1337

HAVERHILL SOLAR ENERGY PROJECT

The design of a solar energy system to provide 150 psi industrial process steam for the production of polystyrene at the USS Chemicals Haverhill, Ohio plant.

FINAL DESIGN REPORT

ROUGH DRAFT

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TABLE OF CONTENTS

SECTION I

INTRODUCTION

Under Cooperative Agreement DE-FC03-79CS30310, the U.S. Department of Energy, the Columbia Gas System Service Corporation and the USS Chemicals Division of United States Steel Corporation jointly funded a project to design a 50,400 square foot solar energy system to provide 150 psi industrial process steam for the production of polystyrene at the USS Chemicals Haverhill, Ohio plant. The design phase of the project (Phase I) was conducted during the ten month period from September 28, 1979 through July 31, 1980, and was divided into five tasks:

Task 1 - Preliminary Design

Task 2 - Economic Analysis

Task 3 - Environmental Assessment

Task 4 - Safety Analysis

Task 5 - Detailed Design

Individual final reports on Tasks 1 through 4 were submitted to the U.S. Department of Energy - San Francisco Operations Office during the course of Phase I. The material in these task 1 through 4 Reports will not be reproduced, for the most part, in this report. This report presents information on Task 5 - Detailed Design.

SECTION II

INDUSTRIAL PROCESS

A. Selection of Industrial Partner

The Columbia Gas System Service Corporation evaluated many of our industrial natural gas customer's plants as potential sites for a solar industrial process heat installation. The USS Chemicals Haverhill plant in Haverhill, Ohio was selected because the plant offered a combination of site characteristics necessary for a successful industrial process heat solar installation. Some of these characteristics are: excellent air quality at the site; daily solar radiation comparable to, or better than, other sites in Columbia's seven state distribution area; potential for widespread application of the specific solar technology to industry throughout the industrial northeast, in general, and the Ohio River valley, in particular; availability of land surrounding the polystyrene plant within the USS Chemicals Haverhill complex; large continuous steam loads; and enthusiastic desire of the company's management to participate in the project.

B. Selection of Industrial Application

There is large potential for widespread application of the specific solar technology that would be utilized in this project. A survey by Battelle-Columbus Laboratories[1] indicated that 70% of the steam used by industry nationally is in the temperature range 212°F-350°F. The proposed solar energy system for this project will supply steam at a temperature of 373°F, and thus is directly applicable to the 70% of the national usage of steam identified by Battelle.

[1] "Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat", BCL, January, 1977, Volume II, Page 6

There is also tremendous potential for widespread application of the proposed solar technology in industrial applications in the geographic area for the project. A recent study by Columbia indicates that 80% of our industrial customers' steam requirements are in the temperature range of 212°F to 350°F. Table 1 compares the quantities of energy used nationwide to produce steam by the industries studied by Battelle, and the quantities used by Columbia's customers to produce steam in these same industries. The right hand column in Table 1 shows the percentage of national energy requirements for industrial process steam that is accounted for by Columbia's industrial customers on an industry by industry basis. A much larger percentage of the national energy requirements for industrial process steam would be accounted for by all industrial customers with solar radiation in the range of 1250 to 1450 Btu/sq. ft.-day typified by the Ohio River Valley and the Haverhill plant. Large sections of the midwest and industrial northeast have solar radiation in this range.

Many of the industries with the largest national energy requirements for process steam are concentrated in (or have significant percentages of their capacity located in) the midwest, east north central, west north central and middle Atlantic regions. Of relevance for this proposal, Battelle[2] shows the U.S. capacity for producing polystyrene in each state and reports, "From the point of view of solar energy, it is noteworthy that only 16 percent of the polystyrene capacity is in states with high insolation." An endless array of other industry statistics could be recited to further document the tremendous industrial capacity in the "mild belt" of the nation. It is important to demonstrate the feasibility of solar energy in this region.

Without question, solar energy is a scarcer resource (and concomitantly more costly) in southern Ohio than in Arizona. However, the traditional forms

[2] IBID, Volume II, Page 479

ANNUAL ENERGY REQUIREMENTS - PROCESS STEAM PRODUCTION

Industry	National Energy Requirements[1] 10^6 BTU/year 212°F - 350°F	>350°F	Columbia Customer Requirements[2] 10^6 BTU/year 212°F - 350°F	>350°F	Columbia Customer Requirements As A % of National Requirements
Aluminum		38,400,000		215	Not significant
Automobiles and Trucks	1,400,000		16,069		1.1%
Cement					-
Ceramics			340,173		None shown in Battelle Report
Concrete Block & Brick	9,700,000	4,600,000	216,700	102,770	2.2%
Gypsum		31,900,000		731,998	2.3%
Chemicals	212,000,000		12,079,902		5.7%
Coal Mining & Cleaning					-
Copper					-
Food Processing	68,000,000	25,300,000	4,580,000	1,705,208	6.7%
Glass	9,800,000		284,123		2.9%
Lumber	13,100,000	2,500,000	345,100	65,872	2.6%
Mining	43,700,000				-
Paper & Pulp	465,000,000		5,804,109		1.2%
Petroleum Refining	120,000,000	380,000,000	859,600	2,722,080	0.7%
Plastics	7,600,000	9,400,000	1,558,200	1,927,347	20.5%
Rubber	5,400,000		1,835,596		34.0%
Steel & Iron	65,000,000		2,106,800		3.2%
Textiles	191,000,000	4,300,000	1,256,000	28,277	0.6%

[1] "Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat", BCL, January, 1977

[2] Columbia's "Industrial Customer Classification Information System".

TABLE 1

of energy with which solar must compete tend to be more costly in the northeast than in the southwest.

There is tremendous potential for widespread application of this solar technology in the chemical industry, which is currently one of the most dynamic growth industries in the United States. In the "Summary of Process Heat Requirements Including Extrapolations" presented in the Battelle report[3], chemical industry requirements account for 50% of the steam utilized in the 212°F to 350°F range, and over 40% of all industrial steam and hot water. The Ohio River Valley, from Pittsburgh to Louisville, is one of the largest chemical producing areas in America, and provides a vast opportunity for the commercialization of solar energy. Much of the chemical industry in this area is presently served by the Columbia Gas System and its 96 affiliated and non-affiliated retail distribution companies.

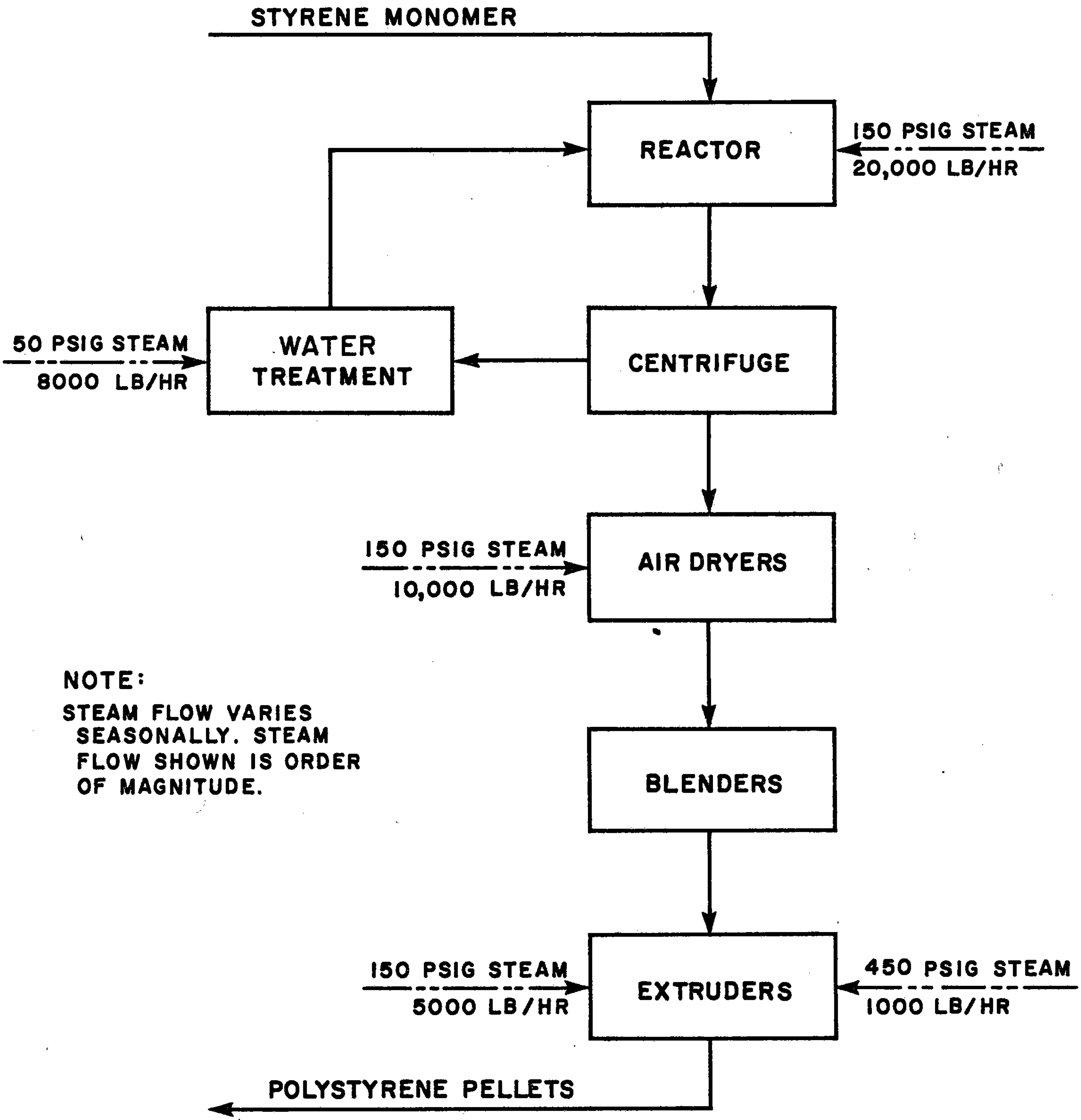
C. Selection of Industrial Process

During the preliminary design task, USS Chemicals evaluated the consumption of 20 psig, 50 psig, 150 psig steam at the Haverhill plant. The survey of steam uses in close proximity to the candidate solar collector array site was undertaken to determine the best use for the solar energy collected at the Haverhill site. After evaluating piping run lengths, solar system cool down/warm-up thermal losses, solar system operating losses, solar collector efficiency at operating temperature, and the quantity and profile of steam usage, Columbia and USS Chemicals selected a 150 psig steam application in the reactor area of the polystyrene plant. This particular steam load offers the advantage of high continuous steam usage 24 hours per day, 365 days per year.

3 IBID, Volume II, Page 11

This application also has the shortest possible solar system piping run, which will minimize installation cost and cool down/warm-up and operational heat losses.

Polystyrene is produced at USS Chemicals Haverhill plant by a batch suspension polymerization process. In the process, styrene monomer is dispersed into droplets in an agitated vessel containing water and carefully measured amounts of suspension agents and additives. Polymerization initiated by heat addition and the use of catalysts and consisting of controlled time and temperature sequences, results in the formation of beads of polystyrene. This polymerization process would utilize the steam generated by the solar energy system. The beads are dried using steam heat and then sold or extruded to form pellets for sale. A simplified block diagram of the polystyrene batch production process is shown in Figure 1.



POLYSTYRENE BATCH PRODUCTION PROCESS

FIGURE 1

SECTION III

SOLAR ENERGY SYSTEM

A. Solar System Diagram

A simplified schematic diagram of the Haverhill Solar Energy System is presented in Figure 2. This diagram highlights the solar energy system major components, all of which will be covered in more detail in later sections of this report.

The solar energy system design includes a 50,400 square feet of single-axis tracking, concentrating solar collectors. The solar collector loop pump will be activated when there is sun available. The solar system will include multiple solar collector loop pumps which will be automatically staged to give a low solar collector loop flow rate when there is nominal solar radiation available. High solar collector loop flow rate will be selected when there is maximum solar radiation available. Pump staging is utilized in the design to conserve electric pumping energy.

After flow is established in the solar collector loop, the controls cause the solar collectors to rotate up towards the sun into the tracking position. A synthetic oil solar collector loop heat transfer fluid was selected for this application to prevent freezing of the solar fluid and to permit the collector field to deliver 500°F fluid to the steam generator. At maximum radiation conditions, the heat transfer fluid is heated from 390°F to 500°F in the solar collectors. The hot fluid goes from the solar collectors to the tube side of the unfired steam generator which is shown in Figure 2. The heat in the heat transfer fluid is used to generate 150 psig steam and in this process the heat transfer fluid is cooled from 500°F down to 390°F. The heat transfer fluid is then returned to the inlet side of the solar collectors and the 150 psig solar produced steam is delivered to the polystyrene process.

HAVERHILL
SOLAR ENERGY SYSTEM

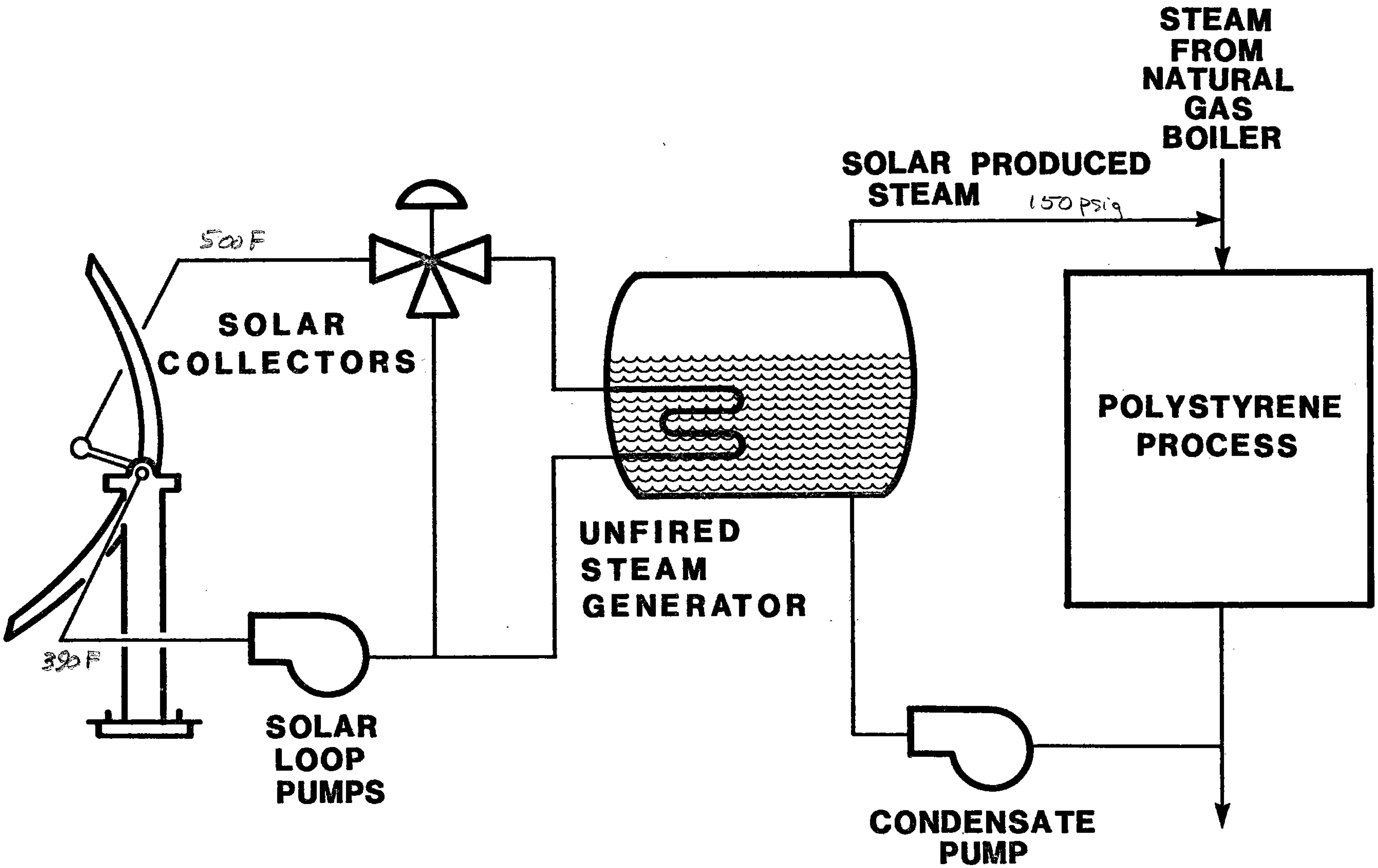


FIGURE 2

The water level in the unfired steam generator is maintained by primary and back-up condensate pumps. The maximum steam generation rate of the solar energy system will be about 11,000 pounds per hour which is below the instantaneous steam requirements of the polystyrene unit. Therefore, no thermal energy storage will be required with this system.

B. Solar System Layout and Component Location

The solar collectors will be sited in a rectangular area that conforms to the N-S, E-W road system throughout the Haverhill plant complex to efficiently utilize land area and to minimize the piping runs. The axis of the collectors will be aligned with plant East-West as shown on Drawing M-1, page 39. Plant North is 65 degrees East of true North. After evaluation of several different solar collector array layouts, the project team selected a layout of three banks of solar collectors with each bank containing 20 rows. Each row of collectors will have six, 20 foot long reflector panels. Drawings M-1 and M-5 present this layout. With the selected layout only one supply and one return header are required.

A 120 foot long solar collector "row" consists of six panels all driven by a single drive motor. The Haverhill solar collector array has three solar collector "rows" placed end to end as shown on Drawing M-1. Fluid flows in series through these three solar collector rows. There are 20 parallel sets of three series-connected collector rows. Fluid flow is in parallel through these 20 sets of three series-connected collector rows. All solar collector loop plumbing will be located above grade.

The solar collector array will be fenced in order to include the solar collector array within the USS Chemicals Haverhill plant security area. An access road to the collector field will be placed along the plant East side of the collector array. The soil under and around the collectors will be sterilized and locally available graded slag will be applied to the entire area. A limestone deposit often occurs on solar collectors when crushed rock is applied to the area under and around solar collectors. Graded slag is much cleaner than crushed rock and is also less expensive to purchase in the Haverhill, Ohio area.

Drawing M-2, page 40, shows the location of the steam generator building at the northeast corner of the solar collector array. A new steam line approximately 90 feet long will connect the steam generator to the Haverhill plant 150 psig steam system. This location for the steam generator yields extremely short solar collector loop heat transfer mains to the steam generator and also very short steam lines to connect with the existing plant steam system. Drawing M-2 also shows the location of the condensate receiver and the steam generator feed pumps.

Drawing M-3, page 41, contains the solar system piping schematic and presents the interconnection of all of the solar system components. Drawing M-4, page 42, shows the location of the solar system components in the steam generator building.

C. Solar System Operation, Control and Safety Provisions

The control system is designed to automatically operate and control the Haverhill solar energy system and all subsystems. The solar energy system is designed to operate unattended. Safeties are designed to automatically protect the solar energy system and to prevent any hazardous conditions in the event of equipment malfunction or failure. An alarm circuit will be run from the solar energy system to the polystyrene plant operators' console which is attended 24 hours per day. This alarm circuit would notify the polystyrene plant operator when out-of-tolerance solar energy system parameters are detected. The following sections detail the automatic controls and safeties.

1. Solar Collector Operation, Control and Safeties - Solar Kinetics provides a central direct normal light switch which is an aluminum casting that contains three phototransistors with sun shades that block out approximately 80% of the diffuse solar radiation. When any of the three phototransistors detect normal solar radiation above 95 BTU/hr-ft^2 (adjustable) a contact closure occurs in the central direct normal light switch. The solar controller detects this contact closure and if this contact closure persists for 15 minutes the solar controller issues a "start" command to the pump controller which starts the solar collector loop pump. After a 2 minute delay, if fluid flow is established in the solar collector loop, the solar controller directs the solar collectors to rotate (in a "fast track" mode) out of the stow position and into an angular position where each individual collector row can automatically track the sun.

As each of the 60 collector rows approaches the sun within 20° of focus, a light switch mounted on each solar collector row switches that row from fast track to the "auto-track" mode under the control of the shadow-well tracker for that individual row. The collectors continue in the "auto-track" mode until the central direct normal light switch detects a solar radiation level below 95 BTU/hr-ft^2. At this point the solar controller directs the solar collector loop pumps to continue running but directs the solar collectors to remain stationary. The solar collectors are maintained in this non-tracking mode for 45 minutes. If the central direct normal light switch senses solar radiation above 95 BTU/hr-ft^2 during this 45 minute period, the solar collectors are returned to the "auto-track" mode. If the direct solar radiation does not increase above the minimum level required for tracking during this 45 minute period, the solar controller directs the solar collectors to return to the stow position.

Safeties are built into the solar collector controls to prevent hazardous conditions from occurring. The solar collectors would be automatically returned to the stow position by conditions of high-wind speeds, loss of solar collector loop flow and over-temperature. Each solar collector drive system has a high-pressure hydraulic accumulator which has sufficient stored energy to drive that solar collector row to the stow position in the event of loss of electric power. During the loss of electric power, a 5 kW battery D.C. to A.C. inverter system provides A.C. power for the solar collector control logic and for solenoids associated with the hydraulic power units that drive the collectors to the stow position.

2. Solar Collector Loop Pump Operation and Control - This subsection discusses only the operation and control of the solar collector loop pumps. A discussion of the engineering details for the solar collector loop pumps will appear in a later subsection. The solar collector loop for the Haverhill solar energy system must operate over a very wide temperature range, from 0°F to +500°F. The solar collector loop controls are designed to start a positive displacement pump (Pump P-13001, shown on Drawing M-3, page 41), when the solar collector loop is cold and the heat transfer oil is very viscous. When the central direct normal light switch detects direct solar radiation above 95 BTU/hr-ft^2 a field relay closes. After this level of direct normal solar radiation has persisted for 15 minutes the solar controller sends a "start" signal to the Pump Controller, shown on Drawing E-3, page 49, which will start Pump P-13001.

As the solar collector outlet temperature increases, the pump controller is designed to stop the low-flow-rate positive displacement pump (Pump P-13001) and start a high-flow-rate, high-efficiency centrifugal pump (Pump P-13003, shown on Drawing M-3, page 41). Pump P-13001 will run until the solar collector outlet temperature reaches 150°F. At that point Pump P-13001 is stopped and Pump P-13003 is started.

The solar system is designed to operate with one centrifugal pump on during most of the operating hours. During periods of very high solar insolation pump P-13003 will remain running and a second pump P-13004 will be started when the solar collector outlet temperature reaches 480°F (adjustable).

Should the solar collector outlet field temperature reach 500°F (adjustable) which is expected to occur less than 1% of the solar system seasonal operating time, the pump controller will continue running pumps P-13003 and P-13004 and will restart pump P-13001.

As the solar radiation decreases and the solar collector outlet temperature decreases, the solar collector loop pumps will be staged off in the reverse order that they were started.

There is a backup solar collector loop pump (Pump P-13002) plumbed into the Haverhill solar energy system. This pump is designed for manual control and can be used as a direct replacement for any of the three primary solar collector loop pumps should one of them fail.

3. Steam Generator Operation, Control and Safeties - This subsection discusses only the <u>operation</u> and <u>control</u> of the steam generator. A discussion of the steam generator engineering details will appear in a later subsection. The steam generator will be supplied with a normally closed pneumatic 3-way diverting valve. Solar collector loop fluid will bypass the steam generator until the solar collector loop temperature (as measured near the steam generator) reaches 400°F (adjustable).

At temperatures above 400°F, the steam generator controls are designed to actuate the diverting valve and direct the solar collector heat transfer fluid to the tube side of the generator. An automatic stop and check valve will allow any steam generated to flow from the shell side of the steam generator into the 150 psig steam main.

The steam generator feed water pump (Pump P-817A(R), shown on Drawing M-3 page 41), will operate when the pump controller receives a "start" signal from the solar collector. A modulating level control furnished with the steam generator will modulate a pneumatic feed water control valve to allow feed water to enter the steam generator at the same rate that steam is generated.

Several safeties will be incorporated in the unfired steam generator. The steam generator shellside will be protected by an ASME Section I steam safety valve. The tube side will also be protected by a relief valve. A pneumatic steam pressure control, furnished with the steam generator, will direct the heat transfer fluid diverting valve to the bypass position if the steam pressure rises above 175 psig (adjustable). A backup steam generator feed water pump is included in the solar system. Backup Pump P-817B(R) will automatically start should Pump P-817A(R) fail.

SECTION IV

SOLAR SYSTEM COMPONENTS

A. Solar Collectors

During Task 1, the Preliminary Design, Columbia evaluated four line-focusing, concentrating solar collectors for the 150 psig steam application in the polystyrene unit at the USS Chemicals Haverhill plant complex. The following four collectors were analyzed:

1. Acurex 3001
2. General Electric TC-300
3. Solar Kinetics T-700
4. Suntec SH-1655

Columbia held discussions with these manufacturers, evaluated their solar collector hardware and visited large commercial and industrial process heat installations using these collectors.

Columbia evaluated technical information and actual cost quotations on these collectors. Based on collector cost quotations, estimated installation cost, estimated maintenance cost, measured single collector module peak performance, estimated solar collector array seasonal performance, and estimated solar collector durability, the Haverhill solar energy project team selected the Solar Kinetics T-700 solar collector for this project.

The T-700 solar collector has been under development by Solar Kinetics for several years. Technical information and catalog data on the collector is available from Solar Kinetics and will not be reproduced here. There are several design improvements in the T-700 that have recently become available and would be incorporated in the Haverhill solar energy project. A modular drive pylon assembly has been designed which includes a self-contained hydraulic power supply and tracker electronics. Solar Kinetics has incorporated a shadow well tracker that has greater sensitivity and is less influenced by diffuse radiation than earlier shadow band trackers. The control system for the hydraulic pump has been redesigned to minimize pump operation. The hydraulic pump is now actuated only when both of two conditions exist: accumulator pressure less than 700 psi + the presence of a tracking signal (i.e. a need for tracking power). The drive pylon assembly now also includes automatic sun acquisition at high speed and a new fail-safe emergency stow.

Solar Kinetics is developing several other improvements. One of these improvements, a new 10 foot long modular sealed receiver assembly, will probably be available for the Haverhill solar energy system. This modular receiver assembly has significantly less pressure drop than the present absorber tube and solar collector fluid pumping power would be correspondingly reduced. The sealed assembly should also improve the life of the absorber selective surface.

B. Solar Collector Loop Heat Transfer Fluid

Because winter temperatures in Haverhill, Ohio are frequently below 32°F, using water for the solar collector loop heat transfer fluid is not feasible unless the fluid is heated in the pipes or drained into heated vessels during periods of freezing temperatures. These approaches are not energy efficient and are costly to implement.

The Haverhill solar energy system is designed to operate with collector outlet temperatures of up to 500°F. The heat-transfer agents most commonly used in this temperature range are petroleum-derived heat-transfer oils. There are many heat-transfer fluids made by many manufacturers that are applicable to the temperature range of interest for the Haverhill solar energy system (0°F - 500°F).

Several physical and thermal characteristics were considered in the selection of a heat transfer fluid for this application. The flammability and toxicity of the fluid are of great importance to the Haverhill project design team. Therefore, the first two screening steps for potential heat transfer fluids were (a) high fire point and (b) low toxicity, using the Sterner and Hodge acute toxicity classification system. The third screening step was to select heat transfer fluids with a usable temperature range equal to, or greater than, 0°F - 500°F. A list of heat transfer fluids passing the first three screening steps is presented in Table 2. Some of the properties of these fluids are given in Table 3.

As a fourth step in the screening process a heat-transfer efficiency analysis was conducted for the heat transfer fluids listed in Table 3. This analysis computes a heat transfer efficiency factor (HTEF) which is an expression of the ratio of the heat transfer coefficient to the frictional energy expended pumping the fluid.

In this analysis the HTEF increases with increasing values of specific heat, thermal conductivity, and density and decreases with increasing values of viscosity. Some of the fluids, such as Dowtherm J, which are very good from a HTEF standpoint, do not have sufficiently high fire points for the Haverhill application and thus were eliminated in earlier screening steps. Table 4 presents values for the four physical properties that are required to calculate the Heat Transfer Efficiency Factor. The Heat Transfer Efficiency Factors did not vary greatly for the fluids that remained in consideration after the first three screening steps.

Of the twelve heat transfer fluid that remained after the four screening steps, the polyalphaolefins appear to have the best combination of properties for this application. Of the polyalphaolefins, Gulf Synfluid 4cs has the best combination of physical properties for the Haverhill application. Two other polyalphaolefins, BRAYCO 888HF and Ethyl ESH-4, were not selected because they do not have as high a fire point or as high a heat transfer efficiency factor as Synfluid 4cs. Two other polyalphaolefins, Ethyl ESH-6 and Synfluid 6cs, were not selected because of their higher viscosity at low temperature and lower HTEF.

HEAT TRANSFER FLUID

COMPOSITION AND TEMPERATURE RANGE

Number	Trade Name	Producer	Composition	Usable Temperature Range °F
1	BRAYCO 888 HF	Bray Oil Co.	Polyalphaolefin	-80 to +550
2	Dowtherm LF	Dow Chemical	Alkylated Diphenyl- Diphenyl Oxide	-25 to +600
3	Ethyl ESH-4	Ethyl Corp.	Polyalphaolefin	-90 to +600
4	Ethyl ESH-6	Ethyl Corp.	Polyalphaolefin	-90 to +600
5	Mobiltherm 600	Mobil Oil	Alkylated Aromatic	+5 to +600
6	Synfluid 4cs	Gulf Oil	Polyalphaolefin	-100 to +600
7	Synfluid 6cs	Gulf Oil	Polyalphaolefin	-90 to +600
8	Therminol 55	Monsanto	Alkylated Aromatic	0 to +600
9	Therminol 60	Monsanto	Polyaromatic Hydrocarbon	-60 to +600
10	Therminol 66	Monsanto	Partially Hydrogenated Terphenyl	0 to +650
11	Sun-Temp	Resource Technology	N.A.	-40 to +671
12	UCON HTF 500	Union Carbide	Inhibited Polyalkylene Glycol	-35 to +500

N.A. - Not Available from Manufacturer

TABLE 2

HEAT TRANSFER FLUID

THERMAL PROPERTIES

Number	Trade Name	Pour Point °F	Flash Point °F	Fire Point °F	Auto Ignition °F
1	BRAYCO 888HF	-85	440	475	730
2	Dowtherm LF	-25	260	280	1020
3	Ethyl ESH-4	-90	435	475	740
4	Ethyl ESH-6	-90	460	510	760
5	Mobiltherm 600	0	350	390	710
6	Synfluid 4cs	-100	445	495	710
7	Synfluid 6cs	-90	465	520	710
8	Therminol 55	-40	355	410	675
9	Therminol 60	-90	310	320	835
10	Therminol 66	-18	355	382	705
11	Sun-Temp	-40	380	N.A.	824
12	UNCON HTF 500	-35	540	600	750

N.A. - Not Available from Manufacturer

TABLE 3

HEAT TRANSFER FLUID PHYSICAL PROPERTIES AT 400°F

Fluid	Specific Heat (BTU/lb - °F)	Conductivity (BTU/hr-ft - °F)	Density (lb/cu ft)	Viscosity (lb/hr-ft)
Brayco	0.650 (a)	0.0732 (a)	45.1 (b)	2.447 (b)
Dowtherm LF	0.520	0.067	55.6	0.895
Ethyl ESH-4	0.690	0.065	43.7	2.032
Ethyl ESH-6	0.590	0.067	44.1	2.734
Mobiltherm	0.560	0.0620	53.7	2.438
Synfluid 4cs	0.669	0.0737 (a)	45.0	1.935
Synfluid 6cs	0.590	0.0745 (a)	45.1	2.449
Therminol 55	0.611	0.0627	47.3	1.887
Therminol 60	0.543	0.0681	54.6	1.303
Therminol 66	0.534	0.0612	55.0	2.068
Sun-Temp	0.560 (c)	N.A.	56.2	2.974 (a)
UCON HTF 500	0.560	0.0810	56.6	7.457

(a) A+ 300°F
(b) Columbia Gas engineering estimate from available data
(c) A+ 72°F

N.A. Not available from manufacturer

TABLE 4

SECTION V

ON-SITE DATA SYSTEM

The on-site data system for the Haverhill solar energy system has three functions: (1) automatically gather analog sensor data, (2) convert and process this data, and (3) provide a permanent record of the reduced data in digital form. The on-site data system is designed to operate unattended. The following subsections identify the intent of the on-site data system and the specific data system components and sensors that would be employed.

A. Solar System Performance Evaluation

The site data system is designed to provide an accurate record of daily, monthly, and yearly energy information; such as solar energy available at the site, solar collector energy output, solar collector loop piping cool-down/warm-up losses, system operational losses and useful energy delivered to the process load. Additionally, the data system is designed to provide real time diagnostics on all solar energy system components. Instantaneous solar radiation, temperatures, and fluid flows will be measured and displayed on-site. Instantaneous energy flows and component efficiencies will be computed and also displayed on-site.

The Haverhill solar energy system will be evaluated using energy balance methods. The following three subsystems of the solar energy system will be individually analyzed:

1. Solar Collector Array
2. Solar Collector Loop Piping
3. Steam Generator

For each subsystem the energy entering, energy leaving, and internal energy change will be computed.

The Haverhill data system is designed to gather analog sensor readings, to complete A to D conversions, to complete engineering unit conversions, and to store a permanent record of this data every minute on a tape cartridge. This data may prove to be invaluable in analyzing subtleties of the solar energy system during system start-up and shakedown. The following data will be acquired and recorded:

(a) Total solar energy available on horizontal plane

(b) Total solar energy available on fixed tilted plane

(c) Direct normal beam radiation

(d) Diffuse radiation on fixed tilted plane

(e) Collector array inlet and outlet temperature

(f) Collector array flow rate

(g) Ambient temperature

(h) Wind speed

(i) Temperature and pressure of process steam delivered to load

(j) Flow rate for process steam delivered to load

(k) Parasitic power consumed

In addition to the basic sensor readings, the data system will calculate energy flows and system efficiencies. At the end of each hour this data will be summed and averaged as applicable. These hourly sums and averages will be printed out at the site as well as stored on the cartridge tape unit. The stored hourly averages will be retrieved as required to produce single day tables, monthly summary tables, and yearly summary tables.

B. Data System Major Components

The Haverhill data system provides significant data gathering capability and flexibility. The data system includes a Hewlett Packard 3052A Automatic

Data Acquisition System linked to a Hewlett Packard 9835A programmable desktop computer. The computer is equipped with a 12" CRT, which allows viewing of 20 lines of program or data at a time; four additional lines are reserved for keyboard entries and system comments. Peripheral equipment will include a Hewlett Packard Model 9871A Printer, which is a character impact printer with printing speed of 30 characters per second. This printing system will provide hardcopy output at the site and will simplify record keeping and monthly report writing.

The Data Acquisition System also includes a Hewlett Packard Model 9875A Cartridge Tape Unit for peripheral mass storage. This unit provides a reliable means of data storage for backup of the hardcopy print output and for further data processing such as yearly energy balance summaries.

The Hewlett Packard 3052A is a fully automatic data acquisition system. Analog signals from the solar system sensors are searched by a Hewlett Packard Model 3295A Scanner and connected to a Hewlett Packard Model 3455A Digital Voltmeter. The 3455A DVM is a 6-digit integrating volt meter with DC, AC, and resistance measurement capability. The 3455A DVM has high accuracy, good sensitivity, and high noise rejection. Analog signals from the scanner are converted to digital signals by the 3455A DVM.

Information from the digital voltmeter common data bus will interface with the on-site HP 9835A desktop computer, which will process and store data and direct output to the printer and/or cartridge tape unit. The on-site computer will scan and read the sensor data and will compute instantaneous collector array efficiencies, solar energy delivered to the polystyrene process and fossil fuel savings. The desktop computer will also integrate the solar energy available, the solar energy delivered and all other solar system energy flows.

The data acquisition system will also be used for temperature balancing the solar collector field. The outlet temperature for all collector rows can be displayed on the HP 9835A screen simultaneously. At operating temperature the flow in each collector row will be adjusted to produce the same collector outlet temperature from each row. The Haverhill design team would like to ensure that no individual solar collector row has an outlet temperature that exceeds a bulk fluid temperature of about 500°F. At this temperature the maximum fluid film temperature in the solar collector absorber tube should not exceed 540°F. The maximum continuous service temperature recommended by Gulf for Synfluid 4cs is 600°F.

C. Specific System Sensors

The sensors selected for the Haverhill data system are those necessary to support the energy balance calculations. Sensors used to instrument the Haverhill solar energy system will be located as shown on Figure 3. Sensor type, manufacturer, and model number are shown in Table 5. A detailed description of each type of sensor is provided below.

<u>Solar Radiation Measurement</u>

Since the Haverhill solar energy system will utilize concentrating, tracking solar collectors, it is necessary to measure total horizontal radiation, total radiation on a fixed tilted plane, direct beam normal radiation and diffuse radiation.

- Total horizontal radiation and total radiation on a fixed tilted plane will be measured with an Eppley Laboratories, Inc. pyranometer Model PSP.

Instrument Sensitivity	9 Microvolts per watt per square meter
Impendance	650 ohms
Temperature Dependence	$\pm$ 1% over ambient temperature range, -20°C to 40°C

HAVERHILL SOLAR ENERGY SYSTEM
INSTRUMENTATION PLAN

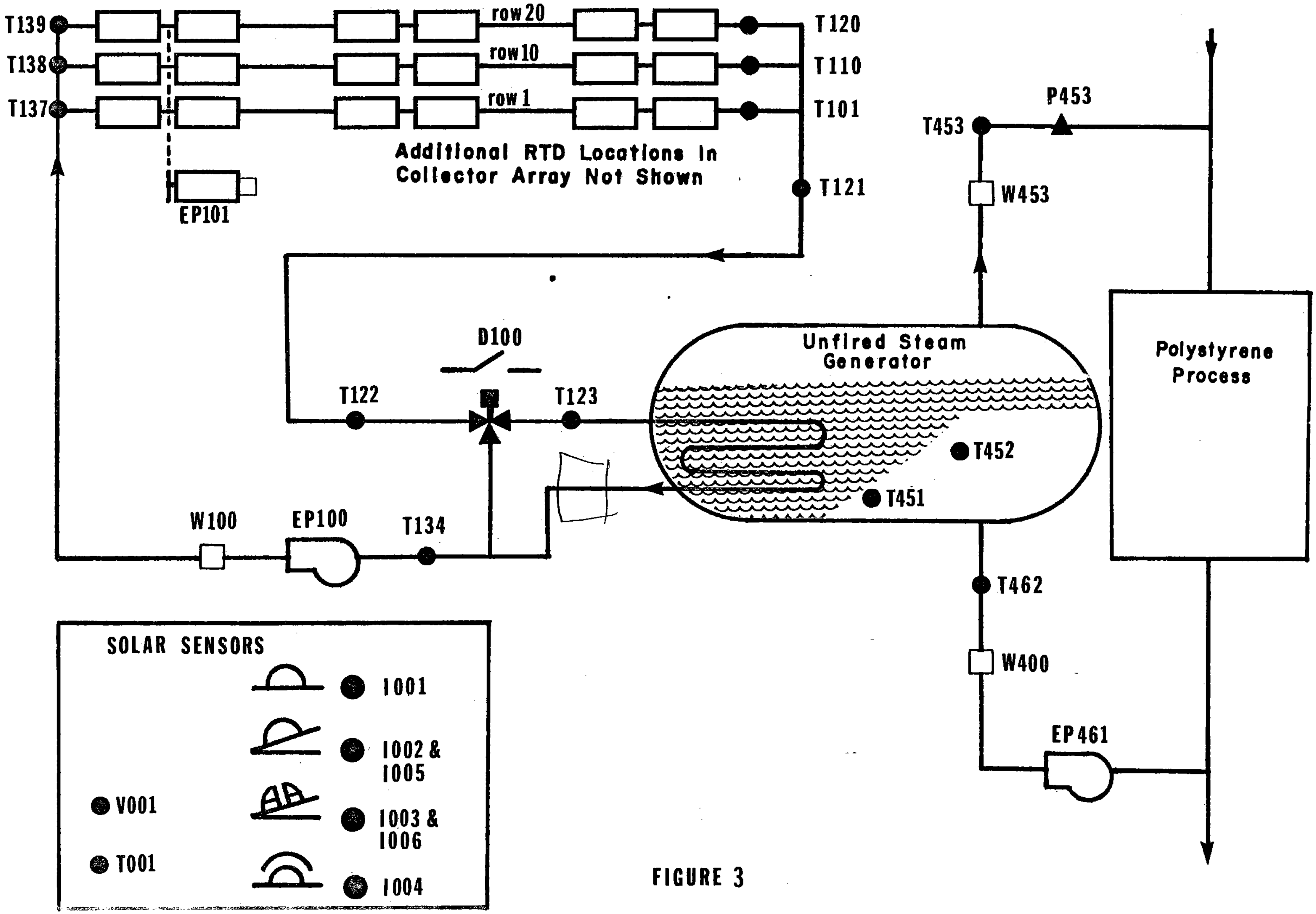


FIGURE 3

CHANNEL	IDENTIFICATION	NOMENCLATURE	SENSOR TYPE	MANUFACTURER & MODEL
1	I001	Total Horizontal Radiation	Pyranometer	Eppley PSP
2	I002	Total Radiation on Fixed Tilted Plane	Pyranometer	Eppley PSP
3	I003	Direct Normal Beam Radiation	Pyrheliometer w/ solar tracker	Eppley NIP w/ST-1
4	I004	Diffuse Radiation on Fixed Tilted Plane	Pyranometer w/shadow band	Eppley PSP w/SBS
5	I005	Total Radiation on Fixed Tilted Plane (Backup to 1002)	Pyranometer	Eppley PSP
6	I006	Direct Normal Beam Radiation (Backup to 1003)	Pyrheliometer w/solar tracker	Eppley NIP w/ST-1
7	V001	Wind Velocity	Windspeed Transducer	Weather Measure SKYVANE 1-W102-P
8	T001	Ambient Temperature	RTD	YSI 4116PT w/radiation shield
9	T101	Collector Row 1 Outlet Temperature	RTD	YSI 4116PT
10	T102	Collector Row 2 Outlet Temperature	RTD	YSI 4116PT
11	T103	Collector Row 3 Outlet Temperature	RTD	YSI 4116PT
12	T104	Collector Row 4 Outlet Temperature	RTD	YSI 4116PT
13	T105	Collector Row 5 Outlet Temperature	RTD	YSI 4116PT
14	T106	Collector Row 6 Outlet Temperature	RTD	YSI 4116PT
15	T107	Collector Row 7 Outlet Temperature	RTD	YSI 4116PT
16	T108	Collector Row 8 Outlet Temperature	RTD	YSI 4116PT
17	T109	Collector Row 9 Outlet Temperature	RTD	YSI 4116PT
18	T110	Collector Row 10 Outlet Temperature	RTD	YSI 4116PT
19	T111	Collector Row 11 Outlet Temperature	RTD	YSI 4116PT
20	T112	Collector Row 12 Outlet Temperature	RTD	YSI 4116PT
21	T113	Collector Row 13 Outlet Temperature	RTD	YSI 4116PT
22	T114	Collector Row 14 Outlet Temperature	RTD	YSI 4116PT
23	T115	Collector Row 15 Outlet Temperature	RTD	YSI 4116PT
24	T116	Collector Row 16 Outlet Temperature	RTD	YSI 4116PT
25	T117	Collector Row 17 Outlet Temperature	RTD	YSI 4116PT
26	T118	Collector Row 18 Outlet Temperature	RTD	YSI 4116PT
27	T119	Collector Row 19 Outlet Temperature	RTD	YSI 4116PT
28	T120	Collector Row 20 Outlet Temperature	RTD	YSI 4116PT
29	T121	Collector Array Outlet Temperature	RTD	YSI 4116PT
30	T122	Solar Loop Temperature In Route to Steam Generator	RTD	YSI 4116PT
31	T123	Solar Loop Temperature Inlet to Steam Generator	RTD	YSI 4116PT
32	T134	Solar Loop Temperature Outlet from Steam Generator	RTD	YSI 4116PT
33	T137	Collector Array Header Inlet Temperature	RTD	YSI 4116PT
34	T138	Collector Array Header Inlet Temperature @ Row 10	RTD	YSI 4116PT
35	T139	Collector Array Header Inlet Temperature @ Row 20	RTD	YSI 4116PT
36	W100	Solar Collector Loop Flow Rate	Impact Flow Meter	Ramapo MARK V
37	EP100	Solar Collector Loop Pump Motor Electric Power	Watt Transducer	Scientific Columbus DL-A2
38	EP101	Collector Array Tracking Drivemotors Electric Power	Watt/Watt-Hour Transducer	Scientific Columbus DL-A2-6070
39	D100	Valve Position Switch	Contact Closure	Square D
40	W400	Condensate Flow Rate	Impact Flow Meter	Ramapo MARK V
41	T451	Steam Generator Fluid Temperature	RTD	YSI 4116PT
42	T452	Steam Generator Fluid Temperature	RTD	YSI 4116PT
43	T453	Steam Generator Outlet Steam Temperature	RTD	YSI 4416PT
44	P453	Steam Generator Outlet Steam Pressure	Pressure Transmitter	ITT/Barton 753-1
45	W453	Steam Flow Rate	ΔP Transmitter	ITT/Barton 752
46	W454	Steam Flow Rate	ΔP Transmitter	ITT/Barton 752
47	EP461	Condensate Pump Motor Electric Power	Watt Transducer	Scientific Columbus DL-A2
48	T462	Steam Generator Condensate Inlet Temperature	RTD	YSI 4116PT

SPECIFIC SENSOR LIST

TABLE 5

Linearity	± 0.5% from 0 to 2,800 watts per square meter
Response Time	1 second

- Diffuse radiation will be measured with an Eppley Laboratories, Inc. pyranometer MODEL PSP mounted on an Eppley Shadow Band Model SBS.
- Direct normal beam radiation will be measured with an Eppley Laboratories, Inc. normal incidence pyrheliometer Model NIP mounted on the power driven Eppley Solar Tracker Model ST-1.

Pyrheliometer

Instrument Sensitivity	8 Microvolts per watt per square meter
Impedance	200 ohms
Temperature Dependence	± 1% over ambient temperature range, -20°C to 40°C
Linearity	± 0.5% from 0-2,800 watts per square meter
Response Time	1 second

Solar Tracker

Pointing Accuracy	± 0.25% daily
Latitude Setting	0° to 90°
Declination Setting	-23.5° to +23.5°

Temprature Measurements

All system temperatures will be measured with Yellow Springs Instruments (YSI) Industrial platinum resistance temperature detectors. Each RTD will be spring loaded in a thermowell with a connector head and with a signal conditioning transmitter.

The use of signal conditioning transmitters to convert the resistance output of platinum thermometers to a two-wire, 4 to 20 mA signal is good instrumentation practice where the lead length is more than 25 feet and where the possibility of electrical noise pickup exists. Signal conditioning transmitters are highly recommended for platinum resistance thermometers used in industrial environments, such as Haverhill, where the signal carrying wires may be in proximity to power lines and where resistance, especially at connections and contacts, can be expected to change with time.

At the Haverhill site some RTD's will have several hundred feet of lead wire. The cost of the signal transmitter for these RTD's will be partially offset by savings from the use of two wires instead of the four needed for direct remote resistance measurement.

Yellow Springs Instruments

Resistance Temperature Device	
Model Number	4116PT-139AP/P/EX
Resistance	100 ohms @ 32°F
Temperature tolerance	± 0.18°F @ 32°F
Temperature range	-328°F to 932°F
Thermowell	Model L (type 316SS)
Connection Head	Model EX
Temperature Transmitter	Model 1260/0-932/F/392
Temperature range	0°F to 932°F
Ambient operating range	-13°F to 185°F
Accuracy	± 0.1% of temperature span
Response time	10 milliseconds
Signal output	4 to 20 mADC

System Flow Rates

- Solar collector fluid flow rate will be measured with a Ramapo Instrument Company, Inc. target (impact) flow meter.

Model Number	MARK V-6"-W-01, wafer housing body meter for mounting between ANSI flanges
Pressure rating	
Primary sensing element	1,000 psi max.
Flange rating	ANSI 150# flange equivalent
Temperature rating	-65°F to 750°F
Materials	
Primary sensing element	17-4 PH SS
Wafer type line housing	Carbon steel
Seals	Buna-N
Flow range	60 to 600 GPM
Pressure drop	0.2 psi at full flow
Accuracy	0.25% of full scale with flow calibration
Repeatability	0.15% of reading including hysteresis
Signal output	4 to 20mADC linearized with respect to flow

Flow meter accuracy is of particular interest for this project. We have contacted several laboratories about the calibration of relatively large flow meters (400 GPM, 6 inch line) with the heat transfer fluid of interest (Gulf Synfluid 4 CS) at several different temperatures throughout the range of operation for this application. Changes in the flow meter calibration as the temperature of the heat transfer oil changes from cold to hot (and the oil viscosity concommitantly changes from high to low) must be identified and brought into the energy calculation software.

In addition to the total solar collector loop flow rate, the flow rate through each individual collector row may be measured using a clamp-on ultrasonic flowmeter furnished by Columbia Gas. This flowmeter may be a Controlotron Corp 241MP-1 Multipipe Portable Flow Display Computer. As discussed previously the solar collector rows will be temperature balanced, not flow balanced. Since each solar collector row inlet and outlet temperature is available, the energy delivered and efficiency of each individual collector row could be calculated with these flow measurements.

- Steam flow rate will be measured with Vickery-Simms Inc. calibrated calibrated orifice plates. These will be of the paddle type, Model MARK 52-SS. The differential pressure across the orifice plate will be measured with an ITT Barton Differential Pressure Electronic Transmitter with temperature compensation.

  The electronics condition the differential pressure reading to provide a 4-20mADC signal linearly proportional to flow rate. The steam flow rate produced by the solar energy system will vary over a wide range (from zero to 11,000# steam per hour). Because of this wide range two separate Differential Pressure Electronic Transmitters will be used to improve measurement accuracy at low flow rates. One Differential Pressure Electronic Transmitter will be used for low steam flow rates (below 3,500# steam per hour) and one for high steam flow rates (above 3,500# steam per hour).

Differential Pressure Electronic Transmitter

Model Number	752
Sensitivity	0.01% of calibrated span

Accuracy	± 0.25% of rated span includes linearity hysteresis and repeatability
Repeatability	± 0.1% of rated span

Flow range

0 to 3,000# steam per hour 0 to 30 inches H_2O

0 to 10,000# steam per hour 0 to 200 inches H_2O

Static Pressure Range	3,000 psig
Signal output	4 to 20 mADC

System Pressures

- Steam generator outlet pressure will be measured with an ITT Barton Pressure Electronic Transmitter

Model Number	Model 753-1
Sensitivity	0.01% of calibrated span
Accuracy	± 0.25% of rated span (includes linearity, hysteresis and repeatability)
Repeatability	± 0.10% of rated span
Pressure range	0 to 300 psig
Signal output	4 to 20 mADC linear with respect to steam pressure

Power Measurements

All solar energy system parasitic power will be measured with Scientific-Columbus AC Watt Transducers. The power consumption for the solar collector drive motors, the solar collector loop pumps and the steam condensate pumps will be monitored. Watt readings will be taken at one-minute intervals. These watt readings will be integrated over time with the HP 9835A desktop computer to obtain electrical energy consumption.

Model Number	DIGILOGIC DL-A2-Series
Accuracy	0.1% of reading
Analog output	0.1 mA DC

Wind Velocity

Wind velocity will be monitored with Weather Measure Corporation wind sensor equipped with a DC Generator to give an output voltage proportional to wind speed.

Wind Sensor	Model SKYVANE I, W102-P

HAVERHILL PLANT SOLAR ENERGY PROJECT

FOR

THE COLUMBIA GAS SYSTEM SERVICE CORP.

DIST. 431 COLUMBUS, OHIO

AND

USS CHEMICALS

DIVISION OF UNITED STATES STEEL CORPORATION

CONSULTING ENGINEERS : H. A. WILLIAMS & ASSOCIATES, INC.
980 WEST HENDERSON ROAD
COLUMBUS, OHIO

DRAWING INDEX:

ARCHITECTURAL

- A-1 SITE & GRADING PLAN
- A-2 STEAM GENERATOR BUILDING

STRUCTURAL

- S-1 FOUNDATION PLAN FOR COLLECTOR FIELD
- S-2 PLAN VIEW OF TOWER PIPE SUPPORT

MECHANICAL

- M-1 COLLECTOR FIELD SITE PLAN
- M-2 AREA 200 & 800 SITE PLAN
- M-3 SOLAR SYSTEM PIPING SCHEMATIC

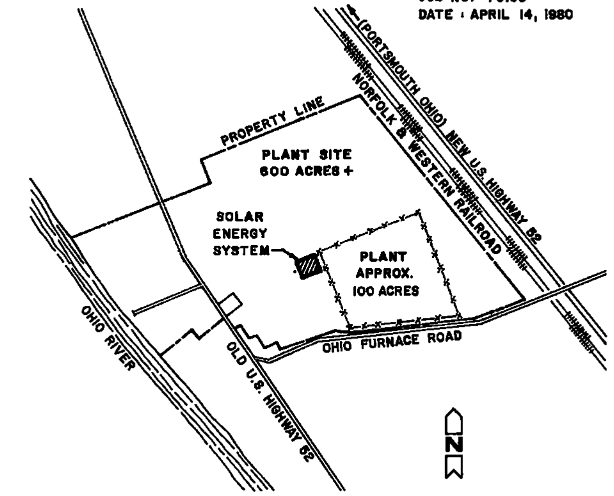
MECHANICAL (cont'd.)

- M-4 STEAM GENERATOR BUILDING MECHANICAL PLANS & SECTIONS
- M-5 COLLECTOR QUADRANT PIPING PLAN
- M-6 ANCHORS, GUIDES & MISCELLANEOUS DETAILS
- M-7 PIPING & INSTRUMENTATION
- M-8 CONTROL DIAGRAMS

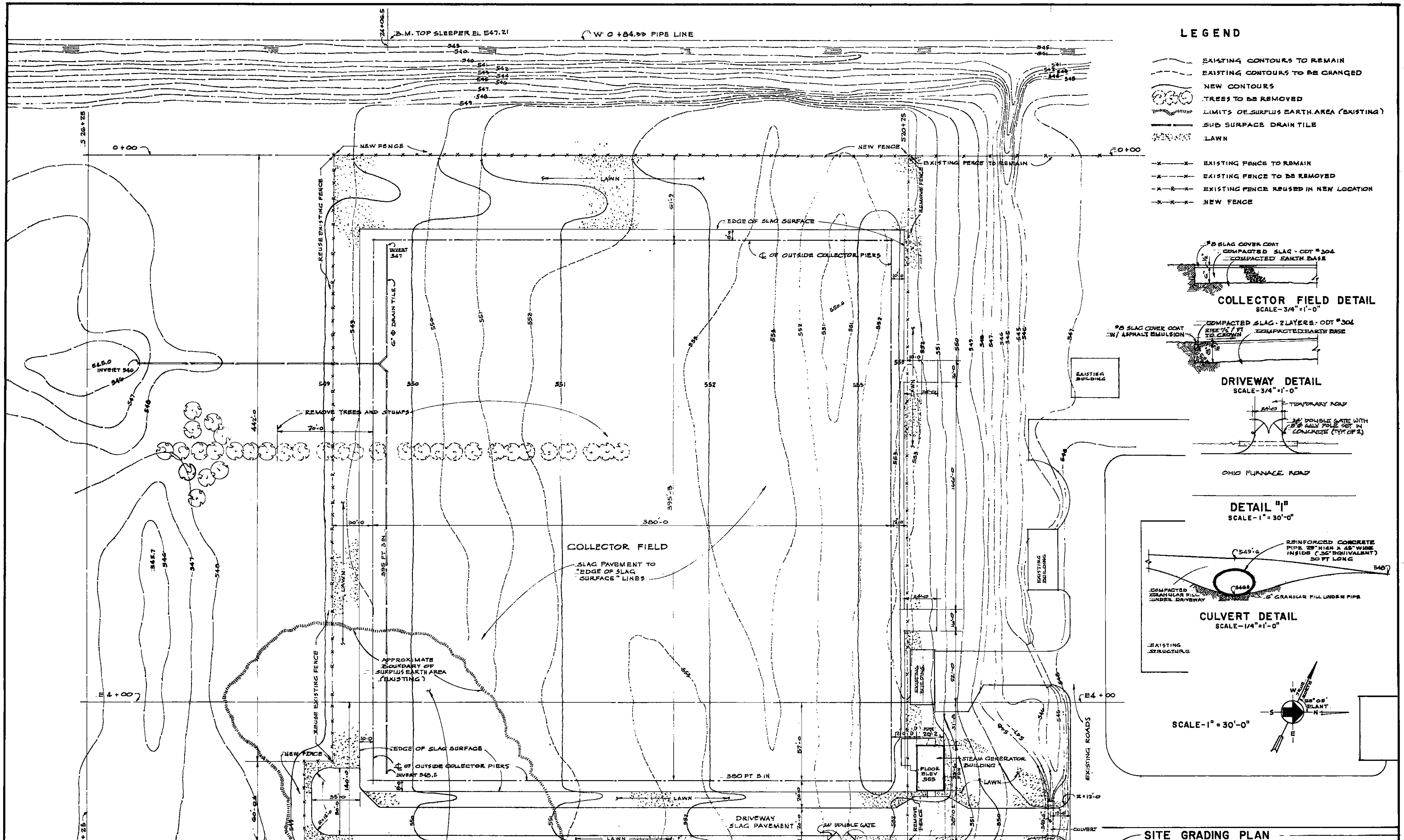
ELECTRICAL

- E-1 COLLECTOR FIELD ELECTRICAL PLAN
- E-2 ELECTRICAL SCHEDULES
- E-3 CONTROL DIAGRAMS & PYLON DETAILS

JOB NO. 79199
DATE : APRIL 14, 1980



SITE PLAN



SITE GRADING PLAN

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

JOB NO. 79199
DATE JUNE 20 1980
SET OF 15

DESIGNED BY C.R. GALLOGLY
DRAWN BY CRG
CHECKED BY W.R. LOGAN

REVISIONS

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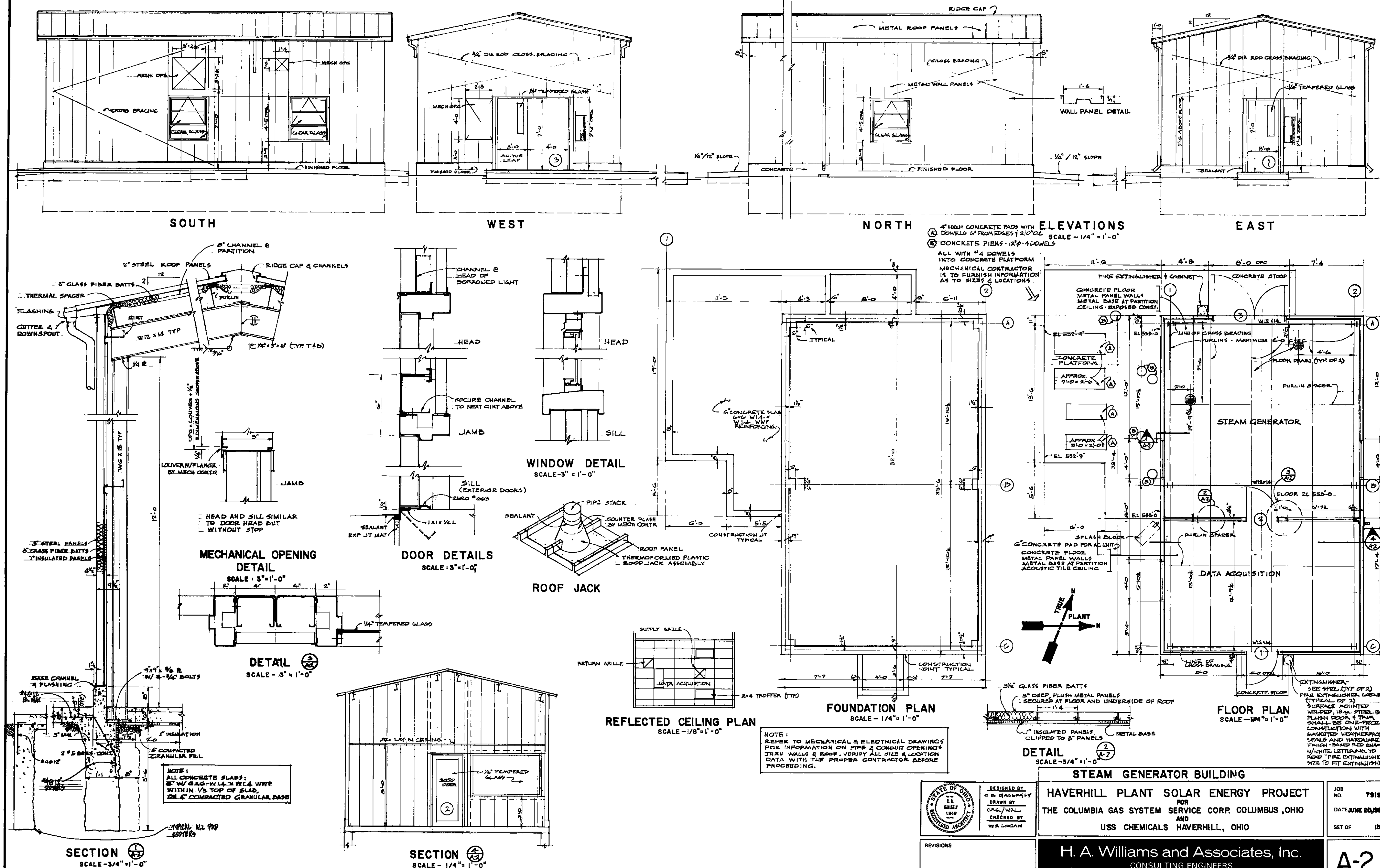
A-1



STEAM GENERATOR BUILDING

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

JOB NO.	79199
DATE	JUNE 20, 1980
SET OF	18

DESIGNED BY C.R. GALLOGLY
DRAWN BY CRG/WRL
CHECKED BY W.R. LOGAN

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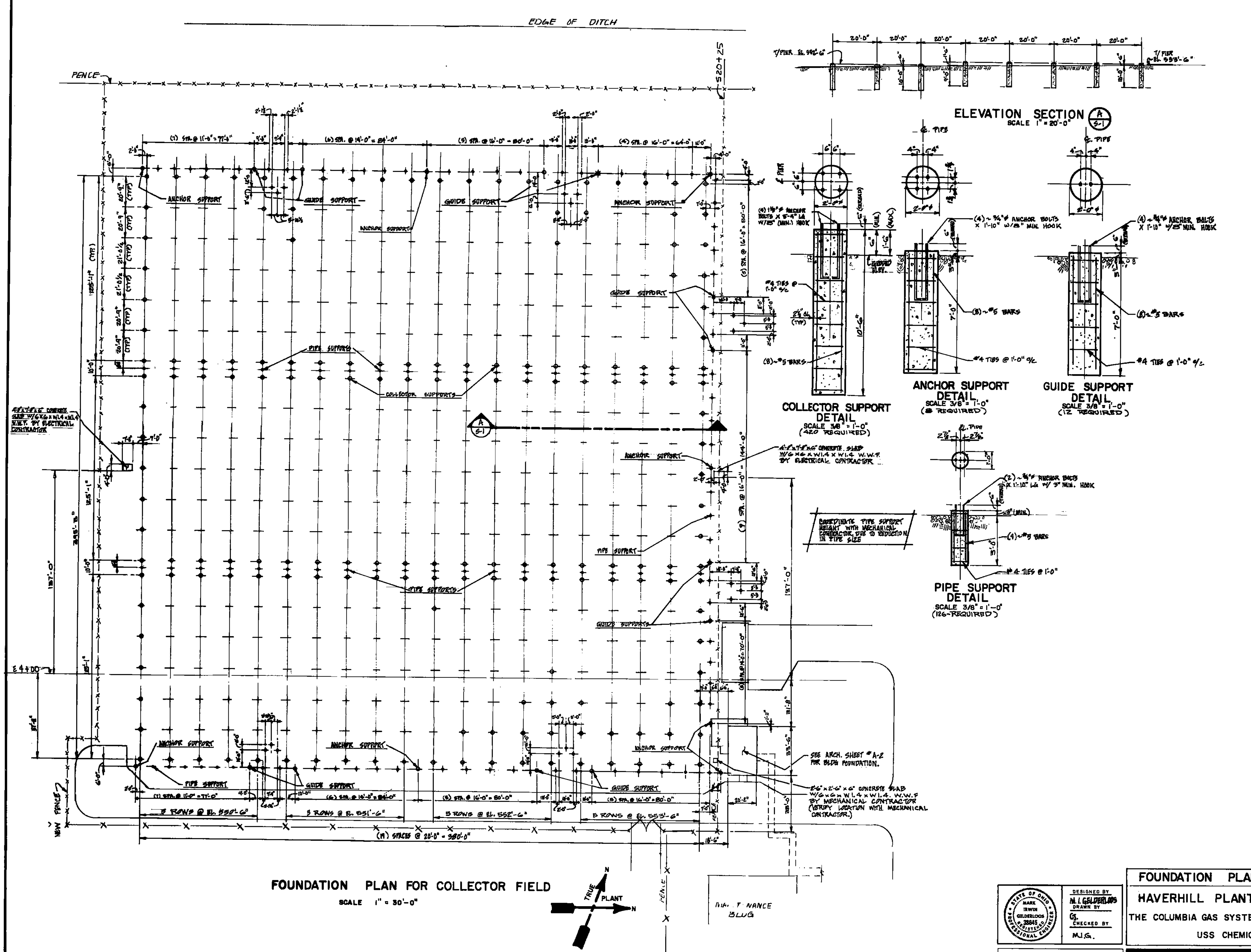
A-2



STRUCTURAL ABBREVIATIONS

A.B.	ANCHOR BOLT	I.F.	INSIDE FACE
ADJ.	ADJUSTABLE	INT.	INTERIOR
ALT.	ALTERNATE	MAX.	MAXIMUM
@	AT	MIN.	MINIMUM
BTM.	BOTTOM	MK.	MARK
BM.	BEAM	N.F.	NEAR FACE
BRG.	BEARING	N.S.	NEAR SIDE
BT.	BENT	N.T.S.	NOT TO SCALE
C/C	CENTER TO CENTER	O.F.	OUTSIDE FACE
℄	CENTER LINE	OPG.	OPENING
CL.	CLEAR	OPP.	OPPOSITE
COL.	COLUMN	PL	PLATE
C.T.	COLUMN TIE	QUAN.	QUANTITY
CONST. JT.	CONSTRUCTION JOINT	REINF.	REINFORCING
CONC.	CONCRETE	REQ'D	REQUIRED
CONT.	CONTINUOUS	SCHED.	SCHEDULE
C.	CONTROL	SECT.	SECTION
DIA.	DIAMETER	SHT.	SHEET
DIM.	DIMENSION	SPC	SPACES OR SPACING
DWG.	DRAWING	S.S.	SOLID SLAB
EA.	EACH	ST.	STRAIGHT
E.F.	EACH FACE	STD.	STANDARD
EXP. JT.	EXPANSION JOINT	STL.	STEEL
EL.	ELEVATION	S.STL.	STAINLESS STEEL
E.W.	EACH WAY	STIR.	STIRRUP
EXIST.	EXISTING	STR.	STRUCTURAL
F.F	FAR FACE	SYM.	SYMMETRI
F.S.	FAR SIDE	T.	TOP
FDN.	FOUNDATION	T.&B.	TOP & BOTTOM
FLR.	FLOOR	TYP.	TYPICAL
FTG.	FOOTING	VERT.	VERTICAL
GA.	GAUGE	W/	WITH
HORIZ.	HORIZONTAL		

STRUCTURAL NOTES

1. ALL STR. STEEL: ASTM A36; BOLTS A307; BOLTS A325; STRUCTURAL TUBES AND PIPES ASTM A500, GRADE B, Fy = 46 KSI; ELECTRODES ASTM A233 SERIES E60 OR E70.
2. COMPLY WITH AISC SPECS. FOR DESIGN, FABRICATION, ERECTION OF STRUCTURAL STEEL FOR BUILDINGS.
3. PROVIDE ALL HOLES REQUIRED BY OTHER TRADES.
4. CONNECTIONS SHALL BE SHOP WELDED AND FIELD-BOLTED AND SHALL DEVELOP FULL STRENGTH OF MEMBER. CONNECTIONS SHALL BE DESIGNED BY THE STEEL FABRICATOR ACCORDING TO THE ABOVE DESCRIBED REQUIREMENTS.
5. STEEL SUPPORTING OR CONNECTING TO MECHANICAL OR OTHER EQUIPMENT AND ROOF OPENINGS AS SHOWN ON MECHANICAL AND OR STRUCTURAL DRAWINGS ARE SHOWN FOR BIDDING PURPOSES ONLY. CONTRACTOR SHALL RECONCILE EXACT SIZE AND LOCATION.
6. USE NON-SHRINKING GROUT (EMBECO OR EQUIVALENT) UNDER BEARING PLATES. (NON-METALIC)
7. COMPLY WITH AWS STRUCTURAL WELDING CODE, AWS D1.1-72.
8. STRUCTURAL SUPPORTS ARE DESIGNED FOR EQUIPMENT LOADS SHOWN ON DRAWINGS. VERIFY EQUIPMENT WEIGHTS AND DIMENSIONS AND CONTACT STRUCTURAL ENGINEER IF ACTUAL WEIGHTS ARE GREATER THAN SHOWN.

CONCRETE NOTES

1. COMPLY WITH SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDING (ACI-318-77, ACI-301 & ACI-315) AND ADDITIONAL PROVISIONS SPECIFIED.
2. KEEP COPY OF "FIELD REFERENCE MANUAL" ACI PUBLICATION SP-15(72) AT PROJECT FIELD OFFICE. USE CRSI RECOMMENDED PRACTICE FOR PLACING REINFORCING BARS.
3. PROVIDE CONCRETE WITH FOLLOWING 28 DAY STRENGTH:

   4000 PSI WITH ENTRAINED AIR--CONCRETE EXPOSED TO THE WEATHER IN THE FINISHED STRUCTURE.

   4000 PSI WITHOUT ENTRAINED AIR--ALL OTHER CONCRETE UNLESS NOTED. SEE CHEM-COMP, CEMENT-CONCRETE SPECS.
4. TESTING LABORATORY TO SUBMIT ONE COPY OF ALL CONCRETE TEST REPORTS DIRECTLY TO STRUCTURAL ENGINEER.
5. PROVIDE REINFORCING STEEL WITH 40 KSI MINIMUM YIELD.
6. BEND ALL HORIZONTAL WALL AND FOOTING BARS 1'-0" AROUND CORNERS OR PROVIDE CORNER BARS WITH 2'-0" LAP.
7. FOUNDATIONS DESIGNED FOR SOIL PRESSURE OF 3000 PSF. NOTIFY ARCHITECT IF FOUNDATION CONDITIONS ENCOUNTERED DIFFER SIGNIFICANTLY FROM SOILS EXPLORATION INFORMATION MADE AVAILABLE TO CONTRACTOR.
8. COPIES OF THE SOILS AND FOUNDATION INVESTIGATION REPORT ARE AVAILABLE FOR INSPECTION IN THE OFFICES OF THE ARCHITECT.
9. STRUCTURAL SUPPORTS ARE DESIGNED FOR EQUIPMENT LOADS SHOWN ON DRAWINGS. VERIFY EQUIPMENT WEIGHTS AND DIMENSIONS AND CONTACT STRUCTURAL ENGINEER IF ACTUAL WEIGHTS ARE GREATER THAN SHOWN.
10. ALL W.W.F. SHALL BE PLACED WITHIN THE TOP 1/3 OF THE SLABS.
11. ANCHOR, GUIDE AND PIPE SUPPORTS
    - A. ALL SUPPORTS ON "PLANT NORTH" SIDE OF COLLECTOR FIELD SHALL BE KEPT AT A CONSTANT ELEVATION 3" (MIN.) ABOVE FINAL GRADE.
    - B. ALL SUPPORTS ON "PLANT EAST" AND "PLANT WEST" OF COLLECTOR FIELD SHALL BE SLOPED DOWN AT A CONSTANT GRADE TOWARD "PLANT SOUTH" AND KEPT AT A MINIMUM OF 3" ABOVE FINAL GRADE.

FOUNDATION PLAN FOR COLLECTOR FIELD

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

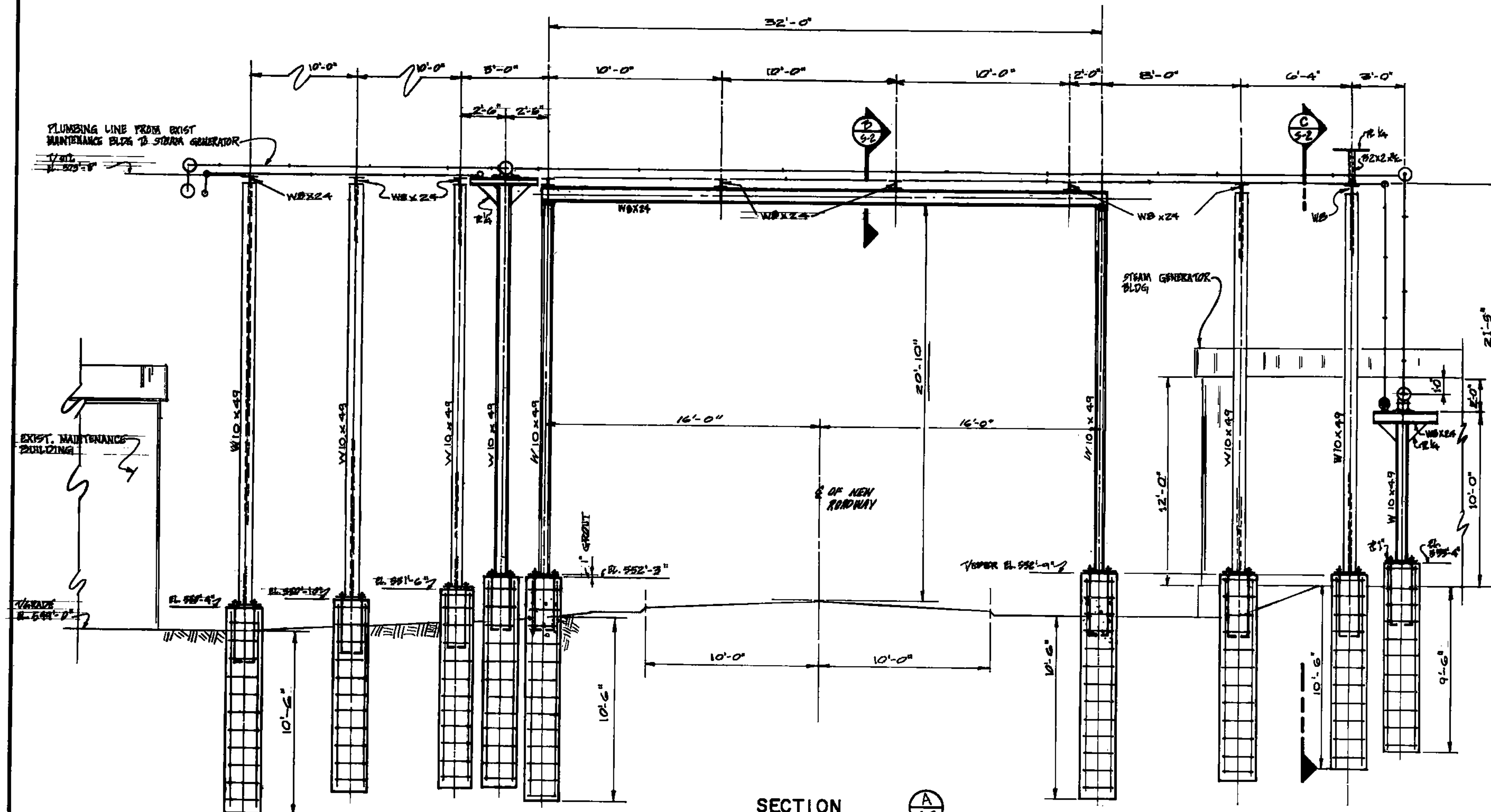
DESIGNED BY M. I. GELDERLOOS
DRAWN BY GS.
CHECKED BY M.I.G.

REVISIONS

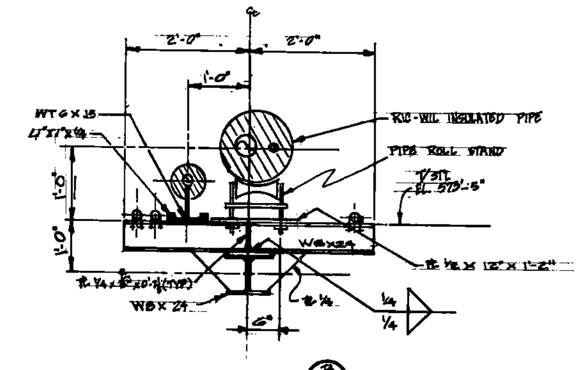
JOB NO. 79199
DATE JUNE 20, 1980
SET OF 15

H. A. Williams and Associates, Inc.
CONSULTING ENGINEERS
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

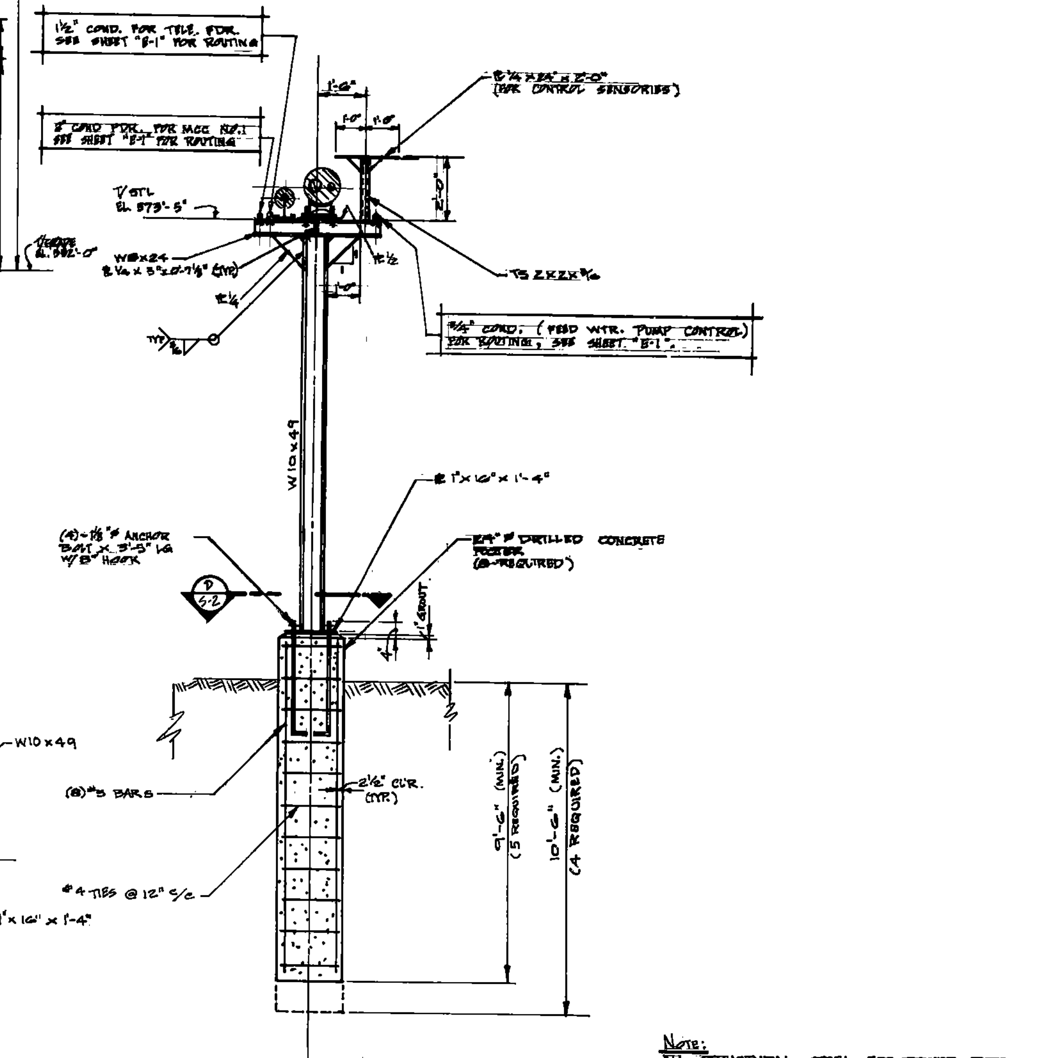
S-1



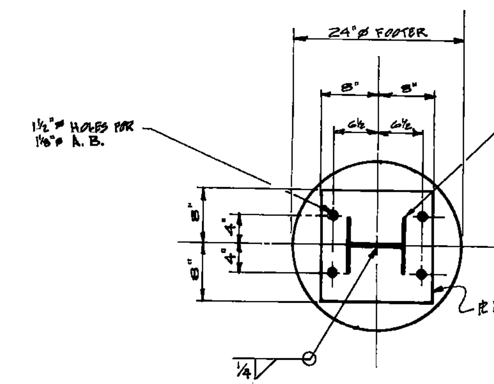
SECTION A/S-2
SCALE 1/4" = 1'-0"



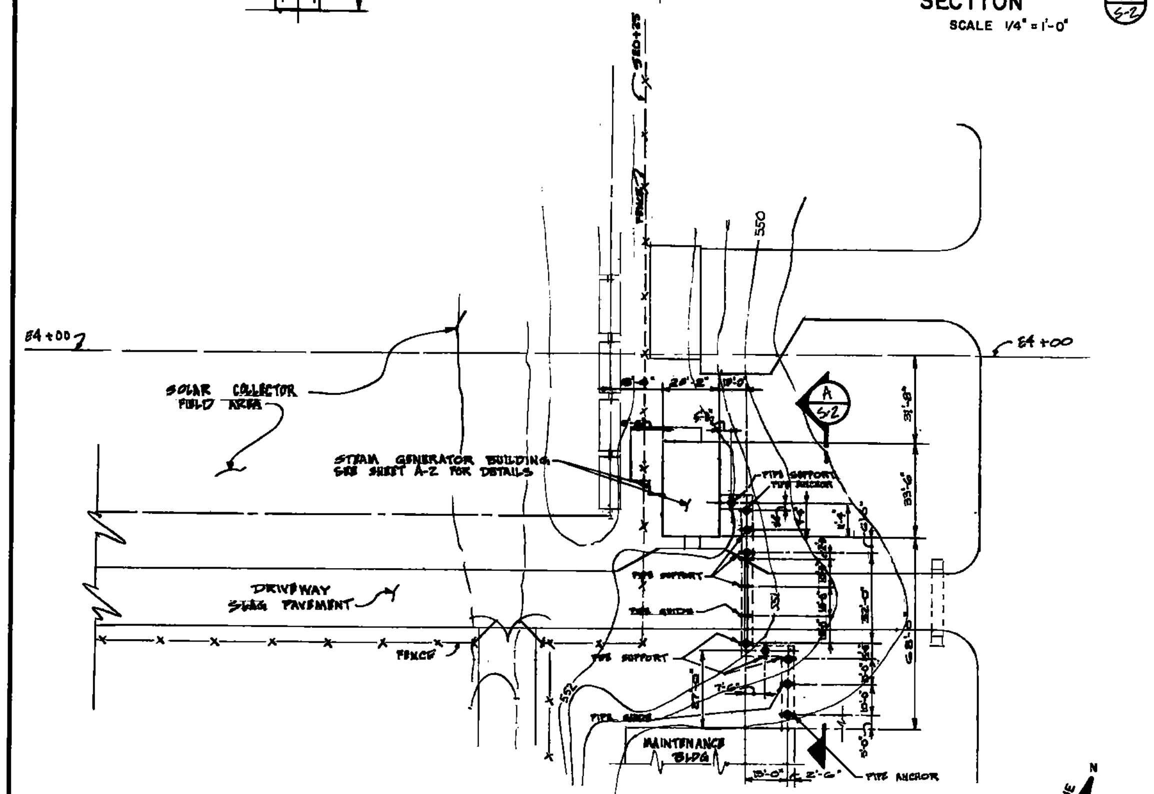
SECTION B/S-2
SCALE 3/4" = 1'-0"



SECTION C/S-2
SCALE 3/8" = 1'-0"



SECTION D/S-2
SCALE 1" = 1'-0"



PLAN VIEW OF TOWER PIPE SUPPORT
SCALE 1" = 30'-0"

NOTE:
ALL STRUCTURAL STEEL FOR TOWER PIPE SUPPORTS SHALL BE GALVANIZED WITH A G-90 ZINC COATING AFTER FABRICATION. FINAL TOUCH-UP SHALL BE WITH A ZINC RICH PAINT.

DESIGNED BY	M.I. GEDERLOOS
DRAWN BY	C.J.
CHECKED BY	M.I.G.

REVISIONS

PLAN VIEW OF TOWER PIPE SUPPORT

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

JOB NO. 79198
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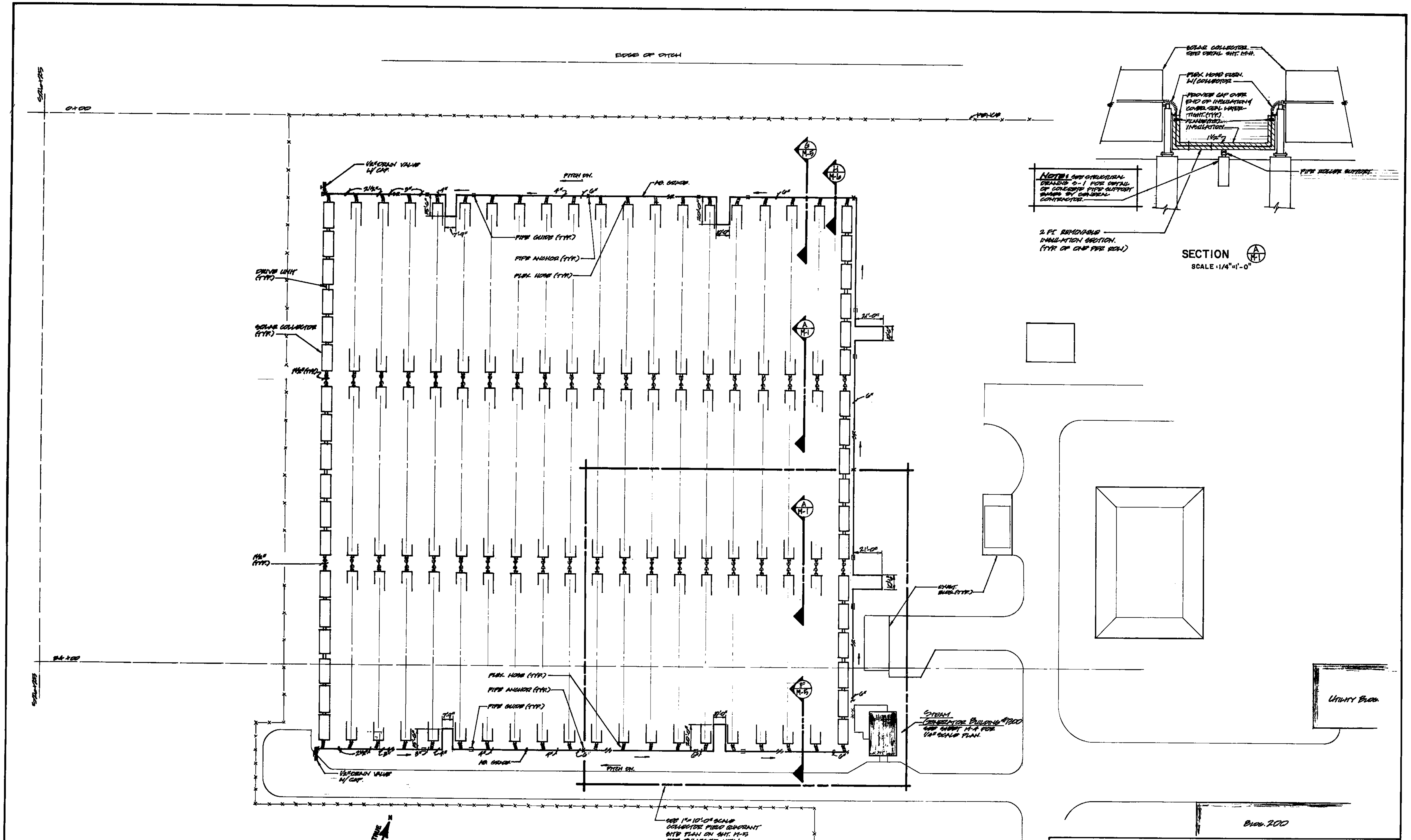
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

S-2



COLLECTOR FIELD SITE PLAN
SCALE: 1"=30'-0"

COLLECTOR FIELD SITE PLAN

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

STATE OF OHIO RICHARD W. PAYNE 30219 REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY J.R. LOCKARD, P.E.
DRAWN BY R.A.H./K.C.B.
CHECKED BY R.W.P. & L.L.R.

REVISIONS

JOB NO 79199
DATE JUNE 20, 1980
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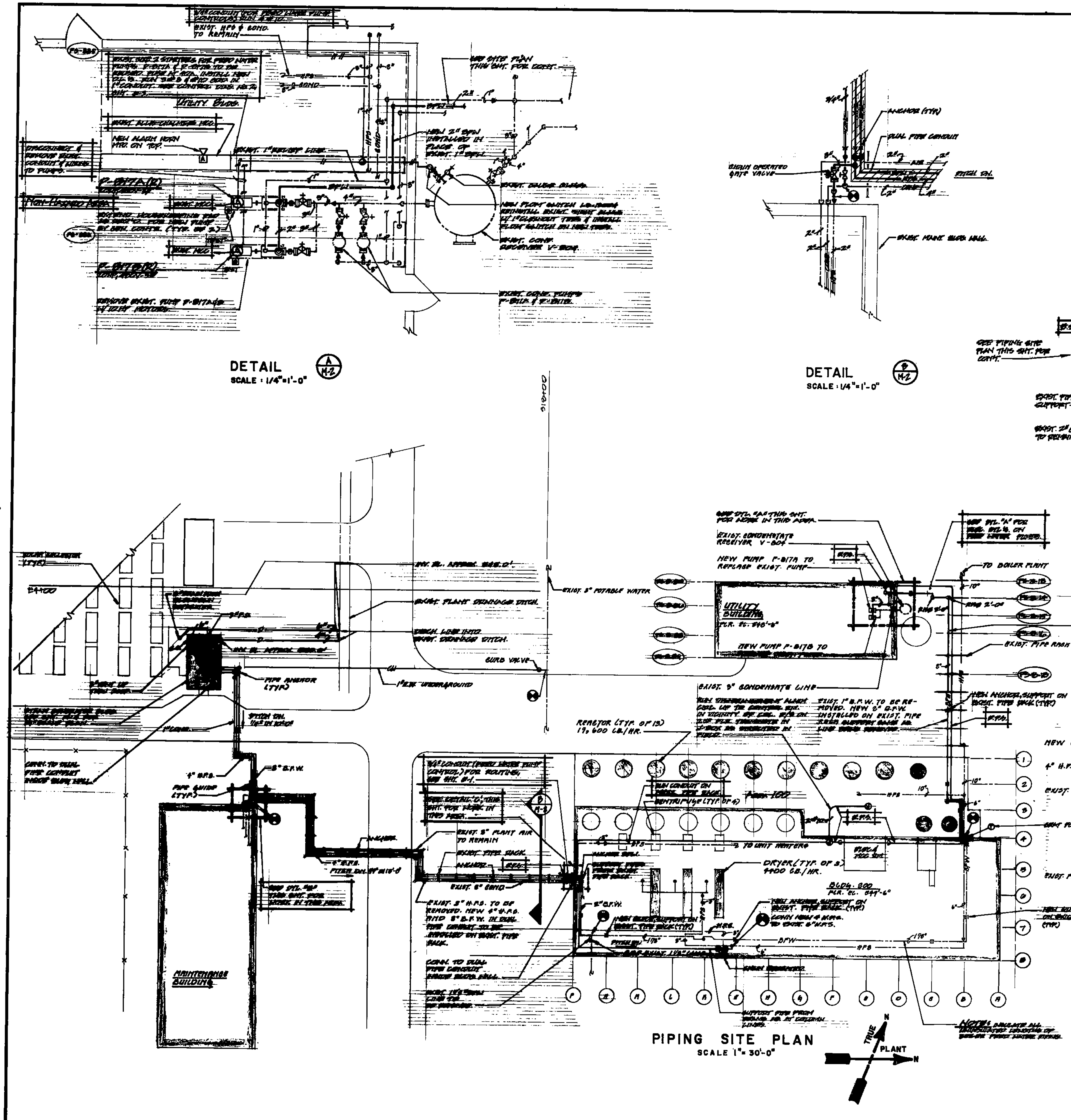
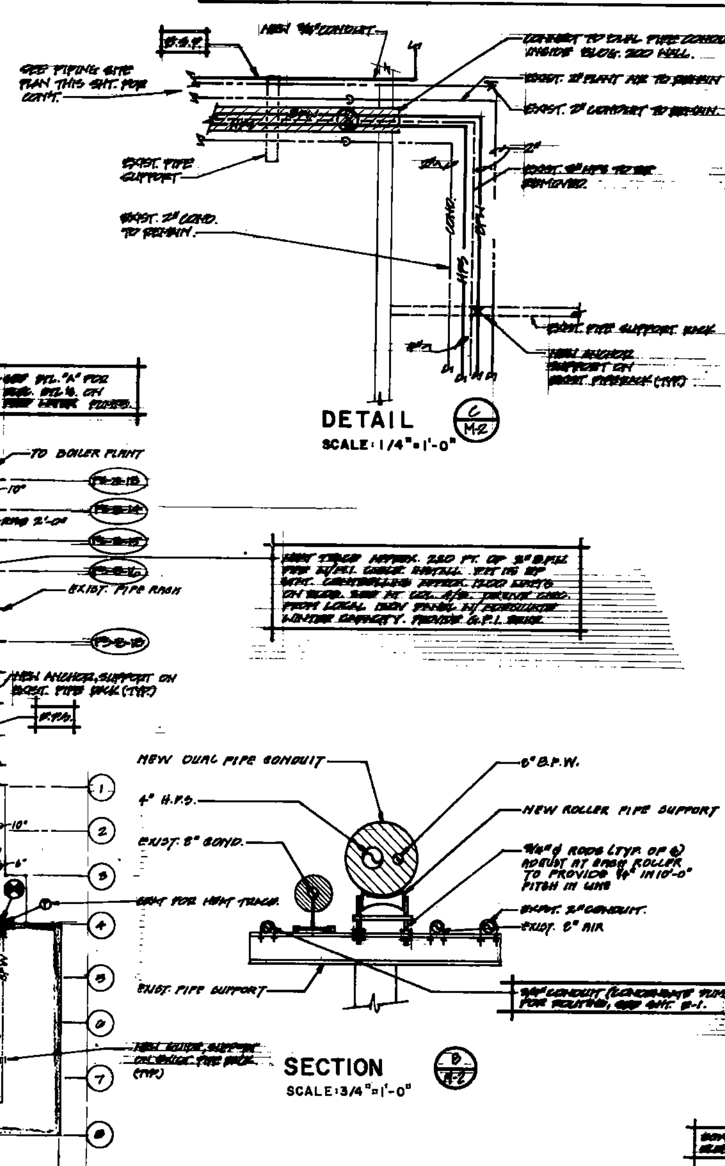
CONSULTING ENGINEERS
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

M-1





MECHANICAL NOTES

1. PIPING AND DUCT LAYOUT IS ONLY SCHEMATIC, EXACT LOCATION OF PIPES AND DUCTS TO BE COORDINATED ON JOB WITH BUILDING STRUCTURE, AND WORK OF OTHER CONTRACTORS.
2. SUPPORT ALL STEEL PIPE AT INTERVALS OF NOT MORE THAN 10 FT., COPPER PIPE AT 8 FT., UNLESS OTHERWISE SHOWN.
3. OPENINGS THROUGH OUTSIDE WALL FOR LOUVERS AND SHUTTERS BY GENERAL CONTRACTOR. ALL LINTELS AND WEATHERTIGHT SETTING OF STATIONARY LOUVERS BY GENERAL CONTRACTOR.
4. NOTIFY GENERAL CONTRACTOR OF SIZE AND LOCATION OF ALL RECESSES AND OPENINGS REQUIRED FOR MECHANICAL WORK.
5. RUN ALL DRAIN LINES INDIRECT TO NEAREST FLOOR DRAIN.
6. INSTALL AIR VENTS AT HIGH POINTS OF THE SYSTEM, AS SHOWN ON THE DRAWINGS AND AS REQUIRED FOR PROPER AIR VENTING OF SYSTEM.
7. STEAM PIPING SYSTEM - PITCH STEAM AND CONDENSATE MAINS DOWN IN DIRECTION OF FLOW 1/4" IN 10 FT.
8. STEAM RUNOUTS TO UNITS TO BE TAKEN FROM TOP OF MAINS. PITCH 1" IN TEN (10) FEET. PITCH BACK TO MAINS.
9. ALL VALVES IN SOLAR FLUID PIPING MUST BE INSTALLED WITH STEMS IN HORIZONTAL POSITION.

MECHANICAL SYMBOLS

—TW—	DOMESTIC TEMPERED WATER		FLEX. DUCT
—180°—	DOMESTIC 180°F WATER		PIPE GUIDES
—CW—	DOMESTIC COLD WATER LINE		PIPE ANCHOR
—HW—	DOMESTIC HOT WATER LINE		CONCENTRIC REDUCER
—HWR—	DOMESTIC HOT WATER LINE		ECCENTRIC REDUCER
—STM—	STORM LINE		P-TRAP (PLAN VIEW)
—SAN—	SANITARY LINE		TEE W/NIPPLE & CAP
—V—	VENT LINE		PLUG TEE
—G—	GAS LINE		Y-TYPE STRAINER
—W—	WATER SERVICE LINE		AIR VENT - PLAN VIEW
—A—	AIR LINE		GAGE COCK
—COMB—	COMBINED SEWER		BALANCE VALVE
—CWS—	CHILLED WATER SUPPLY		GATE VALVE
—CWR—	CHILLED WATER RETURN		BALANCE FITTING
—CS—	CONDENSER WATER SUPPLY		DRAIN VALVE
—CR—	CONDENSER WATER RETURN		GLOBE VALVE
	HOT WATER SUPPLY		SOLENOID VALVE
	HOT WATER RETURN		CHECK VALVE
—D—	DRAIN LINE		GAS COCK OR BALANCE VALVE (SCREWED)
—HPS—	HIGH PRESSURE STEAM		GAS COCK OR BALANCE VALVE (FLANGED)
—COND—	HIGH PRESSURE CONDENSATE		GATE VALVE (FLANGED)
—HG—	HOT GAS LINE		FLUSH AREA DRAIN
—LIQ—	LIQUID LINE		THERMOSTAT
—SUCT—	SUCTION LINE		THERMOMETER
—CPD—	CONDENSATE PUMP DISCHARGE		CURB BOX OR VALVE
—FOS—	FUEL OIL SUPPLY		[illegible]
—FOR—	FUEL OIL RETURN		[illegible]
—BD—	BLOW DOWN		[illegible]
—BFW—	BOILER FEED WATER		[illegible]
	SUPPLY RISER		SUPPLY DUCT-DOWN
	RETURN RISER		RETURN OR EXHAUST DUCT-UP
	CAPPED LINE		RETURN OR EXHAUST DUCT-DOWN
	PIPE FLANGES		ELBOW TURNING VANES
	PIPE UNION		FIRE DAMPER
	CONNECT TO EXISTING		ACCESS DOOR
	RISER NUMBER		THRU FLOOR AS SHOWN
JR. DN.	JANITOR OR SHOWER TRIM	—SS—	SOLAR SUPPLY
	EXISTING WORK	—SR—	SOLAR SUPPLY
	HOSE BIBB		

MECHANICAL ABBREVIATIONS

AB.	ABOVE	H.W.	HOT WATER
A.DR	ACCESS DOOR	H.W.R.	HOT WATER RETURN
A.D.	AREA DRAIN	INV. EL.	INVERT ELEVATION
BTM.	BOTTOM	J.R.	JANITORS RECEPTOR
BLDG.	BUILDING	LAV.	LAVATORY
CAB.	CABINET	M.H.	MANHOLE
CAP.	CAPACITY	MAN.DPR.	MANUAL DAMPER
CLG.	CEILING	MECH.	MECHANICAL
CONC.	CONCRETE	M.A.	MIXED AIR
C.O.	CLEANOUT	O.A.	OUTSIDE AIR
CONN.	CONNECT	PLBG.	PLUMBING
CONTR.	CONTRACTOR	PRESS.	PRESSURE
C.W.	COLD WATER	P.R.V.	PRESSURE REDUCING VALVE
DTL.	DETAIL	R.D.	ROOF DRAIN
DIA.	DIAMETER	REG.	REGISTER
DIFF.	DIFFUSER	REL.	RELIEF
DISCH.	DISCHARGE	R.A.	RETURN AIR
D.S.	DOWNSPOUT	ø	ROUND
DN.	DOWN	S/M	SHEET METAL
ELECT.	ELECTRICAL	S.A.	SUPPLY AIR
ELEM.	ELEMENT	SAN.	SANITARY
EXH.	EXHAUST	S.D.	SHOWER DRAIN
EXIST.	EXISTING	SH.	SHOWER
FT.HD.	FEET OF HEAD	S.I.	SURFACE INLET
E.W.C.	ELECTRIC WATER COOLER	S.S.	SERVICE SINK
FLEX.	FLEXIBLE	STM.	STORM
		T.C.C.	TEMPERATURE CONTROL CONTR.
F.E.	FIRE EXTINGUISHER	TEMP.	TEMPERATURE
F.E.C.	FIRE EXTINGUISHER CABINET	THERM.	THERMOMETER
F.H.C.	FIRE HOSE CABINET	STAT.	THERMOSTAT
FLR.	FLOOR	TYP.	TYPICAL
F.D.	FLOOR DRAIN	UR.	URINAL
F.DPR.	FIRE DAMPER	V.	VENT
FURN.	FURNISH	VIB. ISO.	VIBRATION ISOLATOR
H.B.	HOSE BIBB	W/	WITH
H & A/C	HEATING & AIR CONDITIONING	W.C.	WATER CLOSET

AREA 200 & 800 SITE PLAN AND DETAILS

HAVERHILL PLANT SOLAR ENERGY PROJECT

FOR

THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO

AND

USS CHEMICALS HAVERHILL, OHIO

STATE OF OHIO — RICHARD W. PAYNE — 30219 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY [illegible] P.E.

DRAWN BY E.A.W.

CHECKED BY R.W.P. & [illegible]

REVISIONS

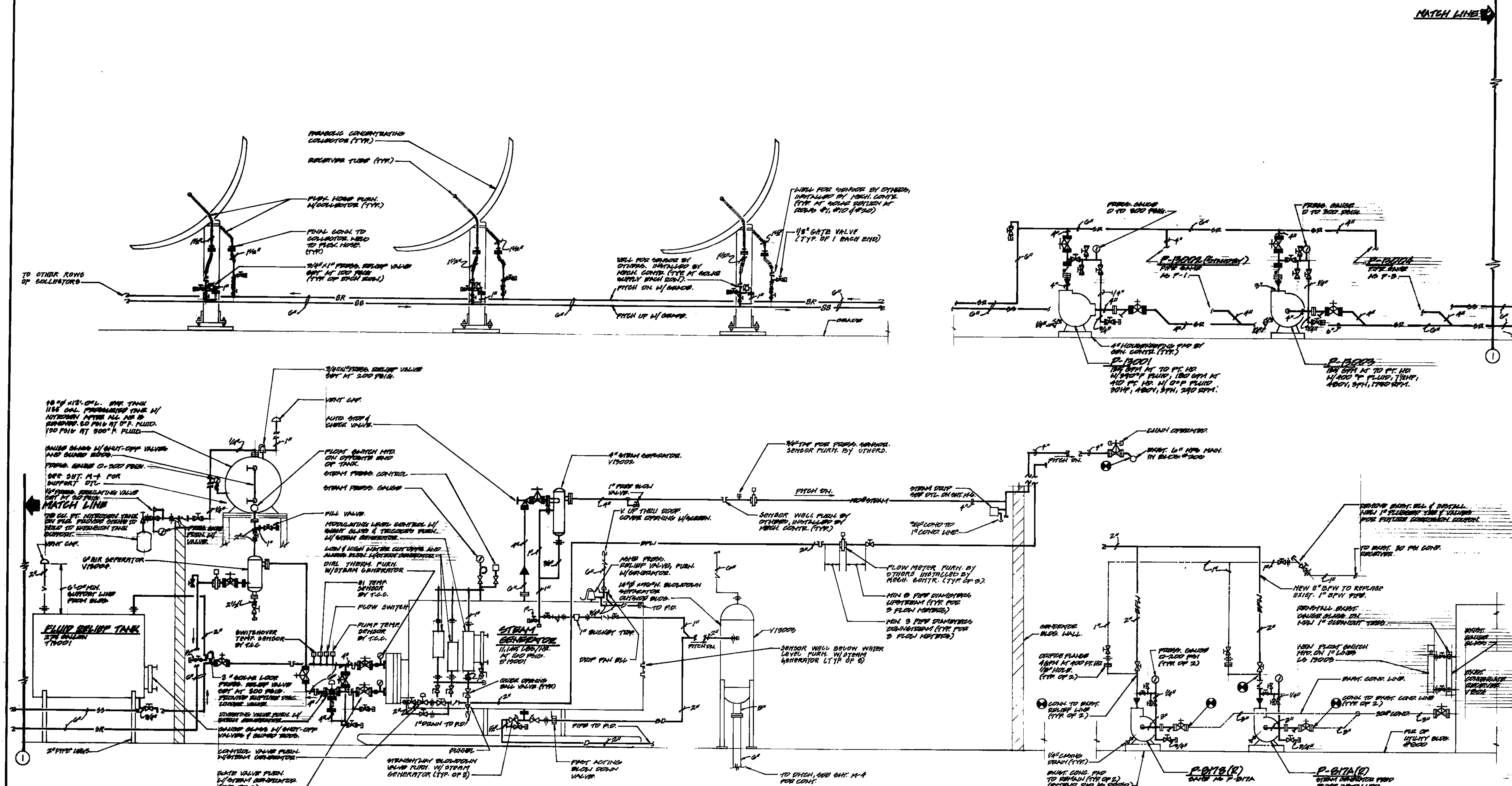
JOB NO. 79199

DATE JUNE 20, 19[illegible]

SET OF [illegible]

H. A. Williams and Associates, Inc.
CONSULTING ENGINEERS
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

M-2



SOLAR SYSTEM PIPING SCHEMATIC

SOLAR SYSTEM PIPING SCHEMATIC

HAVERHILL PLANT SOLAR ENERGY PROJECT

FOR

THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO

AND

USS CHEMICALS HAVERHILL, OHIO

STATE OF OHIO — RICHARD W. PAYNE — 30219 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY J.R. LOUARD, P.E.

DRAWN BY S.A.W./K.C.B.

CHECKED BY R.W.P. & L.L.R.

JOB NO 79199

DATE JUNE 20, 1980

SET OF 15

REVISIONS

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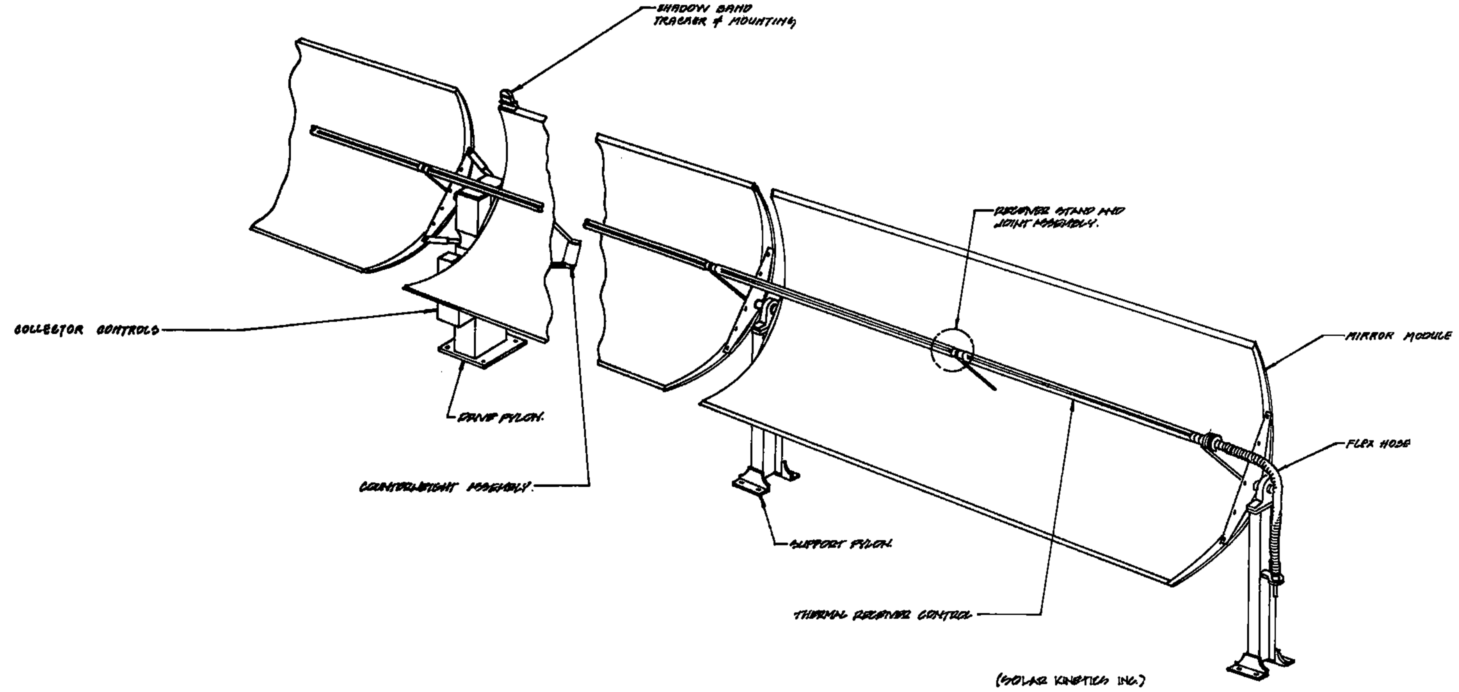
M-3



SOLAR COLLECTOR DETAIL
NO SCALE

OHIO MODEL ENERGY CODE DATA:

1. EXTERIOR DESIGN CONDITIONS (BASED ON 97-1/2% WINTER, 2-1/2% SUMMER).

WINTER	9°F. D.B.
SUMMER	92°F. D.B. / 72°F. W.B.
DEGREE DAYS HEATING	4344
DEGREES NORTH LATITUDE	38° 35'

2. INTERIOR DESIGN CONDITIONS

HEATING	72°F. D.B.
COOLING	78°F. D.B. / 50% R.H.

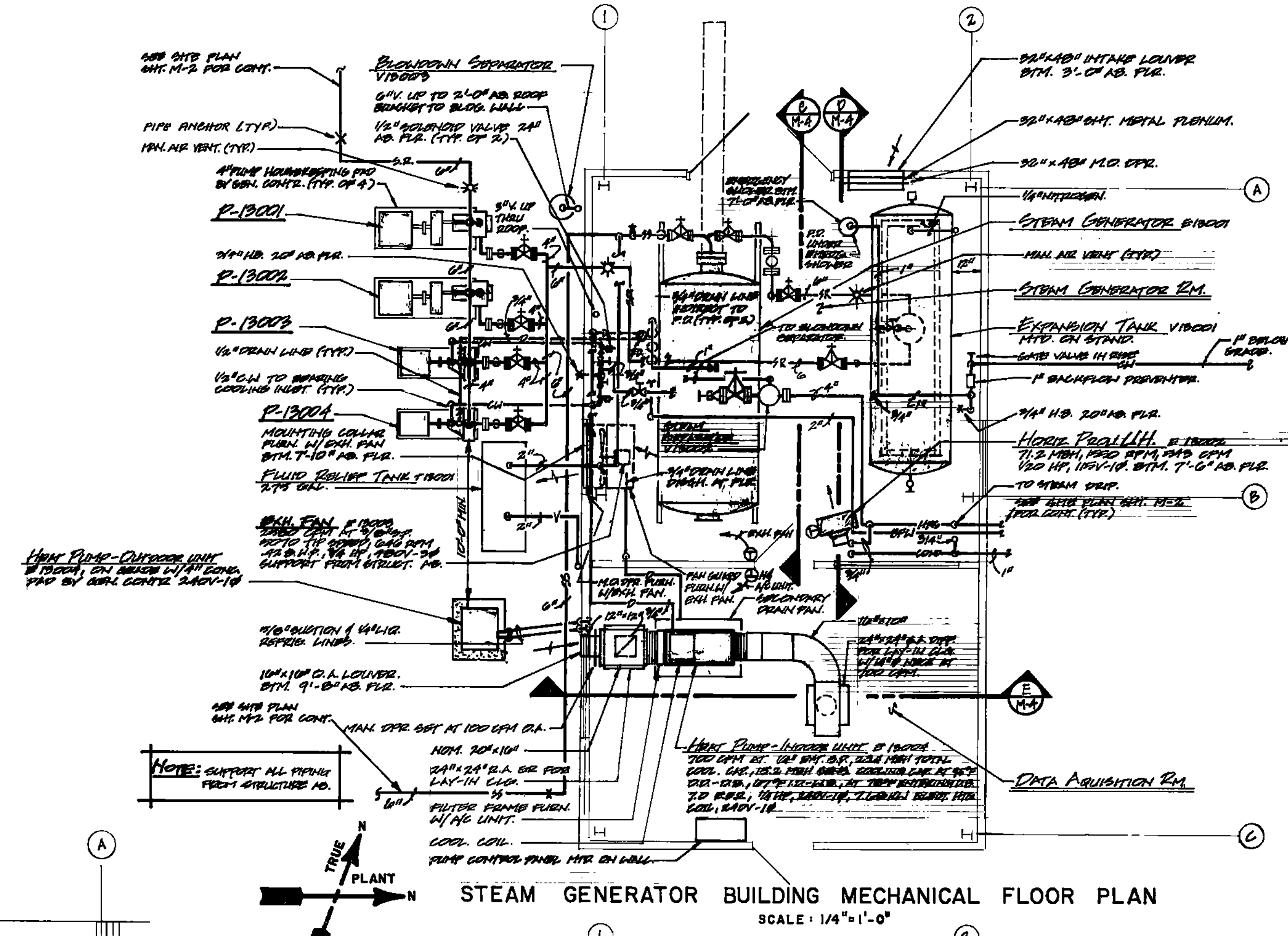
3. INFILTRATION

BASED ON 11 C.F.M./L.F. OF CRACK FOR DOORS
BASED ON 0.5 C.F.M./L.F. OF CRACK FOR WINDOWS

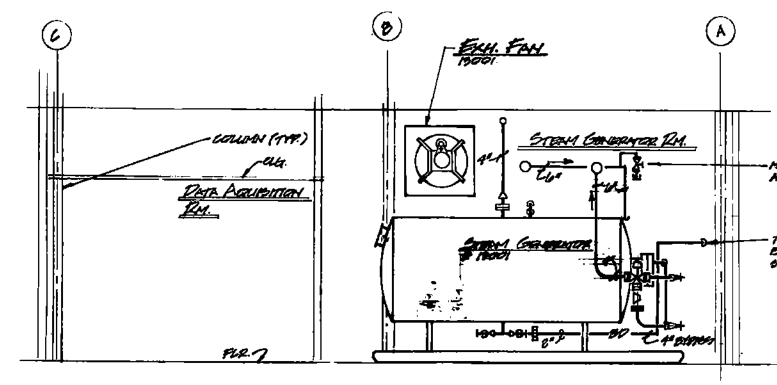
4. ENVELOPE SYSTEM U-VALUES (BTU/HR - FT.^{2} - °F.)

ROOF	.078
WALLS	.068
GLASS	1.13

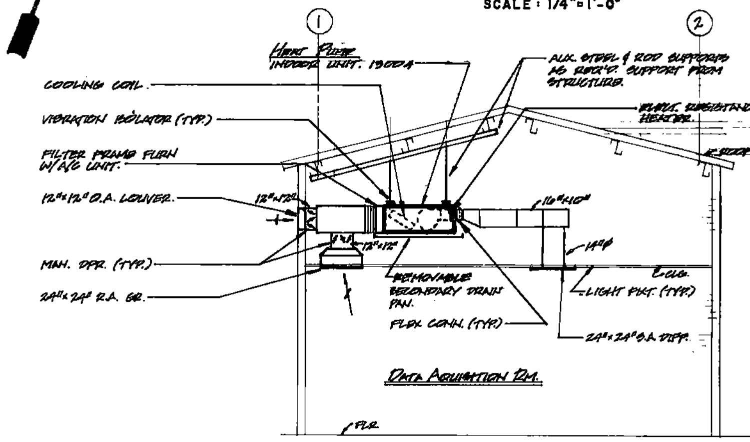
5. DUCT INSULATION SHALL BE 1½" THICK, 1# DENSITY, R-VALUE - 3.6



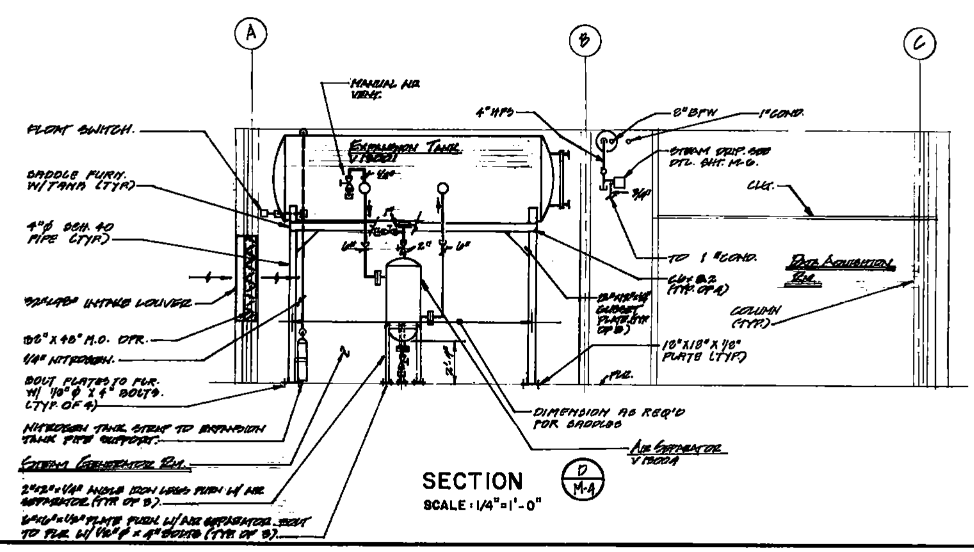
STEAM GENERATOR BUILDING MECHANICAL FLOOR PLAN
SCALE: 1/4"=1'-0"



SECTION C/M-4
SCALE: 1/4"=1'-0"



SECTION E/M-4
SCALE: 1/4"=1'-0"



SECTION D/M-4
SCALE: 1/4"=1'-0"

STEAM GENERATOR BUILDING MECHANICAL PLAN & SECTIONS

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

STATE OF OHIO — RICHARD W. PAYNE — 30219 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY J.D. LOCKWOOD, P.E.
DRAWN BY E.A.W.
CHECKED BY R.W.P. & L.L.R.

REVISIONS

JOB NO 79199
DATE JUNE 20, 1980
SET OF 18

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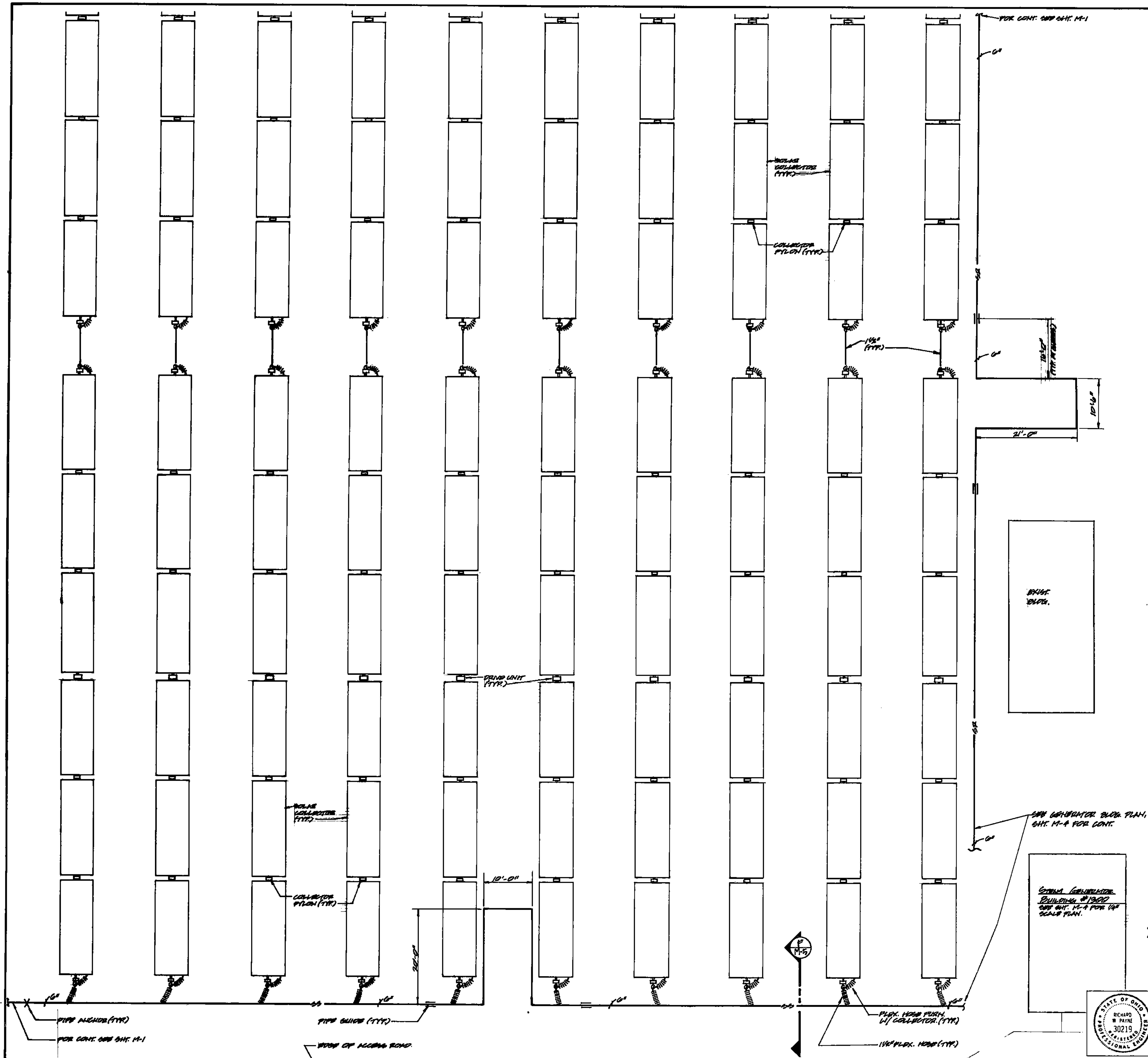
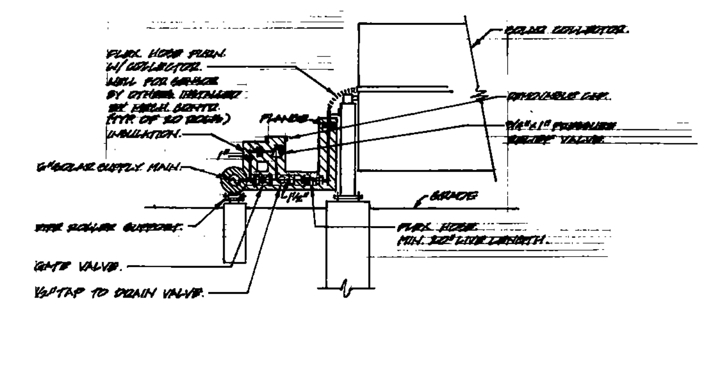
M-4



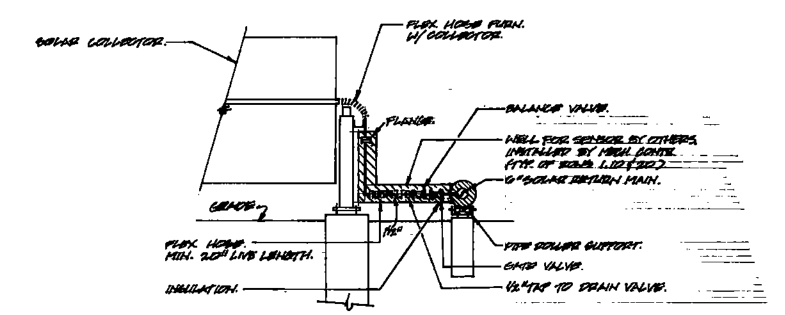
COLLECTOR FIELD QUADRANT SITE PLAN

SCALE : 1"=10'-0"



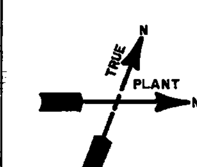
SECTION F/M-5

SCALE 1/4"=1'-0"



SECTION B/M-5

SCALE 1/4"=1'-0"



COLLECTOR QUADRANT PIPING PLAN

HAVERHILL PLANT SOLAR ENERGY PROJECT

FOR

THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO

AND

USS CHEMICALS HAVERHILL, OHIO

STATE OF OHIO — RICHARD W PAYNE — 30219 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY

DRAWN BY

CHECKED BY

JOB NO 79199

DATE JUNE 20, 1980

SET OF 15

REVISIONS

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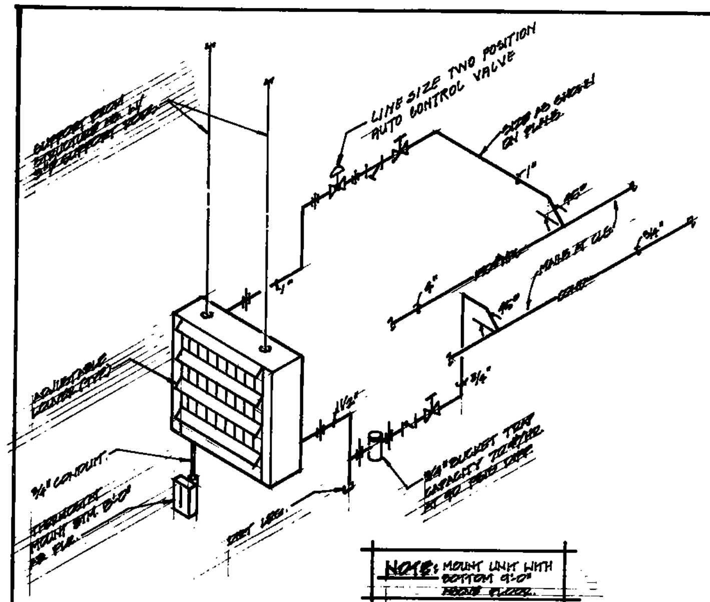
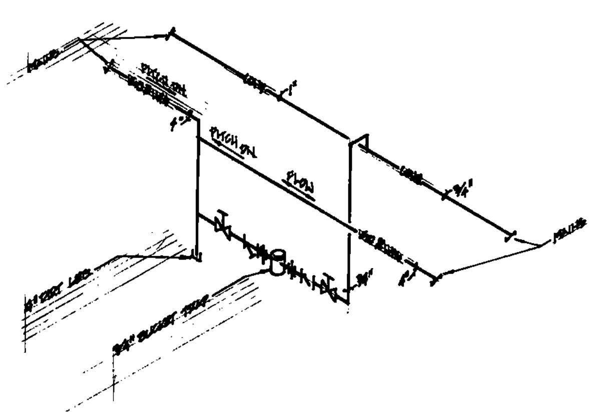
CONSULTING ENGINEERS

980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

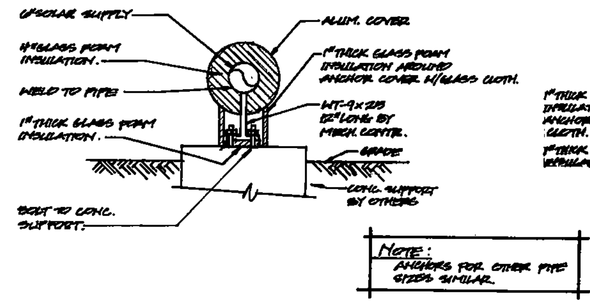
M-5



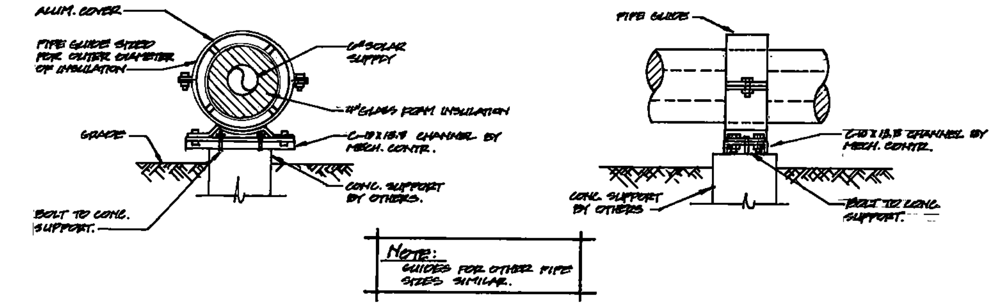
STEAM HORIZONTAL PROJECTION
UNIT HEATER PIPING



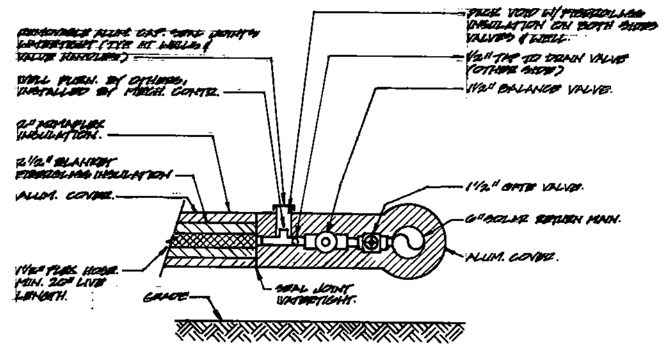
HIGH PRESSURE STEAM
DRIP PIPING DETAIL



PIPE ANCHOR DETAIL
SCALE: 3/4" = 1'-0"

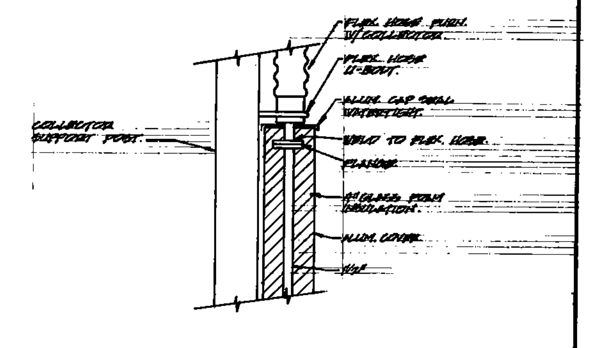


PIPE GUIDE DETAIL
SCALE: 3/4" = 1'-0"

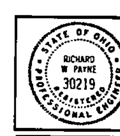


SECTION (H / M-6)
SCALE: 3/4" = 1'-0"

NOTES:
1. VALVES INSIDE STEAM [illegible] BUILDING INSULATED SIMILAR, EXCEPT DELETE ALUMINUM COVER.
2. ALL GATE & BALANCE VALVES SHALL BE INSTALLED WITH STEMS & HANDLES IN HORIZONTAL POSITION.



COLLECTOR CONNECTION DETAIL
SCALE: 3/4" = 1'-0"



DESIGNED BY: J. LOCKARD, P.E.
DRAWN BY: T.A.G.
CHECKED BY: R.W.P. & L.L.R.

ANCHORS, GUIDES & MISCELLANEOUS DETAILS

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

JOB NO. 79199
DATE JUNE 20, 1980
SET OF 18

REVISIONS

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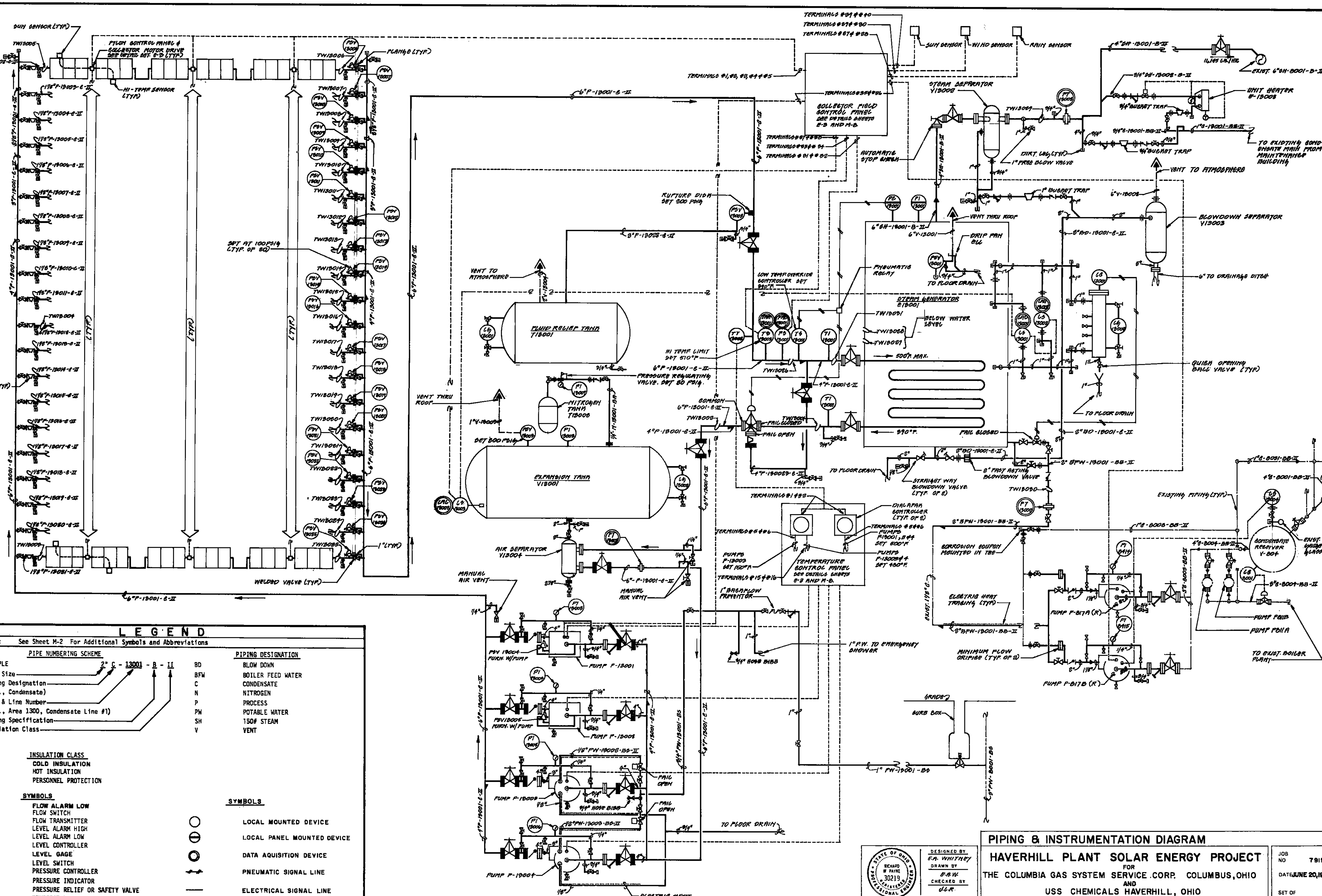
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

M-6



L E G E N D

NOTE: See Sheet M-2 For Additional Symbols and Abbreviations

PIPE NUMBERING SCHEME

EXAMPLE 2" C - 13001 - B - II

- Line Size
- Piping Designation (i.e., Condensate)
- Area & Line Number (i.e., Area 1300, Condensate Line #1)
- Piping Specification
- Insulation Class

PIPING DESIGNATION

BD	BLOW DOWN
BFW	BOILER FEED WATER
C	CONDENSATE
N	NITROGEN
P	PROCESS
PW	POTABLE WATER
SH	150# STEAM
V	VENT

INSULATION CLASS

I	COLD INSULATION
II	HOT INSULATION
III	PERSONNEL PROTECTION

SYMBOLS

FAL	FLOW ALARM LOW
FS	FLOW SWITCH
FT	FLOW TRANSMITTER
LAH	LEVEL ALARM HIGH
LAL	LEVEL ALARM LOW
LC	LEVEL CONTROLLER
LG	LEVEL GAGE
LS	LEVEL SWITCH
PC	PRESSURE CONTROLLER
PI	PRESSURE INDICATOR
PSV	PRESSURE RELIEF OR SAFETY VALVE
TI	TEMPERATURE INDICATOR
TW	TEMPERATURE TEST CONNECTION WITH WELL
TAH	TEMPERATURE ALARM HIGH
TS	TEMPERATURE SENSOR
TT	TEMPERATURE TRANSMITTER

SYMBOLS

- LOCAL MOUNTED DEVICE
- LOCAL PANEL MOUNTED DEVICE
- DATA AQUISITION DEVICE
- PNEUMATIC SIGNAL LINE
- ELECTRICAL SIGNAL LINE
- PNEUMATIC CONTROL VALVE
- ELECTRIC CONTROL VALVE

PIPING AND INSTRUMENTATION DIAGRAM

STATE OF OHIO — RICHARD W PAYNE 30219 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY E.A. WHITNEY
DRAWN BY B.A.W.
CHECKED BY J.L.R.

REVISIONS

PIPING & INSTRUMENTATION DIAGRAM

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
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JOB NO 79199
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CONSULTING ENGINEERS
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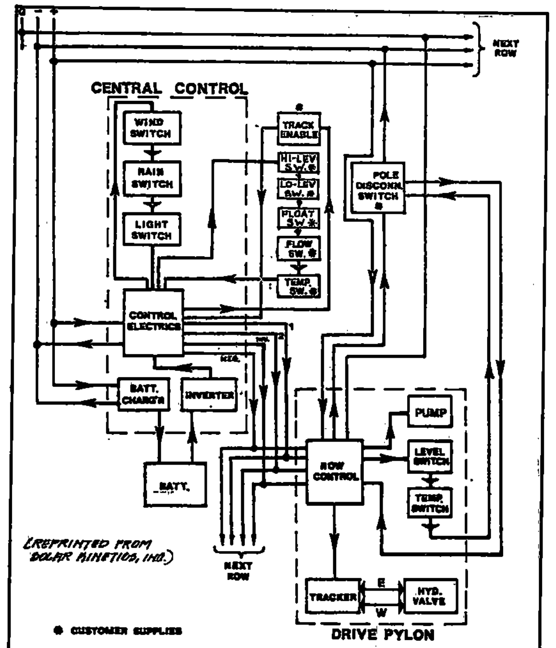
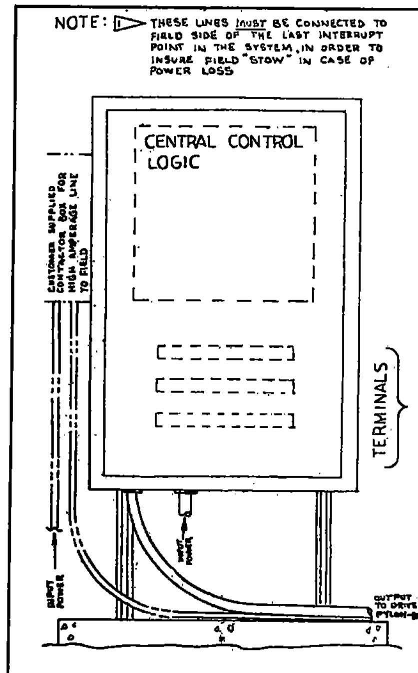
M-7



COLLECTOR TRACKER CONTROL SCHEMATIC



CENTRAL CONTROL BOX
(REPRINTED FROM SOLAR KINETICS, INC.)

No.	DESCRIPTION
1	LOGIC 1
2	LOGIC 2
3	LOGIC 3
4	LOGIC 4
5	120 VAC-Φ INVERTER +
6	120 VAC-NEUT. INVERTER −
7	120 VAC-Φ
8	120 VAC-NEUT
9	GROUND
27	RAIN SWITCH
28	
29	WIND SWITCH
30	
31	FLOW SWITCH
32	(SEE SHEET E-1 FOR LOCATION)
33	OVER TEMP. SWITCH
34	(SEE SHEET E-1 FOR LOCATION)
35	FIELD READY
36	(CONNECTS WHEN SYSTEM IS READY)
37	TRACK ENABLE
38	FLOAT SWITCH
39	LIGHT SWITCH
40	

COLLECTOR FIELD CONTROL

UPON SENSING SUFFICIENT SUNLIGHT FOR 15 MINUTES, (FROM THE REMOTE MOUNTED SUN SENSOR), THE COLLECTOR FIELD CONTROL PANEL ISSUES A "TRACK READY" SIGNAL. RELAY F-1 THEN STARTS THE "LEAD" SOLAR FLUID PUMP (P-13001) AND THE "LEAD" STEAM GENERATOR FEEDWATER PUMP (P-817A). AFTER A 5 MINUTE DELAY TO ALLOW FLUID FLOW TO BE ESTABLISHED (FS-13001), THE SOLAR CONTROL PANEL DIRECTS THE COLLECTORS OUT OF THE STOW POSITION TO START THE TRACKING PROCESS. EACH INDIVIDUAL COLLECTOR ROW CONTROLLER HAS SUFFICIENT ACQUISITION TIME TO FOLLOW THE SUN IF THEIR "TRACK READY" SIGNAL IS MAINTAINED OR REPEATED WITHIN A ONE HOUR PERIOD. IF THE SOLAR CONTROL PANEL DOES NOT SENSE SUFFICIENT SUNLIGHT FOR A 45 MINUTE PERIOD, IT WILL PROVIDE A "STOW" SIGNAL TO THE FIELD. AT THIS TIME, THE COLLECTORS WILL BE DRIVEN TO THE STOW POSITION, PUMPS STOPPED AND SYSTEM WILL REMAIN THERE UNTIL THE SUN SENSOR IS RE-ENERGIZED.

OTHER CONDITIONS THAT WILL CAUSE STOW ARE:

POWER FAILURE, LACK OF SOLAR RADIATION, RAINFALL, HIGH WIND SPEED, LOW FLUID LEVEL (LS 13003), FLUID OVERTEMPERATURE (TS-13002), LOW FLUID FLOW (FS-13001), LOW STEAM GENERATOR WATER LEVEL (LS-13001), AND HIGH STEAM GENERATOR WATER LEVEL (LS-13002).

THE ACCUMULATED, PRESSURIZED HYDRAULIC FLUID IN THE TRACKING SYSTEM DRIVE HAS SUFFICIENT POWER TO STOW THE COLLECTORS IN THE EVENT OF A/C POWER LOSS. A BATTERY INVERTER SYSTEM WILL SUPPLY EMERGENCY POWER TO OPERATE CONTROLS AT EACH DRIVE PYLON DURING LOSS OF POWER. STOW POSITION WILL BE MAINTAINED DURING THE POWER OUTAGE.

SOLAR FLUID PUMP SEQUENCE

UPON A SIGNAL FROM THE COLLECTOR FIELD CONTROL PANEL, RELAY F-1 WILL CLOSE AND PUMP P-13001 WILL START. A PROPORTIONING TEMPERATURE TRANSMITTER (TT-13002), SHALL SENSE THE TEMPERATURE IN THE SOLAR SUPPLY LINE AND SEND A SIGNAL TO THE TWO "DIALAPAK" STEP CONTROLLERS. PUMP P-13001 RUNS UNTIL THE SOLAR FLUID SUPPLY TEMP ERATURE REACHES 150°F. AT THAT TIME PUMP P-13001 STOPS AND PUMP P-13003 STARTS. WHEN THE SOLAR FLUID REACHES 480°F. PUMP P-13003 REMAINS RUNNING AND PUMP P-13004 IS STARTED. WHEN THE SOLAR FLUID REACHES 500°F., PUMPS P-13003 AND P-13004 REMAIN RUNNING AND PUMP P-13001 IS RESTARTED.

AS THE SOLAR ENERGY DECREASES AND THE SOLAR SUPPLY FLUID TEMPERATURE DROPS, THE PUMPS WILL BE STAGED OFF IN THE REVERSE ORDER THAT THEY WERE STARTED.

WHENEVER PUMP P-13003 OR P-13004 OPERATES A CORRESPONDING SOLENOID VALVE SHALL OPEN ALLOWING COOLING WATER TO FLOW THROUGH THE PUMP BEARING COOLING JACKET.

PUMP P-13002 IS A BACKUP FOR PUMPS P-13001, P-13003 OR P-13004, AND WILL BE MANUALLY SWITCHED AT THE MOTOR CONTROL CENTER.

STEAM GENERATOR CONTROL

A PNEUMATIC TEMPERATURE SENSOR (TS-13001) LOCATED IN THE SOLAR SUPPLY LINE SHALL, THROUGH A PNEUMATIC RELAY, CONTROL THE 3-WAY PNEUMATIC DIVERTING VALVE TO THE BYPASS POSITION WHEN THE SOLAR SUPPLY LINE TEMPERATURE DROPS BELOW 390°F.

A PNEUMATIC STEAM PRESSURE CONTROL (PC-13001) SHALL CONTROL THE PNEUMATIC DIVERTING VALVE TO THE BYPASS POSITION IF THE STEAM PRESSURE RISES ABOVE THE SET PRESSURE (160 PSI).

THE PNEUMATIC MODULATING LEVEL CONTROL (LC-13001) SHALL MODULATE THE TWO-WAY PNEUMATIC FEEDWATER CONTROL VALVE TO ALLOW FEEDWATER TO ENTER THE STEAM GENERATOR AT THE SAME RATE THAT STEAM IS BEING GENERATED. STEAM GENERATOR FEEDWATER PUMP P-817A SHALL OPERATE WHENEVER RELAY F-1 IS CLOSED. P-817B SHALL RUN WHEN P-817A FAILS.

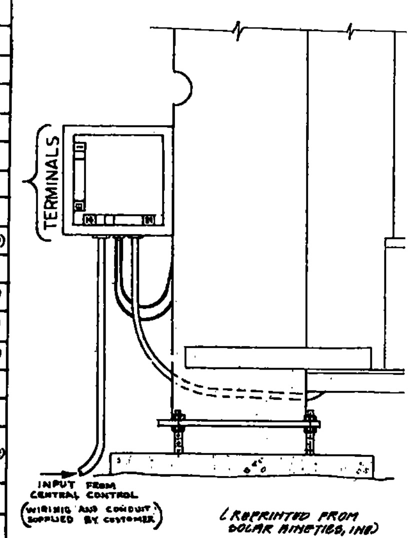
TRACKER CONTROL
OPERATION EXPLANATION
AUTOMATIC TRACKING

Automatic tracking of Solar Kinetics' collectors is accomplished through the use of an electronic light sensor "shadow-well" tracker on each trackable row and a central controller which uses a minimum direct normal light switch. The tracker head which uses a curved lens with a minimum aperture opeing and three sensors determines the presence of minimum direct normal light levels and then directs the drive system to an electronic balance.

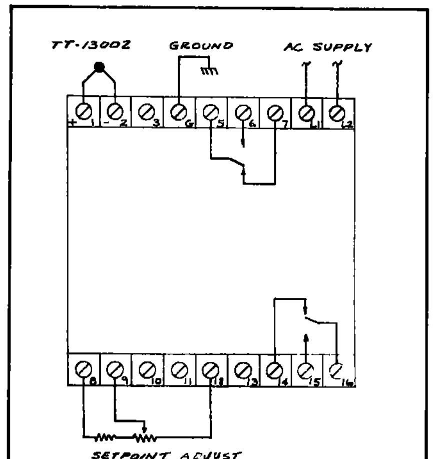
When the central direct normal light switch indicates minimum present direct normal levels for a minimum period of 15 minutes, the central controller issues a "track ready" command which may be used to start the fluid pump. After a 5 minute delay to allow fluid flow to be established, the two collector control wires are given a "++" signal which directs the collectors out of stow position. This signal is continued for a minimum period which will allow each row to acquire the sun. As each collector row approaches the sun and falls within 20° of focus, one of the light sensors will switch the row from "++" to "+-." The "+-" signal is the automatic track signal and is maintained until the minimum direct normal light level is not met. At this point, a "-+" signal provides for central dead band and all collectors will remain in dead band until the central controller resumes the signal "+-", or automatic track signal. Each tracker has sufficient acquisition aperture to reacquire the sun if this signal is replaced within one hour. If direct normal minimums are not met for a preset period up to 45 minutes, the central controller will provide a "--" stow signal. The collectors will be driven to the stow position at this time and will remain there until the original automatic scenario is reinitialized. Other conditions will provide a "--" signal to stow the collectors. Some of these conditions are : Nightfall, rainfall, high wind speeds or other field contact closure devices such as flow switches and temperature switches provided by the owner. The accumulated, pressurized hydraulic fluid in the tracking system has sufficient power to stow the collectors in the event of A/C power line loss which will obviously provide a "--" signal. A small D/C inverter is supplied with the system to provide the power to drive two solenoids on each drive pylon for this loss of power, hazard condition. The battery inverter system will vary with the size of the collector field and provide up to 66 watts of inverted power for each row.

(REPRINTED FROM SOLAR KINETICS, INC.)

No.	DESCRIPTION
1	LOGIC 1 OR 3
2	LOGIC 2 OR 4
3	SPARE
4	SPARE
5	120VAC-Φ INVERTER +
6	120VAC-NEUT. INVERTER −
7	120VAC-Φ
8	120VAC-NEUT.
9	GROUND
10	TRK. SENSOR (BRN LEAD)
11	TRK. SENSOR (BLUE LEAD)
12	TRK. SENSOR (GRN. LEAD)
13	DIRECTION SOLENOID (EAST)
14	DIRECTION SOLENOID (WEST)
15	HYD. MOTOR
16	HYD. PRESS SW. (HI SIDE)
17	HYD. PRESS SW. (LOW SIDE)
18	
19	BY-PASS RELAY COIL
20	HAZARD INTERRUPT
21	
22	LT. SENSOR (WHITE LEAD)
23	LT. SENSOR (RED LEAD)
24	V-TO LT. SENSOR BD.
25	TEMP. SWITCH
26	



DRIVE PYLON



DIALAPAK CONTROLLER TERMINAL CONNECTIONS

STATE OF OHIO RICHARD W. PAYNE 30219 REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY J.R. LOBHARD, P.E.
DRAWN BY BRW
CHECKED BY RHW

REVISIONS

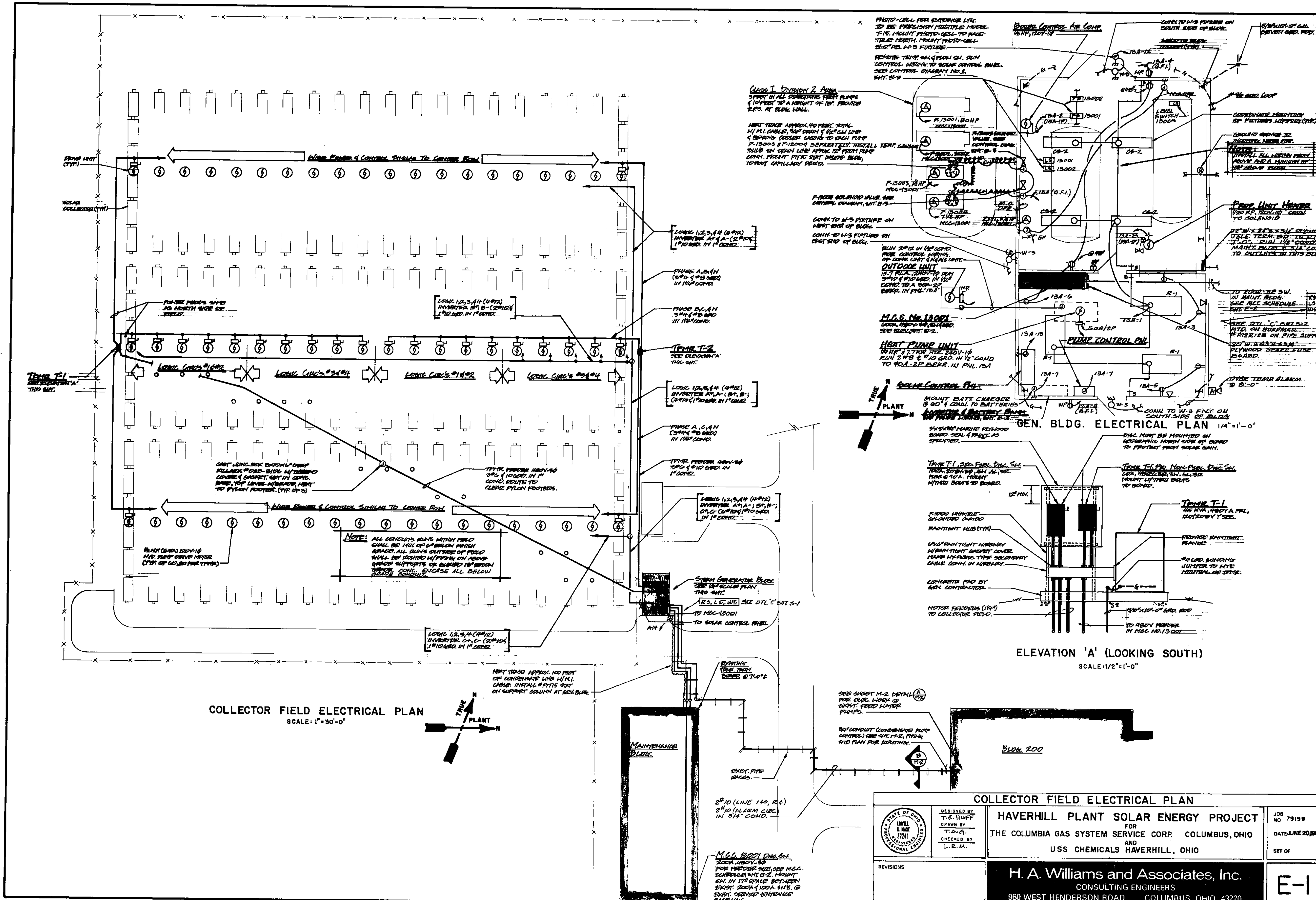
CONTROL DIAGRAMS

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

JOB NO. 79199
DATE JUNE 20, 1980
SET OF 15

H. A. Williams and Associates, Inc.
CONSULTING ENGINEERS
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

M-8



COLLECTOR FIELD ELECTRICAL PLAN

HAVERHILL PLANT SOLAR ENERGY PROJECT
FOR
THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
AND
USS CHEMICALS HAVERHILL, OHIO

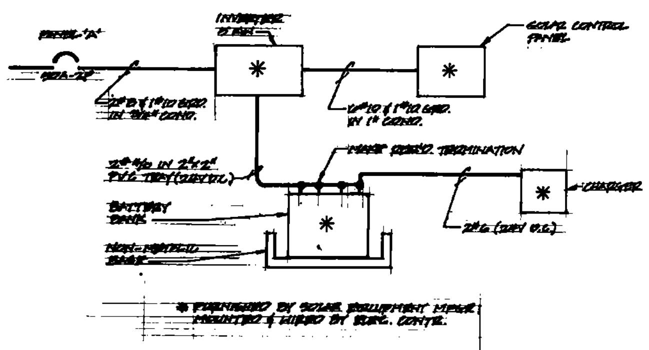
DESIGNED BY T.E. HUFF
DRAWN BY T.A.G.
CHECKED BY L.R.M.

JOB NO 79199
DATE JUNE 20, 1980
SET OF

REVISIONS

H. A. Williams and Associates, Inc.
CONSULTING ENGINEERS
980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220

E-1



INVERTER & BATTERY BANK WIRING DIAGRAM

MOTOR CONTROL CENTER SCHEDULE – MCC No. 13001

KEY: COMB.– COMBINATION MAGNETIC ACROSS THE LINE; S.D.– STAR DELTA; MAN.– MANUAL; MAG.– MAGNETIC ACROSS THE LINE; A.T.– AUTO TRANSFORMER; H.O.A.– HAND-OFF-AUTO SELECTOR SWITCH; P.– PILOT LIGHT; S.S.– START-STOP PUSHBUTTONS; O.O.– ON-OFF MAINTAINED CONTACT SELECTOR SWITCH; H.A.– HAND-AUTO SELECTOR SWITCH; P.S.– PUMP SELECTOR SWITCH

MCC START NO.	MECH. EQUIP. NO.	EQUIPMENT NAMEPLATE	MOTOR H.P.	VOLTAGE & PHASE	FUSED SWITCH SIZE	FUSE SIZE	FEEDER SIZE: WIRE	FEEDER SIZE: COND.	STARTER: TYPE	STARTER: NEMA SIZE	STARTER: AUX. CONT. N.O.	STARTER: AUX. CONT. N.C.	120 VOLT CONTROL TRANSFORMER	PILOT DEVICES: IN MCC.	PILOT DEVICES: REMOTE	REMARKS
1		MAIN SWITCH		480/3φ	200A	150A	3#3/0 & 1#6 GRD.	2"	—	—	—	—	—	—	—	FROM 200A SW. IN MAINT. BLDG.
2	P-13001	PUMP NO. 13001	30	480/3φ	60A	60A	3#6 & 1#10 GRD.	1"	COMB.	3	1	0	NO	H.O.A., P.	P.S. *	C.D. #1 SHT. E-3
3	P-13002	PUMP NO. 13002	30	480/3φ	60A	60A	3#6 & 1#10 GRD.	1"	COMB.	3	1	0	NO	H.O.A., P.	—	C.D. #1
4	P-13003	PUMP NO. 13003	7½	480/3φ	30A	20A	3#12 & 1#12 GRD.	3/4"	COMB.	1	1	0	NO	H.O.A., P.	P.S. *	
5	P-13004	PUMP NO. 13004	7½	480/3φ	30A	20A	3#12 & 1#12 GRD.	3/4"	COMB.	1	1	0	NO	H.O.A., P.	P.S. *	
6	EF	EXHAUST FAN	3/4	480/3φ	30A	2.5A	3#12 & 1#12 GRD.	3/4"	COMB.	1	1	0	YES	H.O.A., P.	—	C.D. #3 SHT. E-3
7		(BLANK)		480/3φ	30A				COMB.	1	1	0	YES	H.O.A., P.	—	SPARE
8	T-1	TRANSFORMER T-1	45 KVA.	480/3φ	60A	60A	3#6 & 1#10 GRD.	1"	—	—	—	—	—	—	—	
9	T-2	TRANSFORMER T-2	45 KVA.	480/3φ	60A	60A	3#6 & 1#10 GRD.	1"	—	—	—	—	—	—	—	
10	T-3	TRANSFORMER T-3	25 KVA.	480/1φ	60A	60A	2#4 & 1#6 GRD.	—	—	—	—	—	—	—	—	
11		CONTROL SPACE			—	—	INTERNAL TO MCC	—	—	—	—	—	300 VA 3 POS. SEL. SW.	(3) P.S. *	—	CONTROL TFMR., SELECTOR SW'S. & RELAY SPACE
12	C-1	CAPACITOR C-1	15 KVAR	480/3φ	—	—	INTERNAL TO MCC	—	—	—	—	—	—	—	—	FOR PUMP P-13001
13	C-2	CAPACITOR C-2	7.5 KVAR	480/3φ	—	—	INTERNAL TO MCC	—	—	—	—	—	—	—	—	FOR PUMP P-13002
14		SPACE														
15		SPACE														
16		SPACE														

* (3) P.S. FOR P-13001, 13003 & 13004 LOCATE IN SECTION 11 OF MCC. ALSO "ALARM SILENCE" P.B.

ELECTRICAL ABBREVIATIONS

INDUSTRY STANDARD ABBREVIATIONS NOT SHOWN

AWG	AMERICAN WIRE GAUGE	FSBL	FUSIBLE
A	AMPERE	GEN	GENERAL
AB	ABOVE	GRD	GROUND
APPROX	APPROXIMATE	HTG	HEATING
ARCH	ARCHITECT	IC	INTERCOM
AUX	AUXILIARY	JUNC	JUNCTION
BD	BOARD	K.E. CONTR.	KITCHEN EQUIP. CONTR.
BRKR	BREAKER	K O	KNOCKOUT
BLDG	BUILDING	LTG	LIGHTING
BTM	BOTTOM	L/V	LOW VOLTAGE
CAB	CABINET	M.H.	MANHOLE
CLG	CEILING	MFGR	MANUFACTURER
℄	CENTERLINE	MAX	MAXIMUM
CIRC	CIRCUIT	MECH	MECHANICAL
C/B	CIRCUIT BREAKER	MTL	METAL
CONC	CONCRETE	MIN	MINIMUM
COND	CONDUIT	MTD	MOUNTED
CONN	CONNECTION/CONNECTOR	MTG	MOUNTING
CONTR	CONTRACTOR	OPNG	OPENING
CONT	CONTROL	PLBG	PLUMBING
COORD	COORDINATE	OPER	OPERATOR/OPERATED
C/T	CURRENT TRANSFORMER	PNL	PANEL
C/C	CENTER TO CENTER	P/T	POTENTIAL TRANSFORMER
DTL	DETAIL	PB	PUSHBUTTON
DIAG	DIAGRAM	P.A.	PUBLIC ADDRESS
DIA	DIAMETER	RECEPT	RECEPTACLE
DISC	DISCONNECT	REQ'D	REQUIRED
DN	DOWN	RM	ROOM
DR	DOOR	SCHED	SCHEDULE
DWGS	DRAWINGS	SHT	SHEET
EA	EACH	STAT	THERMOSTAT
ELEC	ELECTRICAL	SW	SWITCH
ELEV	ELEVATION	SW/BD	SWITCHBOARD
EMERG	EMERGENCY	TELE	TELEPHONE
EQUIP	EQUIPMENT	T.V.	TELEVISION
EXH	EXHAUST	TEMP	TEMPERATURE
EXIST	EXISTING	TERM. BD.	TERMINAL BOARD
FDR	FEEDER	TRANS	TRANSFER
FA	FIRE ALARM	TFMR	TRANSFORMER
FIX	FIXTURE	TYP	TYPICAL
FLEX	FLEXIBLE	T.C.C.	TEMPERATURE CONTROL CONTR.
FLR	FLOOR	WP	WEATHERPROOF
FLUOR	FLUORESCENT	W	WIRE
FRACT	FRACTIONAL	W/	WITH
FURN	FURNISH	EPS	EXPLOSION PROOF SEAL

FIXTURE SCHEDULE

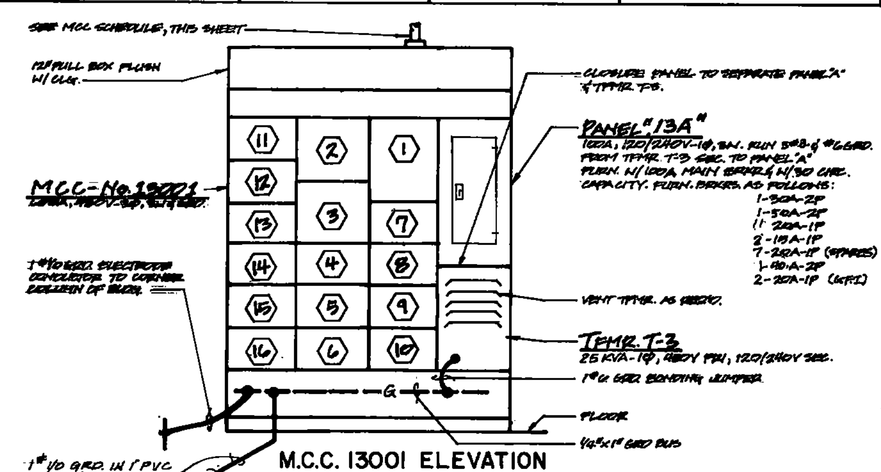
NOTE: FIXTURE NUMBER, LETTER PREFIX INDICATES TYPE OF MOUNTING AS FOLLOWS:
CL-CEILING MOUNTED; S-STEM SUSPENDED; W-WALL MOUNTED; R-CEILING RECESSED; WR-WALL RECESSED; CV-COVE MOUNTED; UC-UNDER CABINET; RF-ROOF MOUNTED; P-POST; GR-GROUND MOUNTED; H-MOUNTED IN HOOD

FIXTURE DESIGNATION	MANUFACTURER	CATALOG NUMBER	LAMPS	REMARKS
R-1	LITHONIA	2GS-440-RN-A12-120	4-F40W	
CS-2	LITHONIA	1A-240-120	2-F40W	CHAIN SUSPEND @ 10'-0"
W-3	LITHONIA	TW 100S-120	1-100W HPS	MTD. @ 10'-0"

ELECTRICAL LEGEND

ALL SYMBOLS DO NOT NECESSARILY APPLY

SYMBOL	DESCRIPTION	MOUNTING HGT. TO CENTERLINE UNLESS OTHERWISE NOTED
	CEILING OUTLET	
	WALL OUTLET	SEE DRAWINGS
	SPECIAL OUTLET, AS REQUIRED	SEE DRAWINGS
	WIRED JUNCTION BOX	SEE DRAWINGS
	BLANK OUTLET BOX	SEE DRAWINGS
	DUPLEX RECEPTACLE, 3 WIRE GRD. TYPE	18"
	DUPLEX RECEPTACLE FLOOR MOUNTED	
WP	DUPLEX RECEPTACLE WEATHERPROOF	18"
3, 4	TOGGLE SWITCH - SINGLE, 3-WAY & 4-WAY	48"
P	TOGGLE SWITCH - W/PILOT LIGHT	48"
	RAIN SWITCH	SEE DWGS
	WIND SWITCH	"
	TELEPHONE OUTLET	18"
	MOTOR OUTLET - 1 PHASE	AS REQUIRED
	MOTOR OUTLET - 3 PHASE	AS REQUIRED
	CEILING MOUNTED EXIT LIGHT	
	WALL MTD. EXIT LIGHT W/DIRECTIONAL ARROWS	SEE DRAWINGS
	ELECTRIC PANEL	6'-0" TO TOP
	TELEPHONE PANEL	6'-0" TO TOP
	SAFETY SWITCH	AS REQUIRED
	MAGNETIC MOTOR STARTER	AS REQUIRED
	COMBINATION MOTOR STARTER	AS REQUIRED
	MANUAL MOTOR STARTING SWITCH WITH PILOT LIGHT	48"
	LINE VOLTAGE THERMOSTAT	60"
	CLOCK	96"
F	FIRE ALARM BREAK STATION	54"
F	FIRE ALARM SIGNAL - BELL	96"
F	FIRE ALARM SIGNAL - HORN	96"
	SMOKE DETECTOR - DUCT MOUNTED	SEE DRAWINGS
	SMOKE DETECTOR - CEILING MOUNTED	
	WALL MOUNTED PHOTOCELL	SEE DRAWINGS
E	EMERGENCY BATTERY UNIT	96"
VS	VARIABLE SPEED SWITCH (BY OTHERS)	48"
S	TOGGLE SWITCH, SPECIAL - AS REQUIRED	48"
K	TOGGLE SWITCH - KEY OPERATED	48"
	OVER-TEMP. SWITCH	SEE DWGS
	TERMINALS 1,2,3, ETC.	- -
	STOP-START PUSHBUTTON STATION	48"
	FLOW SWITCH	SEE DWGS
LS	LIGHT SWITCH	- -

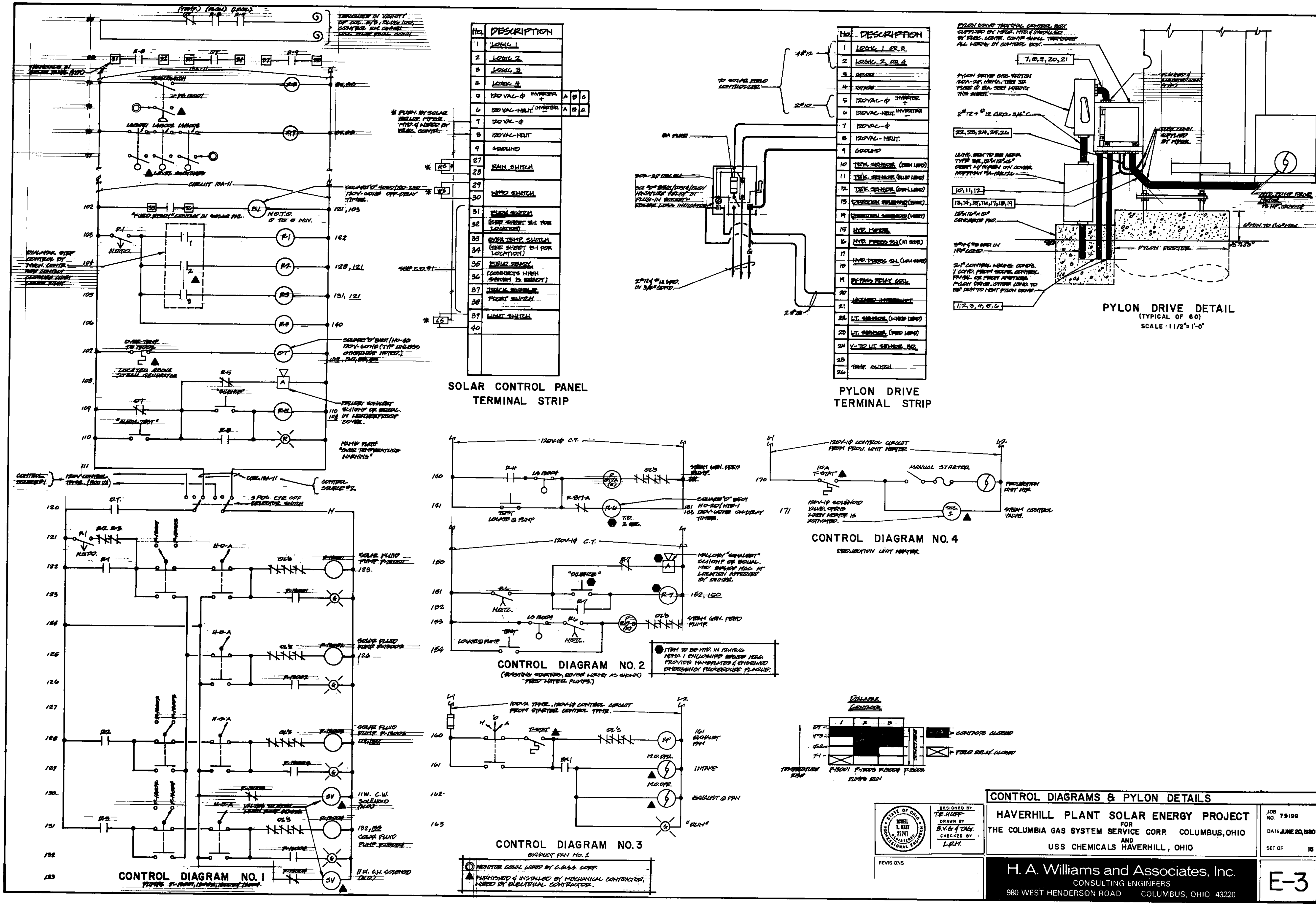


M.C.C. 13001 ELEVATION

SCALE: 1/2" = 1'-0"

ELECTRICAL SCHEDULES		
DESIGNED BY T.E. HUFF DRAWN BY T.A.G. CHECKED BY L.R.M.	HAVERHILL PLANT SOLAR ENERGY PROJECT FOR THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO AND USS CHEMICALS HAVERHILL, OHIO	JOB NO. 79199 DATE JUNE 20, 1980 SET OF 15
REVISIONS	H. A. Williams and Associates, Inc. CONSULTING ENGINEERS 980 WEST HENDERSON ROAD COLUMBUS, OHIO 43220	E-2

STATE OF OHIO · LOWELL R. MAST · 22241 · REGISTERED · PROFESSIONAL ENGINEER



SOLAR CONTROL PANEL
TERMINAL STRIP
PYLON DRIVE
TERMINAL STRIP
PYLON DRIVE DETAIL
(TYPICAL OF 60)
SCALE : 1 1/2" = 1'-0"
CONTROL DIAGRAM NO. 1
CONTROL DIAGRAM NO. 2
CONTROL DIAGRAM NO. 3
CONTROL DIAGRAM NO. 4
CONTROL DIAGRAMS & PYLON DETAILS
HAVERHILL PLANT SOLAR ENERGY PROJECT
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THE COLUMBIA GAS SYSTEM SERVICE CORP. COLUMBUS, OHIO
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