AC 2007-1698: UTILIZING DESIGN SHEETS IN THE DESIGN OF ENERGY AND THERMAL SYSTEMS

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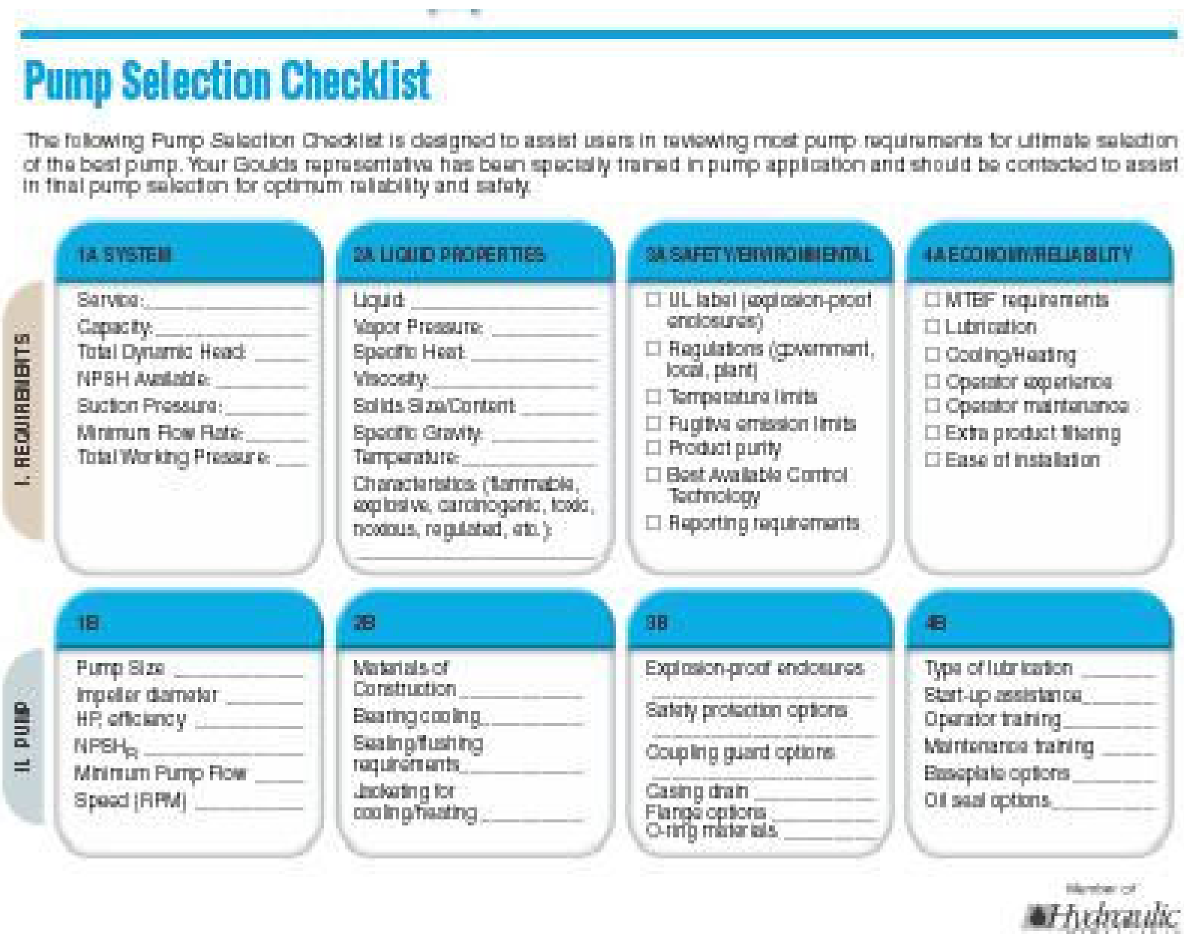
Utilizing Design Sheets in Design of Energy and Thermal Systems

Abstract

In designing an energy system such as a steam power plant or a solar water heating system, an engineer is required to select and size many different components such as pumps, turbines, and solar panels. Proper selection and sizing of these components require understanding of materials covered in basic engineering science courses such as thermodynamics, heat transfer, and fluid mechanics. Moreover, the engineer must have knowledge and understanding of the overall system, the role of each component in the system design, and the interactions among different components. In addition, the selection and sizing process must conform to and follow industry standards and recommendations. As a result, many manufacturers provide design sheets to facilitate the design and selection process of their products. Even though the use of design sheet is prevalent in industry, many engineering textbooks in thermal/fluid sciences do not include or even describe them. This paper provides descriptions of some design sheets relevant to design of thermal and energy systems, and how they can be used in courses such as fluid mechanics, design of thermal systems, energy engineering, and energy conversion systems.

Introduction

For a practicing engineer in industry, it is common practice to be asked to choose or select a component to replace or upgrade an existing system. As an example, an engineer is asked to replace a pump supplying make-up water to the cooling tower in order to increase the flow rate of the make-up water supply. The engineer will need to evaluate several pumps in order to meet the flow rate required as well as other considerations such as size and cost of the pump, pressure drop in the piping system that the pump needs to overcome, selection of a motor to drive the pump, etc. The selection of pump will be commonly done using the design sheet or selection procedure provided by the manufacturer of the pump. The situation is similar for an engineer designing an energy or thermal system such as a solar water heating system. He/she is required to select solar panels, one or more water storage tanks, a pump, and other items such as a temperature controller, valves, piping, etc for the system in question. Proper selection and sizing of these components require understanding of materials covered in basic engineering science courses such as thermodynamics, heat transfer, and fluid mechanics. Moreover, the engineer must have a thorough knowledge and understanding of the overall system, the role of each component in the system design, and the interactions among different components. In addition, the selection and sizing process must conform to and follow industry codes, standards, and recommendations. As a result, many manufacturers provide design sheets to facilitate the design and selection process of their products. Even though the use of design sheets is prevalent in industry, many engineering textbooks in thermal/fluid sciences do not include or even describe them. In the author's opinion, it is important for students to learn the use of design sheets as it will enhance their understanding of engineering design process as well as experience of real-world engineering practices. Some design sheets and engineering guides from manufacturers also provide a comprehensive engineering information and consideration of factors or issues that are very useful for students. For example, in choosing a pump, it is necessary to not only consider flow rate and pressure head but the type of liquid, properties of liquid (corrosive, toxic), construction materials, and maintenance issues. Fig. 1 shows the pump selection checklist provided in the pump selection guide by Goulds pumps[1]. The instructor can provide this kind of early exposure to engineering practice by incorporating design sheets in relevant course materials.


Pump Selection Checklist

The following Pump Selection Checklist is designed to assist users in reviewing most pump requirements for ultimate selection of the best pump. Your Goulds representative has been specially trained in pump application and should be contacted to assist in final pump selection for optimum reliability and safety.

I. REQUIREMENTS

1A SYSTEM: Service; Capacity; Total Dynamic Head; NPSH Available; Suction Pressure; Minimum Flow Rate; Total Working Pressure

2A LIQUID PROPERTIES: Liquid; Vapor Pressure; Specific Heat; Viscosity; Solids Size/Content; Specific Gravity; Temperature; Characteristics (flammable, explosive, carcinogenic, toxic, noxious, regulated, etc.)

3A SAFETY/ENVIRONMENTAL: ☐ UL label (explosion-proof enclosures); ☐ Regulations (government, local, plant); ☐ Temperature limits; ☐ Fugitive emission limits; ☐ Product purity; ☐ Best Available Control Technology; ☐ Reporting requirements

4A ECONOMY/RELIABILITY: ☐ MTBF requirements; ☐ Lubrication; ☐ Cooling/Heating; ☐ Operator experience; ☐ Operator maintenance; ☐ Extra product filtering; ☐ Ease of installation

II. PUMP

1B: Pump Size; Impeller diameter; HP, efficiency; $NPSH_R$; Minimum Pump Flow; Speed (RPM)

2B: Materials of Construction; Bearing cooling; Sealing/flushing requirements; Jacketing for cooling/heating

3B: Explosion-proof enclosures; Safety protection options; Coupling guard options; Casing drain; Flange options; O-ring materials

4B: Type of lubrication; Start-up assistance; Operator training; Maintenance training; Baseplate options; Oil seal options

Member of Hydraulic

Fig. 1 Pump selection checklist from Pump Selection Guide by Goulds Pump[1]

From the literature review, the author found only a few papers that dealt with design sheets or engineering guide from manufacturers. Only two textbooks, one by Fox et al.[2] and the other by Hodge and Taylor[3], provide actual manufacturer data and discuss the selection of pumps in term of these data. Lee and Ceylan[4] mentioned in their paper on Thermal System Design class that the students were required to select heat exchanger based on design conditions. Similarly, Shervin and Mavromihales[5] asked the students to use manufacturers' data to select a heat exchanger. In the paper by Munro[6], the students used the professional software PipeFlo from Engineered Software to select a pump but did not mention the use of manufacturer's information. Somerton and Genik[7] provided uses of design and equipment selection of heat exchanger and pumps in the paper on Thermal Design courses. However, many papers did not discuss how the instructor used these selection and design procedures from equipment manufacturers in class. This paper provides detailed descriptions of some design sheets relevant to design of thermal and energy systems, and examples of how the author has used them in courses such as energy engineering, and energy conversion systems. The design sheets will be discussed according to the relevant subject areas such as fluid mechanics, heat transfer, thermal systems, etc.

Fluid mechanics and Turbomachinery Courses

In fluid mechanics class, the text by Fox et al.[2] provides, in Appendix D, the procedure for selecting a pump and a fan utilizing selection charts and performance curves from Peerless Pump Company and Buffalo Forge Company respectively. Similar materials can be obtained from many manufacturers of pumps and fans. For the topic of pump selection, the author uses the appendix D from Fox et al.[2] supplemented by Pump Selection Guide by Goulds Pump[1] and their online pump selection program, PSS[8]. Students can use the program, PSS, free by registering at the web site of Goulds Pump. More information on the program is available by downloading the User Guide from the same web site. In selecting a fan, the author makes use of Fan Fundamentals booklet by Greenheck Fan Corporation[9] where detail information on fan specifications, types, election process, and fan performance prediction using affinity laws are given. In the booklet, the selection process of fan is given systematically in Section 2 and fan performance in Section 3. From Section 2, students learn that to properly select a fan for a specific application, the engineer needs to consider sound levels, power requirement (horsepower), and installation procedure in addition to flow rate (CFM) and static pressure. Section 3 provides how to obtain performance of the fan at off-design conditions using fan laws that are familiar to students who have taken fluid mechanics. The author also uses Basic Course in Fan Selection and Engineering Guide from Chicago Blower Corporation[10] as an alternative fan selection process. One unique feature provided by Chicago Blower is the correction procedure for selecting a fan for operating at different altitudes from sea level and/or higher air temperature than ambient condition. By using two alternative fan selection procedures, students also gain experience to the essential nature of design process, i.e., many solutions to a single problem. These selection procedures can be used in Turbomachinery course.

Heat Transfer and Design of Thermal Systems Courses

Heat exchangers play a very important role in any thermal or chemical processes. As a result, the author will discuss design sheets for selecting heat exchangers. In a typical heat transfer class, the analysis procedures and theoretical materials on heat exchangers are covered in detailed but the selection and sizing of heat exchangers may not be covered at all. As a result, the topic of heat exchanger selection is covered in Design of Thermal System class at Lamar University. The most common type of heat exchanger for industry is of shell and tube type and Thermo Dynamics Ltd.[11] provides a detailed selection guide together with operating cost estimation for shell and tube heat exchangers. The selection procedure is based on Log Mean Temperature Difference (LMTD) method, which is covered in the heat transfer class and is familiar to all the students taking Design of Thermal Systems class. The last page of the heat exchanger selection guide from Thermo Dynamics is shown in Fig. 2.

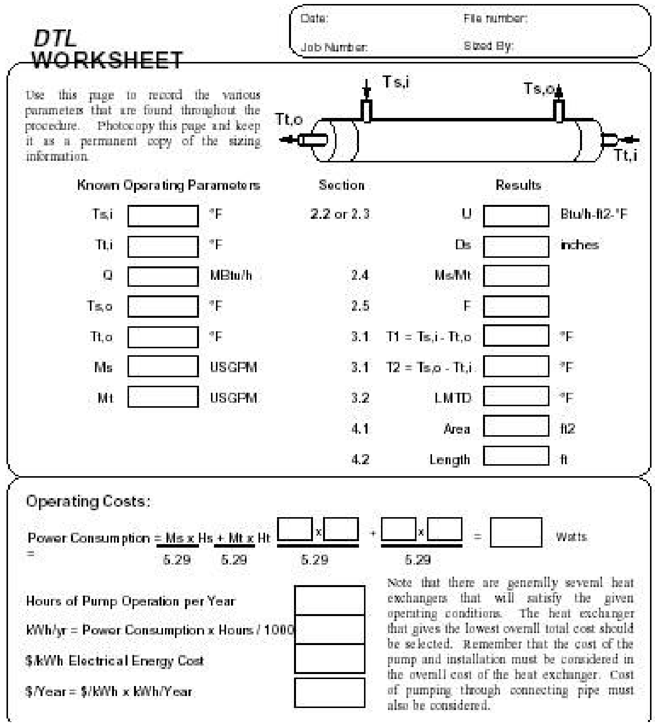


Fig. 2 DTL Heat Exchanger Selection from Thermo-Dynamics Inc.[11]

Another type of heat exchanger that is commonly used in industry is the flat plate type. GEA FlatPlate Inc.[12] provides extensive literature and selection sheets as well as online program to select their flat plat heat exchangers. By providing selection procedures for different types of heat exchangers, the students have significantly improved their understanding and ability to evaluate heat exchangers. In addition, students perform the heat exchanger experiment where the performance of a shell and tube heat exchanger and a flat plate heat exchanger is compared under same operating conditions. According to students, the experiment significantly enhances their understanding of heat exchangers.

Energy Engineering and Energy Conversion Systems Courses

These classes deal with traditional and alternative energy resources and their conversion systems. Here, two design sheets are discussed: one for the photovoltaic system and the other for a solar thermal heating system. Two specific examples are given as examples to demonstrate use of design sheets in these two courses. One of the design exercises assigned to students in Energy Conversion System class is to design a PV system for his/her residence. The steps in the system design consist of determining the electricity loads and usage, estimation of storage requirements, size of the photo voltaic (PV) arrays, and the number of 12 V battery for energy storage. The students utilize the design sheet from Energy Alternatives[13]. Energy Alternatives is a company based in Canada dealing in renewable energy systems for residential and small-scale commercial applications. The design sheet, shown in Fig. 3, is a complete system design. Based on the design, the cost of the system can be estimated from the catalog of Energy Alternatives.

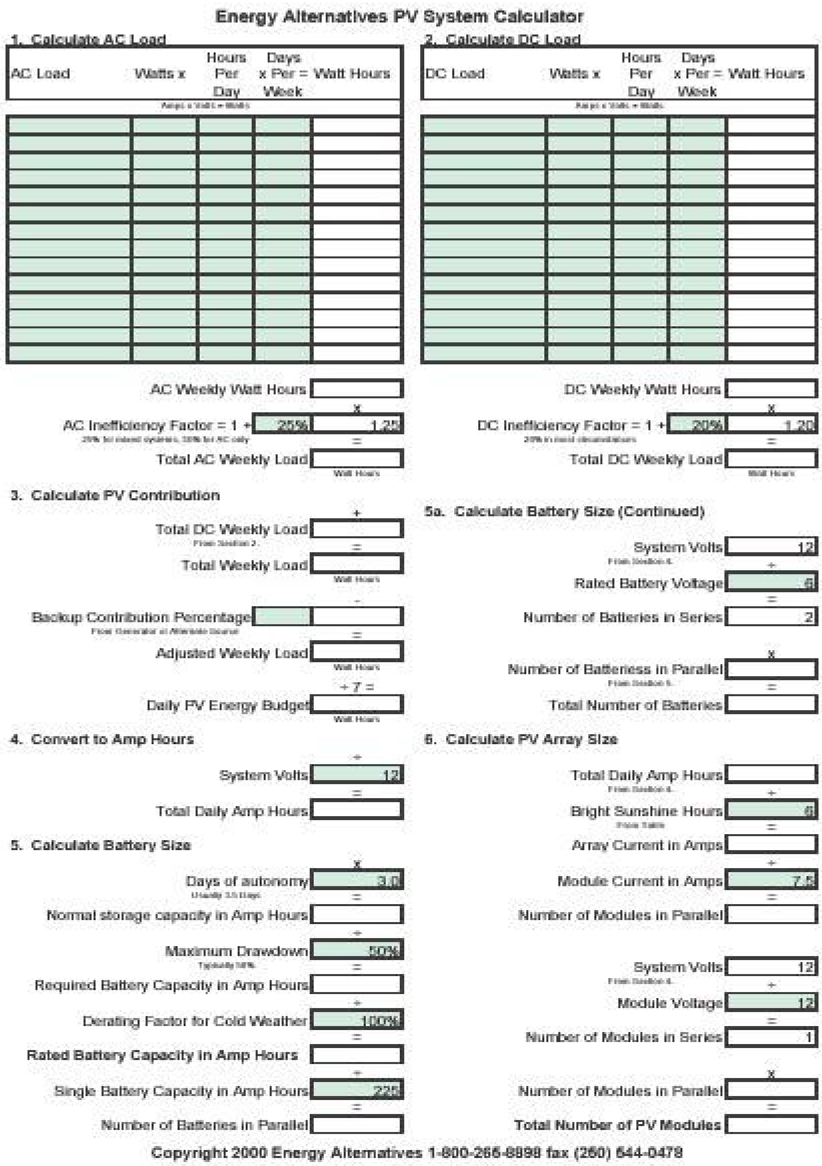


Fig. 3 PV Selection Sheet from Energy Alternatives[13]

Steps 1 and 2 compute weekly electricity requirements for both AC and DC loads. Steps 3 and 4 determine the size of PV in terms of daily requirement of current load (amp-hr) for a 12 V system. Steps 5 and 6 determine the number of battery required and the size of PV array needed for design respectively. Even though the design sheet does not provide the economic analysis, students are asked to perform life cycle analysis based on pricing data available from Energy Alternatives.

Another example of design sheet usage is given for an Energy Engineering course. One of the design problems assigned to students in Energy Engineering class is to size a solar water heating system for a residential home. The design sheet was developed by Florida Solar Energy Center[14] to size a solar water heating system for use in Florida. The first part of the design sheet is shown in Fig. 4. The steps in the system design consist of determining the water usage based on the number of residents, estimation of storage tank size and heating load, determination of number and size of solar water collectors, and economic analysis. Utilizing the design sheet shown in Fig. 4, the students determine the sizes of storage tank and solar collectors. Some of the issues considered in the design sheet are the location and ambient temperature, the orientation and angle of collectors and a final design check to ensure design assumption. Cost data from Florida Solar Energy Center is used to perform cost analysis of the water heating system.

Simplified Sizing Procedure For Solar Domestic Hot Water Systems

Florida Solar Energy Center

FSEC-GP-10-83
Revised April 1992

The following procedure was developed to size residential solar water heating systems in Florida. See last page for limitations and assumptions.

Hot water demand and tank size

Step 1. Using Table 1, estimate daily hot water use (GALLONS) and select a nominal tank size (TANK SIZE).

______ gal/day GALLONS (1)

______ gal TANK SIZE

Table 1. Hot water demand and tank size

Average GALLONS and minimum TANK based upon number of people or bedrooms:

People	(or) Bedrooms	GALLONS	Minimum TANK SIZE (Gallons)
1		20	[illegible]
	1	30	30
2		40	40
	2	50	52
3		55	52
4	3	70	80
5		85	80
	4	90	100
6		100	100
	5	110	120
7		115	120

(Add 15 gallons for each additional person.)
(Add 20 gallons for each additional bedroom.)

Step 2. Using Figure 1, determine the proper cold water temperature (COLDTEMP) for location.

______ °F COLDTEMP (2)

Fig. 4 Solar Water Heater System Selection from Florida Solar Energy Center[14]

Benefits of Using Design Sheets

The author has extensively used design sheets in the senior core course, Design of Thermal Systems and the benefits to the students show up when these senior students start their Capstone Design course. Three out of five teams in the current semester are using these design sheets in their senior design projects. One team is building a demonstration unit of solar water heating system with the water pump driven by a photovoltaic system. In their design, they have used both PV system design sheet and solar water heating design sheet. Another team is working on a project dealing with a conceptual heat exchanger for heat dissipation in space sponsored by Texas Space Grant Consortium (TSGC). They have used the design sheet for selecting heat exchangers in their project. Another team is working on a similar project for TSGC and they have to select three heat exchangers for their project. Initially, they have chosen shell-and-tube heat exchangers for their design but based on the suggestions from the author, they have changed their heat exchangers to the flat plate type. As a result, they have used the flat plate heat exchanger selection software and technical information from FlatPlate Inc. for their final design. When the team presented their results to TSGC, they were surprised to learn that their design was very close to the actual design implemented for the space shuttle by NASA engineers. Based on these observations, the author have concluded that the use of design sheets are very beneficial to the students, especially in their design projects,

Conclusions

The use of design sheet is prevalent in industry but it is not common in the coverage of typical engineering courses. This paper provides descriptions of some design sheets that the instructor use in many of his courses such as fluid mechanics and energy engineering. By incorporating the design sheets in thermal/fluid engineering courses, the learning process and industrial experience of students can be enhanced significantly.

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