Internship Experience at
Lockwood, Andrews & Newnam, Inc.

An Internship Report

by

Jeffery Noel Bolander

Submitted to the College of Engineering

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Lockwood, Andrews & Newnam, Inc.

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ABSTRACT

Internship Experience at Lockwood, Andrews & Newnam, Inc.
(Dec. 1988)

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A one year internship in industry was completed as partial fulfillment of the requirements for the degree of Doctor of Engineering. The internship was with Lockwood, Andrews & Newnam, Inc. (LAN), a medium-size consulting engineering firm based in Houston, Texas. The internship period was from July 1986 to July 1987.

This report shows how the author's internship fulfilled the internship objectives: (1) contribute to LAN's efforts to meet its goals and obligations: professional, technical, economic, and societal; and (2) enhance the author's understanding of the engineering business. These objectives were attained through technical assignments and interaction with clients and members of LAN.

The author's responsibility grew throughout the internship. By the end of the internship, the author had undertaken the responsibilities of a project engineer. This included client contact, coordination and scheduling of work, and budget control.

ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. Dan Turner, Dr. Sriram Somasundaram, Dr. Jerald Caton, and Dr. David VanFleet for the knowledge imparted during my academic tenure at Texas A&M. A special thanks goes to Dr. Dan Turner for making sure that I had employment during my graduate studies and for his advice and encouragement.

I am grateful to LAN's Mr. Randy Lowrance and Mr. Stephen Lavoot for the internship opportunity. I also want to say thanks to Mr. Kim Shinn who has provided encouragement and the type of assignments which make for a successful internship. His management style should be followed by all engineering managers.

I also want to express my gratitude to Mrs. J. J. Pappas for her many hours of typing.

Most importantly, I wish to thank my wife for her encouragement and support and the sacrifices she made so that I could pursue this degree.

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INTRODUCTION

The Doctor of Engineering Program is intended to prepare individuals for professional engineering activities in business, industry, and in the public sector. It is not intended as a research degree since that is the province of the Ph.D. Program. The Doctor of Engineering Program emphasizes engineering practice, not research, in an environment of potential leadership [1].

As part of the degree requirement, the student is required to spend a minimum of one calendar year working under the supervision of a practicing engineer in industry, business, or government. The objectives of the internship are two-fold:

(1) to enable the student to demonstrate and enhance his or her abilities to apply both knowledge and technical training by making an identifiable contribution in an area of practical concern to the organization or industry in which the internship is served; and

(2) to enable the student to function in a non-academic environment in a position in

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The journal used as the model for style and format of this report is the "ASHRAE Journal".

> which he or she will become aware of the employer's approach to problems, in addition to those approaches of traditional engineering design or analysis [1].

A. Lockwood, Andrews and Newnam, Inc.

The author served his internship with Lockwood, Andrews and Newnam, Inc. (LAN), a medium-size engineering and architecture firm based in Houston, Texas. LAN consists of approximately 230 employees and has offices in Dallas, Austin, and San Antonio. LAN is a privately held corporation by its employees and has been in the consulting engineering business since 1935.

LAN is well known for its work in both the public and private sectors. In the public sector, LAN is known for its design of central utility plants for universities, hospitals, airports, its highway design and its design of a City of Houston waste water treatment facility, one of the largest in the country. In the private sector, LAN has designed manufacturing and corporate office facilities.

1. Organization

LAN uses the matrix form of organization for its projects. The matrix organization is the result of superimposing the project organization on the functional organization. The project organization is a type of organization that exists for the purpose of completing a project. When the project is completed the project organization is disbanded. A functional organization, on the other hand, is a type of organization that is designed for continuous use. It is composed of groups (departments), each responsible for a particular expertise. The matrix organization attempts to combine the strengths and minimize the weaknesses of these two types of organization.

When a project is awarded to LAN it is assigned to a project manager. The project manager then draws the manpower (the project team) from the departments to complete the project.

The project manager meets first with representatives (the project engineers) of each department for the purpose of determining the project design budget. Each project engineer then makes an estimate of the budget required to complete its particular part of the project scope and submits it to the department head for approval. After the department head approves it, he sends it to the project manager. Then, depending on the negotiations with the client, each department receives a budget for completing its portion of the project.

The project engineers are the departmental representatives for the project and report to the project manager concerning the project. The project engineer is responsible for controlling his resources for the project, scheduling manpower requirements, and coordinating with other disciplines on the project.

2. Product

Final products produced by LAN are studies, design documents, and construction documents. Studies are what clients use to guide their decisions concerning the future of their organizations. A common study for universities and other large complexes is a master plan. This document guides the development of the facility to provide for a controlled growth. A university campus master plan includes land use plans which show how the land will be used for future needs, such as classroom space, office space, research facilities, dorms, parking, etc. It might also include utility plans that show how the future utility requirements will be met. Integral to any plan is a schedule for coordinating the work so that everything goes smoothly. Master plans typically look at requirements over a ten year horizon.

Design documents consist of preliminary drawings, calculations, and specifications for a project. From these documents the client can achieve a conceptual understanding of the project and how much it is going to cost. These packages are often put together for the purpose of the client getting funding to go forward with the project, whether the funding is coming from the corporate headquarters, government, or bank.

Construction documents consist of drawings and specifications which the client provides to the person(s) responsible for the actual construction of the project. Construction documents are also used when the construction phase of the project is competitively bid.

B. Internship

1. Objectives

The objectives of the internship, as approved by the intern's advisory committee (see Appendix A) are as follows:

(1) to contribute to LAN's efforts to meet its goals and obligations: professional, technical, economic, and societal; and

(2) to enhance his understanding of the consulting engineering business.

To attain these objectives, the intern strived to produce the quality of professional services for which LAN is known. He sought to strengthen his technical expertise through application of academic training. By meeting his project budgets and schedules, the intern contributed to providing a fair return on the shareholders' investment. He made a societal contribution by participating in community service during the internship. Throughout the one year internship, the author submitted quarterly progress reports to his committee chairman (see Appendix B).

2. Internship Position

The author served his internship as an Engineering Assistant II. Within the engineering ranks at LAN, there are six levels. Engineering Assistants levels I through III represent non-registered graduate engineers with increasing levels of experience and responsibility. Once an Engineering Assistant obtains his professional registration he becomes an Engineer IV. Engineer levels V and VI represent further experience and responsibility.

Concerning administrative duties, the Engineering Assistant II may participate in project administration and organization administration. Project administration includes [3]:

(1) preparing a project budget and schedule,

(2) ensuring that work has been adequately checked and reviewed prior to client review,

(3) maintaining a project file, including sufficient documentation of design decisions and project correspondence,

(4) ensuring that the project is completed on schedule and within budget.

Organization administration may include [3]:

(1) preparing workload projections for subordinates,

(2) assisting subordinates in the technical applications made during the design effort and trouble-shooting problems as they arise, and

(3) staying abreast with changes made to the project concerning budget, and/or scope of services which affect subordinates.

The technical duties of an Engineering Assistant II include production design, conceptual design, and drafting. The primary technical duty is production design which includes [3]:

(1) understanding design scope and objectives,

(2) determining appropriate design criteria,

(3) documenting design approach,

(4) performing design calculations,

(5) incorporating necessary details into design effort,

(6) specifying materials and equipment, and

(7) documenting significant design decisions and project correspondence.

The Engineering Assistant II will also participate in conceptual design which includes [3]:

(1) meeting with the client or project manager to determine the design scope and objectives for the project,

(2) encouraging creative ideas, and utilizing the input of others in developing the conceptual design approach,

(3) preparing schematic design sketches and specification outlines for client review,

(4) presenting the conceptual design approach to the client in a clear, concise manner,

(5) obtaining written client approval of conceptual design prior to design development, and

(6) ensuring that technical applications made during design development do not significantly alter the established conceptual design approach.

3. Mechanical Department

The author served his internship as a member of the Mechanical Department. The department is headed by Mr. Kim

E Shinn, P.E., and is responsible for providing the mechanical engineering expertise.

The major strengths in the design function of LAN are HVAC (heating ventilating and air conditioning) system and thermal utility systems. Typical HVAC design work might be for institutional, industrial, or commercial buildings and sporting arenas. Thermal utility systems work covers central boiler and chilled water plants and associated distribution systems.

Besides the department head, there are twelve members in the mechanical department: eight engineers and engineering assistants (non-registered), three designers, and one draftsman.

4. Supervisors

The author's internship supervisor was Mr. Kim E Shinn, P.E., Mechanical Department Head. Through the course of the internship, the author's immediate supervisor varied with the project assignment. The Mechanical Department's project engineer for each project on which the author was assigned became the intern's immediate supervisor.

Mr. Bill Nichols, Senior Project Coordinator, was the project engineer for the Texas Woman's University Cogeneration study. Mr. Nichols has extensive experience in the design and operation of central plants. Mr. Nichols was responsible for the mechanical design of the Lone Star Energy Cogeneration Plant in Dallas.

Mr. George Cobb, Senior Project Coordinator, was the project engineer for the Southwest Texas State University cogeneration/central plant. Mr. Cobb also has extensive experience in the design and operation of central plants. Mr. Cobb was responsible for the mechanical design of the TECO cogeneration plant at the Houston Medical Center.

Mr. Stephen Waller, P.E., Engineer V, was the project engineer for the thermal utility system expansion at the University of Texas Medical Branch-Galveston. Mr. Waller has considerable experience in HVAC design, energy management control systems, and central plant design. In association with Mr. Cobb, Mr. Waller was responsible for the mechanical design of the cogeneration/central plant at Southwest Texas State University.

CHAPTER II

INTERNSHIP ASSIGNMENTS

The following assignments are representative of the type of projects on which the author worked, and demonstrate that the first objective of the internship was met. The assignments included a cogeneration feasibility study, design for a cogeneration plant, and design of thermal utility disribution piping.

A. Texas Woman's University Cogeneration Feasibility Study

The first assignment for the author was a cogeneration feasibility study for Texas Woman's University in Denton, Texas. Mr. Bill Nichols was the project engineer for the mechanical department and, therefore, was the author's supervisor for this work.

1. Background

Cogeneration can be defined as the simultaneous production of electrical and thermal energies from a single fuel input. This technology is as old as commercial electricity production, but due to economies of scale, inexpensive fuel, and remote locations of central power (electricity) plants, cogeneration has not been economically attractive for many decades. However, the large increases in fuel costs over the last fifteen years and the high capital costs of nuclear power plants have made cogeneration attractive to industries and institutions with large electricity and thermal energy needs.

Universities, like TWU, are often ideal candidates for cogeneration. University campuses which have central thermal energy plants generate high temperature water or steam and chilled water for use by the campus facilities. These thermal utilities are distributed to buildings on campus by way of underground piping. A central thermal energy plant in taking advantage of load diversity is generally more efficient and more cost effective than individual building systems.

Electricity is purchased from the local electricity company for use on the campus. Natural gas is used at the central plant for generating hot water or steam. When the central power (electricity) plant generates the electricity, it converts about one-third of the fuel energy input into electricity; the other two-thirds are rejected to the environment as waste heat. Cogeneration, on the other hand, makes use of most of this waste heat.

A typical cogeneration system might include an internal combustion engine which drives an electric generator and a heat exchanger connected to the exhaust of the engine. The heat exchanger is used to transfer heat (i.e., the "waste heat") from the relatively hot exhaust gases to water to produce steam or high temperature water. The steam or hot water produced displaces an amount of fuel equivalent to that required to produce the steam or hot water in a boiler. Cogeneration systems can, therefore, convert 60-75% of the input fuel energy into useful forms of energy: 20-30% to electricity and 40-50% to steam or hot water (thermal energy).

2. Objective and Task

LAN was selected by Texas Woman's University (TWU) to determine the feasibility of cogeneration for the Denton Campus, make a recommendation to TWU, and provide a report to document the feasibility and recommendation. The author was assigned the tasks of gathering the necessary data, performing the economic analysis, determining mechanical practicability, and writing the final report.

3. Procedure

The author was already familiar with the possibility of cogeneration at TWU due to the feasibility study undertaken while he was a graduate student at Texas A&M University (TAMU). The Energy Systems Lab at TAMU was under contract to the Texas Public Utility Commission (PUC) to identify state agencies which were likely candidates for cogeneration and determine the economic potential. TWU was one of the state agencies investigated by the Energy Systems Lab.

The first step in determining the feasibility was to see if cogeneration was a practicable application. TWU has a central steam plant which houses three boilers that serve the steam requirements of the campus through a network of underground steam piping. TWU's steam plant is located on the northern edge of the campus and could be easily expanded to accommodate the cogeneration equipment (see Figure II-1). Most buildings are cooled by means of absorption chillers located in the buildings. The absorption chillers use steam as the energy source, instead of electricity, for driving the refrigeration cycle. Since steam provides cooling as well as heating requirements, a significant year round steam requirement is ensured. It is very desirable for a cogeneration system to have large and constant thermal loads year round.

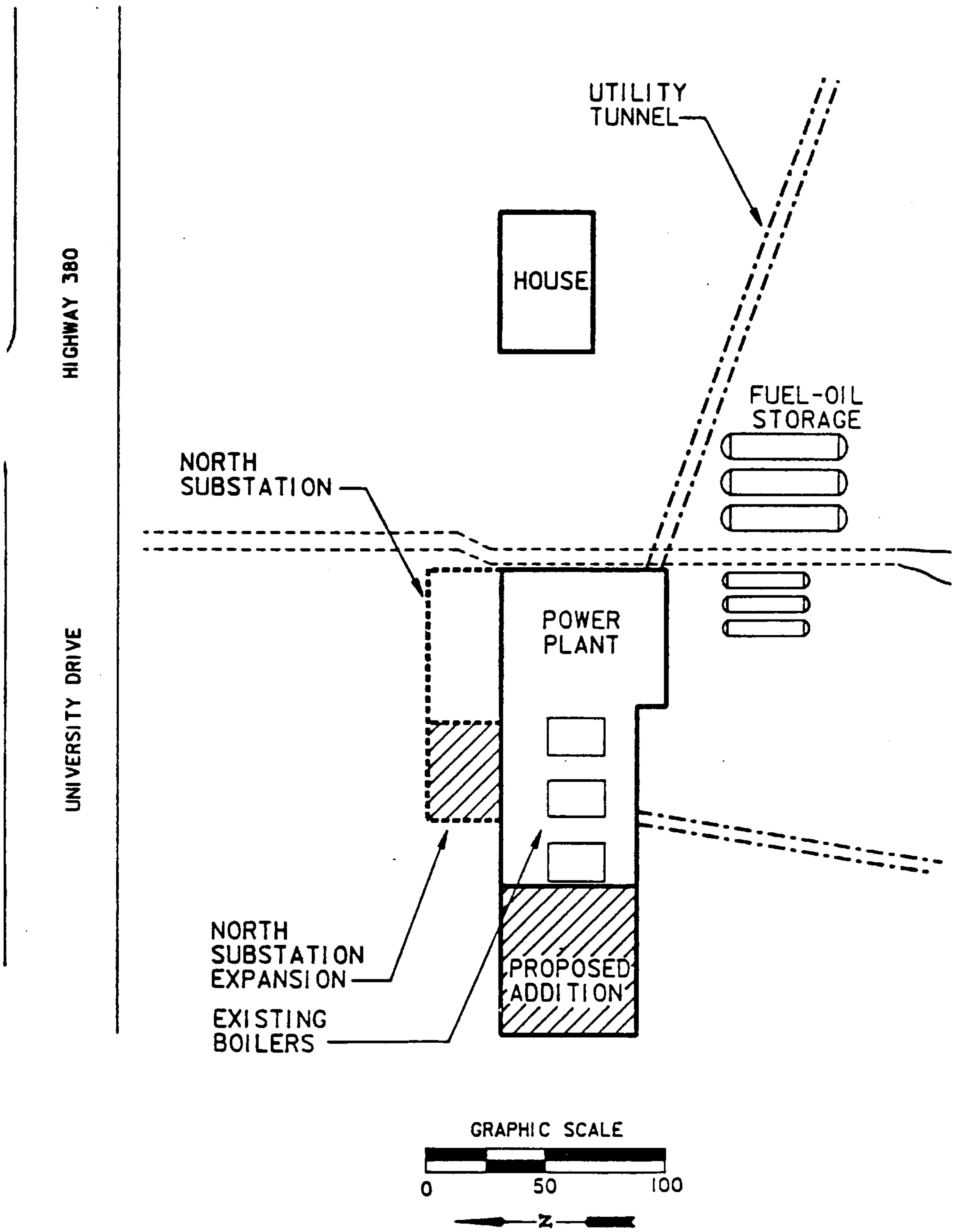

Figure II-1

TWU COGENERATION PLANT

On the electrical side, the electrical engineer assigned to the project determined that most of the electrical needs of the campus are met through the two substations on the campus. There are two electrical distribution systems on the campus, each one being served by a substation. The cogeneration system could be connected to both substations and operate in parallel with the utility company.

The second step was to gather the information required for the economic analysis. Since cogeneration is the simultaneous production of electrical and thermal energies, it was required that something be known about the simultaneous electricity and steam demands and the fuel costs involved.

The energy management system at TWU has the capability to record steam flow from each boiler and electricity demand at each substation. Several months of this data had been collected by TWU for the cogeneration study by the Energy Systems Lab at TAMU. The Energy Systems Lab allowed the author access to this information for the current study.

Since complete data was not available for a full year, some extrapolation of existing data was required. Based on utility bills for the months without steam and electricity demand data, and existing demand data for other months, it was possible to synthesize data for these months.

It is important that the synthesized load data not overestimate the minimum (base) demand of the system. A cogeneration system's economics are based on displacing purchased electricity (from the utility) and gas burned in the boilers to produce steam. In general, a cogeneration system which operates continuously at a high load factor and is not producing more electricity or steam than the user can use is going to be the most economical. If the demands of the system are overestimated, specifically on the minimum demand, there will be periods when the cogeneration system will be less loaded than predicted and/or will be throwing away thermal energy, resulting in poorer economics than predicted.

The next step concerned determining the economics of cogeneration. Simply put, the savings from cogeneration are equal to the value of steam and electricity displaced by the cogeneration system minus the fuel energy and additional operating and maintenance costs required by the cogeneration system. These savings are then used to offset the capital cost of the cogeneration facility. Therefore, it is necessary to estimate the amount of electricity and steam that the specific cogeneration equipment would displace. In practice, this is accomplished by comparing the electricity and steam demand of the campus to the output of each proposed cogeneration system.

As mentioned above, cogeneration systems are typically composed of an internal combustion engine (the prime mover), an electric generator, and a heat recovery steam generator (heat exchanger). It is the prime mover that determines the relative amounts of thermal and electrical energies that can be produced.

The two types of internal combustion engines most commonly considered for use as prime movers in cogeneration systems are the reciprocating piston engine and the gas turbine engine. Relatively speaking, for the same fuel input a reciprocating engine will produce more electricity than a gas turbine. However, a gas turbine produces a higher quality (higher temperature) thermal energy and more of it. Therefore, it is a matter of determining which prime mover will better meet the needs of the user.

For TWU, the steam requirements made gas turbines more attractive. TWU requires steam at a pressure of 200 psig (pounds per square inch-guage) and a temperature of 500 degrees F, which can be easily produced with the heat from the exhaust of a gas turbine. In addition, TWU's steam requirements and electricity demands are more closely matched by a gas turbine. By selecting gas turbines in which full load steam output is less than or equal to the minimum steam requirement of TWU, it is not likely that any thermal energy will have to be dumped.

Gas turbines and reciprocating engines in the range of TWU's steam and electrical demands were selected for evaluation. For each prime mover the author predicted how much electricity and steam would be displaced by the cogeneration system. These values were converted into average hourly outputs and were then used in the cogeneration evaluation computer program which LAN had developed. Throughout the study it was assumed that no electricity would be sold to the utility.

Other inputs to the program were electricity cost, gas cost, heat rate for the prime mover, operation and maintenance cost, standby power charge, cost escalation rates, interest rate, project capital cost, boiler efficiency, heat content of steam, and plant life. The computer program calculates yearly savings, simple payback, net present value, and return on investment (see Table II-1 for a sample output of the program).

In the final report, the author recommended a six MW (megawatt) two gas turbine (three MW each) system with supplementary fired heat recovery steam generators as the optimum choice for TWU. Besides having the greatest net present value of all the systems analyzed, this two gas turbine system provided other incentives. Supplemental firing of the heat recovery steam generator provides greater flexibility in meeting steam demands, and it is also more

Table II-1

COGENERATION ECONOMIC ANALYSIS

COGENERATION AND THERMAL ENERGY ANALYSIS
CLIENT: TEXAS WOMAN'S UNIVERSITY
PROJECT NO: 1355-20-002-000
PRIME MOVER: TWO RUSTON TB-5000 GAS TURBINES (3457 KW EA. ISO) WITH HRSG'S (21,845 LB/HR EA.; W/ SUPP FIRING 51,000LB/HR EA.)

NUMBER OF UNITS:	2	HEAT RATE		ELEC COST ($/KWH):	0.0705	PLANT COST (K$):	7,067	CAPITAL REQUIRED $(1000)	7,491
AVG OUTPUT (KW):	1,567	(BTU/KWH):	18,208	ESC RATE (%):	10.0	PLANT LIFE (YRS):	20	AMOUNT BORROWED $(1000)	7,491
SITE RATING (KW):	3,055	STEAM ENTH		GAS COST ($/MMBTU)	2.57	PLANT COST ESC (%):	6.0	LENGTH OF LOAN (YEARS)	20
ELEC EFF (%):	18.74	(BTU/LBM):	1,267	ESC RATE (%):	3.0	UNFIRED STEAM (LBS/HR):	24,862	FIRST OPERATING YEAR	1989
HRSG EFF (%):	92.00	FDWTR ENTH		STANDBY ($/KW/MO):	2.50	SUPP FIRED STEAM (LBS/HR):	0	INTEREST RATE(%)	8.00
BOILER EFF (%):	80.00	(BTU/LBM):	180	ESC RATE (%):	10.0	SUPP FIRING GAS (MMBTU/HR):	0	SIMPLE PAYBACK (YEARS)	3.89
AVAILABILITY (%):	96.00	LHV (MMBTU/MCF):	0.950	O&M COST ($K/YR):	158.1	TOTAL STEAM (LBS/H	24,862		
		HHV (MMBTU/MCF):	1.050	ESC RATE (%):	6.0	HRSG CAPACITY (LB/	51,000		

ITEM	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
VALUE OF UTILITIES																				
Electricity	2,044	2,248	2,473	2,720	2,992	3,292	3,621	3,983	4,381	4,819	5,301	5,831	6,415	7,056	7,762	8,538	9,392	10,331	11,364	12,500
Gas Offset by Heat Recovery	752	775	798	822	847	872	898	925	953	981	1,011	1,041	1,073	1,105	1,138	1,172	1,207	1,243	1,281	1,319
Gas Offset by Supplementary Firing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	2,796	3,023	3,271	3,542	3,839	4,164	4,519	4,908	5,334	5,801	6,312	6,873	7,487	8,161	8,899	9,710	10,599	11,574	12,644	13,819
COST OF COGENERATION ($x1000)																				
Gas	1,270	1,308	1,348	1,388	1,430	1,473	1,517	1,562	1,609	1,657	1,707	1,758	1,811	1,865	1,921	1,979	2,038	2,100	2,163	2,227
Standby Charge	101	111	122	134	148	162	179	196	216	238	261	288	316	348	383	421	463	510	561	617
Operation & Maintenance	168	178	188	200	212	224	238	252	267	283	300	318	337	358	379	402	426	451	478	507
Subtotal	1,539	1,597	1,658	1,722	1,789	1,859	1,933	2,011	2,092	2,178	2,269	2,364	2,465	2,571	2,683	2,802	2,928	3,061	3,202	3,351
OPERATING SAVINGS	1,257	1,426	1,613	1,820	2,050	2,304	2,586	2,897	3,242	3,622	4,043	4,508	5,022	5,590	6,216	6,908	7,671	8,514	9,443	10,468
SIMPLE PAYBACK	3.89																			
FUTURE VALUE OF OPERATING SAVINGS	5,426	5,699	5,969	6,237	6,503	6,769	7,033	7,296	7,558	7,821	8,083	8,345	8,607	8,870	9,134	9,398	9,663	9,930	10,198	10,468

CUMULATIVE FUTURE VALUE OF OPERATING SAVINGS	NET PRESENT VALUE	NPV LESS PLANT COST	ROI FIRST YEAR	AVG ROI FOR PLANT LIFE	BENEFIT/COST RATIO
159,007	34,115	26,624	16.79%	22.77%	3.55

BOND PAYMENT TABLE ($1000'S	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Beginning Balance	7,491	7,327	7,151	6,960	6,753	6,531	6,290	6,030	5,750	5,447	5,120	4,766	4,385	3,972	3,527	3,046	2,527	1,966	1,361	706
Payment	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763
Interest	599	586	572	557	540	522	503	482	460	436	410	381	351	318	282	244	202	157	109	57
Principal	164	177	191	206	223	241	260	281	303	327	353	382	412	445	481	519	561	606	654	706
Ending Balance	7,327	7,151	6,960	6,753	6,531	6,290	6,030	5,750	5,447	5,120	4,766	4,385	3,972	3,527	3,046	2,527	1,966	1,361	706	(0.)
OPERATING SAVINGS & BOND CO																				
Annual Operating Savings	1,257	1,426	1,613	1,820	2,050	2,304	2,586	2,897	3,242	3,622	4,043	4,508	5,022	5,590	6,216	6,908	7,671	8,514	9,443	10,468
Debt Retirement	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763	763
Annual Net Operating Savings	494	663	850	1,058	1,287	1,541	1,823	2,134	2,479	2,860	3,280	3,746	4,259	4,827	5,453	6,145	6,908	7,751	8,680	9,705
Cumulative Gross Savings	1,257	2,683	4,297	6,117	8,167	10,472	13,058	15,955	19,197	22,819	26,862	31,371	36,393	41,983	48,199	55,107	62,778	71,292	80,734	91,202
Cumulative Net Savings	494	1,158	2,008	3,065	4,352	5,894	7,717	9,851	12,330	15,189	18,470	22,215	26,474	31,301	36,754	42,899	49,807	57,558	66,238	75,943
Bond Coverage (Annual)	1.6	1.9	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.7	5.3	5.9	6.6	7.3	8.1	9.1	10.1	11.2	12.4	13.7

efficient than producing any additional steam in a conventional boiler. (Supplemental firing means to burn additional fuel in the exhaust gas in order to raise the temperature of the exhaust gas.) Two gas turbines also allow greater flexibility in operation and increase the availability of the system. (The availability is the fraction of time that the system is providing electricity and steam to the user.)

In addition to the electrical capacity being six MW, the cogeneration system can provide 22,000 lb/hr (pounds per hour) of steam without supplemental firing and 51,000 lb/hr with supplemental firing. The author predicted that the cogeneration system would save $1,600,000 the first year and pay for itself in 4.24 years. Capital cost for the system was estimated to be $8,417,000.

The two gas turbine system adds to the savings by operating more efficiently at reduced loads than a single large gas turbine. For example, if the campus electricity demand is three MW, only one of the two gas turbines would be required and it would operate under full load conditions, whereas a single six MW gas turbine would operate at half load, and, therefore, lower efficiencies.

Another important economic factor in favor of multiple gas turbines is the standby power charge. The standby power charge is the monthly amount paid to the utility company to provide power to the user (campus) in the event the cogeneration system goes down. In its simplest form, it is equal to the demand charge multiplied by the capacity of the largest generator in the cogeneration system. At TWU, the standby power charge was estimated to be $2.50/KW/month (dollars per kilowatt per month). This amounts to a savings of $90,000 per year when two three MW gas turbines are compared to a single six MW gas turbine.

4. Non-Technical Problems

The biggest non-technical problem to arise as a result of the feasibility study had to do with the local utility's revenue from TWU. The local electricity company in the City of Denton considers TWU a significant customer for its utility revenues, in the amount of $1.8 million per year.

The City indicated that any revenue lost as a result of installing a cogeneration system at TWU would have to be made up by the residential customers. TWU, like any other major economic factor in an area, has to consider public opinion when considering a project that will likely affect the community. Several avenues were explored to lessen the financial impact on the City, specifically, a smaller cogeneration system and a system from which the City could buy electricity when needed. To date, no agreement has been reached.

B. Southwest Texas State University Central/Cogeneration Plant

The intern's second assignment and first design work for construction documents was the underground thermal utility distribution system for the new central/cogeneration plant at Southwest Texas State Universty (SWTSU). Mr. George Cobb and Mr. Steve Waller were the project engineers for the mechanical department.

1. Background

The new central/cogeneration plant consists of a six MW reciprocating engine generator set, a heat recovery steam generator, two 50,000 lb/hr steam boilers, two 1000 ton absorption chillers, one 1500 ton electric drive centrifugal chiller, and a 12,000 gpm (gallons per minute) cooling tower. The plant, when complete, will supply electricity, steam, and chilled water to much of the SWTSU campus.

2. Task

To deliver the steam and chilled water to the buildings on campus, over ten thousand feet of underground piping is required, some 5000 feet of pipe in a utility tunnel and the balance being direct-buried. The author's task was to design the piping system to deliver the steam and chilled water to the buildings and to return the condensate and chilled water to the new plant.

3. Administrative Assignment

The author should have been in charge of the budget for the thermal utility work but was not given and did not ask for a budget for completing the task. This is the type of error that keeps the project from making a profit. The author has since learned that upon receiving an assignment, one should ask the following two questions:

(1) "What is the completion date?"

(2) "What is the budget for the work?"

Needless to say, one cannot control the budget when the budget is not known.

The author was also to coordinate the drafting associated with his design. The idea is to make the work load as steady and as even as possible. It sometimes happens that the draftsman is given a stack of drawings to complete by a particular date and the draftsman must work overtime to complete the drawings. When he finishes and gives the drawings to the designer or engineer he may be out of work until a review iteration takes place and the drawings are "red marked" for changes. This type of "batch" design and drafting process results in increased costs and an unhappy draftsman. Therefore, the person responsible for a particular part of the project must organize the tasks and assign them as the schedule and design permit. The author has realized that a "continuous" process works much better than a "batch" process.

4. Approach to Task

The preliminary design (design documents) had identified the location of the utility tunnel and the general routings of the direct buried piping. The piping sizes were determined as part of the Utility Master Plan and verified in the preliminary design. The author's task, therefore, was to work out the details of the design and produce construction documents.

Inside the utility tunnel, the pipe was supported and restrained, with allowances made for thermal expansion, and provisions were added for condensate removal from steam lines, and piping take-offs to campus buildings were designed. For the direct-buried piping, the routing of the lines was detailed, expansion loops were sized, condensate removal was added, and piping connections at buildings and in manholes were detailed.

At the entrance to the utility tunnel, inside the new cogeneration plant, the chilled water supply and return lines are 24 inches in diameter. The pipes are reduced in size as the take-offs to campus buildings decrease the flow continuing through the tunnel. (A piping take-off is where a branch connection is made to the main supply line and it includes an isolation valve for the branch. The branch line exits through the tunnel wall and is direct-buried between the tunnel and the building being served.) At the end of the tunnel the lines are 12 inches in diameter. The design working pressure is 150 psig. Thermal expansion is -0.2 inches per 100 feet of pipe. (The negative number indicates that the piping will get shorter when the system becomes operational.)

Thermal expansion of piping can be accommodated by either expansion joints or expansion loops. Expansion joints are compact in-line devices that are inserted between two lengths of pipe. The simplest of all expansion joints is the bellows type. It is composed of a series of stainless steel convolutes which give the expansion joint an accordian-like appearance. As the pipes move, the expansion joint deflects longitudinally to absorb the change in length of the pipe (see Figure II-2). Expansion joints, in general, do not restrain the longitudinal pressure force of the fluid inside the pipe. Therefore, the pipe must be anchored on each side of the expansion joint to prevent the expansion joint from being pushed apart.

Expansion loops absorb thermal expansion through the flexibility that results from changes in direction of the pipe. An expansion loop consists of two lengths of pipe perpendicular to the direction of the pipe requiring the loop and one length parallel to it. As the pipe moves, the expansion loop absorbs the movement just as a spring deflects under load. Figure II-3 shows an expansion loop designed to absorb four inches of thermal expansion in a 12 inch steam line.

In preparing the contract documents, the author used the inherent flexibility of the piping system (changes in direction) to absorb the relatively small changes in length of the chilled water piping.

Chilled water piping was anchored at the entrance to the tunnel, at the end of the tunnel, and at the main branch

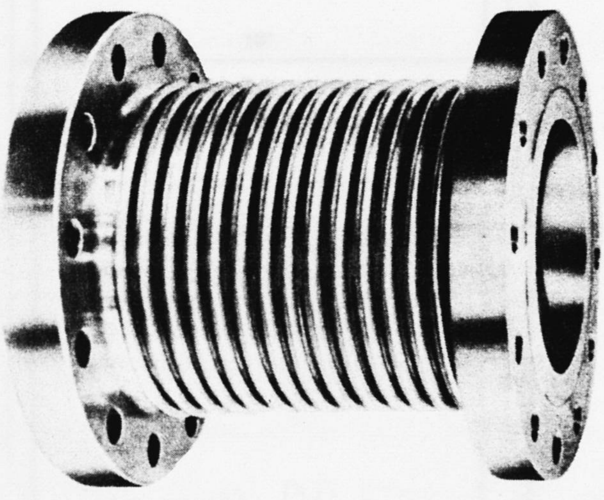

Figure II-2
EXPANSION JOINT

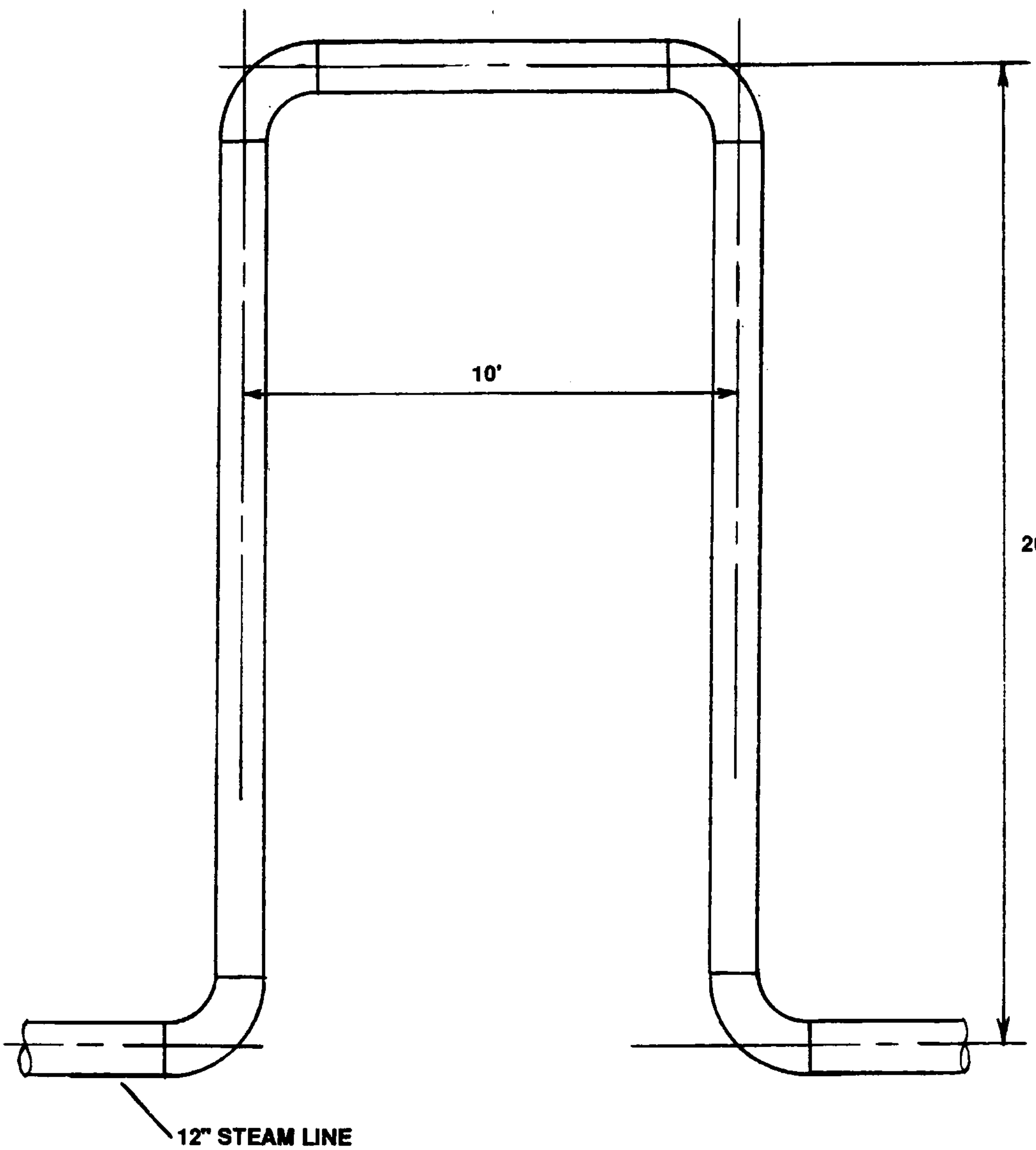

Figure II-3
EXPANSION LOOP

in the tunnel. The project engineers added one more anchor to better control the movement of the system.

The steam line is 14 inches in diameter at the entrance to the tunnel and reduces to 12 inches about half way through the tunnel. The design conditions for the steam system are 50 psig and 366 degrees F. This corresponds to a thermal expansion of 2.7 inches per 100 feet of pipe. The relatively large pipe movement, when compared with the chilled water lines, required the use of expansion joints in straight pipe runs.

Condensate removal is also an important part of a steam distribution system. Generally accepted design criteria state that the steam traps should be located no more than 200 feet apart for systems with unsupervised start-up, and no more than 500 feet apart for supervised start-up. On the construction drawings, a steam trap detail was shown along with the condensate load to be handled by each steam trap.

At several places in the tunnel, take-offs are required in the piping to provide steam and/or chilled water to campus buildings. A typical take-off requires piping, valves, steam traps on steam lines, and air vents. The design should have the shut-off valves in a convenient location, minimize the effect on aisle space, and place the air vents at the high points of the take-off. A typical take-off is shown in Figure II-4.

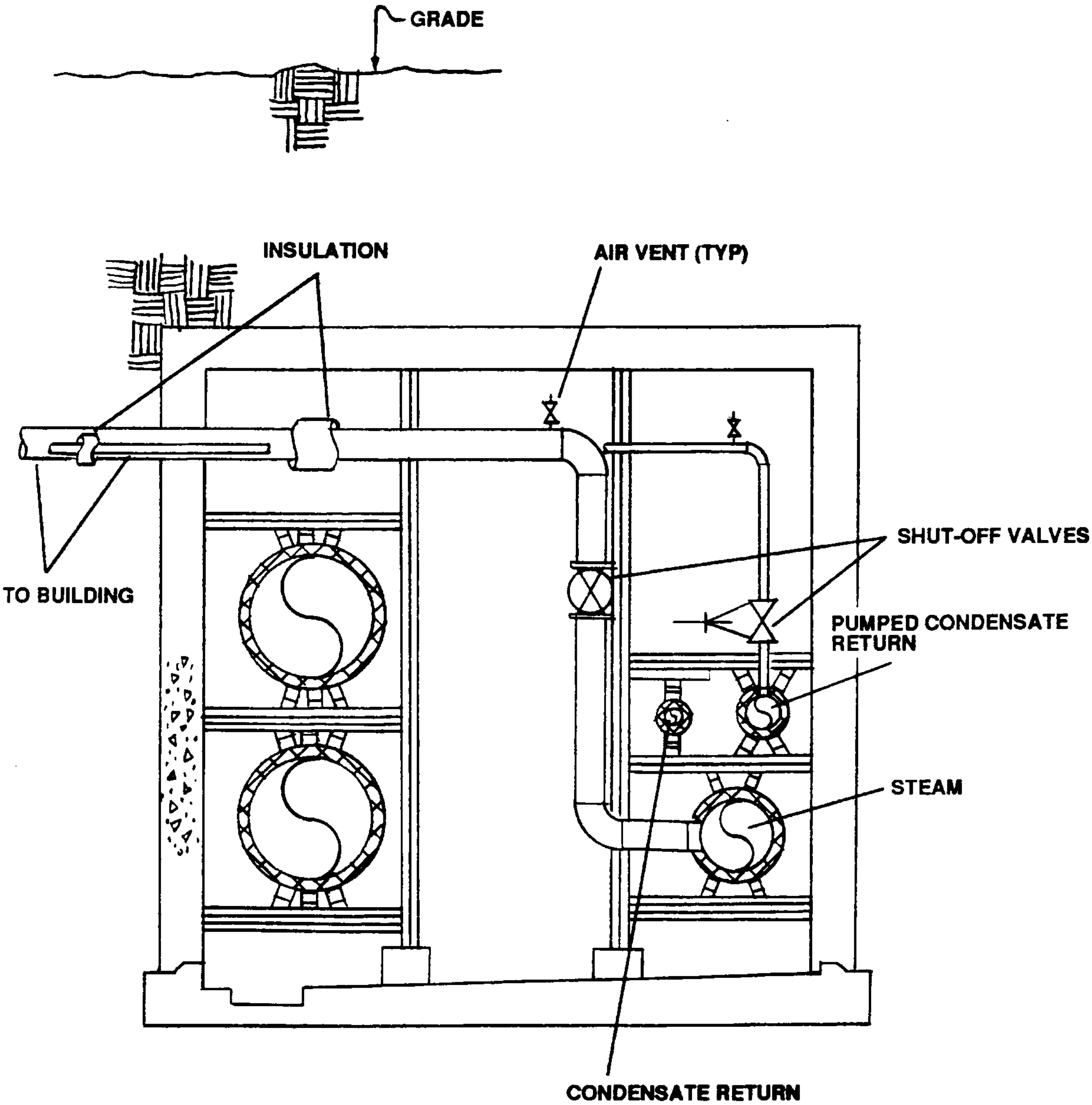

Figure II-4

STEAM PIPING TAKE-OFF

The direct-buried piping design required determining the route to take from the utility tunnel to the building being served, allowing for thermal expansion or contraction, and detailing piping connections at the building and in manholes. The thermal expansion (and contraction) is to be absorbed by expansion loops.

Expansion loops eliminate the internal pressure thrust force that results from the use of expansion joints; however, expansion loops require much more space than expansion joints. For example, to absorb the thermal expansion of four inches in a 12 inch steam line would require an expansion loop that measures 20 feet x 10 feet as shown in Figure II-3. The expansion joint, on the other hand, would be no more than a wide spot in the pipe (see Figure II-2).

Determining the route of the piping from the tunnel to the campus buildings consisted of finding the least disruptive, shortest distance between the tunnel and the building being served. This meant avoiding the removal of any trees if possible, and crossing as few underground utilities as possible.

Survey data of the campus showed only approximate locations of underground utilities in plan view. Very few depths for utilities were known; only a few sewer flow lines were shown on the survey drawings. The depths of existing utilities are extremely important for routing steam lines because of the problem of pocketing the steam line (see Section C for a discussion of direct-buried steam lines). Therefore, the depth of the new utilities will be determined during installation. Also, as part of his contract to install the direct-buried piping, the contractor is to record the location and depth of any encountered underground utility on the "as-built" drawings. This way, at least some additional information will be recorded for future reference.

5. Contribution and Consequence

During the design of the piping system at SWTSU, the author developed a spreadsheet based pipe stress analysis program for comparing calculated stresses to allowable stresses [6]. The program and a sample application are shown in Appendix C. The program was adopted from a slide rule based method outlined in reference [5]. For a little more than the time spent on development of the program a more flexible, user friendly, and powerful pipe stress analysis program could have been purchased.

The author now believes that before setting out to develop a computer program, one should try to put an estimate on the development cost, and compare it with commercially available software. It may be more cost effective to purchase, rather than develop, needed computer programs. Furthermore, many software companies offer demonstration packages which allow a potential buyer to test the program before he buys it.

Public domain computer programs are also available which only cost the price of the publication which documents the program and the price of copying the program onto a magnetic tape or disk. Public domain software, however, is harder to find because it is not widely marketed. It also tends to be less user friendly and too narrow in scope for the practicing engineer.

Equipment manufacturers and suppliers are another source of engineering software. Often, this software is offered at no charge; however, it is usually oriented towards selecting the particular manufacturer's equipment.

C. University of Texas Medical Branch-Galveston Thermal Utility Distribution System Expansion.

1. Background

The University of Texas Medical Branch at Galveston (UTMB-G) has a central thermal energy plant which supplies steam and chilled water to the buildings on the campus by way of an underground piping system (thermal utility distribution system). As buildings are built, the thermal utility distribution system is expanded. Each building added to the system changes the pressure and flow characteristics of the system.

The chilled water and steam systems each consist of two lines, a supply and a return. The main supply lines leave the central plant, then branch to serve the various areas of the campus.

The addition of buildings to a particular branch increases the flow which must pass through the piping. The increased flow results in a higher pressure drop for the branch, which tends to force the chilled water or steam to another branch. Therefore, one or more buildings on the branch may not receive adequate steam or chilled water. In other words, the system becomes unbalanced.

A possible solution to this problem is to connect the ends of two branches together, forming a loop. This allows the distribution system to serve the buildings on the loop by the path of least resistance.

2. Objective

The objectives of this assignment were to close a loop in the thermal utility distribution system (steam and chilled water) and provide connections for a future addition to the system. Mr. Stephen Waller, P.E., was the intern's supervisor for this work.

3. Task

The author was given the task of designing the piping system for accomplishing the objective. Figure II-5 shows the valve pits that are at the ends of two branches of the thermal utility distribution system to be connected.

The new piping system, as directed by UTMB-G, is to consist of a 20 inch chilled water supply and return, a 10 inch steam line, and a six inch pumped steam condensate return. The new lines are to be routed south from the valve pit at the Schools of Allied Health and Nursing Building along Eleventh Street and west from the valve pit at the Learning Resources Center. At the point where the lines intersect, a valve pit is to be provided for housing isolation valves for the new piping system and the future connections. The future connections are to extend to the west and consist of a 10 inch chilled water supply and return, a six inch steam, and a four inch pumped condensate return.

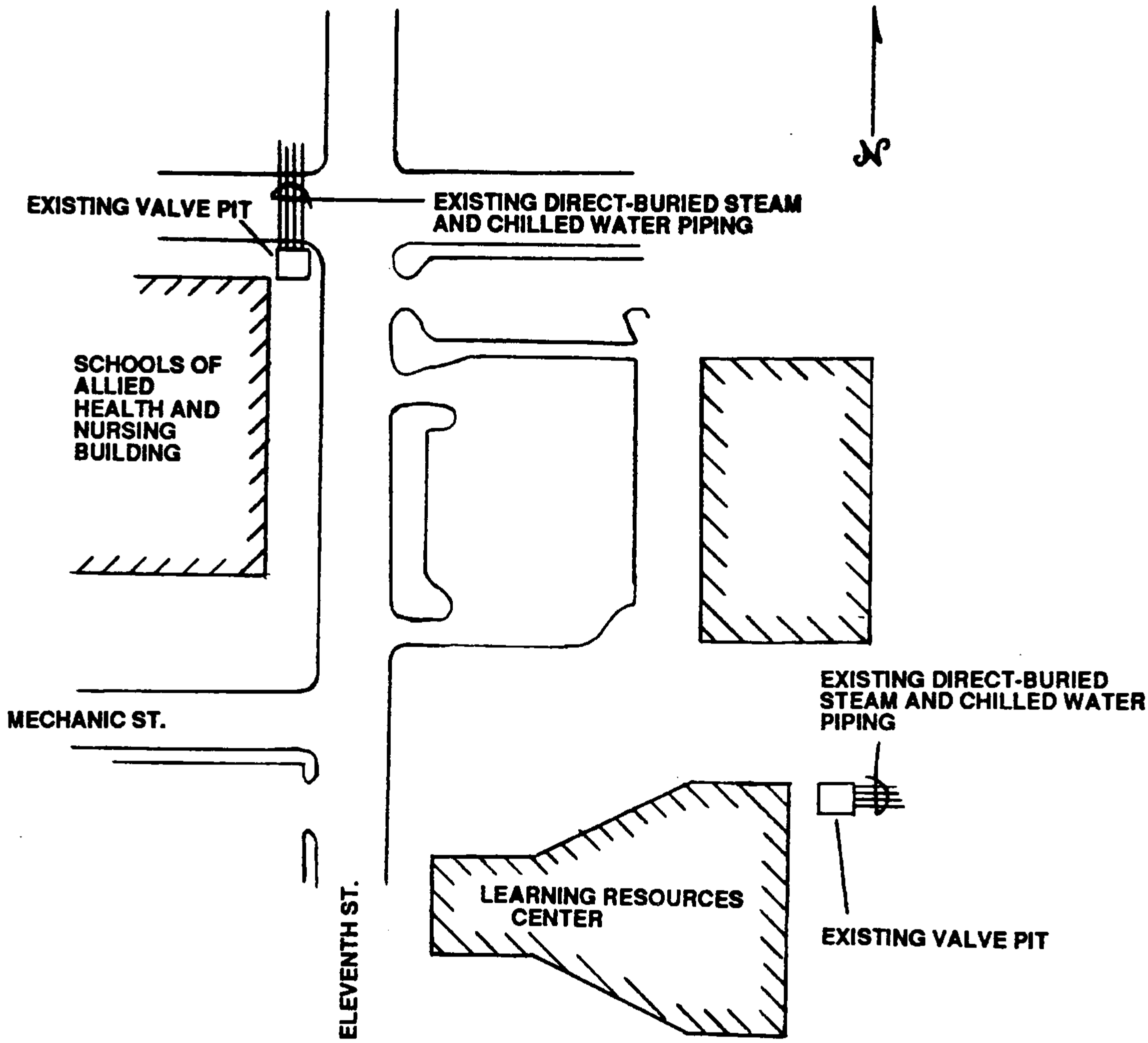

Figure II-5

LOCATION OF EXISTING VALVE PITS

4. Procedure

The author developed two concepts for connecting the steam and chilled water piping systems (See Figures II-6, and II-7.) The concepts were sent to UTMB-G along with a recommendation to use the second concept, Figure II-7. After the owner's concurrence, final design began.

The major concerns when designing direct buried piping are to allow for thermal expansion and avoid "pocketing" of the piping, especially the steam lines. "Pocketing" refers to low points in the piping system where condensate can collect in steam lines or where water cannot be drained in the event the piping is drained. Condensate which collects at low points in steam lines and cannot be removed by a steam trap will eventually be picked up by the steam and accelerated to the speed of the steam (typical steam velocities are 8000-12000 fpm (feet per minute) [7]). The slug of water will impinge on the wall of the pipe at elbows or other devices in the flow and can cause failure of the piping system.

Thermal expansion of the piping system occurs as the result of the temperature difference between the initial temperature of the piping system before operation and the operating temperature. The resulting change in the length of the piping system must be controlled to prevent extreme

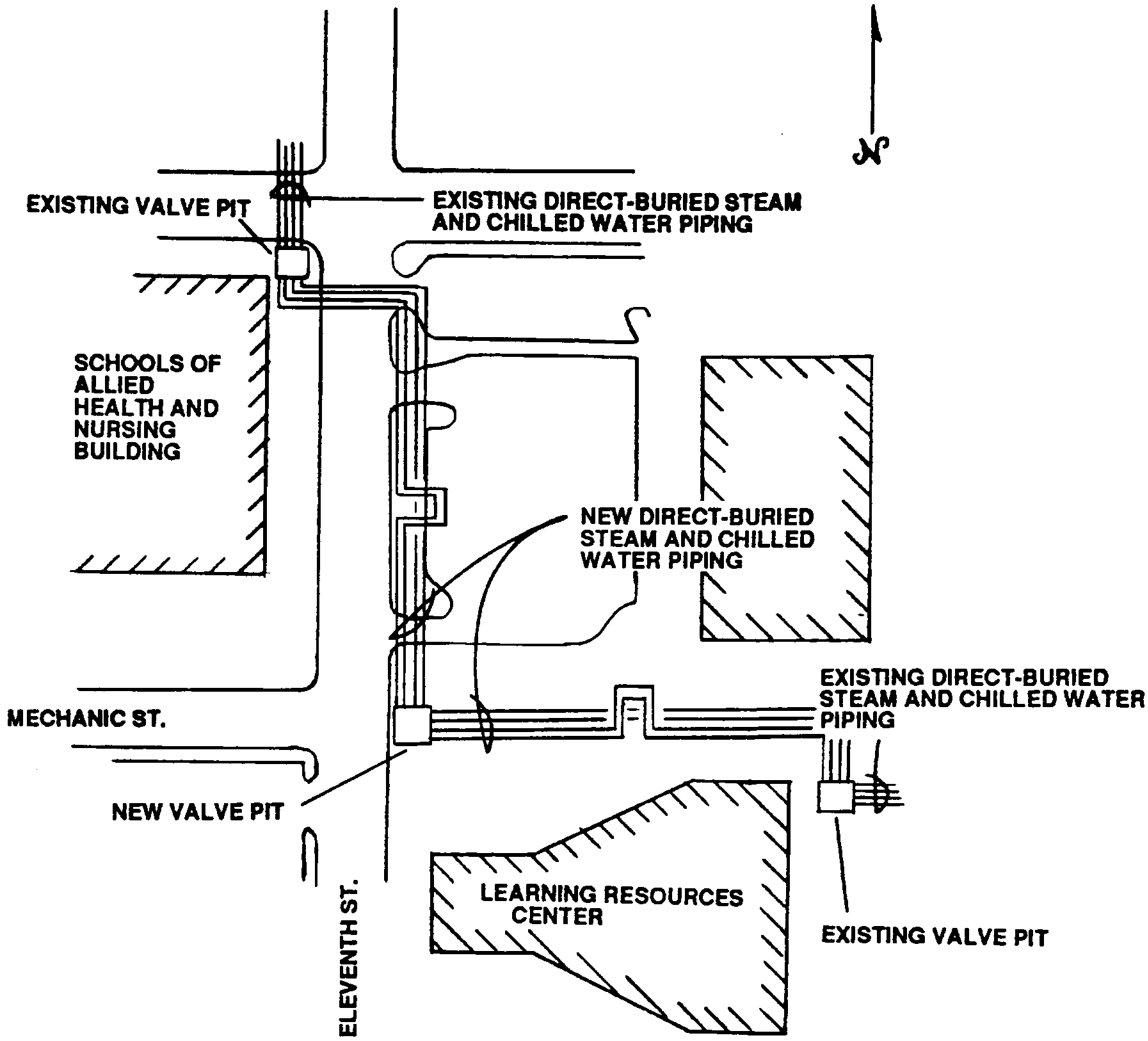

Figure II-6

OPTION "A" PIPE ROUTING

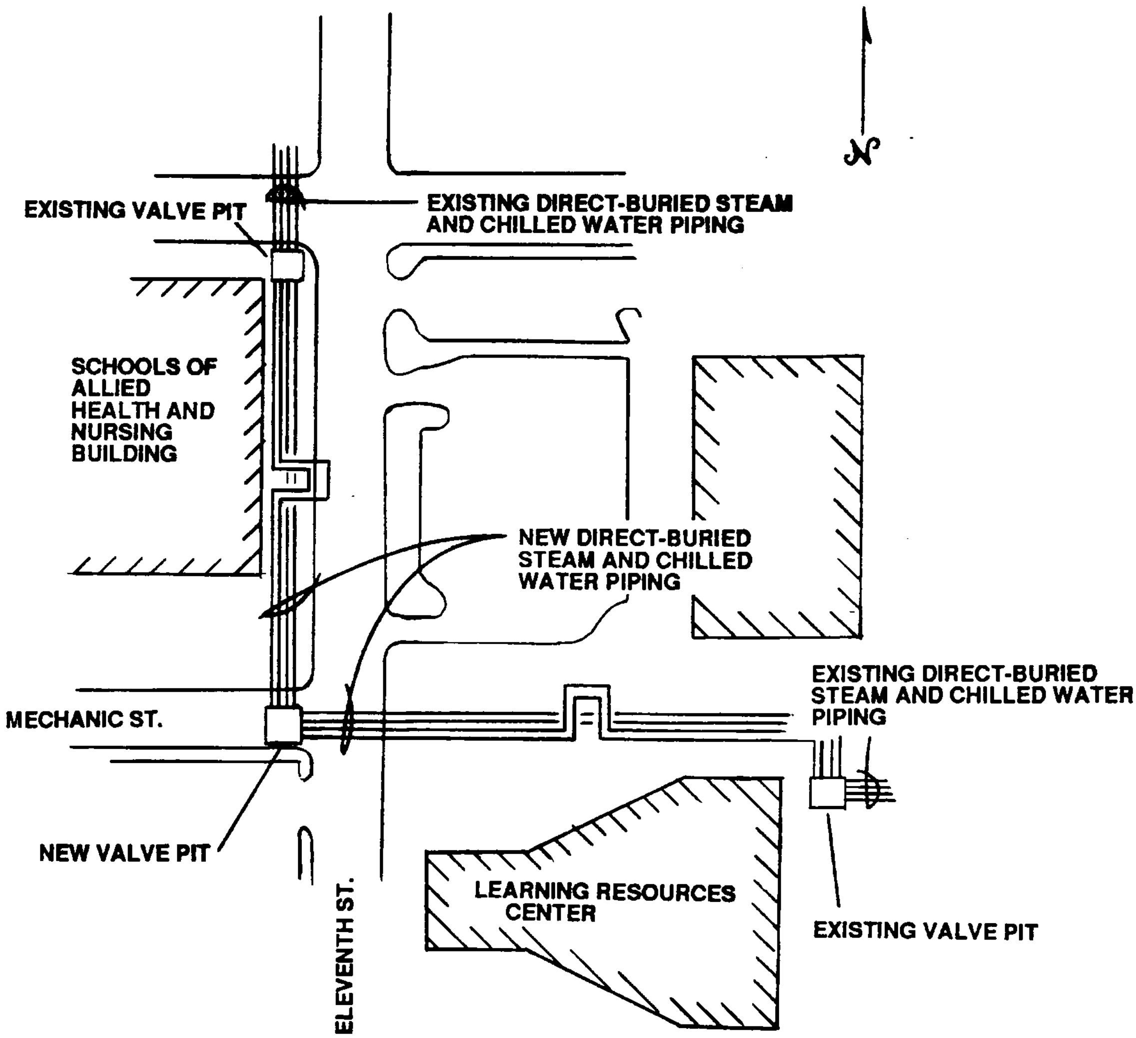

Figure II-7

OPTION "B" PIPE ROUTING

forces on equipment or extreme stresses in the piping system. Expansion loops were chosen for use at UTMB-G due to the fact that space limitations did not dictate the need for expansion joints, and expansion loops do not alter the continuity of the piping system.

The piping system also must compete for space with other underground utilities such as electrical ductbanks, gas lines, sanitary sewers, storm sewers, water lines, and telephone/signal lines. In many cases, including this one, underground utilities already exist. This increases the complexity of determining a proper routing.

The author obtained survey data of the underground utilities in the area from the surveyor hired by the University and from HL&P which has underground duct banks in the area. The author then laid out a piping system which allowed for thermal expansion, avoided other underground utilities, and had no pockets in the piping system.

The author also participated in writing the specifications for the project. The specifications supplement the drawings by adding information important to the project which is not shown on the drawings. Specifications typically specify the criteria which the equipment, materials, and workmanship must meet.

5. Contribution

The author discovered that when allowing for future additions to the underground piping system it is better not to extend the pipes, particularly the ones in steel outer jackets (like the steam and condensates piping), outside the valve pit. The typical construction of underground steam systems consists of a steel pipe which carries the steam. This carrier pipe is surrounded by several inches of insulation, usually calcium silicate or mineral wool. The insulated carrier pipe is concentrically supported inside a round steel outer jacket (often referred to as the conduit) large enough that an annular air space exists between the insulation and the outer steel jacket. The air space allows for drying the insulation and pressure testing the outer jacket. The jacket is coated inside and outside with a material to inhibit corrosion.

When a piping system has taps for future connections, and the pipes for the future connections extend beyond the walls of the valve pit, they may lie unused for many years. When the future connections are eventually made, the weakest area in the system is the outer jacket which has been exposed to the surrounding earth. If the outer jacket leaks, the conduit will fill with water and destroy the insulation, and also accelerate corrosion of the steel carrier pipe.

The ideal method for expanding the piping system is to install all piping for the addition at the same time. The problem, however, is making welds inside the valve pit and getting pipe fittings through the existing manway at the valve pit. (Piping within a valve pit is usually installed before the concrete top is put in place.)

The design of the valve pit at the intersection of Mechanic and Eleventh Street (See Figure II-8) allows for all direct buried piping for the expansion to be installed at the same time. Only one field welded joint is required in the valve pit for each line. The design also allows all fittings to be placed in the pit through the manway. The design for the future connections uses the same pipe sleeves cast into the wall of the valve pit as are used for the new piping. However, instead of installing the piping for the future expansion from the valve to beyond the pit wall, only a short piece of capped pipe is installed to fill the hole made by the sleeve. Then, when the future addition is made, it is only a matter of removing the short capped pipe and installing the service pipes as shown for the current installation.

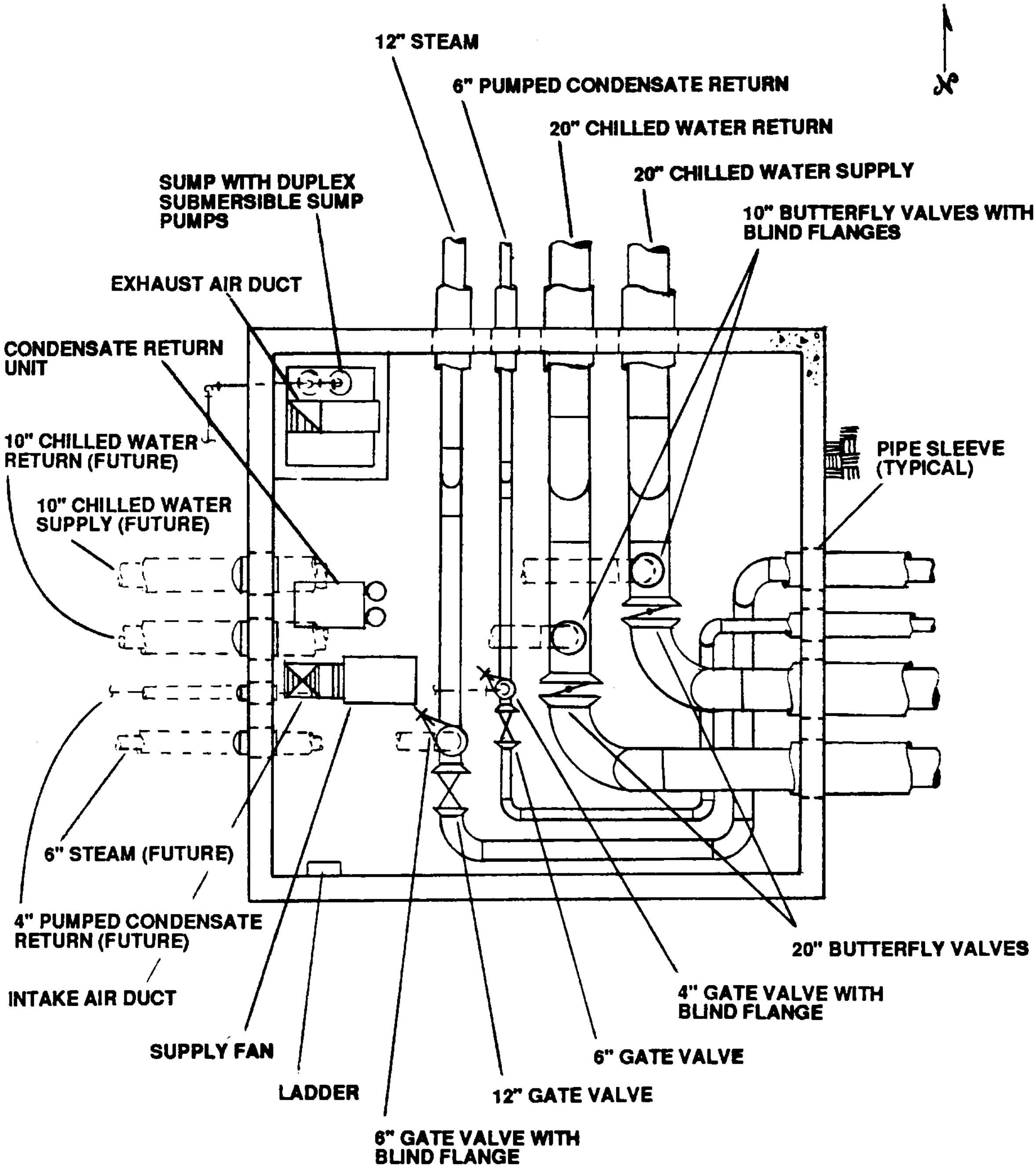

Figure II-8

VALVE PIT

D. NASA Utility Tunnel Chilled Water Tie-In

1. Background

This project developed as the result of a coordination meeting regarding two projects under design. One project concerned modifications in an existing building at NASA. The other was the preliminary design of a new chiller plant. Both projects required connecting to the chilled water headers in the utility tunnel. While discussing the two projects, Mr. Ajay Shah, P.E., the project engineer for the building modification project and the author noticed that the proposed connection of the chilled water lines for the building modification, was in the same vicinity as the connection for one pair of chilled water lines from the new chiller plant.

Mr. Shah and the author discussed the possibility of incorporating the two connections to the chilled water headers into one connection, and decided that this would be the best option for the client. Because the time frames for the two projects did not match, the tunnel distribution system would have to be shut down for each contractor to make his connections to the headers. Combining the two connections would reduce the cost when compared to making two separate connections. Not only would it reduce material costs, but it would reduce inspection, excavation, labor and test costs [4].

Mr. Shah and the author made the recommendation to the project managers for the two projects [4]. They in turn presented the recommendation to NASA. The client agreed with the idea and made the connection to the chilled water headers in the utility tunnel a separate project. The author was selected to act as project engineer.

2. Objectives

The objective of the assignment was to incorporate the two connections to the chilled water header into one connection. The design also was to allow for either project to be connected first without affecting the connection of or service to the other.

3. Task

The task was to design the chilled water connections to the chilled water headers in the utility tunnel, provide the valving necessary to isolate the connections, extend the pipes through the tunnel wall, and cap the pipe ends. Upon completion, it would only be a matter of removing the caps, connecting the new piping for the building modifications project or the chiller plant, and opening two valves to begin operation.

4. Procedure

Mr. Rick Moore, Designer I, and the author went to the Johnson Space Center. We met with the client, made field measurements, and took photographs of the existing conditions.

The part of the utility tunnel where the connection is to be made is approximately 10 feet wide, seven feet high, and runs east/west. At the south side of the tunnel, the 12 inch chilled water lines lie side by side and are supported six inches above the tunnel floor by concrete supports. A four inch steam line and a three inch condensate return line are located approximately three feet above the chilled water lines and are supported by a steel structure attached to the concrete supports below and to the south wall of the tunnel. The steel structure also supports a three inch and a 2-1/2 inch compressed air line, electrical conduits, and two cable trays containing data cables. At the north side of the tunnel is a single cable tray. This cable tray carries the high voltage electrical service conduit and is mounted on the tunnel wall about 3-1/2 feet from the floor. There is a three foot wide walkway between the high voltage cable tray and the steel pipe support structure.

The new chilled water lines for serving the building modification project are eight inches in diameter and are to be located at the south side of the tunnel. The chilled water lines from the new chiller plant are to be 14 inches in diameter and will approach the tunnel from the north. The new chilled water lines will not be contained in tunnels but instead will be direct-buried. The new lines will enter the tunnel through holes cut in the walls.

Refering to Figure II-9, the conceptual design consisted of bringing the 14 inch chilled water lines into the north side of the tunnel as high as possible in order to minimize the effect on the walkway. After crossing the inside of the tunnel, a 14 inch butterfly valve will be placed in each line. An eight inch by 14 inch reducing tee will be provided following each 14 inch valve. An eight inch butterfly valve will be installed at the eight inch side of each reducing tee. Then eight inch pipes are to be routed through the south wall for future connection to the eight inch chilled water lines serving the building modification project. At the 14 inch openings of the reducing tees 14 inch by 12 inch reducers are to be installed. After the reducers, new 12 inch pipes will be

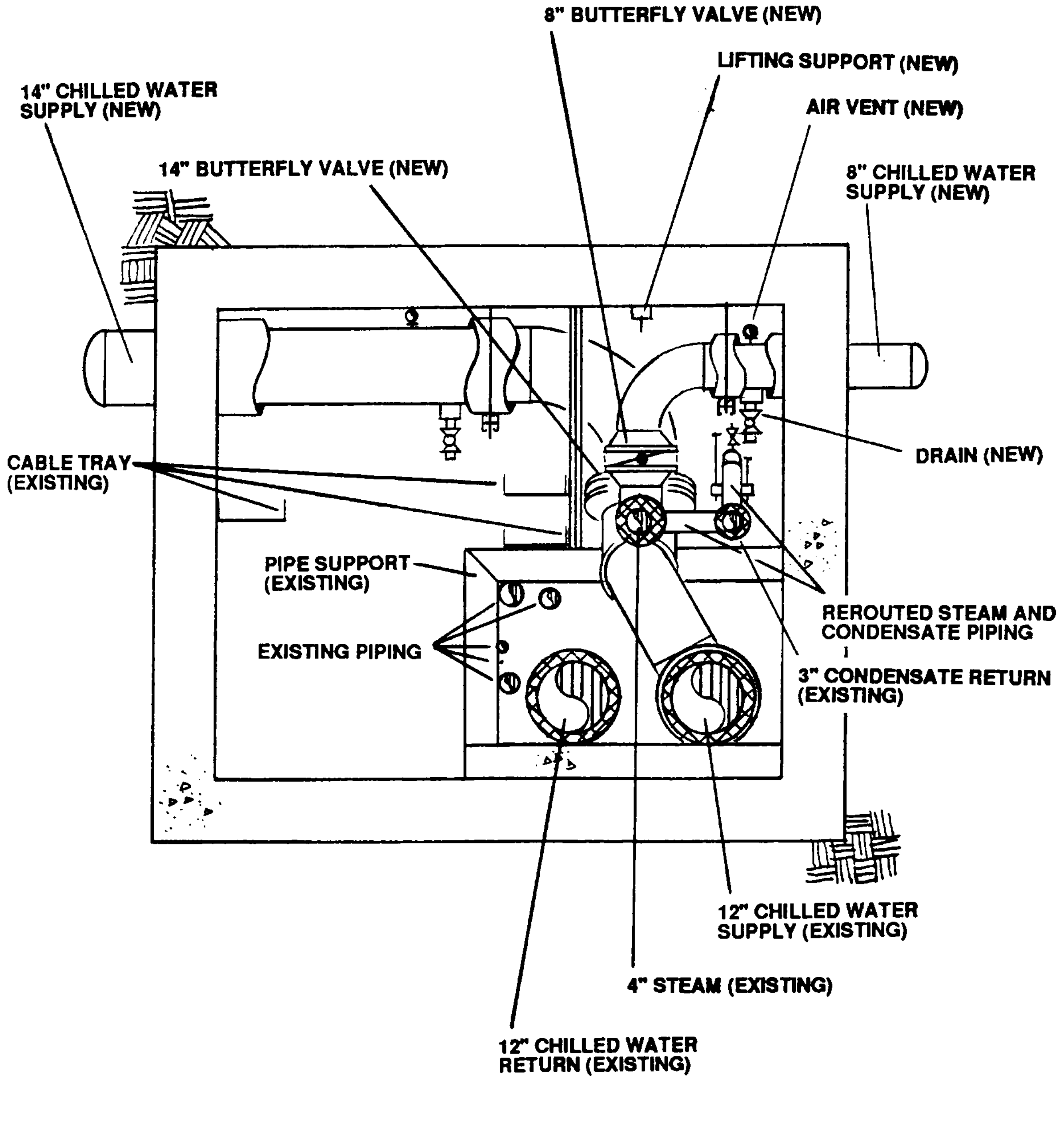

Figure II-9

TUNNEL SECTION

routed and connected to the existing 12 inch chilled water headers.

Mr. Moore worked on the detail design of the piping system. The largest obstacle for the piping was making sure that everything fit and that easy access to the valves was maintained. The author put together the technical specifications for the work and also kept in contact with the client.

5. Administrative

The major administrative goal for the author was to complete the project on time and under budget. Over the internship period, the author had developed a reputation of spending too much time on a problem and thus overrunning the budget.

The project was completed on time and under budget. The author is particularly happy that he had the opportunity to demonstrate his ability to work within a budget and a time frame.

6. Client Contact

Dealing with the client may be as important as the actual engineering work; as is obvious, the client is the one that pays the engineer. Many times the client has in mind what he expects to see as the finished product. This is especially true when the client or his representative is an engineer. Therefore, it is important to keep the client informed of major design decisions as well as seeking his input on these decisions.

In the case of NASA, the client's representative is an engineer and was interested in most aspects of the design. He was well prepared to discuss the design of the chilled water connections and provided his concept of the design.

When the drawings were delivered for NASA's review, the design of the chilled water connection in the utility tunnel located four butterfly valves (two 14 inch and two eight inch) about five feet above the floor of the tunnel. NASA had requested "good" valves, and therefore, the designer selected a flange body butterfly valve with a traveling nut operator from those acceptable in LAN's guide specifications.

There are three types of butterfly valves: flange body, wafer body, and lug body. A flange body butterfly valve allows for the piping downstream of the valve to be removed without having to drain the lines upstream of the valve because it has flanges on each end. A wafer type butterfly valve is sandwiched between two flanged pieces of pipe. The bolts that hold the pipes and valve together go through both flanges. Therefore, if either pipe is removed, the valve will also come out. A lug body butterfly valve is very similar to a wafer type valve except that the lug body has threaded holes around its periphery for accepting bolts from the flanges. This results in the valve being attached independently to both pipes and thus allowing for the removal of the downstream piping without having to drain the line upstream of the valve.

A disadvantage of the lug body and wafer type valve is that they are not as durable as the flange body valve. This is primarily due to the fact that the flange body is a heavier and more rigid valve. A 14 inch flange body valve weighs 210 lb and a 14 inch lug body valve weighs 115 lb.

The design team elected to use flange body valves to ensure the client the greatest durability with the valves. However, during the client review, concern was expressed about the weight of the flange body valve and the ease of removal. The location and weight of the 14 inch valves would make removal of the valves difficult.

The design team developed three options for solving the problem. The first was to provide lifting points in the top of the tunnel for assisting in removing the valves. The second was to move the valves overhead, as that is where the 14 inch line crosses the walkway. A valve could then be removed by supporting the valve from below and then removing the attaching bolts. Putting the valves overhead, however, would reduce clearance of the walkway. The third option was to leave the valves where they were and use a lug body valve which would reduce the weight from 210 lb to approximately 115 lb.

The client elected to go with the first and third options, i.e., use the lighter valve but still provide the lifting points at the top of the tunnel. The drawings were corrected to reflect this decision as well as other comments made by the client. The author then made arrangements to deliver the final drawings and specifications to the client.

As part of the delivery of the final drawings and specifications, the author and the client's representative went over the client's comments from the review process. During this meeting, a member of the client's staff noticed that lug body butterfly valves were being used and that he preferred flange body valves.

The client's representative told the staff member that his department is the one that had initiated and approved the change from the flange body valve to the lug body valve due to weight considerations. The staff member then remarked that anchor bolts will not hold in the top of the tunnel. The client's representative replied that it was also his department that had requested the lifting points and that the structural department had approved the anchor bolts. The staff member then said that he assumed he would get to review the drawings, and left the room.

It appears to the author that the client's project team should consist of the same people throughout the project. This way, once a decision is made, it will not get reversed at the whim of the next reviewer. Fortunately, the client's representative held his ground or else the design would have been changed back to the previous design.

Another change to the original design concerned the connection to the existing 12 inch chilled water lines in the tunnel. The original design consisted of 12 inch weld-o-lets being installed on the existing lines. (A weld-o-let is a pipe fitting which is used to make a branch connection in a pipe without having to use a tee. A hole is cut in the pipe which conforms to the opening in the weld-o-let. The weld-o-let is then welded into place. What results is a reinforced branch connection which performs like a tee fitting. Weld-o-lets are used because they are less expensive than tees, or if a tee cannot be used.)

It is customary to limit the use of weld-o-lets up to one pipe size smaller than the existing line. This is because the hole required to install a size-on-size (line size) weld-o-let significantly reduces the strength of the pipe until the weld-o-let is welded onto the pipe. If the pipe is not carefully supported and restrained it could easily bend at the opening.

The ideal method for making the connection to the existing pipe is to cut the existing 12 inch line and install a 12 inch tee. The problem, however, would be the actual welding required to install the tee. Because the lines are only six inches off the floor of the tunnel and one line is only eight inches from the tunnel wall, it would be extremely difficult to make a proper weld. Therefore, the design team decided to use a weld-o-let.

The reasoning for the use of the line size weld-o-let was explained to the client when he asked why it was used instead of a welded tee as shown in the preliminary design. Being in favor of the tee, the owner suggested that instead of welding the tee in place, install flanges on the pipe and tee and bolt it in. The client described using slip-on type flanges on the existing lines and using a complete weld only between the end of the pipe and the flange (see Figure II-10). The author told the client that any specification from LAN regarding the installation of slip-on flanges would also require a complete circumferential weld at the other end of the flange.

The client insisted on his installation being depicted on the drawings. However, he did want to include a note on the drawings advising the contractor that at the client's

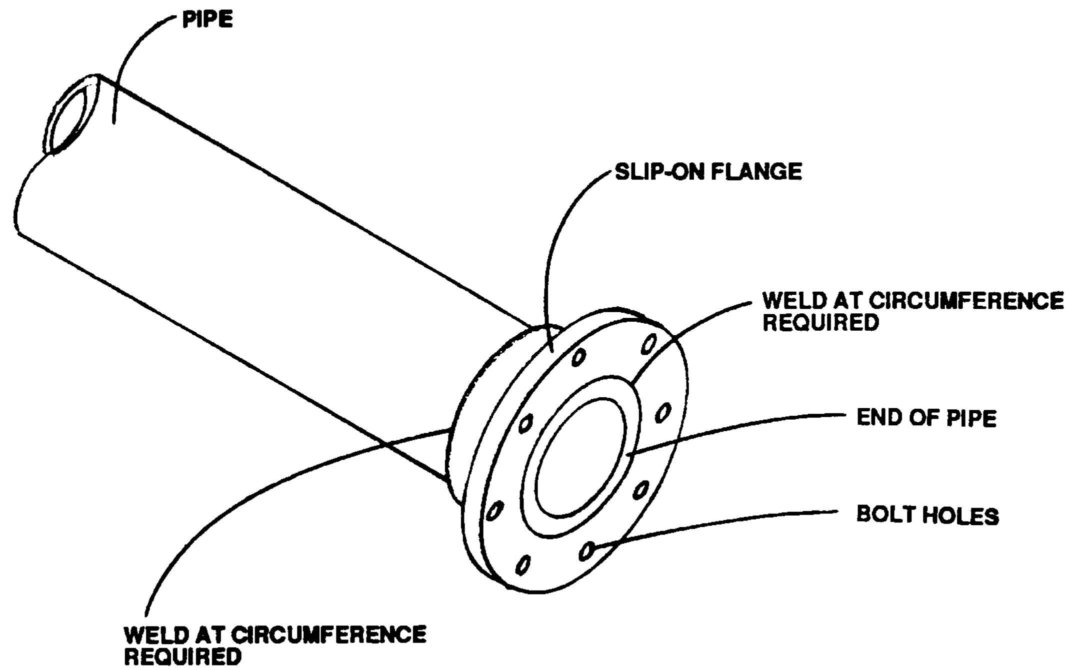

Figure II-10

WELDING OF SLIP-ON FLANGE

option the contractor may use a 12 inch weld-o-let in lieu of the flange and tee arrangement. When submitted for final review, the drawings reflected the client's wishes.

E. Minor Internship Assignments

Besides the four projects discussed above, the author was assigned other smaller assignments during the course of the larger projects. These assignments included project and classroom experiences. The projects discussed below are: a report section concerning air quality regulations researched and written by the author for cogeneration studies; an evaluation of installing and operating a large reciprocating engine which had been in storage for many years; and the preparation of a request for proposals for a third party cogeneration facility at the Harris County Jail. The classroom experiences are: the attendance at an in-house training course for LAN's computer aided design and drafting (CADD) system; and the attendance at a course on a supervisory control system used by the City of Houston.

1. Report on Air Quality Regulations

Construction and operating permits issued by the Texas Air Control Board (TACB) have become as important in the feasibility of cogeneration as the economics. The purpose of the permits is to regulate the amount of emissions released into the air by new sources of contaminants. Permits are issued in accordance with the TACB's air quality regulations. The author was given the task of summarizing the regulations issued by the TACB that pertain to possible cogeneration projects. The resulting report has been used as a section in three LAN cogeneration feasibility studies.

2. Engine Evaluation

LAN's client had purchased a large (7000 KW) reciprocating engine which had been in storage for over five years. The task was to recommend to the client whether or not to put the engine in service. The author was asked to contact as many owners of similar engines as possible and request their experiences with the engines.

The engine that the client had purchased was one of several which had been built initially for standby service at a nuclear power plant. When the plant was not built the engines were put into storage or sold. Most of the engines that were sold ended up in municipal power and peaking plants.

At the conclusion of the investigation, LAN recommmended that the owner not use the engine. The author found that most of the engines had experienced the same mechanical problems and overall satisfaction with the engine was low. Another strike against this engine was the fact that it had been in storage for several years and had not been prepared for storage and also had not been attended to while in storage.

3. Request for Proposals for Third Party Cogeneration at the Harris County Jail

Harris County pursued the possibility of reducing its utility costs at the jail in downtown Houston by seeking a third party cogeneration plant. The county selected LAN to prepare the request for proposals (RFP) and evaluate the proposals.

The purpose of an RFP is to solicit proposals from interested parties which can be compared on an equal basis. The RFP gives all parties the same information and sets out the guidelines for preparing a proposal.

The author was assigned the tasks of gathering pertinent technical data and participating in the writing of the RFP. Technical data which the author obtained included electrical demand profiles, types of building equipment, number of people, hours of operation, and utility costs. Writing of the RFP included incorporating the technical data into the document and stipulating the form and types of information to be included in the proposal, e.g., guaranteed savings and method of supplying standby power.

None of the proposals received was for an actual third party arrangement; they all proposed leasing the required equipment only. The County was not interested in undertaking the responsibility of operating and maintaining cogeneration equipment, therefore, LAN recommended that the County not pursue any of the proposals. The author believes that no third party cogenerator responded because of the small amount of savings available. During the gathering of the technical data, the author found that the thermal (steam) requirements indicated a cogeneration system of 500 KW at best.

4. CADD Training

The author has found the CADD (computer aided drafting and design) system to be a powerful tool even if it is used primarily for drafting purposes. The CADD system allows the user to draw his drawings at full scale and then plot them at any desired scale. The CADD system also is helpful in coordinating the disciplines on a project. For example, once the architects have established the floor plan for a building, the structural, mechanical, and electrical designers can electronically reference the architectural drawings and use them as backgrounds for placing structural steel, routing ductwork, and laying out lighting. Also when the architect changes something on the floor plans, everyone finds out about it, instantaneously.

5. Supervisory Control System Training

The supervisory control system, for which the author attended a training course, is software used for overseeing the controls in a distributed control system. The City of Houston uses this software at several of its wastewater treatment facilities.

In a distributed control system the control of processes is handled by a controller located in the vicinity of the process. The supervisory control system allows the operator to view the processes and communicate with the controllers from a central control room. The supervisory control performs functions which reduce the requirements on the process controllers. These functions include logging trends and alarms, schematic displays of the process with real time process information, and manual override of the distributed controller.

The author received training on the software for the purpose of assisting the computer supplier in troubleshooting his hardware and assisting the City of Houston plant operators. Besides meeting the needs of the City of Houston, the course carried 3.2 continuing education credits (CEU's).

F. Chapter II Summary

In this chapter the author discussed several assignments on which he worked during the internship. This section summarizes these assignments as they relate to the first internship objective.

The first assignment was the cogeneration feasibility study for TWU. The author defined cogeneration, discussed the steps involved in analyzing cogeneration, identified the information required of the user and the possible cogeneration systems, and summarized the recommendation. This demonstrates the author's technical contribution to the assignment.

The report produced for the cogeneration feasibility study represents the author's professional contribution to the project. The report presents the technical aspects of the cogeneration study in a manner that people with non-technical backgrounds can understand.

The second assignment was the design of the thermal utility distribution system for the new cogeneration plant at SWTSU. This was largely a technical assignment for the author. The work consisted of routing steam and chilled water piping in a utility tunnel and also direct-buried, sizing expansion loops, and providing steam traps. The author's significant technical contribution was the development of a pipe stress program for analyzing pipe stress due to thermal expansion.

The third assignment for the author was the design of new thermal utility distribution piping at UTMB-G. This work had technical requirements similar to the second assignment, but it also included professional aspects including contact with the client and the surveyors. The author presented two options for the proposed work to the owner along with his recommendation. The owner concurred with the author and the design proceeded.

The author's technical contribution to this project was the design of the valve pit to allow for future addition to the piping system without having to extend the pipes outside the valve pit. This eliminated the need to have piping for future connections lying exposed to the soil while providing no service to the owner.

The fourth assignment undertaken by the author was to act as project engineer on the utility tunnel chilled water tie-in at NASA. This project was the most comprehensive concerning the first internship objective. The author dealt directly with the owner throughout the project, answering technical concerns, as well as delivering and reviewing the drawings and specifications. The author believes that the project was handled in a professional manner. From a technical standpoint, the author performed the conceptual design of the tie-in and reviewed the detailed drawings. The author's economic contribution came from completing the project within the budget and on schedule.

The fifth section of the chapter presented five minor assignments the author received during the internship. The project assignments represent the authors' contribution to serving the needs of the respective clients. The classroom experiences, however, demonstrate LAN's contribution to expanding the capabilities of the author.

As outlined above, this chapter has demonstrated that the first objective of the internship has been met with the exception of the author's societal contribution. This portion of the objective was fulfilled and is discussed in Chapter IV.

CHAPTER III

BUSINESS EXPERIENCES

The purpose of this chapter is to show that the second of the internship objectives was met. This chapter includes a discussion of the matrix organization in practice, and business ethics of some manufacturer's representatives.

A. The Matrix Organization

The matrix organization is the result of superimposing a project form of organization onto a functional (departmental) form of organization. A functional organization is characterized by grouping similar activities (functions) under a functional title, such as mechanical design, marketing, or quality control. As is evident from the Engineering Division organization chart (see Figure III-1), a functional organization exists. Each grouping represents a particular engineering discipline or area of expertise.

The functional form of organization, to a degree, allows for the acquisition of specialized skills and/or

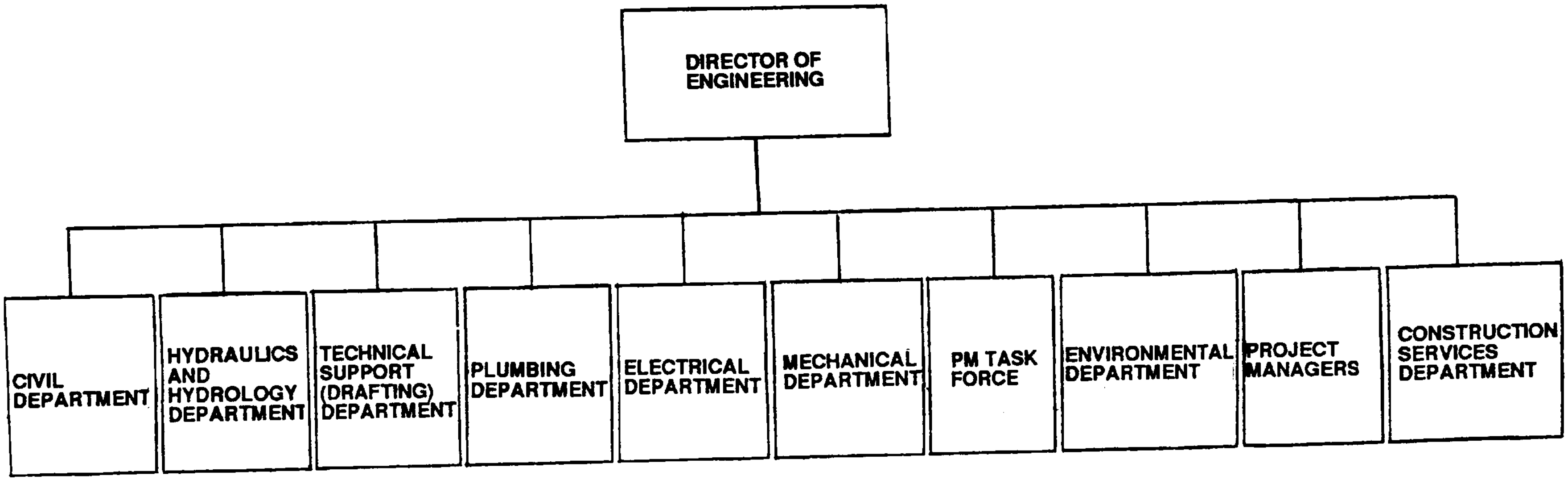

Figure III-1

ORGANIZATION CHART

expensive equipment because the costs associated with these skills and equipment can be shared by the projects that require such services. This eliminates the need to have separate expertise and equipment to justify on the basis of one project.

The functional organization facilitates dissemination of information important to the functional activity. For example, technical articles can be easily circulated among the individuals who will likely use the information in their work.

The problem with the functional organization is that there is no group or individual responsible for coordinating and guiding the efforts of the functional areas. Moreover, the common bond among members of a functional area tends to build a barrier between them and other functional groups.

The project organization brings together, under one organizational roof, all the administrative, technical, and support personnel needed to complete a project. The objective of this type of organization is the completion of a specified task within cost and performance goals, and on schedule. It is not intended to be a self-perpetuating organization; it exists as long as the project is not completed [2]. The project form of organization tends to reduce the time and resources needed to complete the project. This is due to the fact that the project team exists only for the purpose of completing the project.

A shortcoming of the project organization is that it makes use of highly-specialized people more difficult because a full-time specialist may not be needed. As a result, a less specialized person may be used on the project because of other tasks that can then be assigned to him or her, or the budget will have to suffer from inefficient utilization of the specialist.

The matrix organization attempts to combine the strengths of the function and project organizations and nullify their disadvantages. The matrix organization is believed to be efficient because of the inherent competition involved in its implementation. The author found the efficiency of the matrix organization most clearly demonstrated by the project budget allocation process and subsequent budget performance.

The matrix organization can be thought of as many entities (i.e., the functional departments), with each trying to make a profit on the work they perform. In practice, each department strives to stay within the negotiated budget to complete its scope of work. Just as a company is evaluated on its financial performance, each department is evaluated on its budget performance.

Consider a project which requires electrical and mechanical work. The project manager meets with a representative from each department and explains the scope of the project and asks them to develop a budget for doing the work.

The electrical and mechanical representatives submit budgets of $1000 and $3000, respectively. The project manager then negotiates a fee with the client. For the sake of discussion, the fee is $5000; this leaves $1000 to cover the project manager's time, the company profit, travel, etc.

Now consider two scenarios for completion of the project: (1) the electrical group spends $1000, the mechanical group spends $3000, and all other expenses add up to $500, leaving a company profit of $500; or (2) the electrical group spends $800, the mechanical group spends $3100, and all other expenses amount to $600, also resulting in a $500 profit. Obviously, in each scenario the profit on the project is the same; however, the budget performance of each department is different in each case.

In the first scenario, both departments completed their respective scopes of work using their entire budgets. This performance indicates good budget estimating and good budget control. In the second case, the electrical department completed its work $200 under budget while the mechanical department was $100 over budget. Even though the profit is the same, the mechanical department's budget performance was poor.

It is the responsibility of the department's representative, the project engineer, to negotiate a budget with the project manager which he can meet. What sometimes happens, though, is that after a sufficient budget is negotiated, the scope of work changes or redesign is required and the project engineer does not attempt to, or does not get his budget adjusted for such changes. The argument might be that the fee has already been negotiated with the client and that there is no more money available; therefore, the work has to be completed with the current budget. Besides, the company's profit or loss on the project will not be affected since the scope of work is already defined and the fee is set.

It is true that the overall financial success of the project would not be affected by altering an individual department's budget. However, when the department is evaluated on the basis of its budget performance, it will rate poorly if it does not meet its budget constraints. For this reason, it is important that the budget be updated as required.

Just as the project manager is responsible for the overall project and the project engineer for his department's work, each person assigned to a project needs to understand the scope of the tasks assigned to him, and the budget allowed to complete the work. This way, each person can contribute to the efficiency of the project completion by his own performance.

B. Manufacturers' Representatives

When performing any phase of engineering services, the engineer must often rely on manufacturers' representatives (vendors) for information. The objective of the engineer is to determine the right equipment or system for the client, and the objective of the vendor is to sell his equipment or system.

The author's experiences with vendors varied from good to bad. Some vendors represent their equipment fairly and honestly, while others rely on deception or unprofessional means to sell their products.

While working on one project the author helped write technical specifications for a direct-buried, preinsulated, steam and condensate piping system. The author discussed the offerings of several manufacturers with the project engineer who recommended a particular system based on his good experience with the product and the manufacturer.

The recommended preinsulated piping system consisted of the carrier pipe (i.e., the pipe that actually conveys the steam or condensate) covered with the specified thickness of calcium silicate insulation. The carrier pipe and insulation are concentrically supported inside a steel outer jacket (conduit) large enough for a specified air space to exist between the insulation and the conduit. The outer jacket is painted with primer on the inside and is covered with epoxy on the outside to protect it from corrosion.

Since the project was a government contract, the specifications had to ensure a competitive bid. The author found that there were at least two recognized manufacturers that produce this type of a system and asked each to come by and discuss his particular product.

Both representatives brought new catalogs of the preinsulated piping systems offered by the manufacturers. The author explained the desired type of system. Each vendor identified the system in their catalog that would meet the requirements.

The specifications were then written for the piping system as well as stating the acceptable manufacturers and their respective products. The author would not know which system was the successful bidder until the submittals came from the general contractor.

When the submittal for the preinsulated piping system was received, the author noticed that the system submitted was not one of the two expected, even though it was from one of the two manufacturers with which the author had spoken. However, the catalog "cut-sheet" which came with the submittal showed that the system would meet the specifications.

The author discussed the situation with the project engineer who then called the vendor and the manufacturer. The vendor said that he knew nothing of the system submitted since it was not in the catalog; and the manufacturer admitted that it was not a catalog item at that time. The submittal was rejected because it was not the system specified by name and was not a standard offering of the manufacturer.

The second submittal for the preinsulated piping system contained the same "cut-sheet" that had been submitted the first time, except that the trade name of the system had been changed to infer that it was the second generation of the specified system (e.g., "System II" might be the second generation of "System I"). After discussing this with the project engineer, the department head, and the construction manager, it was decided to accept the submittal.

The author feels that he was deceived by both the manufacturer and its representative by their intention to offer a product different from the one asked for in the specifications, and even going so far as to modify the "cut-sheet" so that it appeared that the product was the second generation of the one asked for. The product was accepted because the information provided on the "cut-sheet" showed that the system would meet the specifications. However, the system was somewhat inferior to the one offered in the catalog.

C. Chapter III Summary

In this chapter the author discussed some of his business related experiences. This section summarizes these experiences as they relate to the second internship objective.

The first section describes the matrix form of organization and compares it with the organization form from which it is derived, the functional and project organizations. The author discussed the inherent competition of the matrix form in practice. The matrix organization should be very efficient in the use of funds available for the project. The author, however, found that some people do not understand their role in the matrix organization and, therefore, do not make sure that the budget is monitored and/or properly adjusted when changes in scope occur.

The second section of the chapter concerns the author's experience with two manufacturers and their representatives.

Some vendors represent their products fairly and honestly; others use deceptive means to sell their product. The author described a case involving the specification of a pre-insulated piping system. The manufacturer submitted a product which was not the one he had led the author to believe would be submitted. The manufacturer even went so far as to change the name of the product so that it had a name similar to the originally specified product.

As shown in this chapter and summarized in this section, the author has met the second objective of the internship. He has enhanced his understanding of the consulting engineering business.

CHAPTER IV

SUMMARY

A. Internship Objectives

The preceding chapters have presented a summary of the author's internship at Lockwood, Andrews and Newnam, Inc. Specific internship assignments and experiences in the engineering business have been discussed. This final chapter is intended to show how the internship experiences relate to the internship objectives presented in Chapter I.

The first objective of the internship was that the author contribute to LAN's efforts to meet its goals and obligations: professional, technical, economic, and societal. To ensure the level of professional services offered by LAN, all the design work and studies that go to the clients have quality control reviews. These reviews check for interdisciplinary coordination, consistency in drawings, and any errors. All final products of the assignments presented in this report received the same scrutiny as any other LAN project. The author believes, based on the quality control comments, that he produced the high quality professional services for which LAN is known.

Secondly, the author demonstrated professionalism in dealing with the client. During the NASA assignment the author kept the client's representative up to date regarding the project. As evident from the change in the butterfly valves being used, the author also provided for the client's representative to have an influence on the final design by developing options from which the client may make a choice.

Finally, LAN encourages its technical people to obtain professional registration. The author plans to apply for his engineering license in the coming year.

The author's technical contributions include improvements to the cogeneration analysis model which was used in the study for TWU and the development of a LOTUS 1-2-3 based pipe stress program which was used on the SWTSU and UTMB-G projects. The major improvement to the cogeneration analysis program was the addition of a subprogram which estimates the amount of fuel needed during supplemental firing of a waste heat steam generator to produce a given amount of steam. The pipe stress program estimates the stress developed in a piping system due to thermal expansion (or contraction) of the system.

Concerning the economic aspect of the first objective, LAN's success is dependent on projects being completed within the budget alloted. The author contributed to this success by completing the NASA project within budget and on schedule.

LAN supports many community service functions and charitable organizations. Although not specifically discussed in the report, the author met the societal requirement of the internship by participating in LAN sponsored events as well as volunteering his time to the Sugar Land Exchange Club.

The second objective of the internship was for the author to enhance his understanding of the engineering business. The author demonstrated this objective through his experience in the matrix form of organization and with two manufacturers' representatives.

The matrix organization is intended for use by companies that undertake projects which require expertise from various disciplines. It promotes an efficient use of people and equipment through the sharing of these resources between projects. It also promotes good budget performance by allowing the individual in charge of a specific part of the project to negotiate a budget for his particular scope of work.

A shortcoming in its application at LAN is the lack of action on the part of the project engineer to negotiate a change in budget with the project manager when the scope of work is changed. The train of thought is that the budget negotiated with the client is fixed, and it was agreed that the change be absorbed by the existing budget. Even when this happens the group responsible for making the changes must seek additional budget support instead of absorbing the costs of changes over which they had no control; if not, the project engineer becomes responsible for the poor budget performance. The idea is to make sure that the person(s) responsible for negotiating the budgets with the client get a true picture of what it is costing to complete the project.

The professional (or unprofessional) behavior of a manufacturer and his representative has had an effect on the author. The author feels that it is going to be difficult to specify the use of a product which is offered by a manufacturer or representative who has forced the use of another product in lieu of the intended product. The substitution of the specified pre-insulated piping system by a product not contained in the manufacturer's catalog makes the author suspicious of dealing with the manufacturer and his representative in the future.

B. Closing Remarks

The author enjoyed his internship at LAN. Being a member of LAN, the author has experienced the commitment to quality that permeates the organization. LAN's excellent reputation is reinforced by the employees' pride in being a part of this excellent engineering firm.

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APPENDIX A

INTERNSHIP PROPOSAL

Internship with

Lockwood, Andrews & Newnam, Inc.

ENGR 684

A Proposal

by

Jeffery Noel Bolander

Approved by:

W.D. Turner
Committee Chairman, MEEN

M. Rabins
Department Head, MEEN

S. Somasundaram
Committee Member, MEEN

C. A. Erdman
Doctor of Engineering
Program Coordinator

J. A. Caton
Committee Member, MEEN

K.E. Shinn
Committee Member, LAN

D. D. VanFleet
Committee Member, MEEN

L. ~~D~~ Berner, Jr.
Dean of Graduate College

July 1986

Proposal

The proposed internship in partial fulfillment of the requirements for the degree of Doctor of Engineering is with Lockwood, Andrews and Newnam, Inc. (LAN). The one year period required for the internship will begin July 7, 1986.

LAN's business is engineering, architecture, planning, and project management. It is a Houston based firm and is in its fifty-first year of service.

The intern will be a member of the Mechanical Department of the Engineering Division. Naturally, the department is responsible for the mechanical engineering needs of the client and company. Most of the department's work is in HVAC (heating, ventilating, and air conditioning), central plants (e.g., chiller and boiler plants and cogeneration facilities), and waste water treatment plants.

The objectives of the intern are: 1) to contribute to LAN's effort to meet its goals and obligations: professional, technical, economic, and societal and 2), to enhance his understanding of the consulting engineering business.

The responsibilities of the intern will include mechanical engineering support and administrative duties for the projects assigned to him. This will include mechanical design, drawings, and calculations required by the project. The intern will participate in coordinating interdisciplinary projects, i.e., assure that the other members of the project team are aware of the mechanical aspects of the project and that the requirements of the other disciplines are taken into account during mechanical design. The intern will also be responsible for monitoring job cost and the schedule for his particular part of the project.

Projects on which the intern is scheduled to work include cogeneration feasibility studies. The scope of the studies is to determine the economic and practical feasibility of cogeneration. A report will be written that summarizes the analysis, states the feasibility of cogeneration, and when applicable recommends the size and type of equipment required.

The intern will also work on the design of a new central/cogeneration plant. The assignment will include equipment selection, equipment layout, piping, and specification writing.

A third task planned for the intern is to become familiar with the air quality regulations as they pertian to the projects pursued by LAN. This work will likely involve identifying and obtaining documents from the Texas Air Control Board and the Environmental Protection Agency.

The benefits of this internship to the intern are several. The intern will have the opportunity to apply the knowledge gained from his formal education. He will gain practical engineering experience from working with engineers who have been in the consulting engineering field for many years. He will also have first-hand experience working in the matrix organization used by LAN.

Mr. Kim E Shinn, P.E., is the Mechanical Department Head; he will be the internship supervisor and will serve on the intern's advisory committee. A copy of Mr. Shinn's resume is attached to this proposal. His address is:

Mr. Kim E Shinn, P.E.
Mechanical Department Head
Lockwood, Andrews & Newnam, Inc.
1500 City West Boulevard
Houston, TX 77042
(713) 266-6900

The intern will file an interim report with his committee chairman and the internship supervisor every three months during the course of the internship. At the end of one year the internship report will be written and submitted to all committee members for approval.

KIM E SHINN, PE
Mechanical Engineer

Education
Texas Tech University, Bachelor of Science cum laude, Engineering Physics
Texas Tech University, Masters of Science, Mechanical Engineering

Registration
Texas No. 51106

Membership
Texas Society of Professional Engineers
National Society of Professional Engineers
American Society of Mechanical Engineers
Engineering Council of Houston
Tau Beta Pi

Experience
Mr. Shinn specializes in the design of mechanical systems including heating, ventilation and air conditioning; plumbing; and fire protection. He has been responsible for equipment selection and the preparation of mechanical construction documents. He has worked with governmental, commercial and industrial clients. He recently completed a three-year assignment in Spain which has broadened his experience with governmental clients and included a variety of multidisciplined projects. He has provided project direction and design for the rehabilitation and improvement of several U.S. military installations in the Mediterranean basin including unaccompanied personnel housing, billeting, aircraft maintenance and support facilities, petroleum fuel storage and distribution systems, central steam plants, security enhancement and building renovations. Representative projects include:

- Cogeneration Feasibility Study; Texas Tech University, Lubbock, Texas
- Central Plant Expansion; Southwest Texas State University, San Marcos, Texas
- Emergency Generator Design/Installation; Diagnostic Center Hospital, Houston, Texas
- Central Plant Expansion; Prairie View A&M University, Prairie View, Texas
- Electronics Building; General Dynamics, Fort Worth, Texas
- Renovation of ATACMS Program; LTV Aerospace & Defense Company, Fort Worth, Texas
- Composite Lay-Up Expansion; LTV Aerospace & Defense Company, Fort Worth, Texas
- Integrated Machining System; LTV Aerospace & Defense Company, Fort Worth, Texas
- Open-End Services Contract; OICC MED, Torrejon Air Base, Rota, Spain
- Open-End Services Contract; OICC MED, Naval Station, Rota, Spain
- 69th Street Wastewater Treatment Plant; City of Houston, Houston, Texas
- Ball Valve Plant; Cameron Iron Works, Inc., Sealy, Texas
- Technical Center; Cameron Iron Works, Inc., Brookshire, Texas

APPENDIX B

PROGRESS REPORTS

P. O. Box 35437
Houston, TX 77235
November 19, 1986

Dr. W. D. Turner, P.E.
Department Head, Mechanical Engineering
Texas A & M University
College Station, TX 77843

Dear Dr. Turner:

This is the first of four interim reports to be filed with you and my advisory committee during the internship. My work experiences at LAN over the first quarter of the internship are summarized below.

For the most part my efforts have concerned a cogeneration feasibility study for Texas Woman's University (TWU). We recently finished the study and submitted a report to TWU in which we confirmed the economic attractiveness of cogeneration for the Denton campus. I gathered much of the information required to perform the analysis from TWU and vendors. I also performed the economic analysis and wrote much of the final report.

From a job cost standpoint (i.e., the budget allotted to complete the project), I was slightly over budget. The project, however, was completed on schedule.

As you are aware, LAN uses the matrix form of organization; therefore, each project received has a project team. The members of the team are drawn from the functional departments required to complete the task. I do not think the feasibility study was a true test of the effectiveness of the matrix organization because of the small number of people (5) on the project team. However, the project ran smoothly.

LAN is currently putting together a request for proposals for a third party cogeneration plant at the Harris County Jail in downtown Houston. My responsibility is to assist in gathering pertinent data and writing the document.

As part of another project, I have been working on the evaluation of a 6000 KW reciprocating engine which LAN's client is considering purchasing to use in a cogeneration plant. The engine has been in storage about ten years and was originally bought for service in a nuclear power plant which was never built. I have been contacting operators that have the same model engine as the one in question in order to find any common problems with the engine, the degree of satisfaction with manufacturer service, and the level of confidence with the engine. I will pass along my findings to the project manager who will present LAN's recommendation to the client.

Because of the environmental impact of cogeneration, I have also been researching the regulations concerning air quality. I have written a short report on this subject which has been included in three of LAN's cogeneration studies.

My next report will cover the second quarter of my internship.

Sincerely,

Jeffery N. Bolander

cc: Mr. Kim E Shinn, P.E.
Mechanical Department Head
Lockwood, Andrews & Newnam, Inc.
1500 City West Boulevard
Houston, TX 77042

P. O. Box 35437
Houston, TX 77235
January 26, 1987

Dr. W. D. Turner, P.E.
Associate Professor, Department of Mechanical Engineering
Texas A & M University
College Station, TX 77843

Dear Dr. Turner:

This is the second of four interim reports to be filed with you and my advisory committee during the internship. My work experiences for the second quarter of the internship are summarized below.

Concerning the evaluation of the reciprocating engine included in the first interim report, LAN recommended that the client not purchase this engine due to similar major failures in engines of the same model and lack of operator confidence in operating the engine at full load.

LAN is currently designing a $15 million central/cogeneration plant for Southwest Texas State University (SWTSU). The plant will include 2 - 1000 ton absorption chillers, a 1500 ton centrigugal chiller, a 6000 KW engine generator set, a heat recovery steam generator, and two 100,000 lb/hr boilers. The project will also include a thousand feet of underground utility tunnel and several thousand feet of direct-buried piping for steam and chilled water distribution.

I will be primarily involved with the design of the steam and chilled water distribution system in the utility tunnel and direct-buried. I will also be working on the HVAC system design for the control room and the electrical switchroom in the plant.

Because of a coincident project in the same vicinity at SWTSU by another architect, I have been helping coordinate the two projects by providing drawings and information to the architect. A new library which the architect is designing will include a utility tunnel with which our tunnel must connect and in which we will install steam and chilled water piping.

LAN is also currently updating a central plant master plan for a hospital complex at the Houston Medical Center. I have been planning equipment installations, relocations, and removals in order to meet the future utility requirements of the hospital. Space in the central plant is very limited and, therefore, must be efficiently utilized.

My next report will cover the third quarter of my internship.

Sincerely,

Jeffery N. Bolander

cc: Mr. Kim E Shinn
Mechanical Department Head
Lockwood, Andrews and Newnam, Inc.
1500 City West Boulevard
Houston, TX 77042

P. O. Box 35437
Houston, TX 77235
May 13, 1987

Dr. W. D. Turner, P.E.
Associate Professor, Department of Mechanical Engineering
Texas A & M University
College Station, TX 77843

Dear Dr. Turner:

This is the third of four interim reports to be filed with you and my advisory committee during the internship. My work experiences for the third quarter of the internship are summarized below.

The central/cogeneration plant design for Southwest Texas State University (SWTSU) is now being reviewed by the University. It is expected that the job will go out for bid in June. As I wrote in the previous interim report, I am responsible for the mechanical aspects of the new thermal distribution system at SWTSU and parts of the HVAC system in the plant.

I have recently attended two training and development courses. One was concerned with a supervisory control software package which is being implemented by LAN for the City of Houston. This package is used to communicate with all the controllers in a distributed control system (e.g., an energy management system). I will use my knowledge of the software to assist the operators at the City of Houston. Incidentally, the course carried with it 3.2 continuing education units.

The other course I attended concerned how to use the CADD (computer aided design and drafting) system at LAN. I have had the opportunity to use the system for the SWTSU project.

We have submitted preliminary design documents for a central plant addition and thermal distribution system expansion at University of Texas Medical Branch at Galveston (UTMB-Galveston). This information will be used by UTMB-Galveston to gain funding for the project. My responsibility on this project was to prepare preliminary design drawings and specifications.

Dr. W. D. Turner, P.E.
May 13, 1987
Page 2.

We are evaluating the proposals received in response to the request for proposals for a third party cogeneration plant that LAN prepared for Harris County Jail in downtown Houston. I am evaluating the proposals and will prepare a report to be submitted to our project manager. He will then prepare a recommendation to the County.

The next interim report will cover the last quarter of my internship.

Sincerely,

Jeffery N. Bolander

cc: Mr. Kim E Shinn
Mechanical Department Head
Lockwood, Andrews and Newnam, Inc.
1500 City West Boulevard
Houston, TX 77042

P. O. Box 35437
Houston, TX 77235
August 19, 1987

Dr. W. D. Turner, P.E.
Associate Professor, Department of Mechanical Engineering
Texas A & M University
College Station, TX 77843

Dear Dr. Turner:

This is the last of four interim reports to be filed with you and my advisory committee concerning my internship. My work experiences for the last quarter of the internship are summarized below.

The central/cogeneration plant design for Southwest Texas State University has been bid and a contract will be awarded shortly. Construction is scheduled to begin in Sepember. My work from this point will include checking submittal information from the contractor and making site visits which concern utility tunnel and thermal distribution construction.

We are currently preparing construction documents for the central plant addition and thermal utility distribution system expansion at the University of Texas Medical Branch at Galveston (UTMB-Galveston). As of my last letter we were preparing preliminary design documents for this project.

Basically, we are adding two new 3700 ton electric drive chillers and corresponding pumps and cooling tower capacity; and closing a loop in the thermal distribution system. I have been primarily involved in preparing the specifications for the prepurchase of the pumps and the design of the thermal distribution system.

Concerning the proposals we evaluated for a third party cogeneration plant for the Harris County Jail in downtown

Dr. W. D. Turner, P.E
August 19, 1987
Page 2.

Houston, none of the proposals submitted met the requirements of the RFP. Generally, what was proposed was the sale of specific equipment to the County. I feel that the economics did not attract a "true" third party proposal due to the utility costs and the small size of cogeneration needed.

I will prepare a preliminary schedule for my intership report and submit it to you for your comments.

Sincerely,

Jeffery N. Bolander

cc: Mr. Kim E Shinn, P.E.
Mechanical Department Head
Lockwood, Andrews & Newnam, Inc.
1500 City West Boulevard
Houston, TX 77042

APPENDIX C

THERMAL PIPE STRESS COMPUTER PROGRAM

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

PIPE DIAMETER (in)	12.0
PIPE SCHEDULE	STD
WALL THICKNESS (in)	0.375
CROSS SECTION MOMENT OF INERTIA (in^4)	279.3
SECTION MODULUS (in^3)	43.8
MODULUS OF ELASTICITY COLD (psi)	2.79e+07
MODULUS OF ELASTICITY HOT (psi)	2.70e+07
RATIO OF Ec TO Eh	1.03
THERMAL EXPANSION (in/100 ft)	1.8
ELBOW RADIUS (in)	18.0
ELBOW STRESS INTENSIFICATION FACTOR	2.75
BEND RADIUS (in)	36.0
BEND STRESS INTENSIFICATION FACTOR	1.73

BRANCH 1 (ft)

AB	0.0
BC	0.0
CD	0.0
DE	0.0
EF	12.0
FG	31.0
GH	177.0
HI	31.0
IJ	12.0
JK	0.0
KL	0.0
LM	0.0
MN	0.0
NO	0.0
OP	0.0

THERMAL EXPANSION (in)

DELx	-3.66
DELy	0.00
DELz	0.00

DELxEI	-1.6e+07
DELyEI	0.0e+000
DELzEI	0.0e+000

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

X-Y PLANE

CENTROID

BRANCH	l(ft)	x(ft)	y(ft)	l*x	l*y
AB	0.0	-201.0	0.0	0	0
BC	0.0	-201.0	0.0	0	0
CD	0.0	-201.0	0.0	0	0
DE	0.0	-201.0	0.0	0	0
EF	12.0	-195.0	0.0	-2340	0
FG	40.3	-189.0	0.0	-7617	0
GH	177.0	-100.5	0.0	-17788	0
HI	40.3	-12.0	0.0	-484	0
IJ	12.0	-6.0	0.0	-72	0
JK	0.0	0.0	0.0	0	0
KL	0.0	0.0	0.0	0	0
LM	0.0	0.0	0.0	0	0
MN	0.0	0.0	0.0	0	0
NO	0.0	0.0	0.0	0	0
OP	0.0	0.0	0.0	0	0
SUM	281.6			-28301	0

X	-100.5
Y	0.0

MOMENT ARMS FROM POINT TO CENTROID

	x(ft)	y(ft)
A	100.5	0.0
B	100.5	0.0
C	100.5	0.0
D	100.5	0.0
E	100.5	0.0
F	88.5	0.0
G	88.5	0.0
H	-88.5	0.0
I	-88.5	0.0
J	-100.5	0.0
K	-100.5	0.0
L	-100.5	0.0
M	-100.5	0.0
N	-100.5	0.0
O	-100.5	0.0
P	-100.5	0.0

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

MOMENTS OF INERTIA

BRANCH	l(ft)	X(ft)	Y(ft)	l*X*X	Ioy	l*Y*Y	Iox	l*X*Y	Ioxy
AB	0.0	-100.5	0.0	0	0	0	0	0	0
BC	0.0	-100.5	0.0	0	0	0	0	0	0
CD	0.0	-100.5	0.0	0	0	0	0	0	0
DE	0.0	-100.5	0.0	0	0	0	0	0	0
EF	12.0	-94.5	0.0	107163	144	0	0	0	0
FG	40.3	-88.5	0.0	315640	0.0	0	0	0	0
GH	177.0	-0.0	0.0	0	462103	0	0	0	0
HI	40.3	88.5	0.0	315640	0.0	0	0	0	0
IJ	12.0	94.5	0.0	107163	144	0	0	0	0
JK	0.0	100.5	0.0	0	0.0	0	0	0	0
KL	0.0	100.5	0.0	0	0	0	0	0	0
LM	0.0	100.5	0.0	0	0	0	0	0	0
MN	0.0	100.5	0.0	0	0	0	0	0	0
NO	0.0	100.5	0.0	0	0.0	0	0.0	0	0.0
OP	0.0	100.5	0.0	0	0	0	0	0	0
SUM				845605	462391	0	0	0	0

Iy 1307996 ft^3

Ix 0 ft^3

Ixy 0 ft^3

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

Y-Z PLANE

CENTROID

BRANCH	l(ft)	z(ft)	y(ft)	l*z	l*y
AB	0.0	0.0	0.0	0	0
BC	0.0	0.0	0.0	0	0
CD	0.0	0.0	0.0	0	0
DE	0.0	0.0	0.0	0	0
EF	15.6	0.0	0.0	0	0
FG	31.0	15.5	0.0	480	0
GH	230.1	31.0	0.0	7133	0
HI	31.0	15.5	0.0	480	0
IJ	15.6	0.0	0.0	0	0
JK	0.0	0.0	0.0	0	0
KL	0.0	0.0	0.0	0	0
LM	0.0	0.0	0.0	0	0
MN	0.0	0.0	0.0	0	0
NO	0.0	0.0	0.0	0	0
OP	0.0	0.0	0.0	0	0
SUM	323.3			8094	0

Z	25.0
Y	0.0

MOMENT ARMS FROM POINT TO CENTROID

	z(ft)	y(ft)
A	-25.0	0.0
B	-25.0	0.0
C	-25.0	0.0
D	-25.0	0.0
E	-25.0	0.0
F	-25.0	0.0
G	6.0	0.0
H	6.0	0.0
I	-25.0	0.0
J	-25.0	0.0
K	-25.0	0.0
L	-25.0	0.0
M	-25.0	0.0
N	-25.0	0.0
O	-25.0	0.0
P	-25.0	0.0

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

MOMENTS OF INERTIA

BRANCH	l(ft)	Z(ft)	Y(ft)	l*Z*Z	Ioy	l*Y*Y	Ioz	l*Z*Y	Ioyz
AB	0.0	-25.0	0.0	0	0	0	0	0	0
BC	0.0	-25.0	0.0	0	0	0	0	0	0
CD	0.0	-25.0	0.0	0	0	0	0	0	0
DE	0.0	-25.0	0.0	0	0	0	0	0	0
EF	15.6	-25.0	0.0	9778	0	0	0	0	0
FG	31.0	-9.5	0.0	2819	2483	0	0	0	0
GH	230.1	6.0	0.0	8185	0	0	0	0	0
HI	31.0	-9.5	0.0	2819	2483	0	0	0	0
IJ	15.6	-25.0	0.0	9778	0	0	0	0	0
JK	0.0	-25.0	0.0	0	0	0	0	0	0
KL	0.0	-25.0	0.0	0	0	0	0	0	0
LM	0.0	-25.0	0.0	0	0	0	0	0	0
MN	0.0	-25.0	0.0	0	0	0	0	0	0
NO	0.0	-25.0	0.0	0	0	0	0	0	0
OP	0.0	-25.0	0.0	0	0	0	0	0	0
SUM				33379	4965	0	0	0	0

Iy	38344 ft^3
Iz	0 ft^3
Izy	0 ft^3

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

X-Z PLANE

CENTROID

BRANCH	l(ft)	z(ft)	x(ft)	l*z	l*x
AB	0.0	0.0	-201.0	0	0
BC	0.0	0.0	-201.0	0	0
CD	0.0	0.0	-201.0	0	0
DE	0.0	0.0	-201.0	0	0
EF	12.0	0.0	-195.0	0	-2340
FG	31.0	15.5	-189.0	480	-5859
GH	177.0	31.0	-100.5	5487	-17788
HI	31.0	15.5	-12.0	480	-372
IJ	12.0	0.0	-6.0	0	-72
JK	0.0	0.0	0.0	0	0
KL	0.0	0.0	0.0	0	0
LM	0.0	0.0	0.0	0	0
MN	0.0	0.0	0.0	0	0
NO	0.0	0.0	0.0	0	0
OP	0.0	0.0	0.0	0	0
SUM	263.0			6448	-26431
z	24.5				
x	-100.5				

MOMENT ARMS FROM POINT TO CENTROID

	z(ft)	x(ft)
A	24.5	-100.5
B	24.5	-100.5
C	24.5	-100.5
D	24.5	-100.5
E	24.5	-100.5
F	24.5	-88.5
G	-6.5	-88.5
H	-6.5	88.5
I	24.5	88.5
J	24.5	100.5
K	24.5	100.5
L	24.5	100.5
M	24.5	100.5
N	24.5	100.5
O	24.5	100.5
P	24.5	100.5

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

MOMENTS OF INERTIA

BRANCH	l(ft)	Z(ft)	X(ft)	l*Z*Z	Iox	l*X*X	Ioz	l*Z*Y	Ioxz
AB	0.0	-24.5	-100.5	0	0	0	0	0	0
BC	0.0	-24.5	-100.5	0	0	0	0	0	0
CD	0.0	-24.5	-100.5	0	0	0	0	0	0
DE	0.0	-24.5	-100.5	0	0	0	0	0	0
EF	12.0	-24.5	-94.5	7213	0	107163	144	27802	0
FG	31.0	-9.0	-88.5	2521	2483	242800	0	24738	0
GH	177.0	6.5	0.0	7439	0	0	462103	0	0
HI	31.0	-9.0	88.5	2521	2483	242800	0	-24738	0
IJ	12.0	-24.5	94.5	7213	0	107163	144	-27802	0
JK	0.0	-24.5	100.5	0	0	0	0	0	0
KL	0.0	-24.5	100.5	0	0	0	0	0	0
LM	0.0	-24.5	100.5	0	0	0	0	0	0
MN	0.0	-24.5	100.5	0	0	0	0	0	0
NO	0.0	-24.5	100.5	0	0	0	0.0	0	0
OP	0.0	-24.5	100.5	0	0	0	0	0	0
SUM				26906	4965	699925	462391	0	0

Iz	1162316 ft^3
Ix	31871 ft^3
Ixz	0 ft^3

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

IxFx	-IxyFy	-IxzFz	DELxEI
-IxyFx	IyFy	-IyzFz	DELyEI
-IxzFz	-IyzFy	IzFz	DELzEI

31871	0	0	-1.6e+07
0	1346340	0	0.0e+000
0	0	1162316	0.0e+000

Fz=	0.0 lb
Fy=	0.0 lb
Fx=	-517.6 lb

CHECK => 0.0

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM OUTPUT

BENDING MOMENTS & TORQUES ABOUT POINT

POINT	XY PLANE(ftlb)		YZ PLANE(ftlb)		ZX PLANE(ftlb)		TOTAL(ftlb)		STRESS(psi)		
	B	T	B	T	B	T	B	T	B	T	C
A	0.0			0.0	-12690.2		12690.2	0.0	3592.7	0.0	3592.7
B-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
B+		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
C-		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
C+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
D-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
D+		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
E-		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
E+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
F-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
F+		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
G-		0.0	0.0		3355.6		3355.6	0.0	2609.9	0.0	2609.9
G+	0.0			0.0	3355.6		3355.6	0.0	2609.9	0.0	2609.9
H-	0.0			0.0	3355.6		3355.6	0.0	2609.9	0.0	2609.9
H+		0.0	0.0		3355.6		3355.6	0.0	2609.9	0.0	2609.9
I-		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
I+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
J-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
J+		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
K-		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
K+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
L-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
L+		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
M-		0.0	0.0		-12690.2		12690.2	0.0	9870.1	0.0	9870.1
M+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
N-	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
N+	0.0		0.0			-12690.2	0.0	12690.2	0.0	3592.7	7185.3
O-	0.0		0.0			-12690.2	0.0	12690.2	0.0	3592.7	7185.3
O+	0.0			0.0	-12690.2		12690.2	0.0	9870.1	0.0	9870.1
P	0.0			0.0	-12690.2		12690.2	0.0	3592.7	0.0	3592.7

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A1: 'PIPE DIAMETER (in)
F1: [W9] 12
A2: 'PIPE SCHEDULE
F2: [W9] "STD
A3: 'WALL THICKNESS (in)
F3: (F3) [W9] 0.375
A4: 'CROSS SECTION MOMENT OF INERTIA (in^4)
F4: [W9] 279.3
A5: 'SECTION MODULUS (in^3)
F5: [W9] 43.8
A6: 'MODULUS OF ELASTICITY COLD (psi)
F6: (S2) [W9] 27900000
A7: 'MODULUS OF ELASTICITY HOT (psi)
F7: (S2) [W9] 27000000
A8: 'RATIO OF Ec TO Eh
F8: (F2) [W9] +F6/F7
A9: 'THERMAL EXPANSION (in/100 ft)
F9: [W9] 1.82
A10: 'ELBOW RADIUS (in)
F10: [W9] 1.5*F1
A11: 'ELBOW STRESS INTENSIFICATION FACTOR
F11: (F2) [W9] 0.9/((F3*F10/((F1/2)^2))^(2/3))
A12: 'BEND RADIUS (in)
F12: [W9] 3*F1
A13: 'BEND STRESS INTENSIFICATION FACTOR
F13: (F2) [W9] 0.9/((F3*F12/((F1/2)^2))^(2/3))
A15: 'BRANCH
B15: "1 (ft)
D15: 'REV:
E15: (D4) @NOW
A17: 'AB
B17: (F1) 0
A18: 'BC
B18: (F1) 0
A19: 'CD
B19: (F1) 0
A20: 'DE
B20: (F1) 0
A21: 'EF
B21: (F1) 12
A22: 'FG
B22: 31
A23: 'GH
B23: 177
A24: 'HI
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
B24: 31
A25: 'IJ
B25: 12
A26: 'JK
B26: 0
A27: 'KL
B27: 0
A28: 'LM
B28: 0
A29: 'MN
B29: 0
A30: 'NO
B30: (F1) 0
A31: 'OP
B31: (F1) 0
A33: 'ANG1(RAD)
B33: (F2) 45*@PI/180
A34: 'ANG2(RAD)
B34: (F2) 30*@PI/180
A36: 'THERMAL EXPANSION (in)
A38: 'DELx
B38: (F2) -(B17+B18*@COS(B33)+B19+B21+B23+B25+B27+B28*@COS(B33)+B29+B30*@COS(B34)+B31)*F9/100
A39: 'DELy
B39: (F2) (B30*@SIN(B34))*F9/100
A40: 'DELz
B40: (F2) (B18*@SIN(B33)+B28*@SIN(B33))*F9/100
A42: 'DELxEI
B42: (S1) +B38*F6*F4/(12^3)
A43: 'DELyEI
B43: (S1) +B39*F6*F4/(12^3)
A44: 'DELzEI
B44: (S1) +B40*F6*F4/(12^3)
A59: 'X-Y PLANE
A62: 'CENTROID
A64: 'BRANCH
B64: "l(ft)
C64: "x(ft)
D64: "y(ft)
E64: "l*x
F64: [W9] "l*y
A66: 'AB
B66: (F1) +$B$17
C66: (F1) -$B$31-$B$30*@COS($B$34)-$B$29-$B$28*@COS($B$33)-$B$27-$B$25-$B$23-$B$21-$B$19-$B$18*@COS($B$33)-$B$17/2
D66: (F1) +$B$30*@SIN($B$34)
E66: (F0) +B66*C66
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
F66: (F0) [W9] +B66*D66
A67: 'BC
B67: (F1) +$B$18
C67: (F1) +C66+$B$17/2+$B$18*@COS($B$33)/2
D67: (F1) +D66
E67: (F0) +B67*C67
F67: (F0) [W9] +B67*D67
A68: 'CD
B68: (F1) +$B$19
C68: (F1) +C67+$B$18*@COS($B$33)/2+$B$19/2
D68: (F1) +D67
E68: (F0) +B68*C68
F68: (F0) [W9] +B68*D68
A69: 'DE
B69: (F1) +$B$20*1.3
C69: (F1) +C68+$B$19/2
D69: (F1) +D68
E69: (F0) +B69*C69
F69: (F0) [W9] +B69*D69
A70: 'EF
B70: (F1) +$B$21
C70: (F1) +C69+$B$21/2
D70: (F1) +D69
E70: (F0) +B70*C70
F70: (F0) [W9] +B70*D70
A71: 'FG
B71: (F1) +$B$22*1.3
C71: (F1) +C70+$B$21/2
D71: (F1) +D70
E71: (F0) +B71*C71
F71: (F0) [W9] +B71*D71
A72: 'GH
B72: (F1) +$B$23
C72: (F1) +C71+$B$23/2
D72: (F1) +D71
E72: (F0) +B72*C72
F72: (F0) [W9] +B72*D72
A73: 'HI
B73: (F1) +$B$24*1.3
C73: (F1) +C72+$B$23/2
D73: (F1) +D72
E73: (F0) +B73*C73
F73: (F0) [W9] +B73*D73
A74: 'IJ
B74: (F1) +$B$25
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
C74: (F1) +C73+$B$25/2
D74: (F1) +D73
E74: (F0) +B74*C74
F74: (F0) [W9] +B74*D74
A75: 'JK
B75: (F1) +$B$26*1.3
C75: (F1) +C74+$B$25/2
D75: (F1) +D74
E75: (F0) +B75*C75
F75: (F0) [W9] +B75*D75
A76: 'KL
B76: (F1) +$B$27
C76: (F1) +C75+$B$27/2
D76: (F1) +D75
E76: (F0) +B76*C76
F76: (F0) [W9] +B76*D76
A77: 'LM
B77: (F1) +$B$28
C77: (F1) +C76+$B$27/2+$B$28*(@COS($B$33))/2
D77: (F1) +D76
E77: (F0) +B77*C77
F77: (F0) [W9] +B77*D77
A78: 'MN
B78: (F1) +$B$29
C78: (F1) +C77+$B$28*@COS($B$33)/2+$B$29/2
D78: (F1) +D77
E78: (F0) +B78*C78
F78: (F0) [W9] +B78*D78
A79: 'NO
B79: (F1) +$B$30
C79: (F1) +C78+$B$29/2+$B$30*@COS($B$34)/2
D79: (F1) +D78-$B$30*@SIN($B$34)/2
E79: (F0) +B79*C79
F79: (F0) [W9] +B79*D79
A80: 'OP
B80: (F1) +$B$31
C80: (F1) +C79+$B$30*@COS($B$34)/2+$B$31/2
D80: (F1) +D79-$B$30*@SIN($B$34)/2
E80: (F0) +B80*C80
F80: (F0) [W9] +B80*D80
A82: 'SUM
B82: (F1) @SUM(B66..B80)
E82: (F0) @SUM(E66..E80)
F82: (F0) [W9] @SUM(F66..F80)
A84: 'X
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
B84: (F1) +E82/B82
A85: 'Y
B85: (F1) +F82/B82
A87: 'MOMENT ARMS FROM POINT TO CENTROID
B88: "x(ft)
C88: "y(ft)
A89: 'A
B89: -(C66-$B$17/2)+B84
C89: +D66-B85
A90: 'B
B90: +B89-B17
C90: +C89
A91: 'C
B91: +B90-B18*@COS(B33)
C91: +C90
A92: 'D
B92: +B91-B19
C92: +C91
A93: 'E
B93: +B92
C93: +C92
A94: 'F
B94: +B93-B21
C94: +C93
A95: 'G
B95: +B94
C95: +C94
A96: 'H
B96: +B95-B23
C96: +C95
A97: 'I
B97: +B96
C97: +C96
A98: 'J
B98: +B97-B25
C98: +C97
A99: 'K
B99: +B98
C99: +C98
A100: 'L
B100: +B99-B27
C100: +C99
A101: 'M
B101: +B100-B28*@COS(B33)
C101: +C100
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A102: 'N
B102: +B101-B29
C102: +C101
A103: 'O
B103: +B102-B30*@COS(B34)
C103: +C102-$B$30*@SIN($B$34)/2
A104: 'P
B104: +B103-B31
C104: +C103-$B$30*@SIN($B$34)/2
A106: 'MOMENTS OF INERTIA
A108: 'BRANCH
B108: "l(ft)
C108: "X(ft)
D108: "Y(ft)
E108: "l*X*X
F108: [W9] "Ioy
G108: "l*Y*Y
H108: "Iox
I108: "l*X*Y
J108: "Ioxy
A110: 'AB
B110: (F1) +$B$17
C110: (F1) +C66-$B$84
D110: (F1) +D66-$B$85
E110: (F0) +B110*C110^2
F110: (F0) [W9] +B110^3/12
G110: (F0) +B110*D110^2
H110: (F0) 0
I110: (F0) +B110*C110*D110
J110: (F0) 0
A111: 'BC
B111: (F1) +$B$18
C111: (F1) +C67-$B$84
D111: (F1) +D67-$B$85
E111: (F0) +B111*C111^2
F111: (F0) [W9] ((B111*@COS(B33))^3)/12
G111: (F0) +B111*D111^2
H111: (F0) 0
I111: (F0) +B111*C111*D111
J111: (F0) 0
A112: 'CD
B112: (F1) +$B$19
C112: (F1) +C68-$B$84
D112: (F1) +D68-$B$85
E112: (F0) +B112*C112^2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
F112: (F0) [W9] (B112^3)/12
G112: (F0) +B112*D112^2
H112: (F0) 0
I112: (F0) +B112*C112*D112
J112: (F0) 0
A113: 'DE
B113: (F1) +$B$20*1.3
C113: (F1) +C69-$B$84
D113: (F1) +D69-$B$85
E113: (F0) +B113*C113^2
F113: (F0) [W9] 0
G113: (F0) +B113*D113^2
H113: (F0) 0
I113: (F0) +B113*C113*D113
J113: (F0) 0
A114: 'EF
B114: (F1) +$B$21
C114: (F1) +C70-$B$84
D114: (F1) +D70-$B$85
E114: (F0) +B114*C114^2
F114: (F0) [W9] +B114^3/12
G114: (F0) +B114*D114^2
H114: (F0) 0
I114: (F0) +B114*C114*D114
J114: (F0) 0
A115: 'FG
B115: (F1) +$B$22*1.3
C115: (F1) +C71-$B$84
D115: (F1) +D71-$B$85
E115: (F0) +B115*C115^2
F115: [W9] 0
G115: (F0) +B115*D115^2
H115: (F0) 0
I115: (F0) +B115*C115*D115
J115: (F0) 0
A116: 'GH
B116: (F1) +$B$23
C116: (F1) +C72-$B$84
D116: (F1) +D72-$B$85
E116: (F0) +B116*C116^2
F116: (F0) [W9] +B116^3/12
G116: (F0) +B116*D116^2
H116: (F0) 0
I116: (F0) +B116*C116*D116
J116: (F0) 0
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A117: 'HI
B117: (F1) +$B$24*1.3
C117: (F1) +C73-$B$84
D117: (F1) +D73-$B$85
E117: (F0) +B117*C117^2
F117: [W9] 0
G117: (F0) +B117*D117^2
H117: (F0) 0
I117: (F0) +B117*C117*D117
J117: (F0) 0
A118: 'IJ
B118: (F1) +$B$25
C118: (F1) +C74-$B$84
D118: (F1) +D74-$B$85
E118: (F0) +B118*C118^2
F118: (F0) [W9] +B118^3/12
G118: (F0) +B118*D118^2
H118: (F0) 0
I118: (F0) +B118*C118*D118
J118: (F0) 0
A119: 'JK
B119: (F1) +$B$26*1.3
C119: (F1) +C75-$B$84
D119: (F1) +D75-$B$85
E119: (F0) +B119*C119^2
F119: [W9] 0
G119: (F0) +B119*D119^2
H119: (F0) 0
I119: (F0) +B119*C119*D119
J119: (F0) 0
A120: 'KL
B120: (F1) +$B$27
C120: (F1) +C76-$B$84
D120: (F1) +D76-$B$85
E120: (F0) +B120*C120^2
F120: (F0) [W9] +B120^3/12
G120: (F0) +B120*D120^2
H120: (F0) 0
I120: (F0) +B120*C120*D120
J120: (F0) 0
A121: 'LM
B121: (F1) +$B$28
C121: (F1) +C77-$B$84
D121: (F1) +D77-$B$85
E121: (F0) +B121*C121^2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
F121: (F0) [W9] ((B121*@COS(B33))^3)/12
G121: (F0) +B121*D121^2
H121: (F0) 0
I121: (F0) +B121*C121*D121
J121: (F0) 0
A122: 'MN
B122: (F1) +$B$29
C122: (F1) +C78-$B$84
D122: (F1) +D78-$B$85
E122: (F0) +B122*C122^2
F122: (F0) [W9] +B122^3/12
G122: (F0) +B122*D122^2
H122: (F0) 0
I122: (F0) +B122*C122*D122
J122: (F0) 0
A123: 'NO
B123: (F1) +$B$30
C123: (F1) +C79-$B$84
D123: (F1) +D79-$B$85
E123: (F0) +B123*C123^2
F123: [W9] +B123^3*(@COS(B34))^2/12
G123: (F0) +B123*D123^2
H123: +B123^3*(@SIN(B34))^2/12
I123: (F0) +B123*C123*D123
J123: +B123^3*@SIN(2*150/180*@PI)/24
A124: 'OP
B124: (F1) +$B$31
C124: (F1) +C80-$B$84
D124: (F1) +D80-$B$85
E124: (F0) +B124*C124^2
F124: (F0) [W9] +B124^3/12
G124: (F0) +B124*D124^2
H124: (F0) 0
I124: (F0) +B124*C124*D124
J124: (F0) 0
A128: 'SUM
E128: (F0) @SUM(E110..E126)
F128: (F0) [W9] @SUM(F110..F126)
G128: (F0) @SUM(G110..G126)
H128: (F0) @SUM(H110..H126)
I128: (F0) @SUM(I110..I126)
J128: (F0) @SUM(J110..J126)
A130: 'Iy
B130: (F0) +E128+F128
C130: 'ft^3
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A131: 'Ix
B131: (F0) +G128+H128
C131: 'ft^3
A132: 'Ixy
B132: (F0) +I128+J128
C132: 'ft^3
A134: |::
A135: 'Y-Z PLANE
A138: 'CENTROID
A140: 'BRANCH
B140: "l(ft)
C140: "z(ft)
D140: "y(ft)
E140: "l*z
F140: [W9] "l*y
A142: 'AB
B142: (F1) +$B$17*1.3
C142: (F1) +$B$28*@SIN($B$33)+$B$18*@SIN($B$33)
D142: (F1) +$B$30*@SIN($B$34)
E142: (F0) +B142*C142
F142: (F0) [W9] +B142*D142
A143: 'BC
B143: (F1) +$B$18
C143: (F1) +C142-$B$18*@SIN($B$33)/2
D143: (F1) +D142
E143: (F0) +B143*C143
F143: (F0) [W9] +B143*D143
A144: 'CD
B144: (F1) +$B$19*1.3
C144: (F1) +C143-$B$18*@SIN($B$33)/2
D144: (F1) +D143
E144: (F0) +B144*C144
F144: (F0) [W9] +B144*D144
A145: 'DE
B145: (F1) +$B$20
C145: (F1) +C144-$B$20/2
D145: (F1) +D144
E145: (F0) +B145*C145
F145: (F0) [W9] +B145*D145
A146: 'EF
B146: (F1) +$B$21*1.3
C146: (F1) +C145-$B$20/2
D146: (F1) +D145
E146: (F0) +B146*C146
F146: (F0) [W9] +B146*D146
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A147: 'FG
B147: (F1) +$B$22
C147: (F1) +C146+$B$22/2
D147: (F1) +D146
E147: (F0) +B147*C147
F147: (F0) [W9] +B147*D147
A148: 'GH
B148: (F1) +$B$23*1.3
C148: (F1) +C147+$B$22/2
D148: (F1) +D147
E148: (F0) +B148*C148
F148: (F0) [W9] +B148*D148
A149: 'HI
B149: (F1) +$B$24
C149: (F1) +C148-$B$24/2
D149: (F1) +D148
E149: (F0) +B149*C149
F149: (F0) [W9] +B149*D149
A150: 'IJ
B150: (F1) +$B$25*1.3
C150: (F1) +C149-$B$24/2
D150: (F1) +D149
E150: (F0) +B150*C150
F150: (F0) [W9] +B150*D150
A151: 'JK
B151: (F1) +$B$26
C151: (F1) +C150+$B$26/2
D151: (F1) +D150
E151: (F0) +B151*C151
F151: (F0) [W9] +B151*D151
A152: 'KL
B152: (F1) +$B$27*1.3
C152: (F1) +C151+$B$26/2
D152: (F1) +D151
E152: (F0) +B152*C152
F152: (F0) [W9] +B152*D152
A153: 'LM
B153: (F1) +$B$28
C153: (F1) +C152-$B$28*@SIN($B$33)/2
D153: (F1) +D152
E153: (F0) +B153*C153
F153: (F0) [W9] +B153*D153
A154: 'MN
B154: (F1) +$B$29*1.3
C154: (F1) +C153-$B$28*@SIN($B$33)/2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
D154: (F1) +D153
E154: (F0) +B154*C154
F154: (F0) [W9] +B154*D154
A155: 'NO
B155: (F1) +$B$30
C155: (F1) +C154
D155: (F1) +D154-$B$30*@SIN($B$34)/2
E155: (F0) +B155*C155
F155: (F0) [W9] +B155*D155
A156: 'OP
B156: (F1) +$B$31*1.3
C156: (F1) +C155
D156: (F1) +D155-$B$30*@SIN($B$34)/2
E156: (F0) +B156*C156
F156: (F0) [W9] +B156*D156
A158: 'SUM
B158: (F1) @SUM(B142..B156)
E158: (F0) @SUM(E142..E156)
F158: (F0) [W9] @SUM(F142..F156)
A160: 'Z
B160: (F1) +E158/B158
A161: 'Y
B161: (F1) +F158/B158
A163: 'MOMENT ARMS FROM POINT TO CENTROID
B164: "z(ft)
C164: "y(ft)
A165: 'A
B165: +C142-B160
C165: -D142+B161
A166: 'B
B166: +B165
C166: +C165
A167: 'C
B167: +B166-B18*@SIN(B33)
C167: +C166
A168: 'D
B168: +B167
C168: +C167
A169: 'E
B169: +B168-B20
C169: +C168
A170: 'F
B170: +B169
C170: +C169
A171: 'G
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
B171: +B170+B22
C171: +C170
A172: 'H
B172: +B171
C172: +C171
A173: 'I
B173: +B172-B24
C173: +C172
A174: 'J
B174: +B173
C174: +C173
A175: 'K
B175: +B174+B26
C175: +C174
A176: 'L
B176: +B175
C176: +C175
A177: 'M
B177: +B176-B28*@SIN(B33)
C177: +C176
A178: 'N
B178: +B177
C178: +C177
A179: 'O
B179: +B178
C179: +C178+B30*@SIN(B34)
A180: 'P
B180: +B179
C180: +C179
A183: 'MOMENTS OF INERTIA
A185: 'BRANCH
B185: "l(ft)
C185: "Z(ft)
D185: "Y(ft)
E185: "l*Z*Z
F185: [W9] "Ioy
G185: "l*Y*Y
H185: "Ioz
I185: "l*Z*Y
J185: "Ioyz
A187: 'AB
B187: (F1) +$B$17*1.3
C187: (F1) +C142-$B$160
D187: (F1) +D142-$B$161
E187: (F0) +B187*C187^2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
F187: (F0) [W9] 0
G187: (F0) +B187*D187^2
H187: (F0) 0
I187: (F0) +B187*C187*D187
J187: (F0) 0
A188: 'BC
B188: (F1) +$B$18
C188: (F1) +C143-$B$160
D188: (F1) +D143-$B$161
E188: (F0) +B188*C188^2
F188: (F0) [W9] (B188*@SIN(B33))^3/12
G188: (F0) +B188*D188^2
H188: (F0) 0
I188: (F0) +B188*C188*D188
J188: (F0) 0
A189: 'CD
B189: (F1) +$B$19*1.3
C189: (F1) +C144-$B$160
D189: (F1) +D144-$B$161
E189: (F0) +B189*C189^2
F189: (F0) [W9] 0
G189: (F0) +B189*D189^2
H189: (F0) 0
I189: (F0) +B189*C189*D189
J189: (F0) 0
A190: 'DE
B190: (F1) +$B$20
C190: (F1) +C145-$B$160
D190: (F1) +D145-$B$161
E190: (F0) +B190*C190^2
F190: (F0) [W9] +B190^3/12
G190: (F0) +B190*D190^2
H190: (F0) 0
I190: (F0) +B190*C190*D190
J190: (F0) 0
A191: 'EF
B191: (F1) +$B$21*1.3
C191: (F1) +C146-$B$160
D191: (F1) +D146-$B$161
E191: (F0) +B191*C191^2
F191: (F0) [W9] 0
G191: (F0) +B191*D191^2
H191: (F0) 0
I191: (F0) +B191*C191*D191
J191: (F0) 0
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A192: 'FG
B192: (F1) +$B$22
C192: (F1) +C147-$B$160
D192: (F1) +D147-$B$161
E192: (F0) +B192*C192^2
F192: (F0) [W9] +B192^3/12
G192: (F0) +B192*D192^2
H192: (F0) 0
I192: (F0) +B192*C192*D192
J192: (F0) 0
A193: 'GH
B193: (F1) +$B$23*1.3
C193: (F1) +C148-$B$160
D193: (F1) +D148-$B$161
E193: (F0) +B193*C193^2
F193: (F0) [W9] 0
G193: (F0) +B193*D193^2
H193: (F0) 0
I193: (F0) +B193*C193*D193
J193: (F0) 0
A194: 'HI
B194: (F1) +$B$24
C194: (F1) +C149-$B$160
D194: (F1) +D149-$B$161
E194: (F0) +B194*C194^2
F194: (F0) [W9] +B194^3/12
G194: (F0) +B194*D194^2
H194: (F0) 0
I194: (F0) +B194*C194*D194
J194: (F0) 0
A195: 'IJ
B195: (F1) +$B$25*1.3
C195: (F1) +C150-$B$160
D195: (F1) +D150-$B$161
E195: (F0) +B195*C195^2
F195: (F0) [W9] 0
G195: (F0) +B195*D195^2
H195: (F0) 0
I195: (F0) +B195*C195*D195
J195: (F0) 0
A196: 'JK
B196: (F1) +$B$26
C196: (F1) +C151-$B$160
D196: (F1) +D151-$B$161
E196: (F0) +B196*C196^2
```

```
F196: (F0) [W9] +B196^3/12
G196: (F0) +B196*D196^2
H196: (F0) 0
I196: (F0) +B196*C196*D196
J196: (F0) 0
A197: 'KL
B197: (F1) +$B$27*1.3
C197: (F1) +C152-$B$160
D197: (F1) +D152-$B$161
E197: (F0) +B197*C197^2
F197: (F0) [W9] 0
G197: (F0) +B197*D197^2
H197: (F0) 0
I197: (F0) +B197*C197*D197
J197: (F0) 0
A198: 'LM
B198: (F1) +$B$28
C198: (F1) +C153-$B$160
D198: (F1) +D153-$B$161
E198: (F0) +B198*C198^2
F198: (F0) [W9] (B198*@SIN(B33))^3/12
G198: (F0) +B198*D198^2
H198: (F0) 0
I198: (F0) +B198*C198*D198
J198: (F0) 0
A199: 'MN
B199: (F1) +$B$29*1.3
C199: (F1) +C154-$B$160
D199: (F1) +D154-$B$161
E199: (F0) +B199*C199^2
F199: (F0) [W9] 0
G199: (F0) +B199*D199^2
H199: (F0) 0
I199: (F0) +B199*C199*D199
J199: (F0) 0
A200: 'NO
B200: (F1) +$B$30
C200: (F1) +C155-$B$160
D200: (F1) +D155-$B$161
E200: (F0) +B200*C200^2
F200: (F0) [W9] 0
G200: (F0) +B200*D200^2
H200: (F0) (B200*@SIN(B34))^3/12
I200: (F0) +B200*C200*D200
J200: (F0) 0
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A201: 'OP
B201: (F1) +$B$31*1.3
C201: (F1) +C156-$B$160
D201: (F1) +D156-$B$161
E201: (F0) +B201*C201^2
F201: (F0) [W9] 0
G201: (F0) +B201*D201^2
H201: (F0) 0
I201: (F0) +B201*C201*D201
J201: (F0) 0
A203: 'SUM
E203: (F0) @SUM(E187..E201)
F203: (F0) [W9] @SUM(F187..F201)
G203: (F0) @SUM(G187..G201)
H203: (F0) @SUM(H187..H201)
I203: (F0) @SUM(I187..I201)
J203: (F0) @SUM(J187..J201)
A205: 'Iy
B205: (F0) +E203+F203
C205: 'ft^3
A206: 'Iz
B206: (F0) +G203+H203
C206: 'ft^3
A207: 'Izy
B207: (F0) +I203+J203
C207: 'ft^3
A217: |::
A218: 'X-Z PLANE
A221: 'CENTROID
A223: 'BRANCH
B223: "l(ft)
C223: "z(ft)
D223: "x(ft)
E223: "l*z
F223: [W9] "l*x
A225: 'AB
B225: (F1) +$B$17
C225: (F1) +$B$28*@SIN($B$33)+$B$18*@SIN($B$33)
D225: (F1) -$B$31-$B$30*@COS($B$34)-$B$29-$B$28*@COS($B$33)-$B$27-$B$25-$B$23-$B$21-$B$19-$B$18*@COS($B$33)-$B$17/2
E225: (F0) +B225*C225
F225: (F0) [W9] +B225*D225
A226: 'BC
B226: (F1) +$B$18
C226: (F1) +C225-$B$18*@SIN($B$33)/2
D226: (F1) +D225+$B$17/2+$B$18*@COS(C191)/2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
E226: (F0) +B226*C226
F226: (F0) [W9] +B226*D226
A227: 'CD
B227: (F1) +$B$19
C227: (F1) +C226-$B$18*@SIN($B$33)/2
D227: (F1) +D226+$B$18*@COS(C191)/2+$B$19/2
E227: (F0) +B227*C227
F227: (F0) [W9] +B227*D227
A228: 'DE
B228: (F1) +$B$20
C228: (F1) +C227-$B$20/2
D228: (F1) +D227+$B$19/2
E228: (F0) +B228*C228
F228: (F0) [W9] +B228*D228
A229: 'EF
B229: (F1) +$B$21
C229: (F1) +C228-$B$20/2
D229: (F1) +D228+$B$21/2
E229: (F0) +B229*C229
F229: (F0) [W9] +B229*D229
A230: 'FG
B230: (F1) +$B$22
C230: (F1) +C229+$B$22/2
D230: (F1) +D229+$B$21/2
E230: (F0) +B230*C230
F230: (F0) [W9] +B230*D230
A231: 'GH
B231: (F1) +$B$23
C231: (F1) +C230+$B$22/2
D231: (F1) +D230+$B$23/2
E231: (F0) +B231*C231
F231: (F0) [W9] +B231*D231
A232: 'HI
B232: (F1) +$B$24
C232: (F1) +C231-$B$24/2
D232: (F1) +D231+$B$23/2
E232: (F0) +B232*C232
F232: (F0) [W9] +B232*D232
A233: 'IJ
B233: (F1) +$B$25
C233: (F1) +C232-$B$24/2
D233: (F1) +D232+$B$25/2
E233: (F0) +B233*C233
F233: (F0) [W9] +B233*D233
A234: 'JK
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
B234: (F1) +$B$26
C234: (F1) +C233+$B$26/2
D234: (F1) +D233+$B$25/2
E234: (F0) +B234*C234
F234: (F0) [W9] +B234*D234
A235: 'KL
B235: (F1) +$B$27
C235: (F1) +C234+$B$26/2
D235: (F1) +D234+$B$27/2
E235: (F0) +B235*C235
F235: (F0) [W9] +B235*D235
A236: 'LM
B236: (F1) +$B$28
C236: (F1) +C235-$B$28*@SIN($B$33)/2
D236: (F1) +D235+$B$27/2+$B$28*(@COS($B$33))/2
E236: (F0) +B236*C236
F236: (F0) [W9] +B236*D236
A237: 'MN
B237: (F1) +$B$29
C237: (F1) +C236-$B$28*@SIN($B$33)/2
D237: (F1) +D236+$B$28*@COS($B$33)/2+$B$29/2
E237: (F0) +B237*C237
F237: (F0) [W9] +B237*D237
A238: 'NO
B238: (F1) +$B$30
C238: (F1) +C237
D238: (F1) +D237+$B$29/2+$B$30*@COS($B$34)/2
E238: (F0) +B238*C238
F238: (F0) [W9] +B238*D238
A239: 'OP
B239: (F1) +$B$31
C239: (F1) +C238
D239: (F1) +D238+$B$30*@COS($B$34)/2+$B$31/2
E239: (F0) +B239*C239
F239: (F0) [W9] +B239*D239
A242: 'SUM
B242: (F1) @SUM(B225..B240)
E242: (F0) @SUM(E225..E240)
F242: (F0) [W9] @SUM(F225..F240)
A244: 'Z
B244: (F1) +E242/B242
A245: 'X
B245: (F1) +F242/B242
A247: 'MOMENT ARMS FROM POINT TO CENTROID
B248: "z(ft)
```

```
C248: "x(ft)
A249: 'A
B249: -B28*@SIN(B33)-B18*@SIN(B33)+B244
C249: (C66-$B$17/2)-B245
A250: 'B
B250: +B249
C250: +C249+B17
A251: 'C
B251: +B250+B18*@SIN(B33)
C251: +C250+B18*@COS(B33)
A252: 'D
B252: +B251
C252: +C251+B19
A253: 'E
B253: +B252+B20
C253: +C252
A254: 'F
B254: +B253
C254: +C253+B21
A255: 'G
B255: +B254-B22
C255: +C254
A256: 'H
B256: +B255
C256: +C255+B23
A257: 'I
B257: +B256+B24
C257: +C256
A258: 'J
B258: +B257
C258: +C257+B25
A259: 'K
B259: +B258-B26
C259: +C258
A260: 'L
B260: +B259
C260: +C259+B27
A261: 'M
B261: +B260+B28*@SIN(B33)
C261: +C260+B28*@COS(B33)
A262: 'N
B262: +B261
C262: +C261+B29
A263: 'O
B263: +B262
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
C263: +C262+B30*@COS(B34)
A264: 'P
B264: +B263
C264: +C263+B31
A266: 'MOMENTS OF INERTIA
A268: 'BRANCH
B268: "l(ft)
C268: "Z(ft)
D268: "X(ft)
E268: "l*Z*Z
F268: [W9] "Iox
G268: "l*X*X
H268: "Ioz
I268: "l*Z*Y
J268: "Ioxz
A270: 'AB
B270: (F1) +$B$17
C270: (F1) +C225-$B$244
D270: (F1) +D225-$B$245
E270: (F0) +B270*C270^2
F270: (F0) [W9] 0
G270: (F0) +B270*D270^2
H270: (F0) (B270^3)/12
I270: (F0) +B270*C270*D270
J270: (F0) 0
A271: 'BC
B271: (F1) +$B$18
C271: (F1) +C226-$B$244
D271: (F1) +D226-$B$245
E271: (F0) +B271*C271^2
F271: (F0) [W9] (B271^3*(@COS(3*B33)^2))/12
G271: (F0) +B271*D271^2
H271: (F0) (B271^3*(@SIN(3*B33)^2))/12
I271: (F0) +B271*C271*D271
J271: (F0) +B271^3*@SIN(2*135*@PI/180)/24
A272: 'CD
B272: (F1) +$B$19
C272: (F1) +C227-$B$244
D272: (F1) +D227-$B$245
E272: (F0) +B272*C272^2
F272: (F0) [W9] 0
G272: (F0) +B272*D272^2
H272: (F0) (B272^3)/12
I272: (F0) +B272*C272*D272
J272: (F0) 0
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A273: 'DE
B273: (FI) +$B$20
C273: (F1) +C228-$B$244
D273: (F1) +D228-$B$245
E273: (F0) +B273*C273^2
F273: (F0) [W9] +B273^3/12
G273: (F0) +B273*D273^2
H273: (F0) 0
I273: (F0) +B273*C273*D273
J273: (F0) 0
A274: 'EF
B274: (F1) +$B$21
C274: (F1) +C229-$B$244
D274: (F1) +D229-$B$245
E274: (F0) +B274*C274^2
F274: (F0) [W9] 0
G274: (F0) +B274*D274^2
H274: (F0) (B274^3)/12
I274: (F0) +B274*C274*D274
J274: (F0) 0
A275: 'FG
B275: (F1) +$B$22
C275: (F1) +C230-$B$244
D275: (F1) +D230-$B$245
E275: (F0) +B275*C275^2
F275: (F0) [W9] +B275^3/12
G275: (F0) +B275*D275^2
H275: (F0) 0
I275: (F0) +B275*C275*D275
J275: (F0) 0
A276: 'GH
B276: (F1) +$B$23
C276: (F1) +C231-$B$244
D276: (F1) +D231-$B$245
E276: (F0) +B276*C276^2
F276: (F0) [W9] 0
G276: (F0) +B276*D276^2
H276: (F0) (B276^3)/12
I276: (F0) +B276*C276*D276
J276: (F0) 0
A277: 'HI
B277: (F1) +$B$24
C277: (F1) +C232-$B$244
D277: (F1) +D232-$B$245
E277: (F0) +B277*C277^2
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
F277: (F0) [W9] +B277^3/12
G277: (F0) +B277*D277^2
H277: (F0) 0
I277: (F0) +B277*C277*D277
J277: (F0) 0
A278: 'IJ
B278: (F1) +$B$25
C278: (F1) +C233-$B$244
D278: (F1) +D233-$B$245
E278: (F0) +B278*C278^2
F278: (F0) [W9] 0
G278: (F0) +B278*D278^2
H278: (F0) (B278^3)/12
I278: (F0) +B278*C278*D278
J278: (F0) 0
A279: 'JK
B279: (F1) +$B$26
C279: (F1) +C234-$B$244
D279: (F1) +D234-$B$245
E279: (F0) +B279*C279^2
F279: (F0) [W9] +B279^3/12
G279: (F0) +B279*D279^2
H279: (F0) 0
I279: (F0) +B279*C279*D279
J279: (F0) 0
A280: 'KL
B280: (F1) +$B$27
C280: (F1) +C235-$B$244
D280: (F1) +D235-$B$245
E280: (F0) +B280*C280^2
F280: (F0) [W9] 0
G280: (F0) +B280*D280^2
H280: (F0) (B280^3)/12
I280: (F0) +B280*C280*D280
J280: (F0) 0
A281: 'LM
B281: (F1) +$B$28
C281: (F1) +C236-$B$244
D281: (F1) +D236-$B$245
E281: (F0) +B281*C281^2
F281: (F0) [W9] (B281^3*(@COS(B33)^2))/12
G281: (F0) +B281*D281^2
H281: (F0) (B281^3*(@SIN(B33)^2))/12
I281: (F0) +B281*C281*D281
J281: (F0) +B281^3*@SIN(2*135*@PI/180)/24
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
A282: 'MN
B282: (F1) +$B$29
C282: (F1) +C237-$B$244
D282: (F1) +D237-$B$245
E282: (F0) +B282*C282^2
F282: (F0) [W9] 0
G282: (F0) +B282*D282^2
H282: (F0) (B282^3)/12
I282: (F0) +B282*C282*D282
J282: (F0) 0
A283: 'NO
B283: (F1) +$B$30
C283: (F1) +C238-$B$244
D283: (F1) +D238-$B$245
E283: (F0) +B283*C283^2
F283: (F0) [W9] 0
G283: (F0) +B283*D283^2
H283: (B283*@COS(B34))^3/12
I283: (F0) +B283*C283*D283
J283: (F0) 0
A284: 'OP
B284: (F1) +$B$31
C284: (F1) +C239-$B$244
D284: (F1) +D239-$B$245
E284: (F0) +B284*C284^2
F284: (F0) [W9] 0
G284: (F0) +B284*D284^2
H284: (F0) (B284^3)/12
I284: (F0) +B284*C284*D284
J284: (F0) 0
A287: 'SUM
E287: (F0) @SUM(E270..E285)
F287: (F0) [W9] @SUM(F270..F285)
G287: (F0) @SUM(G270..G285)
H287: (F0) @SUM(H270..H285)
I287: (F0) @SUM(I270..I285)
J287: (F0) @SUM(J270..J285)
A289: 'Iz
B289: (F0) +G287+H287
C289: 'ft^3
A290: 'Ix
B290: (F0) +E287+F287
C290: 'ft^3
A291: 'Ixz
B291: (F0) +I287+J287
```

```
C291: 'ft^3
A300: |::
A302: ' IxFx
B302: '-IxyFy
C302: '-IxzFz
D302: 'DELxEI
A303: '-IxyFx
B303: ' IyFy
C303: '-IyzFz
D303: 'DELyEI
A304: '-IxzFz
B304: '-IyzFy
C304: ' IzFz
D304: 'DELzEI
A306: (F0) +B290+B131
B306: (F0) -(+B132)
C306: (F0) -(+B291)
D306: (S1) +B42
A307: (F0) -(+B132)
B307: (F0) +B205+B130
C307: (F0) -(+B207)
D307: (S1) +B43
A308: (F0) +C306
B308: (F0) +C307
C308: (F0) +B289+B206
D308: (S1) +B44
A310: (F2) +A306/A306
B310: (F2) +B306/A306
C310: (F2) +C306/A306
D310: (S1) +D306/A306
A311: (F2) +A307/$A307
B311: (F2) +B307/$A307
C311: (F2) +C307/$A307
D311: (F2) +D307/$A307
A312: (F2) +A308/$A308
B312: (F2) +B308/$A308
C312: (F2) +C308/$A308
D312: (F2) +D308/$A308
A314: (F2) +A310/A310
B314: (F2) +B310/A310
C314: (F2) +C310/A310
D314: (S1) +D310/A310
A315: (F2) +A310-A311
B315: (F2) +B310-B311
C315: (F2) +C310-C311
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
D315: (F2) +D310-D311
A316: (F2) +A310-A312
B316: (F2) +B310-B312
C316: (F2) +C310-C312
D316: (F2) +D310-D312
A318: (F2) +A314
B318: (F2) +B314
C318: (F2) +C314
D318: (F2) +D314
A319: (F2) +A315/$B315
B319: (F2) +B315/$B315
C319: (F2) +C315/$B315
D319: (F2) +D315/$B315
A320: (F2) +A316/$B316
B320: (F2) +B316/$B316
C320: (F2) +C316/$B316
D320: (F2) +D316/$B316
A322: (F2) +A314
B322: (F2) +B314
C322: (F2) +C314
D322: (F2) +D314
A323: (F2) +A319
B323: (F2) +B319
C323: (F2) +C319
D323: (F2) +D319
A324: (F2) +A319-A320
B324: (F2) +B319-B320
C324: (F2) +C319-C320
D324: (F2) +D319-D320
A326: 'Fz=
B326: +D308/C308
C326: 'lb
A327: 'Fy=
B327: (D307-C307*B326)/B307
C327: 'lb
A328: 'Fx=
B328: (F1) (D322-C322*B326-B322*B327)/A322
C328: 'lb
A330: 'CHECK =>
B330: +A306*B328+B306*B327+C306*B326-D306
A333: 'BENDING MOMENTS & TORQUES ABOUT POINT
A334: 'POINT
B334: '   XY PLANE(ftlb)
D334: '   YZ PLANE(ftlb)
F334: [W9] '   ZX PLANE(ftlb)
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
H334: '       TOTAL(ftlb)
J334: '           STRESS(psi)
B335: '      B
C335: '      T
D335: '      B
E335: '      T
F335: [W9] '      B
G335: '      T
H335: '      B
I335: '      T
J335: '      B
K335: '      T
L335: '      C
A336: 'A
B336: +$B$89*$B$327+$C$89*$B$328
E336: +$B$165*$B$327+$C$165*$B$326
F336: [W9] +$B$249*$B$328+$C$249*$B$326
H336: (B336^2+D336^2+F336^2)^0.5
I336: (C336^2+E336^2+G336^2)^0.5
J336: +H336*12/$F$5*$F$8
K336: +I336*12/$F$5*$F$8
L336: (J336^2+4*K336^2)^0.5
A337: 'B-
B337: +$B$90*$B$327+$C$90*$B$328
E337: +$B$166*$B$327+$C$166*$B$326
F337: [W9] +$B$250*$B$328+$C$250*$B$326
H337: (B337^2+D337^2+F337^2)^0.5
I337: (C337^2+E337^2+G337^2)^0.5
J337: +H337*12*$F$11/$F$5*$F$8
K337: +I337*12/$F$5*$F$8
L337: (J337^2+4*K337^2)^0.5
A338: 'B+
C338: +$B$90*$B$327+$C$90*$B$328
D338: +$B$166*$B$327+$C$166*$B$326
F338: [W9] +$B$250*$B$328+$C$250*$B$326
H338: (B338^2+D338^2+F338^2)^0.5
I338: (C338^2+E338^2+G338^2)^0.5
J338: +H338*12*$F$11/$F$5*$F$8
K338: +I338*12/$F$5*$F$8
L338: (J338^2+4*K338^2)^0.5
A339: 'C-
C339: +$B$91*$B$327+$C$91*$B$328
D339: +$B$167*$B$327+$C$167*$B$326
F339: [W9] +$B$251*$B$328+$C$251*$B$326
H339: (B339^2+D339^2+F339^2)^0.5
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
I339: (C339^2+E339^2+G339^2)^0.5
J339: +H339*12*$F$11/$F$5*$F$8
K339: +I339*12/$F$5*$F$8
L339: (J339^2+4*K339^2)^0.5
A340: 'C+
B340: (F1) +$B$91*$B$327+$C$91*$B$328
E340: +$B$167*$B$327+$C$167*$B$326
F340: [W9] +$B$251*$B$328+$C$251*$B$326
H340: (B340^2+D340^2+F340^2)^0.5
I340: (C340^2+E340^2+G340^2)^0.5
J340: +H340*12*$F$11/$F$5*$F$8
K340: +I340*12/$F$5*$F$8
L340: (J340^2+4*K340^2)^0.5
A341: 'D-
B341: (F1) +$B$92*$B$327+$C$92*$B$328
E341: +$B$168*$B$327+$C$168*$B$326
F341: [W9] +$B$252*$B$328+$C$252*$B$326
H341: (B341^2+D341^2+F341^2)^0.5
I341: (C341^2+E341^2+G341^2)^0.5
J341: +H341*12*$F$11/$F$5*$F$8
K341: +I341*12/$F$5*$F$8
L341: (J341^2+4*K341^2)^0.5
A342: 'D+
C342: (F1) +$B$92*$B$327+$C$92*$B$328
D342: +$B$168*$B$327+$C$168*$B$326
F342: [W9] +$B$252*$B$328+$C$252*$B$326
H342: (B342^2+D342^2+F342^2)^0.5
I342: (C342^2+E342^2+G342^2)^0.5
J342: +H342*12*$F$11/$F$5*$F$8
K342: +I342*12/$F$5*$F$8
L342: (J342^2+4*K342^2)^0.5
A343: 'E-
C343: (F1) +$B$93*$B$327+$C$93*$B$328
D343: +$B$169*$B$327+$C$169*$B$326
F343: [W9] +$B$253*$B$328+$C$253*$B$326
H343: (B343^2+D343^2+F343^2)^0.5
I343: (C343^2+E343^2+G343^2)^0.5
J343: +H343*12*$F$11/$F$5*$F$8
K343: +I343*12/$F$5*$F$8
L343: (J343^2+4*K343^2)^0.5
A344: 'E+
B344: (F1) +$B$93*$B$327+$C$93*$B$328
E344: +$B$169*$B$327+$C$169*$B$326
F344: [W9] +$B$253*$B$328+$C$253*$B$326
H344: (B344^2+D344^2+F344^2)^0.5
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
I344: (C344^2+E344^2+G344^2)^0.5
J344: +H344*12*$F$11/$F$5*$F$8
K344: +I344*12/$F$5*$F$8
L344: (J344^2+4*K344^2)^0.5
A345: 'F-
B345: (F1) +$B$94*$B$327+$C$94*$B$328
E345: +$B$170*$B$327+$C$170*$B$326
F345: [W9] +$B$254*$B$328+$C$254*$B$326
H345: (B345^2+D345^2+F345^2)^0.5
I345: (C345^2+E345^2+G345^2)^0.5
J345: +H345*12*$F$11/$F$5*$F$8
K345: +I345*12/$F$5*$F$8
L345: (J345^2+4*K345^2)^0.5
A346: 'F+
C346: (F1) +$B$94*$B$327+$C$94*$B$328
D346: +$B$170*$B$327+$C$170*$B$326
F346: [W9] +$B$254*$B$328+$C$254*$B$326
H346: (B346^2+D346^2+F346^2)^0.5
I346: (C346^2+E346^2+G346^2)^0.5
J346: +H346*12*$F$11/$F$5*$F$8
K346: +I346*12/$F$5*$F$8
L346: (J346^2+4*K346^2)^0.5
A347: 'G-
C347: (F1) +$B$95*$B$327+$C$95*$B$328
D347: +$B$171*$B$327+$C$171*$B$326
F347: [W9] +$B$255*$B$328+$C$255*$B$326
H347: (B347^2+D347^2+F347^2)^0.5
I347: (C347^2+E347^2+G347^2)^0.5
J347: +H347*12*$F$11/$F$5*$F$8
K347: +I347*12/$F$5*$F$8
L347: (J347^2+4*K347^2)^0.5
A348: 'G+
B348: (F1) +$B$95*$B$327+$C$95*$B$328
E348: +$B$171*$B$327+$C$171*$B$326
F348: [W9] +$B$255*$B$328+$C$255*$B$326
H348: (B348^2+D348^2+F348^2)^0.5
I348: (C348^2+E348^2+G348^2)^0.5
J348: +H348*12*$F$11/$F$5*$F$8
K348: +I348*12/$F$5*$F$8
L348: (J348^2+4*K348^2)^0.5
A349: 'H-
B349: (F1) +$B$96*$B$327+$C$96*$B$328
E349: +$B$172*$B$327+$C$172*$B$326
F349: [W9] +$B$256*$B$328+$C$256*$B$326
H349: (B349^2+D349^2+F349^2)^0.5
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
I349: (C349^2+E349^2+G349^2)^0.5
J349: +H349*12*$F$11/$F$5*$F$8
K349: +I349*12/$F$5*$F$8
L349: (J349^2+4*K349^2)^0.5
A350: 'H+
C350: (F1) +$B$96*$B$327+$C$96*$B$328
D350: +$B$172*$B$327+$C$172*$B$326
F350: [W9] +$B$256*$B$328+$C$256*$B$326
H350: (B350^2+D350^2+F350^2)^0.5
I350: (C350^2+E350^2+G350^2)^0.5
J350: +H350*12*$F$11/$F$5*$F$8
K350: +I350*12/$F$5*$F$8
L350: (J350^2+4*K350^2)^0.5
A351: 'I-
C351: (F1) +$B$97*$B$327+$C$97*$B$328
D351: +$B$173*$B$327+$C$173*$B$326
F351: [W9] +$B$257*$B$328+$C$257*$B$326
H351: (B351^2+D351^2+F351^2)^0.5
I351: (C351^2+E351^2+G351^2)^0.5
J351: +H351*12*$F$11/$F$5*$F$8
K351: +I351*12/$F$5*$F$8
L351: (J351^2+4*K351^2)^0.5
A352: 'I+
B352: (F1) +$B$97*$B$327+$C$97*$B$328
E352: +$B$173*$B$327+$C$173*$B$326
F352: [W9] +$B$257*$B$328+$C$257*$B$326
H352: (B352^2+D352^2+F352^2)^0.5
I352: (C352^2+E352^2+G352^2)^0.5
J352: +H352*12*$F$11/$F$5*$F$8
K352: +I352*12/$F$5*$F$8
L352: (J352^2+4*K352^2)^0.5
A353: 'J-
B353: (F1) +$B$98*$B$327+$C$98*$B$328
E353: +$B$174*$B$327+$C$174*$B$326
F353: [W9] +$B$258*$B$328+$C$258*$B$326
H353: (B353^2+D353^2+F353^2)^0.5
I353: (C353^2+E353^2+G353^2)^0.5
J353: +H353*12*$F$11/$F$5*$F$8
K353: +I353*12/$F$5*$F$8
L353: (J353^2+4*K353^2)^0.5
A354: 'J+
C354: (F1) +$B$98*$B$327+$C$98*$B$328
D354: +$B$174*$B$327+$C$174*$B$326
F354: [W9] +$B$258*$B$328+$C$258*$B$326
H354: (B354^2+D354^2+F354^2)^0.5
```

```
I354: (C354^2+E354^2+G354^2)^0.5
J354: +H354*12*$F$11/$F$5*$F$8
K354: +I354*12/$F$5*$F$8
L354: (J354^2+4*K354^2)^0.5
A355: 'K-
C355: (F1) +$B$99*$B$327+$C$99*$B$328
D355: +$B$175*$B$327+$C$175*$B$326
F355: [W9] +$B$259*$B$328+$C$259*$B$326
H355: (B355^2+D355^2+F355^2)^0.5
I355: (C355^2+E355^2+G355^2)^0.5
J355: +H355*12*$F$11/$F$5*$F$8
K355: +I355*12/$F$5*$F$8
L355: (J355^2+4*K355^2)^0.5
A356: 'K+
B356: (F1) +$B$99*$B$327+$C$99*$B$328
E356: +$B$175*$B$327+$C$175*$B$326
F356: [W9] +$B$259*$B$328+$C$259*$B$326
H356: (B356^2+D356^2+F356^2)^0.5
I356: (C356^2+E356^2+G356^2)^0.5
J356: +H356*12*$F$11/$F$5*$F$8
K356: +I356*12/$F$5*$F$8
L356: (J356^2+4*K356^2)^0.5
A357: 'L-
B357: (F1) +$B$100*$B$327+$C$100*$B$328
E357: +$B$176*$B$327+$C$176*$B$326
F357: [W9] +$B$260*$B$328+$C$260*$B$326
H357: (B357^2+D357^2+F357^2)^0.5
I357: (C357^2+E357^2+G357^2)^0.5
J357: +H357*12*$F$11/$F$5*$F$8
K357: +I357*12/$F$5*$F$8
L357: (J357^2+4*K357^2)^0.5
A358: 'L+
C358: (F1) +$B$100*$B$327+$C$100*$B$328
D358: +$B$176*$B$327+$C$176*$B$326
F358: [W9] +$B$260*$B$328+$C$260*$B$326
H358: (B358^2+D358^2+F358^2)^0.5
I358: (C358^2+E358^2+G358^2)^0.5
J358: +H358*12*$F$11/$F$5*$F$8
K358: +I358*12/$F$5*$F$8
L358: (J358^2+4*K358^2)^0.5
A359: 'M-
C359: (F1) +$B$101*$B$327+$C$101*$B$328
D359: +$B$177*$B$327+$C$177*$B$326
F359: [W9] +$B$261*$B$328+$C$261*$B$326
H359: (B359^2+D359^2+F359^2)^0.5
```

LOTUS 1-2-3 BASED THERMAL PIPE STRESS PROGRAM LISTING

```
I359: (C359^2+E359^2+G359^2)^0.5
J359: +H359*12*$F$11/$F$5*$F$8
K359: +I359*12/$F$5*$F$8
L359: (J359^2+4*K359^2)^0.5
A360: 'M+
B360: (F1) +$B$101*$B$327+$C$101*$B$328
E360: +$B$177*$B$327+$C$177*$B$326
F360: [W9] +$B$261*$B$328+$C$261*$B$326
H360: (B360^2+D360^2+F360^2)^0.5
I360: (C360^2+E360^2+G360^2)^0.5
J360: +H360*12*$F$11/$F$5*$F$8
K360: +I360*12/$F$5*$F$8
L360: (J360^2+4*K360^2)^0.5
A361: 'N-
B361: (F1) +$B$102*$B$327+$C$102*$B$328
E361: +$B$178*$B$327+$C$178*$B$326
F361: [W9] +$B$262*$B$328+$C$262*$B$326
H361: (B361^2+D361^2+F361^2)^0.5
I361: (C361^2+E361^2+G361^2)^0.5
J361: +H361*12*$F$11/$F$5*$F$8
K361: +I361*12/$F$5*$F$8
L361: (J361^2+4*K361^2)^0.5
A362: 'N+
B362: (F1) +$B$102*$B$327+$C$102*$B$328
D362: +$B$178*$B$327+$C$178*$B$326
G362: +$B$262*$B$328+$C$262*$B$326
H362: (B362^2+D362^2+F362^2)^0.5
I362: (C362^2+E362^2+G362^2)^0.5
J362: +H362*12*$F$11/$F$5*$F$8
K362: +I362*12/$F$5*$F$8
L362: (J362^2+4*K362^2)^0.5
A363: 'O-
B363: (F1) +$B$103*$B$327+$C$103*$B$328
D363: +$B$179*$B$327+$C$179*$B$326
G363: +$B$263*$B$328+$C$263*$B$326
H363: (B363^2+D363^2+F363^2)^0.5
I363: (C363^2+E363^2+G363^2)^0.5
J363: +H363*12*$F$11/$F$5*$F$8
K363: +I363*12/$F$5*$F$8
L363: (J363^2+4*K363^2)^0.5
A364: 'O+
B364: (F1) +$B$103*$B$327+$C$103*$B$328
E364: +$B$179*$B$327+$C$179*$B$326
F364: [W9] +$B$263*$B$328+$C$263*$B$326
H364: (B364^2+D364^2+F364^2)^0.5
```

```
I364: (C364^2+E364^2+G364^2)^0.5
J364: +H364*12*$F$11/$F$5*$F$8
K364: +I364*12/$F$5*$F$8
L364: (J364^2+4*K364^2)^0.5
A365: 'P
B365: (F1) +$B$104*$B$327+$C$104*$B$328
E365: +$B$180*$B$327+$C$180*$B$326
F365: [W9] +$B$264*$B$328+$C$264*$B$326
H365: (B365^2+D365^2+F365^2)^0.5
I365: (C365^2+E365^2+G365^2)^0.5
J365: +H365*12/$F$5*$F$8
K365: +I365*12/$F$5*$F$8
L365: (J365^2+4*K365^2)^0.5
```

VITA

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