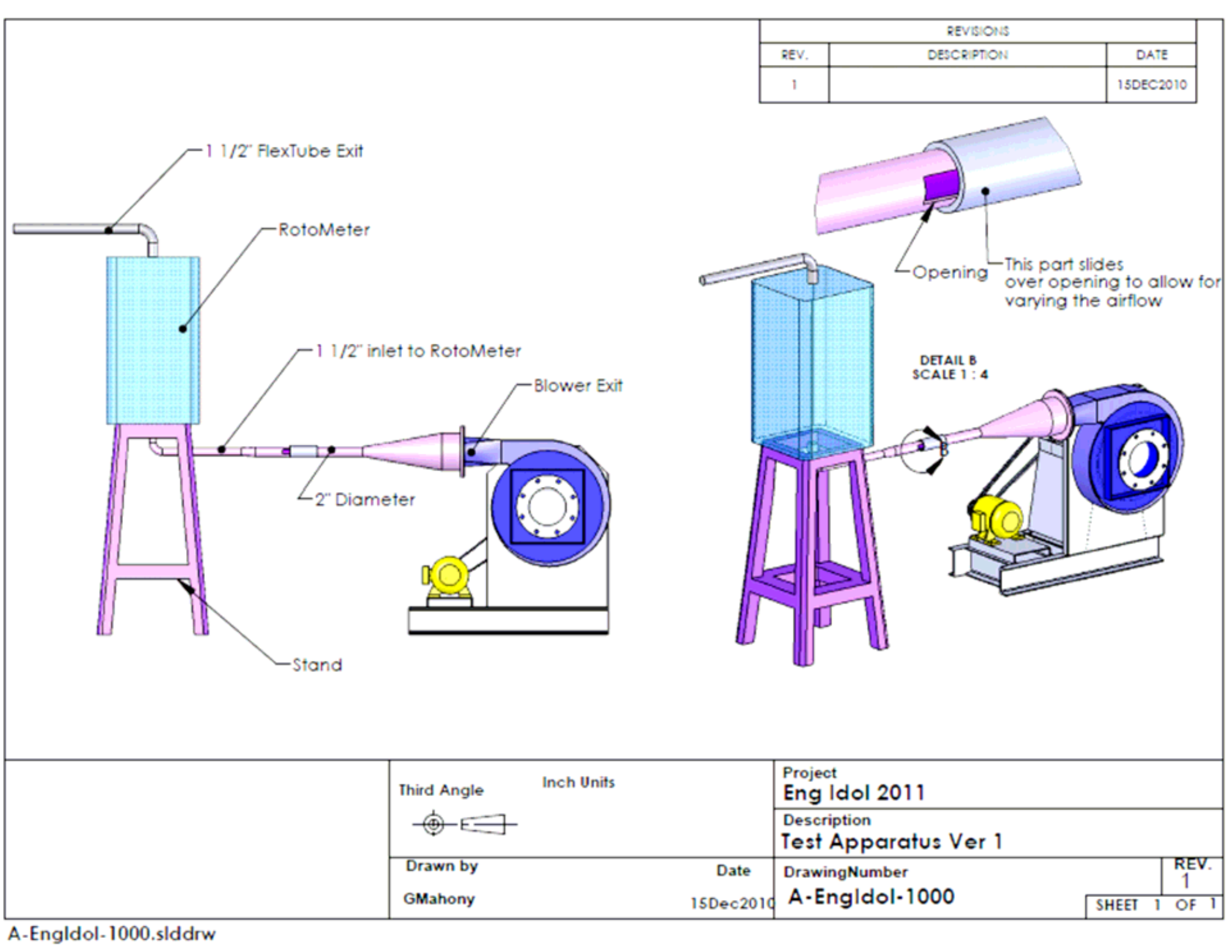
Above is an example of how the prototypes are evaluated against their design parameters.

All numbers and school names are fictitious and for illustration only.

## Appendix 8: Timetable for Competition Day - DRAFT

| | |
|---|---|
| 8:30 a.m. | Registration and T-Shirt Distribution |
| 9:00 a.m. | Opening Ceremonies in Great Hall. |
| 9:15 a.m. | Students begin building Fluidized Beds |
| 10:00 a.m. | Judges arrive and discuss projects with engineering teams |
| 12:00 a.m. | Lunch and Students prepare for their presentations |
| 1:00 p.m. | Testing and presentations start in Auditorium |
| 3:00 p.m. | Judges will begin deliberations |
| 3:05 p.m. | Guests and participants exit the auditorium while judges deliberate. Teams proceed to their workstations and discuss their design with the public. |
| 3:45 p.m. | PEO President addresses audience |
| 4:00 p.m. | Judges announce winners in the Great Hall |
| 4:10 p.m. | Closing Ceremonies by a special guest speaker |
| 4:20 p.m. | Final Photos |
| 4:30 p.m. | End of Event |

# Appendix 9: Testing Apparatus



## Appendix 10: List of Tools Available on Competition Day

There will be a central tool table for your use. Available tools will include:
- wood saws (also usable for plastics) and metal hacksaws
- knives
- screwdrivers
- adjustable wrench
- pliers
- metal hand shears
- tape measures and set squares
- an electric drill with bits (metallic, plastic and wood). A supervisor will oversee the usage of all power tools.
- duct tape

You may bring simple hand tools such as scissors, screwdrivers, etc. You may request that additional tools be provided, by contacting Richard Weldon (below) before February 25, 2011.

*Safety is paramount. Please do not bring any power tools without first receiving permission from Richard Weldon (below). Such tools must only be used at the Tool Table, under supervision and in compliance with the competition day safety rules.*

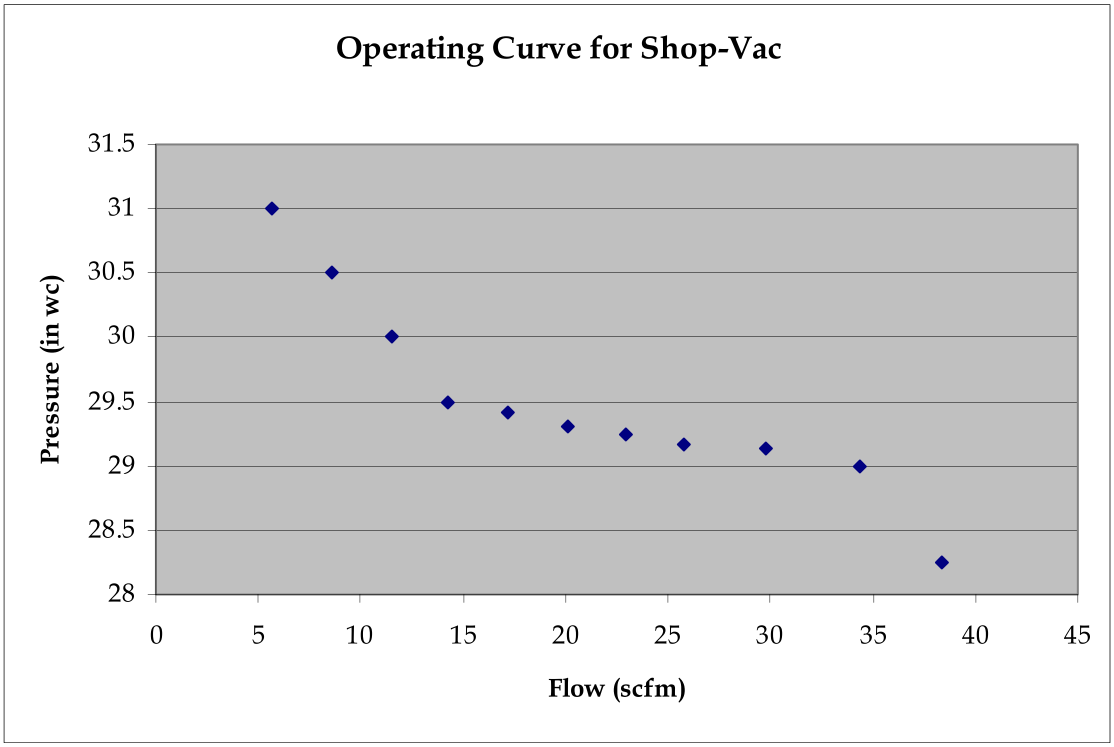
*Richard Weldon at Richard@CDWengineering.com*

# Appendix 11: Solids Characteristics of Table Salt*

The density of salt crystals is about 2.0 g/cm$^3$
The bulk density of salt is about 1,800 kg/m3
The density of gas expected at Test conditions is 1.2 kg/m3.
The diameter of a typical salt particle is 0.3 mm

* the Engineering Idol Executive reserves the right to substitute Table Salt with another solid if its characteristics are close enough. Teams have the option of choosing their own solid for fluidization by submitting a request by Email to the Engineering Idol Executive at rotman789@yahoo.com titled “EIdol – School Name – Solid Substitution”.

# Appendix 12: Gas Source Process Specifications




Note to teams: The shop vac was testing with a considerable leak at the exit flange. It is preferable to run the Gas Source without plugging the leak, however, if your design requires additional pressure, we will be prepared to 'plug the leak' for the duration of a short test. *Rest assured that we are prepared to help you in all ways possible to help fluidize your prototype*

UNITS: The pressure units on this graph (inches of water column) are different to those defined in the calculations. You will have to calculate the conversion. Similarly, the flow (standard cubic feet per minute) will also require converting. Apologies for this but Engineers are experts at manipulating different units and we would hate to rob you of this pleasure.