TEAMS

2006 PROBLEM STATEMENTS

These Problem Statements are the preliminary problem statements for the 2006 TEAM competition. Actual problems may be edited and expanded in the actual TEAMS exam; however the overall thrust of the problems will remain. The order of the problems may not remain the same in the actual exam. Students are encouraged to research the general problem topics and terms they are unfamiliar with in preparation for the competition.

Check the JETS website frequently for additional information about the problems that may become available.

TITLE: PUMP DESIGN

PROBLEM STATEMENT:

Your team has been given the task of selecting the proper pump for an application that involves the pumping of water over a long pipeline. In particular, you have to make sure that the selected pump is able to generate the required flow rate.

BACKGROUND:

Because of gravity, liquids will readily flow downhill. However, power input is required to transport liquids horizontally. Although there is no opposition from gravity to horizontal flow, resistance arises because of the effects of liquid viscosity, which can be thought of as an internal friction. The “layer” of fluid adjacent to the inner surface of the pipe is impeded by the wall thereby slowing it down and the next layer is slowed by this first layer, and so on. As a result of this flow resistance, the fluid must be pumped. Pumping is achieved by creating a higher pressure at the inlet to the pipe than at the exit to the pipe. Figure 1-1 depicts a case of horizontal flow through a pipe as driven by a pump, with the liquid starting at ambient (i.e., atmospheric) pressure being driven some distance away to be discharged at ambient pressure.

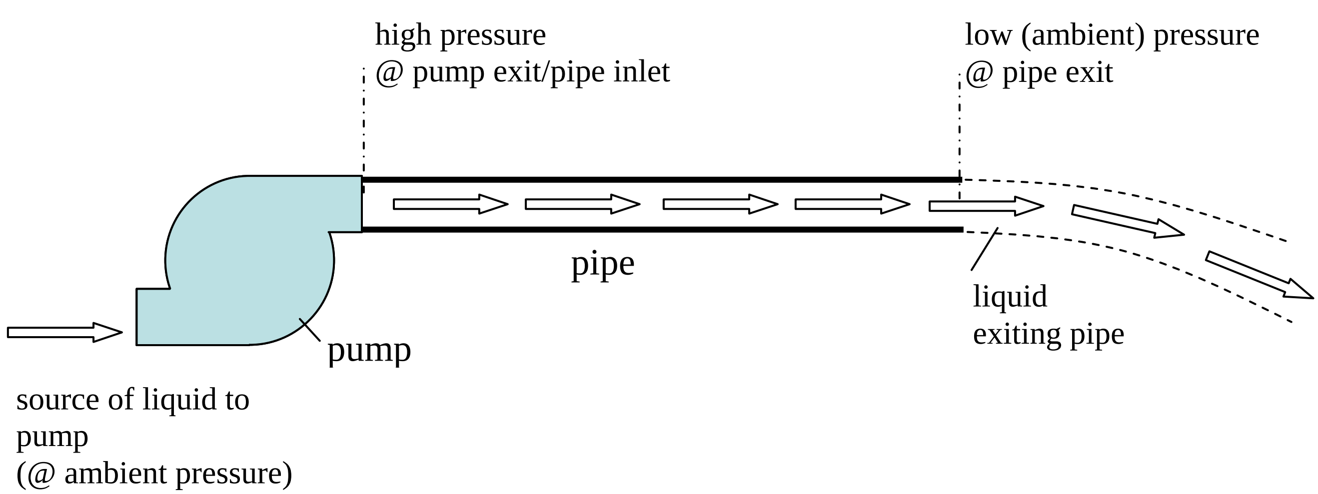

Figure 1-1: Horizontal flow driven by a pump.

It turns out that, for a given pipe diameter, the greater the desired rate of fluid flow, the greater is the required pressure difference between the inlet and exit of the pipe. Similarly, the longer the pipe and the smaller the diameter, the greater the pressure difference must be to achieve a given flow rate. There is a mathematical equation, given in equation (1-1), that expresses the role of pipe diameter, pipe length, kinematic viscosity, fluid density and flow velocity on the associated pressure drop. This equation involves what is termed the friction factor (f), whose value depends on a quantity called the Reynolds Number (Re). The Reynolds Number (Re) is equal to $V \cdot D/\nu$, where V is the mean flow velocity, D is the pipe diameter and ν is the kinematic viscosity.

As mentioned above, it takes power to pump the liquid through the pipe. Since pumps are not 100% efficient, the power input to the pump is greater than the power output of the pump. To determine how much power must be supplied to a pump, one needs to know its efficiency or the ratio of power output to power input.

TITLE: ICE CREAM PLANT

PROBLEM STATEMENT:

Your group has been asked to design a plant to produce 3,000 kgs of ice cream per hour. The process steps include: (1) ingredient blending and mixing; (2) pasteurization; (3) homogenization; (4) cooling; (5) aging; (6) continuous freezing; (7) packaging in market containers; (8) hardening under very cold conditions and (9) cold storage and distribution warehouse where it is ready to be shipped to the supermarket.

BACKGROUND:

You are designing a plant to produce 3,000 kgs of ice cream per hour. The process steps include: (1) ingredient blending and mixing to make a liquid mixture and dissolve all the solids; (2) pasteurization at high temperature to reduce the bacteria count that can cause rapid spoilage; (3) homogenization to create an emulsion and distribute the fat particles equally; (4) cooling to refrigeration temperature to prepare for (5) ageing, where the texture of ingredients blends; (6) continuous freezing to the consistency of soft ice cream which is solid enough for (7) packaging in market containers; (8) hardening under very cold conditions quickly solidifies the product with small ice crystals to improve the texture and (9) cold storage and distribution warehouse where it is ready to be shipped to your local supermarket. A block diagram of the process is shown in Figure 2-1.

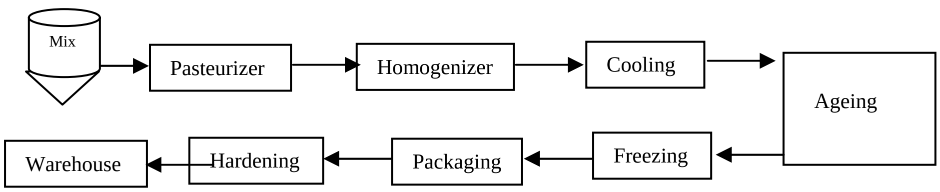

Figure 2-1 Ice Cream Making Process

TITLE: HEAT TREATMENT OF STEEL

PROBLEM STATEMENT:

Your engineering group is working at a steel casting company as manufacturing engineers. Currently, the plant's heat treatment process is operating near its capacity. Because of this, and the rising energy costs, your group has been assigned to investigate the system for possible improvements.

BACKGROUND:

The primary constituents in all steels are iron (Fe) and carbon (C); however, there are many different types of steel that serve a multitude of applications. Different combinations of element additions can create a steel alloy which has enhanced strength, wear resistance, corrosion resistance, fracture toughness, ductility, or ease of manufacturability. There is a tradeoff of one performance factor for another and the cost, therefore all of these capabilities cannot be attained simultaneously.

Heat treatment of the steel components is very important, because it changes the properties of the material. The heat treatment occurs at temperatures between 500 and 1,700 ^{0}F (compared to the melting temperature around 2,700 ^{0}F). During the heat treatment, the alloying elements are able to move, this occurs by solid diffusion, since heat treatment temperature is well below the melting point.

Most metals are made up of many small grains (or crystals). During the heat treatment, the grains can change shape and size. This will also change the material properties. Some heat treatments are designed to relieve internal residual stresses which have developed in the component.

Heat treatment is very important and is valuable because it enhances the material properties of the component. However, the process is very slow and energy intensive. It is slow because it requires the time for the elements to move. It is energy intensive because of the heat capacity of steel, and the high temperatures in which they need to be heated. The parts could be as small as a few ounces, or as large as 100,000 pounds. Typically, the parts are heated in a natural gas fired furnace. A typical heat treatment involves heating the parts to about 1,700 ^{0}F, holding the parts for a period of time at the desired temperature (depending on alloy, size of component, and desired material properties), and then cooled at a specified rate (depending on alloy, size, and desired properties).

TITLE: ALTERNATIVE ENERGY SOURCES

PROBLEM STATEMENT:

Your team has been formed by the National Academy of Sciences to study the global petroleum fuel market and make recommendations to the US government for future energy policy. Your tasks involve assessing petroleum supply versus demand and evaluating various alternatives for decreasing demand.

BACKGROUND:

The 'peak oil' point will occur when worldwide we are pulling as much petroleum oil out of the ground as we'll ever be able to pump. Supply hits its peak and begins an inexorable decline, regardless of demand. Peak oil is not avoidable; it is a fact of geology. Nobody knows for sure when the peak will occur, but expert consensus is that it will occur between 2010 and 2020.

Many experts see the electrification of transportation as a potential solution to the petroleum fuel crisis. Although pure electric vehicles have failed in the market, hybrid-electric vehicles have been successful. Hybrid-electric vehicles with larger battery packs designed for extended electric-only operation (20 - 60 miles) are called plug-in hybrids (PHEV, where a PHEV-40 has a 40 mile range in electric mode). Their great advantage is that they get 3-6 miles per kWh during electric operation, which equates to about 100-200 mpge (miles per gallon equivalent) at an energy equivalence of 33.5 kWh per gallon. One additional benefit is that these vehicles could use off-peak electricity to charge the batteries, which is lower cost and could increase the efficiency and the life of power plants since they would not have to ramp down production on their big generators every day. Running cars off of electricity also generates significantly less greenhouse gases. A 20 mpg vehicle will generate almost 24 pounds of carbon dioxide driving 20 miles, while burning one gallon of gasoline. By contrast, a 40-mile-range plug-in hybrid (PHEV-40) that gets 4 miles per kWh would consume about 5kWh of electricity and emit 7.5 pounds of CO_2 to travel that same 20 miles based on national averages for power production. Emissions would be essentially zero if solar or wind was used to generate the electricity to charge the batteries in the plug-in hybrid.

The major issue with plug-in hybrids is battery life: rechargeable batteries tend to die much faster if they are constantly discharged until empty as they are in a plug-in hybrid or a pure electric vehicle. The batteries in the popular gasoline-electric hybrids avoid this battery problem because whenever battery charge levels decrease, power from the engine is used to turn the generator and keep the charge level in the safe region. In a plug-in hybrid the batteries are discharged more fully and may need to be replaced during the lifetime of the vehicle. Replacement batteries are very expensive and will not likely be covered as part of a warranty. According to the Energy Information Administration, recent improvements in battery cycle life means it is highly probable that NiMH batteries can meet 130,000 – 150,000 lifetime mileage for hybrid electric vehicles (HEVs), PHEVs with 40 to 60 miles of electric driving range, and full function battery electric vehicles (BEVs).

Increases in renewable energy would support the electrification of transportation. Renewable energy alternatives are growing but are a very small part of current energy production. As of January 2003, the worldwide wind power capacity was 27,000 MW. The US had 4,265 MW of generating capacity, producing 11.2 billion kWh of electricity annually. In terms of economics, current wind farms can produce electricity for as little as 5 cents per kWh, but gas-fired combined-cycle plants produce at 3 cents per kWh.

Bio-fuels such as ethanol and bio-diesel are the other major alternative to replace petroleum use in transportation applications. Advanced diesel-fueled passenger vehicles now reach "power-plant-to-wheel" efficiencies of over 25%. Also, instead of diesel from fossil resources a variety of natural or synthetic liquid, biomass-derived hydrocarbons (methanol, ethanol, bio-diesel etc.) can be used.

A realistic analysis of the "power-plant-to-wheel" efficiency of a fuel cell car operated on gaseous hydrogen shows that hydrogen production, compression, and distribution incur energy losses of 45%, which when combined with the 50% efficiency for conversion to electricity in the fuel cell and the other losses in the fuel cell and the drive train yield an overall efficiency of about 22%. Also, hydrogen fuel cell vehicles require major infrastructure changes for hydrogen compression and fueling.

TITLE: SPACE POWER TESTING FACILITY

PROBLEM STATEMENT:

Your engineering team has been asked to assist NASA in the design of a new space power testing facility. The current Space Power Facility is located at NASA Glenn Research Center's Plum Brook Station and is the world's largest space environment simulation chamber. The large chamber can be pumped down to nearly duplicate the vacuum of space. NASA is interested in building a slightly larger version of the facility, but needs your help with the details.

BACKGROUND:

The current Space Power Facility (See Figure 5-1) consists of a large test chamber surrounded by model assembly areas, a control center, associated pumps, and an office facility. Your team is currently only interested in the design of the new test chamber.

Figure 5-1 Space Power Facility

A test chamber is composed of two, large sealed vessels with one placed inside the other. (See Figure 5-2)

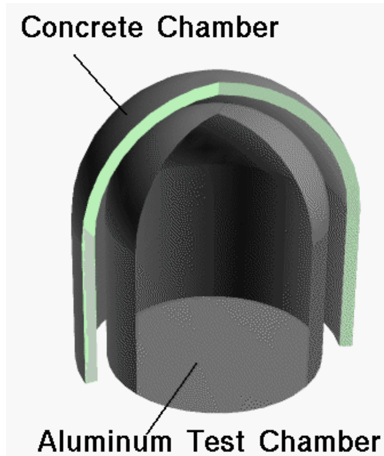

Figure 5-2 Test Chamber

The inner test chamber is made of aluminum and can be evacuated to simulate the vacuum of space. The inner test chamber is enclosed by an outer concrete chamber. The gap between the two chambers can also be evacuated to relieve the loads on the inner chamber.

TITLE: POWER FOR COMPUTER ROOM
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PROBLEM STATEMENT:

Your engineering group has been asked to design a facility with 6,000 ft^2 of computer room floor area. The electrical density in the computer room is estimated at 200 w/ft^2 of floor area and the input power is 1.2 megawatts (i.e., 1.2 MW).

BACKGROUND:

Data centers operate 24/7/365 and are designed to provide mission critical functions under all conditions. A credit card processor receives up to 5,000 transactions per second for millions of customers. Down time cost can be as high as $6 million per hour of outage. The support infrastructure to ensure this level of service is intense. For example, the facility’s electricity is delivered through two different utility substations, either of which could support the full load should the other fail. If both substations fail, there is an on-site standby electrical generator (and often a second generator in case the first one fails.) To bridge the time gap between loss of power from the utility and when power can be switched to the standby generator(s), a battery-powered Uninterruptible Power Supply (UPS) is installed in series with the utility power feed to the Power Distribution Centers (PDCs). The power quality is monitored by electronic filters (to remove harmonics) and both lightning protection and grounding wires are used to ensure a steady, clean input power to the sensitive computers.

Computer servers generate large quantities of heat and will fail in a few minutes if the Computer Room Air-Conditioning (CRAC) system does not remove that heat. If a CRAC unit fails, a standby CRAC unit is available to pick up the thermal load. There are three pumps to transfer the heat to the mechanical room (one pump in operation, a second as a standby in case the first pump fails, and the third in case both pumps fail). In fact, a three-day water supply for the Cooling Tower is maintained just in case the water service to the facility fails. Security, fire detection and sprinkler system design are each critical to maintaining continuous service and reducing the time required to return to service if the best plans are still not sufficient. Figure 6-1 shows the planned system

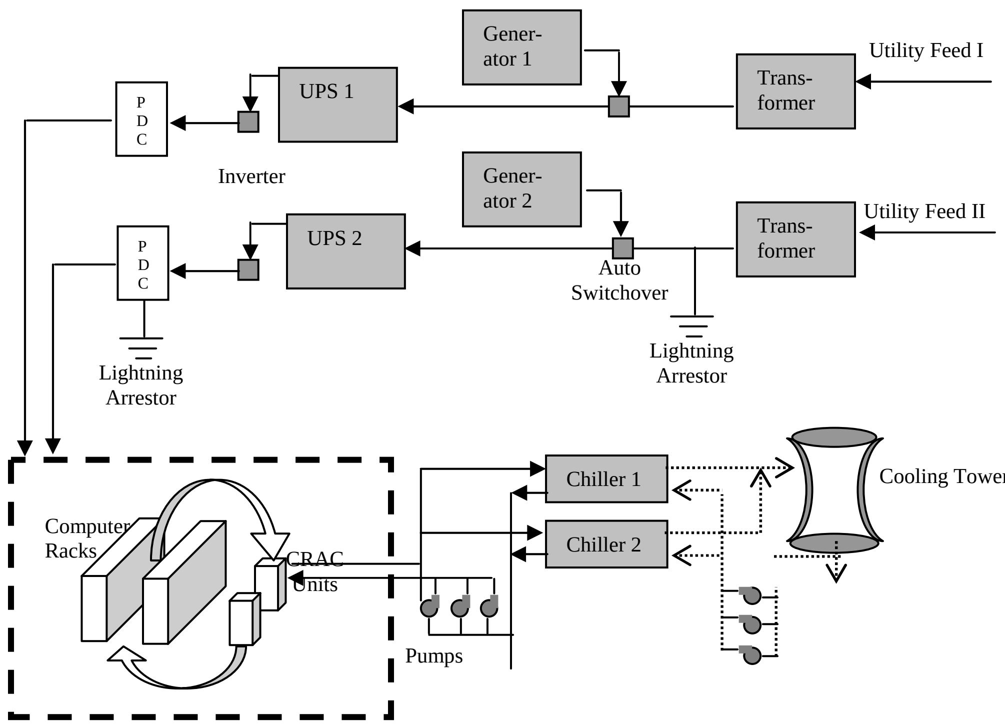

Figure 6-1 Power System

TITLE: DESIGN OF ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

PROBLEM STATEMENT: Your team has been selected to assess and provide the technical requirements for a number of environmental control and life support systems (ECLSS) for a series of space exploration missions. These missions will range from a duration of several days with a small crew to up to two years with a large crew. These missions will support the stepping stone approach to landing humans on Mars.

BACKGROUND:

The functions collectively called life support include providing and maintaining a comfortable and breathable atmosphere, protecting against the harmful radiation, providing food and water, and managing waste. Systems that provide these functions may involve processes that are physical or chemical, like pumps, or biological, like plants.

The environment of space is hostile! The inclusion of humans in space mission design necessitates the design of the ECLSS. Its inclusion directly affects the cost of the mission as well as all the subsystems on the spacecraft, particularly power, thermal control, overall mass, and complexity.

A good place to start in developing the requirements for the ECLSS design is with an understanding of the input/output dynamics of the human metabolism. Humans require food, water and oxygen to maintain basic physiological functions. Sufficient quantities of these fundamental elements must be provided. Humans output trace gasses, perspiration, respired water, carbon dioxide, waste, and particulates. All of this must be managed. Furthermore, environmental conditions such as atmospheric composition, temperature, humidity, and pressure, as well as protection from radiation must be provided.

There are two fundamental types of ECLSS. An open loop (or non-regenerative) system relies on constant re-supply of consumables. Filtration devices are used to maintain acceptable atmospheric conditions. The other approach, called closed loop (or regenerative), begins with an initial supply or consumables and resources and then processes the non-useful waste products to convert them into something that can be used. There are several methods for doing this including physical/chemical, biological (bioregenerative), and hybrid systems.

TITLE: NUCLEAR ENERGY

PROBLEM STATEMENT: Your engineering team has been asked to investigate the use of nuclear reactors for generating energy and to take into consideration economic and safety issues.

BACKGROUND:

Fundamental concepts in engineering are balances, continuity, and conservation. You are familiar with the concept of static balance—if something does not move, we say that it is in static balance. One aspect of static balance is that the forces on the object balance one another so that the net force is zero.

Continuity means that what goes into a system must come out somewhere if it does not stay in the system.

Conservation means that we can account for everything—energy and mass are not lost.

The study of engineering includes the effects of forces, the movement of mass, and the accounting for energy changes. Fundamental engineering concepts are:

1. conservation of mass,
2. conservation of energy,
3. response to forces,
4. in a cycle, heat cannot be completely converted into work.

Among the identifying features of Nuclear Engineering is the nuclear reactor. Fundamentally, the reactor has one of two purposes:

1. it produces neutrons, electrically neutral particles with a mass of approximately 1 atomic mass unit (amu), and
2. it produces heat, allowing us to convert some of the heat energy into electricity.

Much of nuclear engineering analysis is concerned with the movement and effects of the neutrally charged forms of radiation, the neutron and the gamma ray. Nuclear engineering includes two subjects not conventionally found in other disciplines:

1. the interaction of radiation with matter, and
2. the time-dependence of the neutron chain reaction.

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