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SOLAR THERMAL TECHNOLOGY COLLABORATIVE RESEARCH PROGRAM

SOLAR THERMAL ENERGY CENTER

AND

BROOKHAVEN NATIONAL LABORATORY

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TABLE OF CONTENTS

	PAGE
1.0 Introduction	1
1.1 Background	1
1.2 Objectives	1
1.3 Sequence of Activities	2
2.0 The BNL Collector Design	5
2.1 Concept	5
2.2 The Low-Cost Thin-Material Solar Collector	6
3.0 Training Program and Technical Assessment	9
3.1 Training	9
3.2 Assistance in Establishing the Instrumentation Facility	11
3.3 Instrumentation and Calibration	11
3.4 Data Logger Installation and Programming	14
3.5 Establishing the Test Facility at STEC	15
3.6 Solar Collector Performance and Testing	18
3.7 Results of the BNL Collector Test	24
3.8 Performance Results	26
3.9 Conclusions on Performance	27
4.0 Application and Economic Analysis of Solar Thermal Systems	29
4.1 Solar Hot Water Systems--A Preliminary Analysis	29
4.2 Solar Cooling/Cold Storage Systems--Preliminary Assessment	33
5.0 Conclusions and Recommendations for Future Work	38
Appendix 1. Training Program Schedule of Mr. S. K. Gupta	41
Appendix 2. Technical Equipment Specifications	43
Appendix 3. Selected Test Data	74

LIST OF FIGURES

1. BNL Thin-Film Solar Flat-Plate Collector..... 7
2. Indoor View of STEC Workshop..... 16
3. Outdoor View of STEC Facility Showing Collector Testing Area..... 17
4. Test Stand Fabrication in Progress..... 19
5. BNL Collector on the Completed Test Fixture..... 20
6. Flowmeter Readings..... 21
7. Adjusting Flow Value..... 22
8. Functional Diagram of Solar Collector Testing Fixture..... 25
9. Indian Test Results..... 28
10. Solar Cooling System Using a Single Effect Absorption Chiller..... 35

LIST OF TABLES

1. Assumptions in the Economic Analysis of Solar DHW System..... 32
2. Results of Solar DHW Analysis..... 32

1.0 INTRODUCTION

1.1 Background

The collaborative research and development project in solar thermal technology between the Solar Thermal Energy Center (STEC) of the Department of Non-Conventional Energy Sources (DNES), Government of India, and Brookhaven National Laboratory (BNL) of the United States Department of Energy was formally initiated in July 1983. The essential concept behind this project was developed initially in a meeting between Mr. Maheshwar Dayal, then Secretary of the Commission on Additional Sources of Energy, Government of India (and, now, Secretary, DNES) and Dr. Vinod Mubayi of BNL in 1982. The discussion focussed on the growing solar program in India in line with the need to meet the rapid increases in energy demand in the country, the innovative research on new collector designs at BNL to make solar energy an economically viable source and the need for institutional technical support to a newly created central solar R&D facility in India with a broad mandate of undertaking work in new product development, performance evaluation and certification, standards setting, etc. It was felt that a collaborative R&D program between BNL and the newly created STEC would offer some significant advantages both in transferring new research concepts as well as technical skills and equipment to the nascent STEC facility. The AID program with India on Alternative Energy Resource Development provided the essential mechanism under which a joint project between the two institutions, BNL and STEC, could be developed.

1.2 Objectives

At the outset, the project can be said to have had two broad objectives:

(i) The provision of institutional technical support to STEC. This was sought to be done through the transfer of selected instrumentation to STEC for measuring collector thermal performance, training of STEC staff at BNL and the STEC site in use of the instrumentation and the establishment of basic experiments and procedures for thermal performance testing at the STEC facility.

(ii) The introduction of STEC personnel to innovative research concepts in solar thermal technology, in particular, a version of the thin-material polymer film flat plate solar collector designed at BNL and under development there as part of a Department of Energy sponsored research project.

The project was designed around a thermal performance test of the BNL collector at the test facility to allow for a fusion of these two objectives. In addition, the transfer of the BNL-designed and fabricated collectors to the STEC site also permitted an evaluation of their thermal performance and durability under ambient conditions very different from those encountered in the United States.

1.3 Sequence of Activities

The sequence of activities carried out under the project involved the following steps:

(i) Purchase of instrumentation under the terms of the project for transfer to STEC. This included a data logger, a flowmeter, a pyranometer, temperature sensors in the form of RTDs (resistive temperature devices) and a teletypewriter for providing hard copy of data output.

(ii) Test and calibration of the instrumentation purchased.

(iii) Fabrication of sample BNL-design collectors for transfer to STEC.

(iv) Training of STEC staff at BNL in the concept and design of the BNL collector and in the use of the instrumentation for measuring collector thermal performance. The latter included training in calibration techniques and in programming of the datalogger for the input, reduction, and analysis of acquired data.

(v) Visit of BNL staff to STEC facility to transfer the collectors and instrumentation, install and carry out basic experiments for collector performance measurement, and to train a

larger complement of the STEC staff in measurement techniques and procedures.

(vi) Carrying out a preliminary assessment and economic analysis of the possible application of the BNL collector in a system.

The project was formally initiated in July-August 1983 with the completion of a PASA between DOE and AID allowing BNL to proceed with the tasks in the statement of work. The equipment from outside vendors was procured, following the specifications laid down by BNL technical staff, by the Contracts and Procurement Division of the Laboratory. After procurement and verification the equipment was tested and calibrated at BNL in preparation for the training visit of STEC staff. Three collectors, of an early version of the BNL design, were also fabricated for transfer to the STEC facility in India. This phase of the work at BNL was essentially completed by October 1983.

At this stage, when preparations had been made to receive visitors from STEC, some delays were experienced due to problems of reorganization on the Indian side. To sort out some of the problems, Dr. Vinod Mubayi, Program Manager at BNL, made a trip to India in January 1984. Several intensive discussions were held with DNES officials to identify the causes of the delays and to expedite the project. Several memos were exchanged between BNL and DNES to set new schedules for the training visit of STEC staff. During this trip, the STEC facility located outside of New Delhi in Dundahera, Haryana State, was visited twice. A visual inspection was carried out to evaluate most suitable areas for installation of the equipment to be transferred and to determine the supporting logistical work needed to be carried out by STEC in preparation for equipment installation.

The project re-emerged on track in July 1984 with the visit of Mr. S. K. Gupta, Senior Engineer at STEC, to BNL. A month-long training program had been prepared at BNL and Mr. Gupta participated in it intensively and enthusiastically. In this visit, a large amount of library material in the shape of books, reports, and research publications was also given to Mr. Gupta for building up STEC's library reference facilities.

The next phase of the project involved the visit to STEC by a team of BNL scientists including Dr. Vinod Mubayi, Mr. William Wilhelm and Mr. David Hansen in November 1984. During this visit, the BNL collectors and instrumentation were transferred and installed at the STEC facility. Training was provided to a larger number of STEC staff in performance testing procedures, and test performance data were collected. A number of other experiments were conceived and fabricated during the trip as part of laying the groundwork for further collaborative efforts especially in areas related to new materials development for solar thermal applications.

Several discussions were held with senior DNES management including Mr. Maheshwar Doyal, Dr. J. C. Gururaja and Dr. G. D. Sootha. In particular, Dr. Sootha and Dr. Mubayi had several meetings to discuss a follow-on effort to the project which resulted eventually in a formal proposal from DNES to AID in January 1985.

2.0 THE BNL COLLECTOR DESIGN

2.1 Concept

Brookhaven National Laboratory (BNL), with the support of the Office of Solar Heat Technologies, U.S. Department of Energy (DOE), has, since 1978, embarked on research and development activities to develop information that will be of value to the solar and building industry in the production and utilization of low-cost solar components and systems. One key area of research centered on the design of a solar collector sufficiently inexpensive to permit the development of a mass market without the necessity of tax subsidies. As a complement to this, research and development were also initiated on concepts and components designs to similarly reduce the cost of the balance of the solar system.

In the context of the need for new solar technology it is important to recognize that the market acceptance of conventional solar energy technology is handicapped by three liabilities: (1) poor cost competitiveness relative to conventional residential energy systems, (2) architectural incompatibility with conventional buildings, and (3) apprehension about solar system reliability and effectiveness measured in terms of durability and contribution to conventional energy displacement. Poor cost effectiveness was based on conventional solar technology and is well documented by examples in the former DOE Demonstration Program. System-installed cost for space heating in most cases exceeded $600/m^2 with the collector component contributing about half of that amount. Integrating conventional collectors into a variety of architectural structures complicated the cost factor in an effort to achieve maximum performance and aesthetic appeal. The relative high weight of these components often necessitated the use of special equipment causing additional cost.

This understanding was fundamental to developing a research and development direction aimed at producing a marketable solar technology. To define the problem better it was useful to establish criteria and to quantify approximate design constraints for meeting them. This included establishing initial performance and cost goals, and developing an awareness of their implications on the balance of the system considerations, including

architecture. The research at BNL is directed at establishing a target of 20 percent market penetration in residential energy distribution. Addressing payback periods of 7 years or less places an emphasis on major cost reduction in solar technology. This could involve as much as a 3- to 4-fold improvement in system cost reduction over current practice.

The establishment of a broad range of engineering constraints was a distinctive part of the BNL research. These constraints were the critical factors for guiding both the path of discovery and the form of the eventual development. It was a method that permitted a partial characterization of the solution before the solution or solutions were discovered and verified. This procedure provided an efficient and orderly approach to drive creative talents towards evolving the desired results.

2.2 The Low-Cost Thin-Material Solar Collector

The work performed at BNL since 1978 has revealed a flat plate solar collector design that is very simple in construction and potentially very low in cost with the development of new engineering plastics like polymer coatings, films and rigid foams (Figure 1). By using very thin material in a special construction method developed for the aerospace industry, BNL has demnonstrated a solar collector design that weighs as little as 2.3 kg/m^2. The BNL-patented design uses high performance polymer films for the window and weather seal portions of the collector. These films are adhesively attached to a roll-formed aluminum sheet frame that mates with a rigid polymer foam core. In the monocoque construction used in the collector the outer window and back weather seal films are thermally shrunk to form tension members against the rigid insulating polymer foam core. This procedure makes the structure rigid and similar to the construction of an airplane wing. Using such a method of fabrication permits an extremely light structure with little material required in its fabrication.

Most of the design uses materials for multiple functions to minimize the material requirements. The window film functions as a structural member as well as an optical convection suppressor. The back film performs as a tension member and weather seal and the polymer foam core performs the function of insulation as well as being a compression member. These

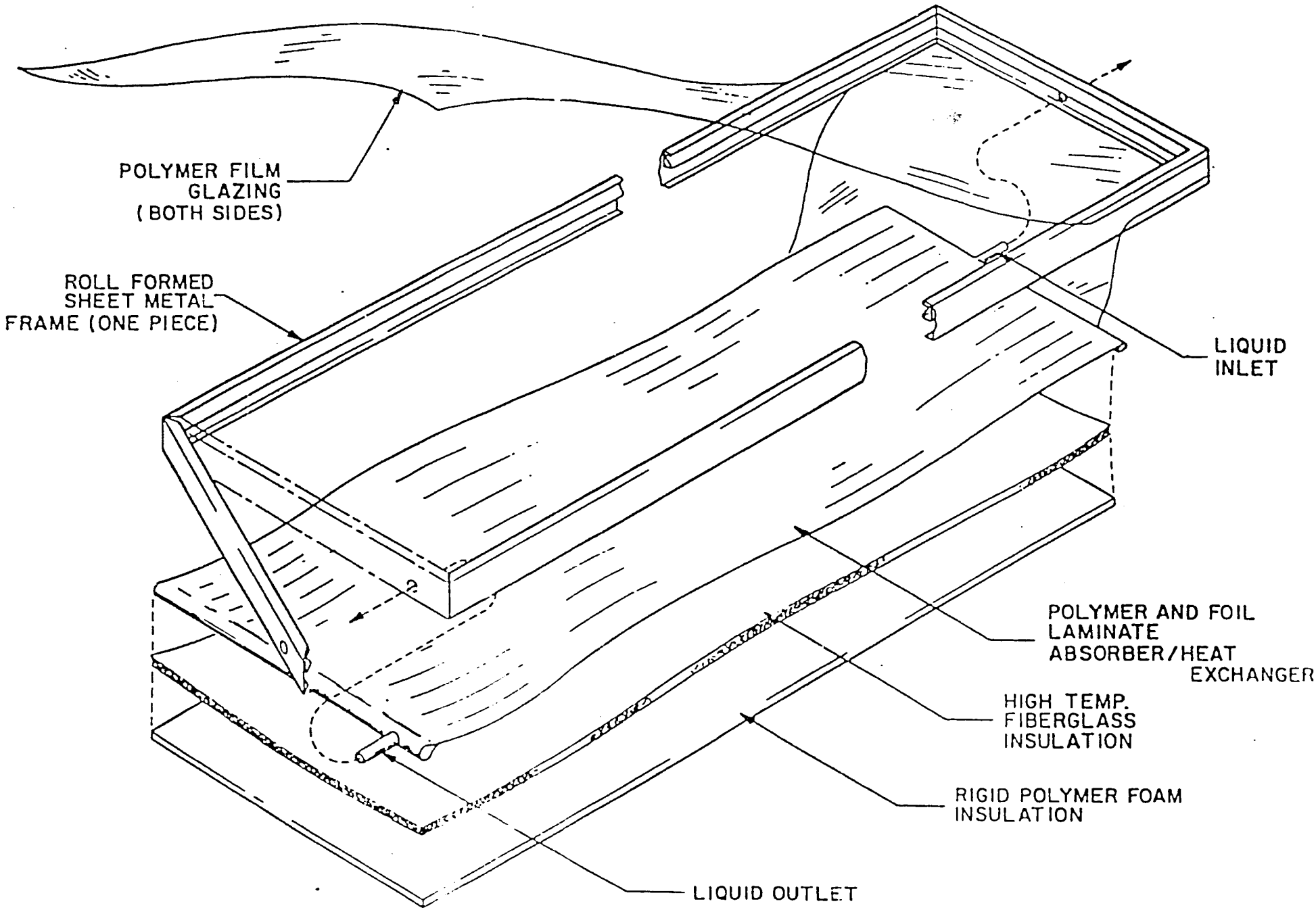


Figure [illegible]. [illegible] Thin-Film Solar Flat-Plate Collector

construction techniques have resulted in a high thermal performance solar panel with a very high strength-to-weight ratio. Experiments suggest this panel will be able to tolerate wind loads in excess of 200 km/hr and can permit a multitude of structural variations to accommodate architectural compatibility.

The absorber coating in the BNL design is by necessity optically selective. This is essential to minimize reradiated losses through the polymer film window which has an optical bandwidth much wider than glass. This wider bandwidth has the advantage of permitting more solar energy to reach the absorber and is measured in an overall improvement in solar transmissivity and thermal performance. The optically selective property is based on a printing technique. By controlling the optical selectivity it is possible in principle, to achieve higher efficiency at a given average operating point while minimizing stagnation temperatures. This reduces the thermal stress on the materials in the absorber-heat-exchanger and can significantly reduce cost by broadening the range of polymer material options.

The object of the research was to demonstrate that low material intensity could result in a viable low cost design. The high performance collectors built and tested at BNL have achieved weights about 10 times lighter than conventional designs. Because of their light weight, it is possible to combine a number of solar panels into a preconnected folded array, which permits a simple one-piece installation of about 10 m^2 of solar collectors without special equipment. In experiments performed at BNL, an unassisted installer was able to carry a folded modular package of five 2 m^2 polymer film panels up a ladder and fasten them to the roof with only the tools carried in his pocket. The installation was done in less than 30 minutes. With the probable development of printable absorber surfaces and the demonstration of attractive panel configurations, the opportunity for versatile architectural integration is apparent. In the concepts generated at BNL a vertically mounted solar panel with a textured absorber surface integrates well with or acts as siding on most conventional and anticipated building structures. It is believed that this will afford enormous opportunities for building designs to combine efficient solar augmented energy collection without compromising attractiveness.

3.0 TECHNICAL COLLABORATION PROGRAM

The substantive technical collaboration activities between BNL and STEC under this project involved the following:

(i) Training of STEC staff

(ii) Identification, procurement and transfer of intrumentation

(iii) Set-up of collector test experiment at the STEC facility

(iv) Data collection and analysis.

In addition, during the visit of BNL staff to STEC a number of other experiments were conceived and implemented including using a BNL collector in a thermosyphon hot water system, construction of a simple manual tracking rig for the collector experiments, design of a temperature controlled oven for fabricating BNL type of collectors and setting up some simple thermal screening tests for materials used in solar components. These are described in more detail below.

3.1 Training

The training of STEC staff was conceived in line with the experience gained over several years at BNL in various training programs for personnel from developing countries that involved energy modelling, systems analysis and energy base technologies. The experience gained in these efforts has revealed the significant role which the more advanced energy technologies could play in the industrial and social growth of developing nations as opposed to the more conventional technologies. These are the technologies that the developed nations are tooling up for and the ones that developing nations will eventually need in order to integrate and compete effectively with the rest of the world. The focus in these new technologies is directed towards major cost reductions in renewable energy alternatives by establishing new design options. To prevent a situation where developing nations will be in a position requiring them to always catch up it is necessary for them to be aware of the new sophistication in materials as well as in design.

Introduction of these technologies as they are still maturing in the development stage offers a unique advantage in assessing their potential in the context of planning and their commercial impact on the country's energy options. For this reason, BNL has encouraged a training program that includes education, training and collaboration in the more advanced technologies influenced by an emphasis in cost-guided research and development. The institutional support activity taking place under this project is in the nature of collaboration between similar institutions in the United States and India. This is in keeping with the object of improving the quality of the technology base of developing countries by enhancing their technical experience. In the collaboration, technical procedures as well as advanced concepts and tools were introduced. These are believed important in accelerating technical growth in this area in India.

The training program schedule arranged for the visit of S. K. Gupta to BNL, shown in Appendix 1, embodied these considerations. A thorough exposure was provided to the calibration and use of the instrumentation through a series of eight sessions involving sensor calibration, circuitry, data logger programming, output recording, etc., with an instrumentation specialist at BNL. Simililarly, a series of eight sessions was arranged on the BNL collector design philosophy, materials specifications and fabrication techniques. A large amount of library materials on solar technologies, designs and materials was made available to Mr. Gupta during the course of his visit. Of course, the intense motivation, enthusiasm and interest shown by Mr. Gupta were very important factors behind the success of his training program.

The training was continued during the visit of the BNL staff to STEC. Since most of the STEC were technicians and not professional engineers or scientists, this training had to be conducted at a somewhat simpler level, mostly by means of a "hands-on" demonstration approach. The basic concepts behind the erection of the test stand, the sensor connections and the operation of the data logger were explained at length. This was also done to ensure proper operation, including start-up and shut-down of the data logger, of the instrumentation after the BNL staff had completed their visit. In this context, it should be noted that the professional staff at STEC has been considerably strengthened by the inclusion of two more full-time scientists so that the lower-level type of training will not be necessary in future.

3.2 Assistance in Establishing the Instrumentation Facility

The order of events that lead to the establishment of an instrumentation facility at STEC occurred over a period of approximately one year. Initial site investigations at the STEC facility at Haryana, India, were made by Dr. Vinod Mubayi prior to a detailed instrumentation package design. This was done to insure a compatible set of instrumentation consistent with any environmental constraints. Of considerable concern were conditions that might effect the long term durability and accuracy of the equipment provided and the versatility it would offer for a full range of anticipated experiments.

It was clear after several consultations with STEC staff that special care had to be taken to account for the extreme environments anticipated. These included high operating temperatures in the summer and high humidity during the monsoon season. An air conditioner was specified as part of the facility and an Acurex Autodata 10/4 data logger was chosen based on specified durability and experience. In addition, line power fluctuations were of major concern, not only because of effects on accuracy but because of potential destruction of critical components in the electronics of the data logger. Such danger could cause serious down time while replacement of components was procured. It would not have been practical to include a complete set of replacement parts because of their high cost. The final concern was the high dust levels of the test site which could cause overheating of the instrument if not maintained regularly. An enclosed room with an air conditioner was the preferred environment considered as the best option for extended reliability. A power line conditioner was also specified but because of general availability and high weight it was left to be purchased in India by STEC.

3.3 Instrumentation and Calibration

The instrumentation package for the Solar Thermal Energy Center (STEC)/BNL collaborative test was configured to provide the optimum of performance in terms of accuracy, durability and versatility. The heart of this engineering data acquisition system is a microprocessor controlled data logger (Acurex Autodata 10/4) designed for use in harsh environments. Within the instrument are modules which accept direct electrical inputs from various sensors. It is capable of both high accuracy and high resolution (V = 1 micro volt). For applications such as required in most thermal solar

experiments inputs can be directly from temperature sensors that include thermocouples and resistive temperature devices (RTDs). RTD sensors were supplied and used in the STEC test because of their high accuracy (>0.1°C) and long term stability.

To improve the overall versatility of the data logger this instrument incorporates a computational interface capability that converts electrical outputs from thermocouples, RTDs, current transmitters and other electrical sensors directly into engineering units with the proper scaling factors. The capability of the device includes a limited arithmetic package that permits real time computations of various input data. This system can add, subtract, multiply or divide one channel by another. It can also apply appropriate correction constants to a given channel to achieve the necessary engineering values including labled units. This capability makes it very convenient to evaluate data while the experiment is in operation.

The data logger is capable of a high resolution (1 microvolt) scan mode of 10 channels per second. Higher data rates are possible with only a small reduction in accuracy. Such a mode might be required when the full input capacity of the instrument is used in a critical real time application. Scanning control of up to 60 three-wire and 120 two-wire channels are possible within the primary mainframe provided. The instrument is also capable of external linear scaling of calibrated sensors. This allows the experimenter the flexibility of inputting his own calibration information on a special sensor into the data so that it will reveal accurate engineering values when in operation. The package can serve a multitude of experiments at one time and can easily be adjusted for new experiments as they come on line.

Instrumentation sensors are the most critical components in the instrumentation package. They are the "eyes and ears' as the data logger is the "brain". The quality of such devices is measured in the accuracy, replicability and reliability they exhibit in a given application. For the STEC facility, temperature is the most common type of data required so most of the sensors are temperature devices.

Basically two types of temperature sensors meet the requirements and are common for such applications. They are copper/constantan thermocouples (TC) which are reasonably accurate (± 1.0°C) over a wide range (-100°C to 200°C) of operation and are considered quite durable under normal use. The RTDs

specified are more accurate (< 0.1°C) than the TCs but are delicate in the low mass, fast response configuration and may require occasional calibration checking to insure their accuracy. The RTD is the important choice here because in heat transfer rate measurements in relation to solar collector experiments the temperature change measured from inlet-to-outlet is often small (from 2°C to 15°C) and an accuracy less than 0.1°C can represent a substantial error in heat transfer.

During Dr. Gupta's technical visit to BNL under the agreement of the collaboration, calibration procedures were demonstrated. The procedures were designed as guidelines to assist STEC in developing its own facilities as well as insuring the quality of future data collection. It is anticipated that extentions of this kind of guidance and the development of other instrumentation needs would continue as part of extended collaboration.

To insure completeness, other instrumentation was supplied and demonstrated. A pyroheliometer, also connected to the data logger, was used to measure solar intensity. While one basic unit was supplied with the shipment to India, others were already on order by STEC in anticipation of the instrumentation facility. Water mass flow was the only data point not measured by the data logger. This was decided on the basis of previous experience at BNL and other laboratories performing similar experiments. To accomplish this measurement, a fixed, external, high accuracy (± 1%) visual flowmeter was chosen as opposed to an electric flowmeter connected to the data logger. Electronic flowmeters tend to be very unreliable in most environments and clearly would have caused difficulty in India. By designing the experiment and the test stand to operate in a constant flow configuration it was possible to set the flow very accurately with valving using the visual flowmeter and maintain it as a constant. It was then possible to treat that value as a numeric constant in the data logger for high accuracy and consistency.

A Teletype 43 teleprinter was supplied for program input to the data logger and for hard copy recording of the data output. While this instrument is simple, it is quite rugged and capable of withstanding extreme environments. In expansion of the facility, a more sophisticated monitor-cum-printer could be considered.

A complete list of all instrumentation items supplied to STEC along with the technical equipment specifications obtained from the manufacturers of the purchased equipment is shown in Appendix 2.

3.4 Data Logger Installation and Programming

The data logger provided for the STEC facility is a precision electronic instrument which will provide multichannel input capability and versatility. In the required initial experiment at STEC a BNL high performance, light weight design, solar flat plate collector was tested to emphasize and validate performance in the climate environment of India. To accomplish this, precision precalibrated RTD-type temperature sensors were attached to designated input terminals on the data logger and were energized in preparation for programming. A programming sequence is necessary to access the sensor signal, condition it and normalize it to the desired engineering values. In addition, conditioned data can be manipulated algebraically by the data logger to form pseudo channel data derived from the information directly accessed. This function provides a very convenient way to access data in forms that are more meaningful to the researchers.

For the solar flat plate collector tests performed at STEC the basic information needed to evaluate thermal performance can be derived from three input temperatures and the amount of insolation falling on the surface. While the data logger is capable of greater input capacity only a limited number of inputs are required for the basic performance testing. It is anticipated that the additional input capability of the data logger will be utilized to expand existing experiments and to add additional experiments as required.

From the four basic input sensors, eight output channels of information are created. Four of the channels are directly derived from the input sensors and four are algebraically derived from the basic four inputs for a total of eight. This kind of flexibility is very useful in analyzing experimental results in the context of deriving meaningful correlative data. In future expansion of this data acquisition, a microcomputer may be added to the data logger to expand the data reduction capability.

3.5 Establishing the Test Facility at STEC

The STEC facility is located in Dundahera, Haryama State, near the border of the Union Territory of Delhi and roughly 20 miles from what can be considered as downtown New Delhi. The facility consists of a large shed with standard workshop industrial equipment such as a brake, lathes, bench drills, welding equipment, etc., and an adjacent open-air yard where solar collectors, solar cookers, driers, etc., are installed for testing. Adjacent to the STEC workshop shed is an Electronics Test and Development Center of the State of Haryana which is heavily promoting and trying to attract private entrepreneurs to set up electronics industries in their state.

An indoor view of the STEC workshop which shows workers fabricating a sheet metal collector frame is shown in Figure 2. An outdoor view of the open-air yard showing collectors installed on test stands is shown in Figure 3.

The primary effort in establishing the test facility was to take all the necessary steps to ensure that collector testing could become operational during the period of the BNL staff visit. This included building the test stand, the storage tank, selecting the piping and pump, connecting up the instrumentation and programming the data logger. The BNL collector was used as part of the shakedown for the testing fixture in preparation for the intended experiment. Many of the ancillary parts had to be made in the STEC machine shop which is well equipped. However, some parts such as pipe fittings and various small hardware were purchased on the outside, usually with considerable difficulty as compared with similar purchases in the U.S. Full dedication was provided by the STEC staff which resulted in an operational experimental fixture at the end of two weeks.

The test fixture erected is intended for testing solar collectors now made by various private companies in India entering the Indian market and requiring Government certification as part of a standardization procedure. The multi-channel capability of the data logger supplied under this project means that a number of collectors and other solar products such as cookers, driers, etc., can be tested simultaneously for thermal performance. Towards the end of the BNL staff visit, it was observed that many manufacturing companies in India were providing samples of their equipment to STEC to obtain

Figure 2. Indoor View of STEC Workshop

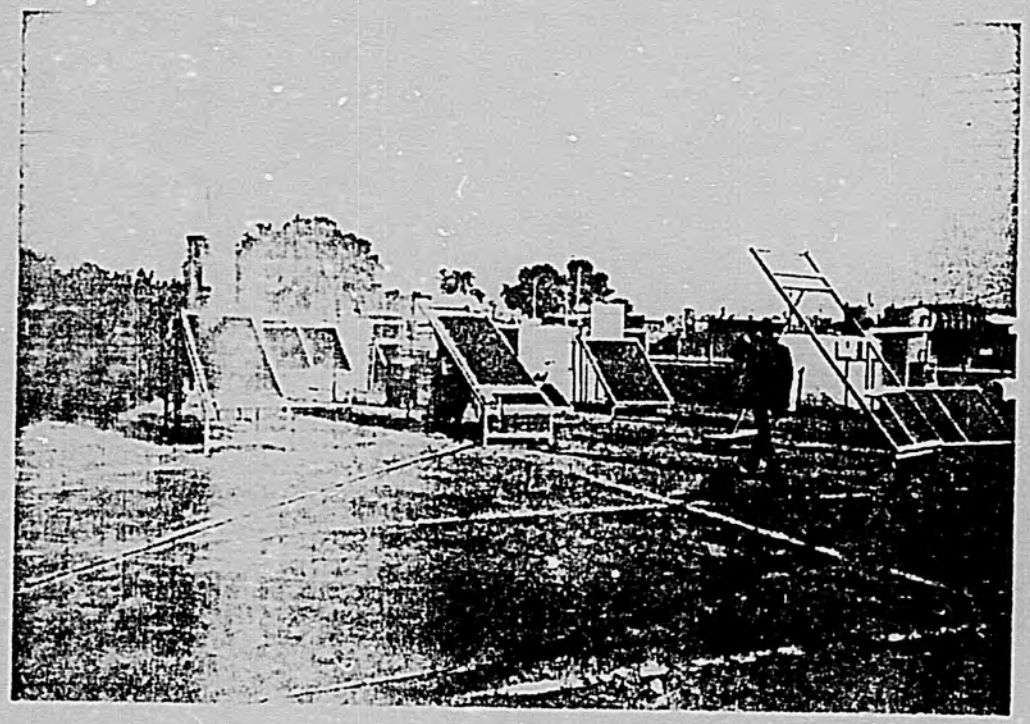


Figure 3. Outdoor View of STEC Facility Showing Collector Testing Area.

On the right is a manual tracking "tube-in-tube" rig built by BNL staff for STEC during their visit.

certification and STEC staff were using the data logger and other instrumentation to measure performance.

Figure 4 shows the STEC technicians working on the test fixture. Figure 5 shows the completed test fixture with the BNL collector; STEC/BNL staff are shown explaining test procedures to Mr. Dayal, Head of DNES. Figures 6 and 7 show STEC/BNL staff taking readings from the flowmeter attached to the test fixture.

3.6 Solar Collector Performance and Testing

Solar collector thermal performance is customarily described by a linear curve which specifies the useful energy as a function of the input radiation and the collector operating temperature relative to its surroundings. The parameter that quantifies the capability of the collector to absorb solar radiation is called the effective transmittance-absorptance product ($\tau\alpha$). The energy absorbed is primarily a function of τ, the transmittance of the glazing, and α, the absorptance of the absorber plate surface, yielding the expression:

$$Q_{solar} = I_T A_c(\tau\alpha) \qquad (3\text{-}1)$$

where

I_T = the total incident radiation per unit area, measured in the aperture plane of the collector (Btu/hr·ft^2(W/m^2),

an A_c = the collector aperture area, ft^2(m^2).

Thermal losses from the solar collector occur in three ways: conduction, convection, and radiation. For both experimental and analytical purposes, it is common to combine the losses to yield a single heat loss coefficient based upon the temperature difference between the average collector absorber plate temperature and the ambient temperature. Thus, the rate of heat loss

$$Q_{loss} = U_L A_c(T_p - T_a), \qquad (3\text{-}2)$$

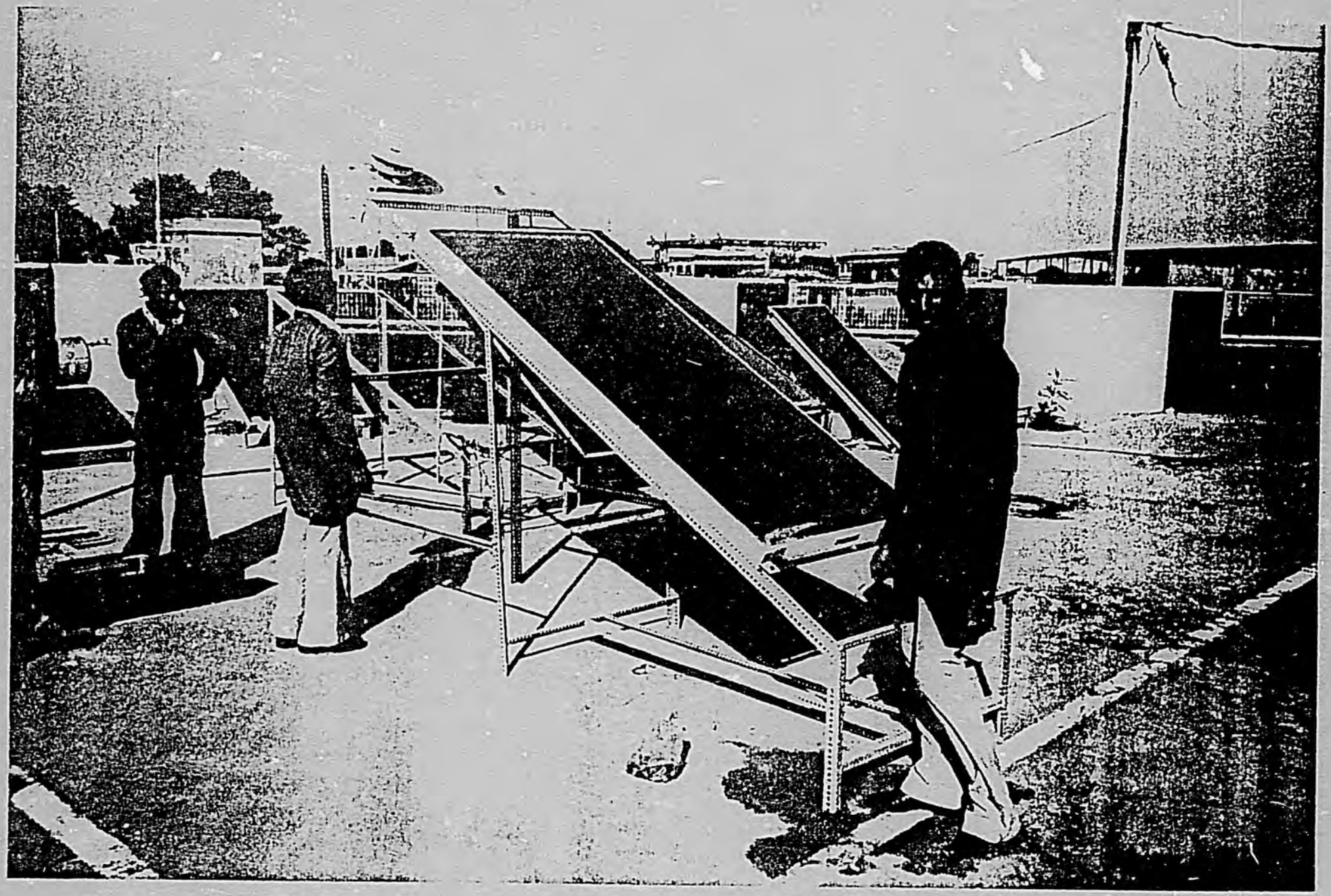


Figure 4. Test Stand Fabrication in Progress

Figure 5. BNL Collector on the Completed Test Fixture.

SIFC/BNL staff explaining test procedure to Mr. Dayal, Head of DNES.

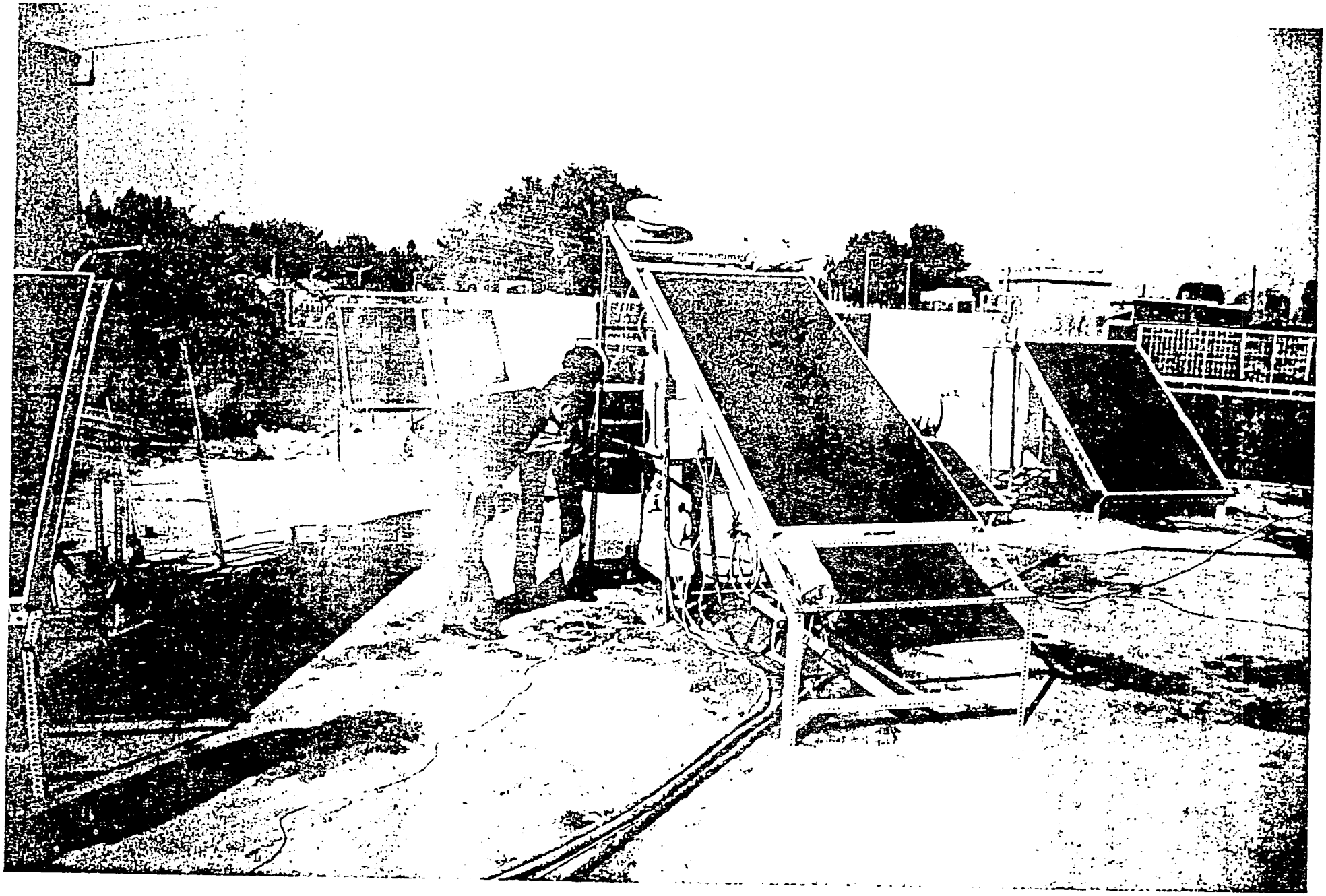


Figure 6. Flowmeter Readings

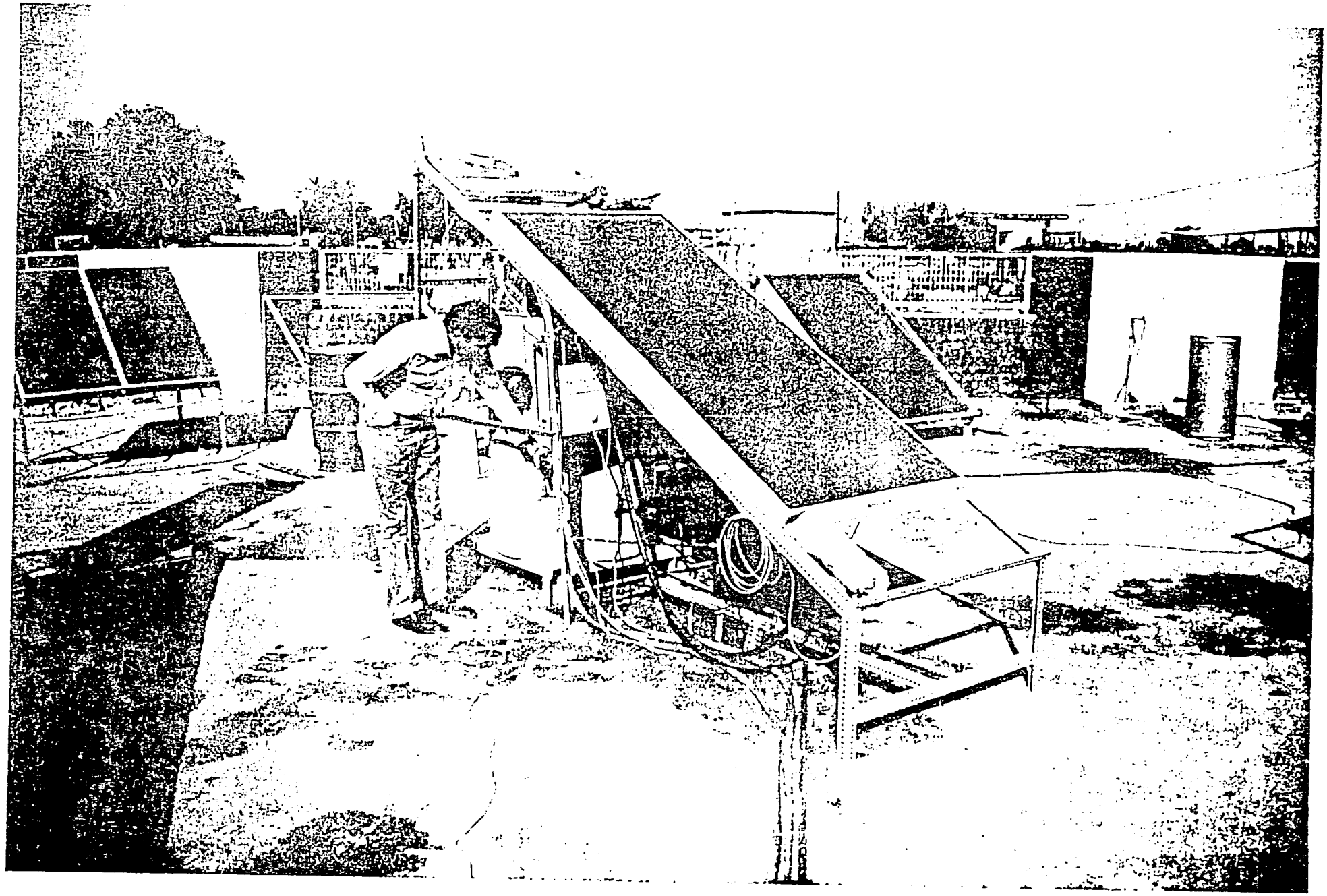


Figure 7. Adjusting Flow Value

where

U_L = the overall collector loss coefficient Btu/h·ft^2·°F (W/m^2·K);

T_p = the average absorber plate temperature, °F(°C);

T_a = the ambient temperature, °F(°C).

The useful energy derived from the collector can be expressed by:

$$Q_u = Q_{solar} - Q_{loss} \cdot \tag{3-3}$$

and, by substitution, the quasi-steady-state performance of the collector becomes:

$$Q_u = A_c\ I_T\ (\tau\alpha) - U_L\ A_c\ (T_p - T_a). \tag{3-4}$$

The efficiency of a flat-plate solar collector is usually defined as the ratio of the useful energy delivered by the collector to the total solar radiation incident on the collector:

$$Q = \frac{Q_u}{Q_{incident}} = \frac{Q_u}{A_c I_T} \cdot \tag{3-5}$$

By substituting Equation 3-4, the collector efficiency becomes:

$$\eta = (\tau\alpha) - U_L(T_p - T_a)/I_T. \tag{3-6}$$

Since the absorber plate temperature is not usually known, following Whillier, a more useful expression for the collector efficiency can be derived by substituting the fluid inlet temperature T_{in}, for the absorber plate temperature and by introducing the collector heat removal factor F_R to approximate the reduced collector heat losses.

$$\eta = F_R[(\tau\alpha) - U_L(T_{in} - T_a)/I_T], \tag{3-7a}$$

or

$$\eta = F_R(\tau\alpha) - F_R\, U_L\, (T_{in} - T_a)/I_T. \tag{3-7b}$$

In this expression. F_R is the ratio of the actual energy collected to the ideal maximum collection that would occur if the absorber plate were at the inlet fluid temperature. Since the fluid inlet temperature is always less than the plate temperature, the heat loss is minimum in the ideal case. F_R depends both on the properties and flow rate of the heat transfer fluid and on the overall thermal resistance between the absorber plate and the fluid.

Equation (3-7b) shows that if the efficiency η is plotted against $(T_{in}-T_a)/I_T$, a straight line will result with a slope of F_RU_L, with an intercept on the ordinate equal to $F_R(\tau\alpha)$. Since U_L is generally a function of temperature, there are second-order corrections to the straight line. However, a linear fit usually provides an adequate approximation to the collector efficiency.

Equation (3-7b), generally known as the Hottel-Whillier-Bliss (HWB) equation, is the basis for the testing of solar collector thermal efficiency. The test procedures were developed at the National Bureau of Standards in the 1970's and later refined and modified by the ASHRAE Technical Committee on solar energy and adopted as ASHRAE Standard 93-77.

3.7 Results of the BNL Collector Test

The BNL collector tested at STEC used a conventional tube and fin absorber plate instead of the thin material unpressurized design currently under development at BNL. This allowed the BNL lightweight design to be applied to conventional pressurized system operation such as in thermosyphoned water heating. The 2 m^2 panels delivered to STEC weighed about 14 kg or about 30 percent as much as conventional designs.

Figure 8 shows a schematic line drawing of the overall test fixture and the sensor connections. The test carried out was a simple sub-set of the procedure specified in ASHRAE 93-77. Since the BNL design collector had been

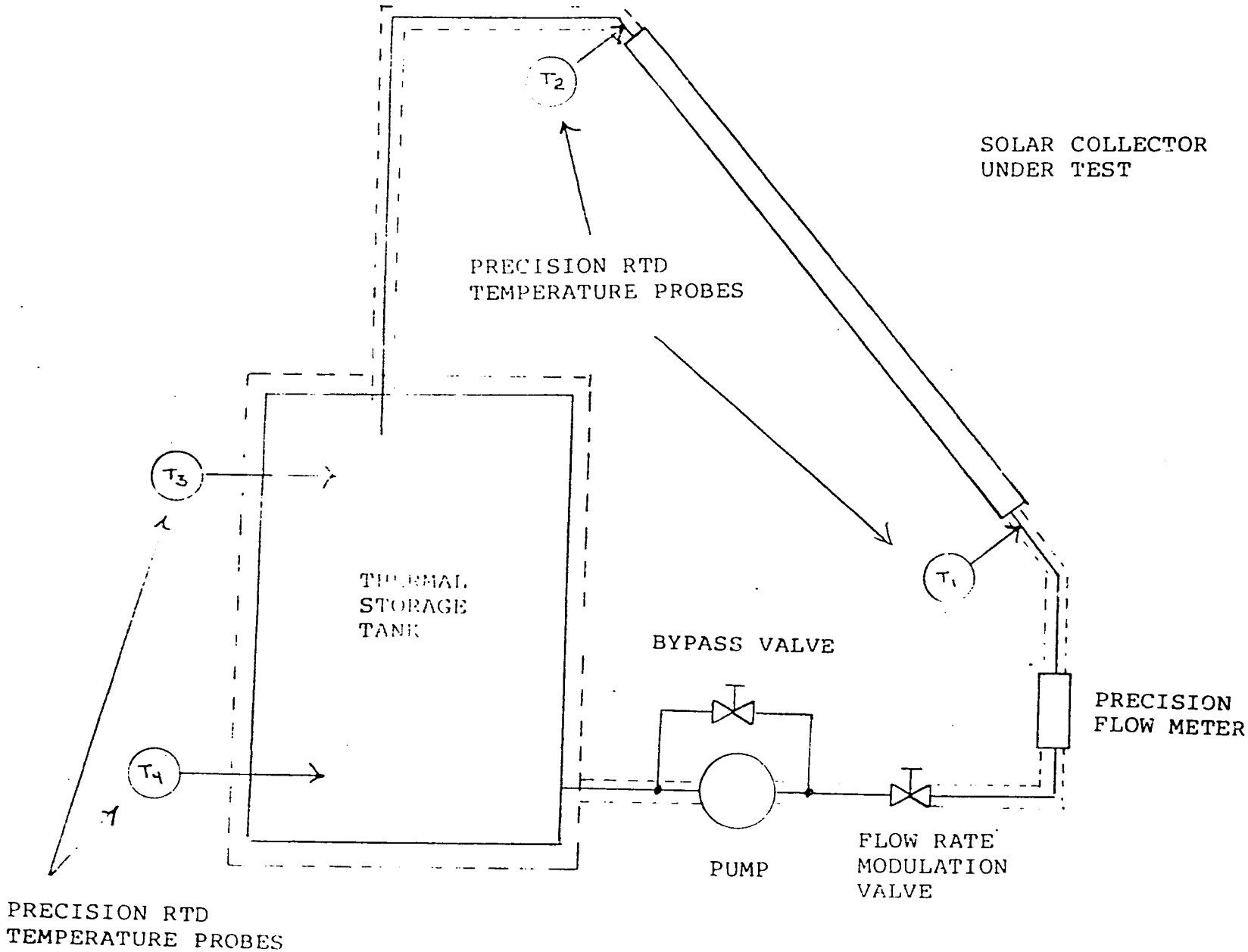


Figure 8. Functional Diagram of Solar Collector Testing Fixture

tested earlier for thermal performance at SERI and the Florida Solar Energy Center, the more important concern on the part of BNL was to obtain information on the durability of the design in Indian conditions. Another goal of the test was to introduce STEC staff to testing procedures, keeping in mind the embryonic state of the facility.

The experiment was performed using continuous pumped flow operation. The collector inlet (Tin) and outlet (Tout) temperatures and the ambient (Ta) temperatures were monitored with precision ($T < \pm 0.1^{o}C$) temperature sensors (resistance temperature devices, [RTDs]) connected to the "smart" datalogger. The datalogger provided under the project is an Acurex Corporation Autodata 10/4 with multichannel capability and an internal programming capability for manipulating and reducing the raw sensor information thus permitting automated data reduction. This instrument is connected to a hard copy terminal for programming and recording of the output.

A constant flowrate of 2.56 l/min was maintained through the collector by means of a motor driven pump and a restricting flow valve system in the water circuit. The mass flowrate ($\dot{m}$) was monitored with a Brooks flow meter with the heat transfer rate (Q_T) estimated from:

$$Q_T = \dot{m}(Tout - Tin)$$

The solar insolation (I) was measured by a Licor pyranometer connected to the datalogger. This permits determination of the total input energy (I_T) relative to the collector gross area (A_c):

$$I_T = IA_c$$

Instantaneous efficiency was simply derived from:

$$\eta_c = \frac{Q_T}{I_T}$$

3.8 Performance Results

Test data were obtained over a period of two months from mid-November 1984 to mid-January 1985. A large number of data points were obtained at

various operating points ($\Delta T/I$) to ensure an adequate statistical data base for the performance curve, as well as to generate confidence in the overall test fixture including test stand and instrumentation. Appendix 3 contains some of the datalogger outputs generated in the test. The Licor pyranometer output was later calibrated with a standard Eppley laboratory pyranometer and an average correction factor of 6.01 percent was applied to the Licor output over the range of insolation data obtained during the test.

The results are shown in Figure 9 which is a standard plot of the instantaneous collector efficiency, η_c, versus $\Delta T/I$ where:

$\Delta T = T_{inlet} - T_{ambient}$ in ^oC

I = solar insolation in watts/m^2.

The curve was estimated by performing a linear regression on 61 quasi steady-state test data points of the form

$$Y = a + bx$$

where Y is the efficiency and $x = \Delta T/I$. Only the first-order curve was estimated.

The results of the regression were as follows:

Estimated value of $a = 0.75$ $(t = 85.7)$

Estimated value of $b = -4.54$ $W/^oC - m^2$ $(t = -28.6)$

The calculated value of the $\Delta T/I$ intercept was:

$(\Delta T/I)$ intercept $= 0.165^oC - m^2/W$.

The t-statistics indicate that the estimates of the regression parameters are highly significant at the 0.01 level.

3.9 Conclusions on Performance

The test data obtained indicate that the BNL ultralight collector design performed well in the fairly severe Indian environment. Conditions at the STEC test site in the season in which the test was performed tended to be desert-like with frequent wind-blown dust. These conditions were much harsher

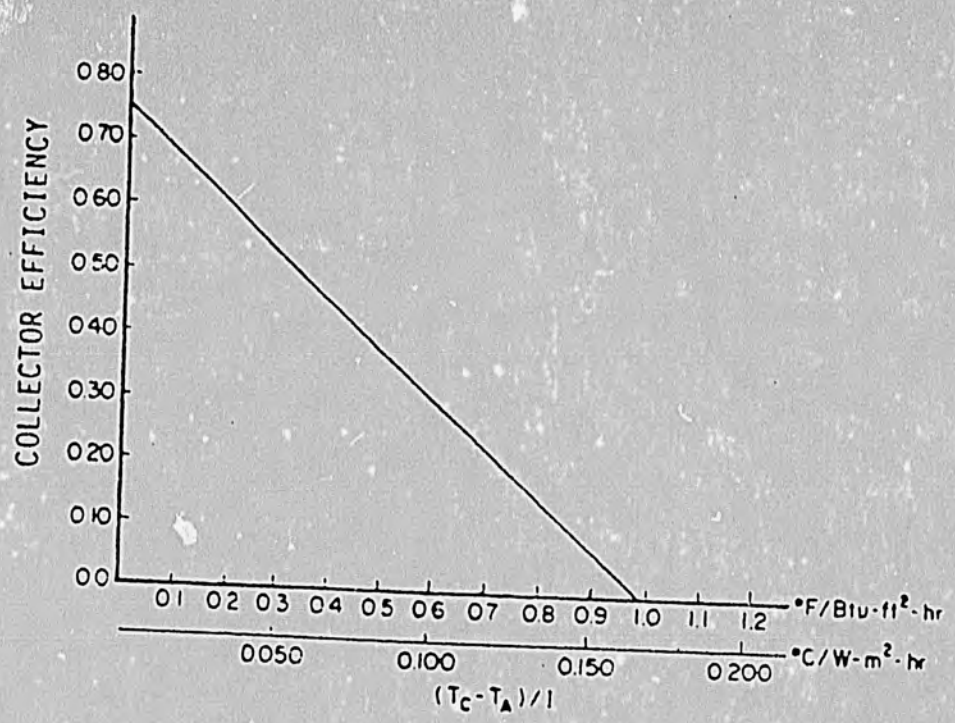


Figure 9. Indian Test Results

than test conditions experienced in the U.S. so the results were quite useful in confirming the potential durability of the design, especially when considering its high thermal performance. Surface dust accumulation occuredat a very high rate requiring frequent washing or wiping of the collector (at least twice daily) in order to maintain test conditions. Since the BNL design uses a polymer film glazing, abrasion and degradation of the window surface were important factors under investigation. Encouragingly, no measurable degradation in performance was detected over the two-month test period. Preliminary indications are that the BNL collector, because of its excellent high temperature efficiency and apparent durability would be a candidate for solar absorption air-conditioning in India.

4.0 APPLICATION AND ECONOMIC ANALYSIS OF SOLAR THERMAL SYSTEMS

The present market for solar thermal energy technologies in India is almost completely restricted to solar hot water and, in a smaller number, hot air systems. A few projects utilizing concentrating systems for producing steam and/or thermally generated electric power have been carried out but these are restricted to the R&D stage. Similarly, a few solar cooling/cold storage systems employing the absorption cooling cycle have been installed, but these are also experimental systems.

4.1 Solar Hot Water Systems--A Preliminary Analysis

The market for solar hot water and hot air systems, in terms of economic subsectors, can be divided into the following categories:

(i) **Domestic hot water:** typical system size and temperatures are 100 liters per day at 60°C.

(ii) **Institutional buildings:** includes hotels, hospitals/health centers, school and college dormitories, rest houses, etc. Typical systems size and temperatures range from 500 to 1000 liters/day to upwards of 30,000 liters/day, for large hotels, at 60°C.

(iii) **Commercial establishments:** laundries, canteens, restaurants, etc. System size and temperatures are in the range of 500 to 2000 liters/day at temperatures between 60°C to 80°C.

(iv) **Industries:** a fairly large range of industries offers a potential market for both hot water and hot air systems. In India these include textiles, chemicals, paints and products, dairy, etc., for hot water systems and agroforestry based processing industries including timber, tea, pepper, cardomom, etc., for hot air systems. Systems installed have ranged up to the largest installation of 75,000 liters/day (textile and dairy industries) with temperatures in the range of 55°C to 85°C.

A preliminary economic and financial analysis has been performed here for a domestic solar hot water system. The size and water temperature of the

solar system has been assumed to be typical of those being marketed in India currently. These deliver 100 liters of water per day at a temperature of 60°C. The economic/financial analysis has been carried out through a comparison with a domestic electric resistance water heater (commonly known in India as a "geyser"), which is sold in quite significant quantities in India's urban areas, delivering approximately the same quantity of water daily at the same temperature.

The analysis has been carried out using a microcomputer software program, specifically developed at BNL for economic and financial analysis of renewable energy and energy conservation technologies. The program is interactive, runs on any DOS-based microcomputer with at least 192 K of RAM, and can be used by persons without significant programming experience. The program calculates economic figures of merit such as net present value, the internal rate of return and the payback period, and can be utilized to perform economic evaluation of systems and projects according to generally accepted criteria used by banks and financial institutions.

The program trades-off the savings of conventional energy, in this case electricity, against the higher capital cost of the solar system and evaluates the various economic figures at an assumed discount rate which is input exogeneously. The analysis reported below assumes climatic conditions and household use patterns typical of the Delhi area in India. It is assumed, for example, that households utilize domestic hot water for about 4 months per year from, say, November to March. Based on the typical mains cold water supply temperature during these months, it is estimated that an average electric water heater will consume about 700 kwh of electricity for supplying 100 liters of water per day at 60°C over this 4-month period. This consumption will be greater if climate or behavior patterns dictate longer usage over the year than that assumed here.

The current, unsubsidized, average retail price of a 100 liter per day, 60°C solar hot water system employing conventional glass/metal collectors, is around Rs. 7000 to Rs. 8000, based on the prices being quoted by various manufacturers such as Jyoti, Allied, Bharat Solar, etc., in India. The average retail price of a "geyser" of the same capacity is about Rs. 1500 as estimated from appliance stores in New Delhi. (Current conversion rate is Rs.12 = $1.00)

Table 1 below shows the assumptions used in the analysis. The capital cost to the consumer (or, the retail price) of the solar hot water system has

been varied from Rs. 8000 (current technology) to Rs. 5000 (as, for example, could be possible with an intermediate technology based on the current BNL collector design), and, finally, Rs. 3000 (for an ultimate advanced design). Moreover, energy price subsidies are an ubiquitous feature of the energy scene in India. The current average electricity prices charged to domestic consumers in the Delhi area by the utility, about Rs. 0.75 per kwh, are known to be below the economic resource cost of generation and distribution. For purposes of analysis, a "shadow" or economic price of electricity of Rs. 1.25 per kwh which is believed to be closer to the true economic production cost of generating, transmitting and distributing electricity in India (see "Report of the Committee on Power," Govt. of India, New Delhi, 1980), has been assumed in an alternative scenario.

Solar hot water systems installed in domestic households qualify for a subsidy of 50 percent from government. This program is administered through DNES and various state nodal agencies responsible for promoting solar technologies. In the analysis done here, four scenarios have been analyzed as follows:

(i) **Scenario I: Unsubsidized Solar, "Shadow" Price Electricity**

This scenario takes the unsubsidized solar hot water system capital cost and the unsubsidized, "shadow" or economic price of electricity

(ii) **Scenario II: Subsidized Solar, Current Price Electricity**

This scenario assumes the 50% subsidy for solar systems and the current (subsidized) prices of electricity.

(iii) **Scenario III: Unsubsidized Solar, Current Price Electricity**

and (iv) **Scenario IV: Subsidized Solar, "Shadow" Price Electricity.**

Two discount rates, 10 percent and 15 percent, typical of project evaluation in India, have been assumed for all scenarios. In each scenario, the prices of the solar hot water system are assumed to be a parameter varying between Rs. 8000 (current), Rs. 5000 (intermediate) and Rs. 3000 (advanced). The results, shown below in Table 2, are for a discount rate of 10 percent.

In Scenario I, where both solar and electricity are unsubsidized, the current systems being marketed would be clearly unattractive to a consumer. The internal rate of return (IRR) is barely positive, the payback period is 8

Table 1. ASSUMPTIONS IN THE ECONOMIC ANALYSIS OF SOLAR DHW SYSTEM

Item	Conventional System	Solar DHW System
Capacity (liters/day)	100	100
Temperature (degrees C)	60	60
Energy use (kwh/year)	707	--
Electricity price (Rs./kwh)	0.75 (current) 1.25 ("shadow")	--
Capital cost (Rs.)	1500	8000 (current) 5000 (intermediate) 3000 (advanced)
Economic life (years)	10	10
Solar subsidy	--	50

Table 2. RESULTS OF SOLAR DHW ANALYSIS
(Discount rate = 10%)

	Solar Cost (Rs.)	IRR (%)	Payback (years)	NPV (Rs.)
SCENARIO I				
	8000	4.8	8	-1354.4
	5000	20.1	5	1635.2
	3000	55.3	2	3628.2
SCENARIO II				
	8000	14.2	6	459.6
	5000	47.4	3	2631.7
SCENARIO III				
	8000	-5.2	>10	-3526.5
	5000	6.3	8	-536.9
	3000	29.9	4	1456.1
SCENARIO IV				
	8000	31.4	3	2631.7
	5000	83.9	2	4126.5

years and the net present value (NPV) is negative. The intermediate system has an acceptable IRR of 20 percent, a more favorable payback period of 5 years and a positive NPV. The advanced system would clearly be a "winner" and clearly require no subsidies to capture the market.

Scenario II, where both solar and electricity are subsidized, is the case operating at present. The current subsidized system is seen to be marginally acceptable, with a payback period of 6 years and an IRR of 14 percent. However, if the discount rate is increased to 15 percent, which may be somewhat more realistic from the point of view of an individual consumer, whose "risk" premium may be somewhat higher, the IRR decreases to 3.7 percent and the payback period rises to 9 years. This could be the reason why current solar hot water systems, even with a 50 percent subsidy, are not making sufficient headway in the Indian market. The cost of these systems is too high and they face competition from subsidized electricity prices. When the system cost is lowered to that of the intermediate system, then the subsidized solar system will be much more acceptable with an IRR of 47 percent and a payback period of 3 years.

In Scenario III, where solar is unsubsidized and electricity is subsidized, only the advanced solar system with an IRR of 30 percent and a payback period of 4 years makes economic sense from the consumer's point of view. In Scenario IV, where solar is subsidized and electricity unsubsidized, the reverse is the case.

4.2 Solar Cooling/Cold Storage Systems--Preliminary Assessment

There is a major electrical load for space cooling/air conditioning developing in India's urban areas. There is also a very large requirement for cold storage to store perishible agricultural commodities in rural areas where grid electric supply is either unreliable or unavailable. Given the climate prevailing in most regions of the country over most of the year, cooling is a high value end-use of energy in India for which consumers are willing to pay a premium. Moreover, cooling is becoming valuable not only as an amenity in high income households or in commercial buildings, but increasingly in productive sectors of the economy where temperature controlled environment is required for the process. This includes growing sectors such as electronics, drugs and pharmaceuticals, dairy, etc. Recognizing this fact, DNES has had an

element in its program devoted to the development of direct solar cooling and cold storage systems.

The usual approach to direct solar cooling is to operate an absorption cooling cycle with energy provided by a solar collector-cum-storage system. For use with flat-plate collectors, the temperature limitations generally restrict the available absorption chiller to one operating on a single-effect lithium bromide-water system. Further research and development work may disclose other refrigerant-absorbant pairs suitable for solar operation, but these have not yet been developed to a point where they could be evaluated from an operational standpoint.

Commercial lithium bromide water absorption chillers are made in a wide range of sizes by Yazaki Corp. of Japan. In the U.S., absorption chillers are manufactured by Trane, York, Carrier, and earlier by Arkla. Most of these are manufactured for natural gas or oil-fired boilers as the energy source. Yazaki, however, makes smaller sizes suitable for solar operation.

A schematic diagram of a single-effect absorption chiller is shown in Figure 10. The theory of the absorption cycle is contained in standard engineering textbooks, for example, Duffie and Beckmann's "Solar Thermal Engineering Processes."

> "The pressure in the condenser and generator is fixed by the condenser fluid coolant temperature. The pressure in the evaporator and absorber is fixed by the temperature of the cooling fluid to the absorber. The generation process is one of increasing the concentration from 55 to 60 percent while the equilibrium temperature of the solution rises from 72 to 82 C at the pressure of the condenser. In the absorber, the solution concentration drops from 60 to 55 percent as the solution temperature drops from 48 to 38 C, all at the evaporator pressure. In a real cycle, some sensible heat will have to be transferred in the generator and absorber (the amount dependent on the effectiveness of exchanger HX), there will be pressure changes through the generator due to hydrostatic head, temperature differences across all heat exchangers, and other non-ideal behavior. Exact pressures, temperatures, and concentrations will vary with the machine and operation conditions.
>
> The maximum solution temperature of the heated fluid to the generator must be above the maximum generator temperature, which is determined by the condenser pressure and the concentration of the solution leaving the generator. The generator temperatures must be kept within the limits imposed by the characteristics of flat-plate collectors. The critical design factors and operational parameters include solution concentrations, effectiveness of the heat exchangers and coolant temperature.

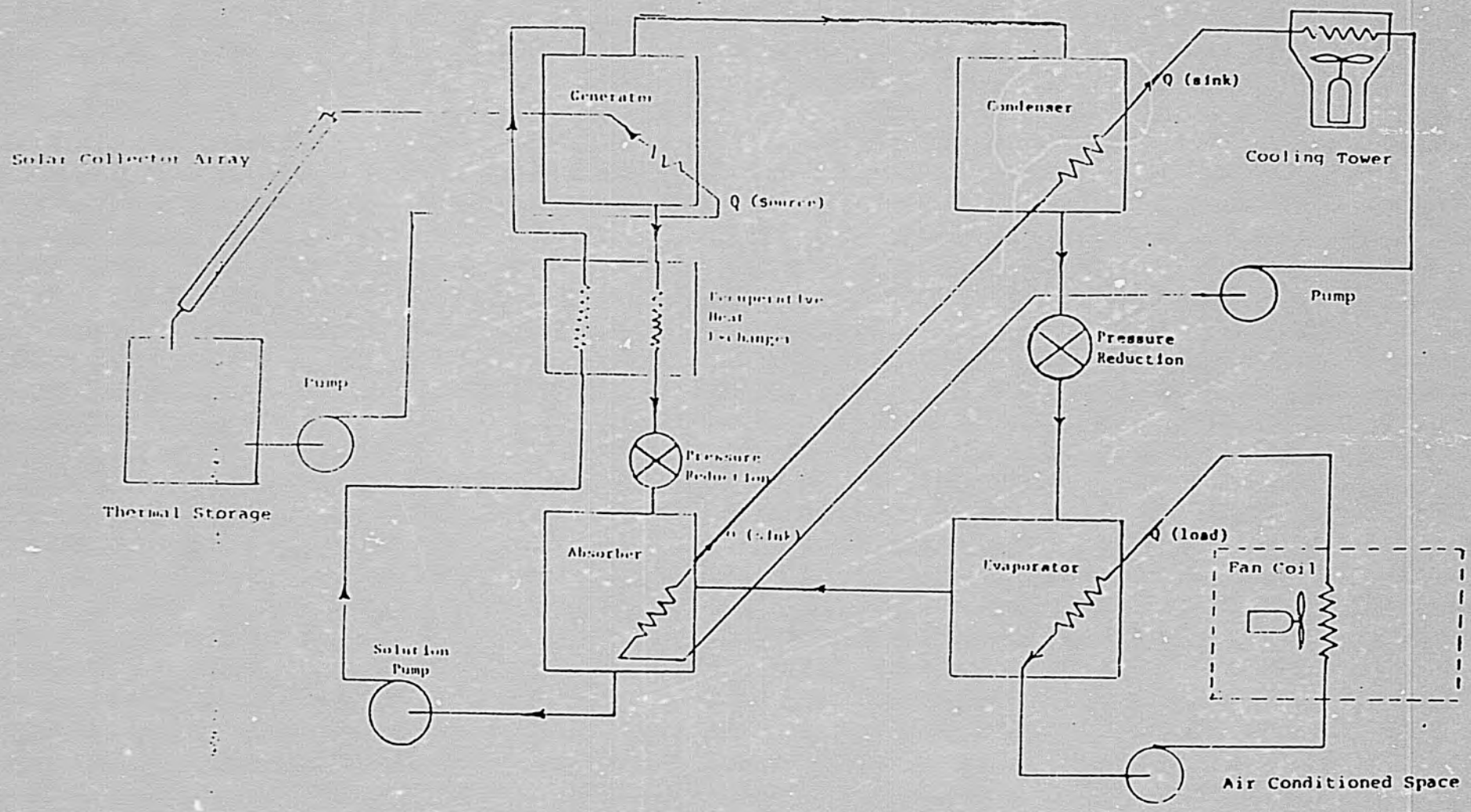


Figure 10. Solar Cooling System Using a Single Effect Absorption Chiller

The pressure difference between the high- and low-pressure sides of LiBr-H_2) systems is small enough that these systems can use a vapor-lift pump and gravity return from absorber to generator as an alternative to mechanical pumping to move the solution from the low pressure to the high pressure side. Early absorption machines used the vapor-lift pump but more recent designs use a mechanical pump because of improved performance.

An overall steady-state energy balance on the absorption cooler indicates that the energy supplied to the generator and to the evaporator must equal the energy removed from the machine via the coolant flowing through the absorber and condenser, plus whatever net losses may occur with the surroundings

$$Q_G + Q_E = Q_A + Q_C + Q_{Losses}$$

The coefficient of performance, COP, is defined as the ratio of energy into the evaporate, Q_E, to the energy into the generator, Q_G:

$$COP = Q_E/Q_G$$

Coefficient of performance is a useful index of performance in solar cooling, where collector costs (and thus costs of Q_E) are important. Many LiBr-H_2O machines have nearly constant COP as the generator temperatures vary over the operating range, as long as they are above a minimum. The COP is usually in the range of 0.6 to 0.8, and the major effect of variation in the solar energy temperature to the generator is to vary Q_E, the cooling rate.

With water used as a coolant in the absorber and condenser, the generator temperatures are in the range 70-95 C. The temperature of the fluid supplied to the generator must be higher than this which means that there is a very small temperature range over which an unpressurized water storage tank can operate."

For this reason in an advanced cooling concept, using the BNL ultra light solar collector, the collector will operate in a constant temperature mode. This will be accomplished by directly connecting the generator circuit in series with the collector loop and varying the flow rate to maintain constant temperature. Under such operation a variable speed motor will modulate the flow rate in proportion to the solar intensity. Such a system will emphasize cold-side storage with little or no hot-side storage. Under operation, the system will operate as long as there is sufficient solar intensity to build cold-side storage. With such a system it is possible to optimize overall efficiency with a minimum of hardware components. In addition, the absorption

chiller will operate at a constant high COP with capacity varying only as a function of solar intensity.

Economic and performance analysis of solar absorption cooling in Indian conditions is expected to be carried out in a follow-on phase to the current project with STEC.

5. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Although solar energy research started in India over 30 years ago, for most of the time it remained confined to the activities of a few scientists in research laboratories. The advent of the "energy crisis" in the mid-1970's coupled with the very rapid growth in energy demand created by the increases in industrialization and urbanization gave rise to a generalized energy shortage which still affects the whole country. This spurred an interest in the development and commercialization of alternative energy sources and technologies. Since sunshine is relatively abundant over all of India for most of the year, there has naturally been an interest in the commercial development of solar technology. The formation of DNES and STEC is an essential step in this process since, within the Indian system, a centralized institution can bring larger resources to bear on the development, diffusion, standardization, and promotion of the new technologies. However, state and local level organizations will be needed to play active and essential roles within their areas of responsibility and private sector manufacturers will require the proper signals and resources to induce them to produce the necessary hardware and systems.

The BNL-STEC project is only a small step in this overall process, but it has played an important role in developing STEC staff and facilities from their early stage. The highlights of the accomplishments under the current project could be described as:

(i) Training of STEC staff in solar thermal technology, including the measurement of thermal performance of solar collectors,

(ii) Transfer to STEC of selected accurate instrumentation to enable them to set up a preliminary testing facility,

(iii) Introduction of new research concepts to STEC, including the BNL high performance, ultralight collector, but also including emphasis on cost-goal guided research and quality control and measurement,

(iv) Introduction to STEC of new materials concepts and the crucial role materials science has to play in solar technology development.

Future collaborative work between BNL and STEC has been identified in joint discussions and is embodied in the memorandum of January 10, 1985, from Dr. G. D. Sootha of DNES to AID. These plans relate to providing institutional support to STEC in key areas related to STEC's R&D plan and objectives where BNL is also carrying out R&D activities. These areas are as follows:

(i) **Systems Engineering and Design**

(a) Materials engineering and design

(b) Component engineering and design

(c) Compact heat exchanger design and development

(d) Hot water systems design including DHW and IPHW systems incorporating high-performance, low-cost components

(e) Solar cooling systems design and prototype fabrication incorporating advanced refrigerant combinations

(f) Concept design and prototype fabrication of low-cost solar concentrators incorporating new and advanced materials concepts.

(ii) **Systems Analysis**

(a) Systems optimization studies

(b) Cost and economic analysis of systems and applications

(c) Development of computer software for analysis taking into account Indian conditions.

(iii) Materials Development

(a) Experimentation with new materials for solar components construction and development

(b) Materials testing studies including thermal stability, corrosion resistance, life testing, etc.

(iv) **Testing and Standardization**

(a) Test rig development for testing of solar components and systems

(b) Computerization of test procedures

(c) Standardization of testing methods

(d) Standards setting for solar components and systems.

(v) **Information Systems**

(a) Building up library and information infrastructure in STEC

(b) Information retrieval methods.

(vi) **Equipment and Materials Supply**

(a) Computer hardware and software and peripherals

(b) Calibration equipment

(c) Accelerated materials testing equipment

(d) Supply of sample materials.

APPENDIX 1

STEC Staff Training Program at BNL, July 1984

BNL - INDIA SOLAR PROJECT

TRAINING PROGRAM SCHEDULE OF MR. S.K. GUPTA

DATE	SUBJECT	BNL STAFF RESPONSIBLE
July 9	Orientation	V. Mubayi
July 10 a.m.	Technology Goals	W. Wilhelm
p.m.	Collector Hardware I	D. Hansen
July 11 a.m.	Collector Hardware II	D. Hansen
p.m.	Instrumentation I	P. Cerniglia
July 12 a.m. & p.m.	Instrumentation II & III	P. Cerniglia
July 13 a.m.	Instrumentation IV	P. Cerniglia
p.m.	Discussion Meeting	V. Mubayi & W. Wilhelm
July 16 a.m. & p.m.	Instrumentation V & VI	P. Cerniglia
July 17 a.m. & p.m.	Instrumentation VII & VIII	P. Cerniglia
July 18 a.m.	Discussion Meeting	V. Mubayi & W. Wilhelm
p.m.	Solar Software	V. Mubayi
July 19 a.m. & p.m.	Collector Hardware III & IV	W. Wilhelm & D. Hansen
July 20 a.m.	Lab Solar Facilities Visit	V. Mubayi
p.m.	Off	--
OPTIONAL 3rd WEEK		
July 23 a.m. & p.m.	Collector Hardware V & VI	D. Hansen
July 24 a.m. & p.m.	Collector Hardware VII & VIII	D. Hansen
July 25 a.m. & p.m.	Independent Test Project	--
July 26 a.m.	Solar Materials Review	V. Mubayi & W. Wilhelm
p.m.	Wrap-Up	V. Mubayi
July 27	Off	--

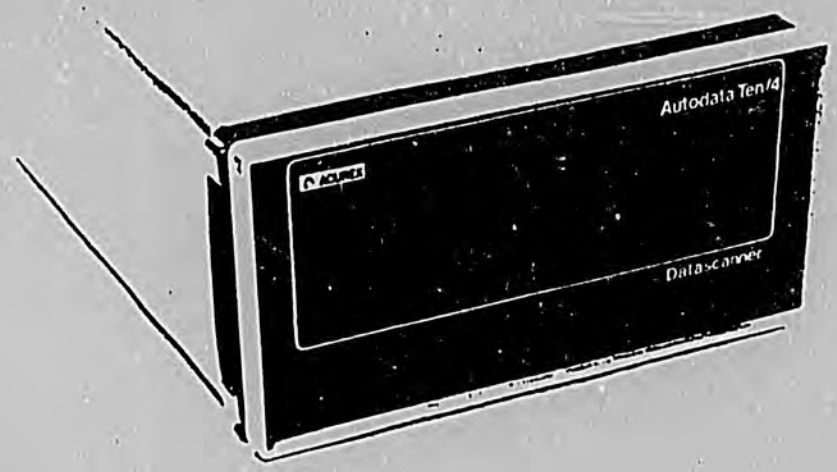
APPENDIX 2

Hardware and Equipment Transferred to STEC

INVENTORY LIST - ITEMS SENT TO INDIA FROM BNL

Item No.	Item
1	Solar Collector, 3' x 7' x 2-3/4"; Serial No. BNL-001
2	Solar Collector, 3' x 7' x 2-3/4"; Serial No. BNL-002
3	Solar Collector, 3' x 7' x 2-3/4"; Serial No. BNL-003
4	Rotometer
5	Ribbon Set
6	Ribbon Set
7	Printer Paper
8	Multi-socket line cord
9	6 RTD's, 50' long, attached to board module
10	Printer Paper
11	LI-Cor Pyranometer and assorted cables
12	Platinum Resistance Temperature Sensors
13	Model 43 Teleprinter
14	Acurex Model Ten/4 Datascanner

MODEL # A-TEN/4 1001-50 COST WITH Required Access $5900
SERIAL No. 7-125



An Innovative Features Package for Sophisticated Distributed Data Acquisition Applications.

The Autodata Ten/4 Datascanner distinguishes itself as an innovative computer front-end. Maintaining the same incomparable Acurex measurement excellence, the Ten/4 proves to be invaluable for a variety of remote datalogging front-end applications.

The competitively-priced Ten/4 offers all the advantages of the Autodata Ten/5 datalogger—high performance A/D converter for performance sp[illegible] accuracy...precision alarm monitoring Mini-MATHPAC™ for mathematical manipulation of raw readings into measurement information...superior noise rejection...and, accuracy of .016% for unparalleled accurate and reliable data acquisition. Plus, the Ten/4 time averaging option can calculate the average values of varying signals or required average values necessary for air pollution, water power or energy usage monitoring. All these Ten/4 features packed into a rugged frame bring intelligence and high reliability to the computer front-end.

The simplified exterior design not only makes the Ten/4 extremely rugged, but it also prevents any access to the programming inside. Access to the Ten/4 can only occur remotely via mini- or mainframe computer or even via dumb terminal, therefore eliminating unplanned program alterations. And, the Ten/4's independent operation allows measurements to continue even if the main computer fails. Programs are downloaded from the computer to the Ten/4 where they are run without further computer commands. Program changes can be made in real time without stopping the system. Alarms continue to be checked, with contact outputs for enunciation or shut down, even if the computer is busy doing another operation.

Built-in Mini-MATHPAC Saves Valuable Computer Time and Programming Expense.

Mini-MATHPAC provides the basic raw data manipulation capability to process the raw readings into true measurement information which the computer can really use. No programming is needed to calculate all the necessary linearizations...the Ten/4 calculates them automatically. The Autodata Ten/4 is designed to handle all the data gathering and to convert it into the terms and units that the computer wants—the computer is now freed to carry out more sophisticated operations.

The seven built-in thermocouple and three RTD linearizations, five current scalings, and the one user-programmable linearization make data available directly in engineering units (degrees F or C, PSI, etc.). The Ten/4's built-in intelligence eliminates complex thermocouple programming in the computer. And, standard in every unit, the 20 mX + b's provide data scaling for true engineering units data. The Ten/4 Mini-MATHPAC offers additional functions allowing cross-channel mathematical manipulation. Add, Subtract, Multiply, and Divide are standard along with Square Root, Time of Day (in seconds) and Group Average. With these functions it is possible also to calculate point difference, group average, BTU, mass flow, or rate of change.

The Time Averaging option provides an average of a channel over a pre-selected number of scans. The user-entered linearization is used for transducers having unique curves, thermocouples with remote cold junctions, or other transducers which are not included in the over 50 types of standard functions available in the Ten/4.

Data Integrity even in Tough Industrial Environments.

Measurement accuracy and high noise rejection are firsts when it comes to the entire Autodata Ten Series family. The Ten/4 is no exception. The standard High-Performance A/D Converter provides unsurpassed accuracy and common mode rejection of over 170 dB, at speeds of up to 20 channels per second. Accuracy of .016% of full scale (high resolution) measures industrial data with accuracy that is more than competitive with others in the industry. The A/D Converter provides two scan speeds selectable on a channel-to-channel level—high speed with standard resolution or slower speed with one extra digit of resolution.

Standard Features

The Autodata Ten/4 Datascanner introduces many unique concepts to the computer front-end and to remote data acquisition applications.

Automatic Calibration

Calibration performed every 5 minutes automatically by the Ten/4 eliminates the need for manual recalibration. Self-contained calibration standard is traceable to NBS. This allows the specifying of a guaranteed one year accuracy.

Multiple Scans

Three totally independent scan intervals can be programmed. These intervals can contain independently assigned contiguous channel groups and varied alarm sounding modes. In addition, continuous scan can be used.

One Scan Buffer

An internal buffer allows the system to scan at its maximum speed, storing data for later printout via the on-board printer or output to peripheral devices.

Fast Scan Speed

A scan rate of 20 channels per second on low resolution and 10 channels per second on high resolution with high noise rejection and accuracy specifications ensure data integrity.

Remote Start/Stop

Screw terminals on the rear of the Autodata Ten/4 provide convenient connections for initiation of Start, Stop, and Alarm Acknowledge by remote contact closures.

Temperature Scaling

Types J, K, T, E, R, S and B thermocouple linearizations, 100 ohm platinum $\alpha = 0.003926$, 100 ohm platinum $\alpha = 0.003851$ and 10 ohm copper RTD linearizations are all included as standard.

Measure Resistances

Five-wire multiplexing provides RTD or other resistance measurements. Constant current and 4-wire measurement eliminates errors of lead length or lead resistance unbalance.

Input Flexibility

The Ten/4 accepts a wide variety of inputs including BCD, pulse rate, contact on-off and resistance as well as thermocouples, AC voltages, DC voltages and DC current—all without external signal conditioning.

Engineering Units Scaling

Up to 20 linear functions of the form $Y = mX + b$ can be operator entered. These scaling functions are used to scale analog inputs to their appropriate engineering units.

Alphanumeric Labels

A five-character alphanumeric units label may be used to identify any parameter being scaled (i.e., PSI, GPM, etc.).

Demand Log

A single character command initiates printout of a block of operator specified channels.

Battery-Backed Clock

The standard clock maintains correct time even through power outages.

Protected Power Supply

Ensures maximum uninterrupted operation. Protects against operational failure due to line voltage sags as low as 105 volts. Also suppresses line transients and voltage spikes caused by such things as dropout of inductive loads.

Mainframe Capacity

Up to 120 channels of inputs are available in the mainframe using 2-wire multiplexing (60 channel capacity with 3- or 5-wire reed relays).

Mini-MATHPAC

Mini-MATHPAC provides a powerful calculating capability. Standard math functions, plus time of day and square root, allow real time solutions to complex engineering problems. Alarms may be assigned to the calculated results.

Algebraic Functions	Initiating Command
Add	+
Subtract	–
Multiply	•
Divide	/
Group Average	^
Time of Day	T
Constant	K
Square Root	S

Averaging

In the Ten/4, group averaging is included in the Mini-MATHPAC. The Time Averaging provides averages over up to 999 samples.

Alarms

User programmable alarm messages provide indication of what's wrong, or what to do. In the Ten/4, up to four alarm setpoints per channel provide flexibility. Any of the forty alarm messages from the message table may be assigned to a channel or an alarm condition on a channel. Any one of the system's ten programmable deadbands is also assignable by channel.

User Entered Linearization

The User Entered Linearization provides sixth order polynomial scaling for special transducers.

Optional Features

IEEE-488-1978

Capable of performing both talker and listener functions.

RS-232-C Communication

Up to two independently controllable output ports for communication with computers, terminals, or other peripheral devices can be accommodated.

Contact Outputs

Contact outputs provide a means of signaling the process or experiment that some action needs to be taken. Outputs can be initiated by alarm conditions or on a calculated value. Contact outputs may be intermixed with analog input cards providing contact outputs at the data site. One contact output card may be used in each remote scanner. Two may be placed in the mainframe in place of two input cards. There are ten relays on each card. Relays are form C rated at 1A, 26 VDC; 0.5A, 120 VAC, resistive. Open collector outputs are also available.

Analog Output

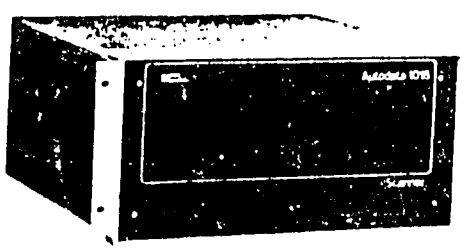
Monitored channels may be converted to an analog output of 4-20 mA or 0-10V under program control. Suitable for driving chart recorders or analog controllers. Up to forty analog outputs are available.

Magnetic Tape Interface

Interface to Kennedy 1600 Series Incremental Recorder, or Kennedy 9832 Buffered Continuous Recorder provides large volume data storage for future computer processing.

Remote Scanner

The 1016 Remote Scanner can be used when there are more than six input cards required. Ten (3-wire) or twenty (2-wire) channel cards may be intermixed in the Remote Scanner. One contact output card may be used in the Remote Scanner in place of an input card. The Remote Scanner may be located up to 5,000 feet from the datalogger. Up to ten Remote Scanners may be used in the system.



Carrying Case

An environmentally rugged, fiberglass carrying case is available for the Autodata Ten/4. It provides protection for the unit during transit.

BCD Output

Four full parallel BCD outputs provide capability of driving six digit BCD displays. Four channels are available on each card, up to four cards per system.

The Autodata Ten/4 is completely live in that you can program "on the fly." You can be continually scanning and outputting data, and, at the same time, you can modify system parameters.

The system utilizes a "prompted programming" approach. A specific series of questions are displayed along with possible answers, numerical limits, or blank spaces. The questions are arranged using major headings, minor headings and tertiary headings...three distinct levels of queries.

Program information is entered on a line-by-line basis, and is not accepted without an ENTER command. All program blanks on a particular line do not have to be filled as long as valid information is contained in some spaces. If the information is accepted, the next query is displayed. If the information is not accepted, an error code is displayed.

Program Control

The Program Control commands are used in conjunction with the Function Select commands as follows:

Exit (E)

Terminates programming of a particular function and returns the display to SYSTEM IDLE. If the system is scanning a channel selected for display, that channel is displayed.

Yes/No (Y/N)

Provides an answer for program questions requiring only a limited response.

Next (N)

Skips minor and tertiary headings. Allows movement from a major heading to the next major heading.

Adv Line (J)

Moves program from a minor heading to the next sequential heading. Cannot be used to move from a major heading.

Enter (Return)

Places operator entry into memory. Initiates the next query.

System Control

The System Control commands are used to initiate distinct actions. Some commands are used for Program Control while others initiate a specific action. Following is a brief description of each command it uses and relationship to other commands.

Alarm Ack (A)

When a channel enters an alarm state, a sharp tone is heard sending an "A" extinguishing the tone.

Log (L)

Operates in conjunction with the program entered under the Format function. If you have programmed a log (OUTPUT SOURCE L) upon sending the Ten/4 an "L," the log is transmitted. Logs are unconditional and interrupt any scan cycle.

Start (G)

Initiates the scan cycle(s) programmed under the SCAN function.

Stop (S)

Halts all scan cycles.

Function One—SCAN

The Scan function is used to program the four scan types. Types 1, 2, and 3 are selected for use with a specified scan interval entered in hours, minutes, and seconds. C refers to a continuous scan. Each scan may be programmed for different groups of channels or overlapping groups of channels.

Output to Display (-Response)

SCAN TYPE (1/2/3/C)
-1 or 2 or 3 or C, RETURN

SCAN ON? (Yes/No)
-Yes or No, RETURN

CHANNELS (FFF-LLL)
-Assign numerical channel identity, RETURN

INTRVL PERIOD (HR-MN-SC)
-Assign numerical hour, minute, second, RETURN

ALRM AUDIO ON? (Yes/No)
-Yes or No, RETURN

Function Two—CHANNELS

Output to Display (-Response)

CHANNELS (FFF-LLL)
-Assign numerical chan ID, ENTER

E/U Number (NN)
-00-99, RETURN

HI RES? (Yes/No)
-Yes or No, RETURN

AVG CHANNEL? (Yes/No)
-Yes or No, RETURN

AVG SCAN COUNT (NNN)
-Assign number of scans for average 0-999, RETURN

SKIP OUTPUT? (Yes/No)
-Yes or No, RETURN

MESSAGE (NN)
-00-40, RETURN

LIMIT 1/MESSAGE (NN/NN)
-Assign limit (01-99) and message (00-40), RETURN

LIMIT 2/MESSAGE (NN/NN)
-See Limit 1

LIMIT 3/MESSAGE (NN/NN)
-See Limit 1

LIMIT 4/MESSAGE (NN/NN)
-See Limit 1

DEADBAND (NN)
-Assign deadband (0-10), RETURN

E/U 38 or 39

CNTCT ON CHNLS (FFF-LLL)
-Assign numerical channel ID, RETURN

CNTCT ON LIMITS (1/2/3/4)
-Select 1, 2, 3, or 4, RETURN

E/U 46

MATH EXPRESSION (.....)
MATH UNITS (....)
-If E/U assigned in 46, enter expression. Channels are C1, C17, etc. Numerical [illegible]

E/U 47

PULSE IN CODE (BD-CH-FN)
PULSE M VALUE (+ NNNNNN)
UNITS (....)
-Select input code for board (0-15), Channel (1-14), Function (0-5). M value must be assigned or enter 1.

E/U 48

DIGITAL ADDRESS (NNN) = 000-255
-Enter 000-255 to energize digital source

In the Channels function, individual or sequential groups of channels are programmed. The E/U number selected determines the usage of the channels. Channels can be programmed as data input locations, mathematical expressions, or as contact outputs.

Prompts for channel averaging, messages, and limits also occur in the Channel function.

Deadband allows you to enter a hysteresis value that must be exceeded in either direction prior to an alarm being cleared. This allows you to avoid nuisance alarms caused by minute fluctuations around the limit region. Deadband is assigned as a numerical equivalent (1–10) and further defined in the Options Function.

E/U CONVERSIONS/DESCRIPTION

No.	Function
1	SKIP
2	AUTORANGE
3	50 MV RANGE
4	500 MV RANGE
5	5V RANGE
6	10V RANGE
7	T/C J
8	T/C K
9	T/C T
10	T/C E
11	T/C S
12	T/C R
13	T/C B
14	RTD = 0.003926
15	RTD = 0.00385
16	RTD 10 CU
17	USER ENTERED LINEARIZATION
18–37	Y = MX + B
38	CONT OUT, ACK
39	CONT OUT, NON-ACK
40	CONT IN, ALARM ON OPEN
41	CONT IN, ALARM ON CLOSE
42	CURRENT 10–50 MA
43	CURRENT 4–20 MA
44	CURRENT 0–1 MA
45	CURRENT 1–5 MA
46	ALGEBRAIC/LOGICAL
47	DIGITAL INPUT, PULSE
48	DIGITAL INPUT, BCD
49	HI VOLTAGE, 150V
50	AC VOLTAGE, 150VAC
51	RESISTANCE, 500
52	RESISTANCE, 5K
53	RESISTANCE, 50K

Function Three—E/U CONVERSION

Output to Display (-Response)

E/U of MX + B (NN) = 18-37
-Select 18-37, RETURN

UNITS (.....)
-Assign 5-character units, RETURN

E/U of X (NN)
-Assign 01-17, RETURN

VALUE OF M (+ NNNNNN)
-Assign polarity and value as decimal fraction, RETURN

VALUE OF B (+ NNNNNN)
-See Value of M

TEMP IN C? (Yes/No)
-Yes or No, RETURN

The third function, E/U CONV, allows you to do scaling and conversion of any linear function. You can convert U.S. to metric units, convert degrees C to Kelvin or scale any result to direct reading engineering units. Twenty unique linear conversions may be programmed and used repeatedly in conjunction with other system programming.

Function Four—FORMAT

Output to Display (-Response)

OUTPUT SOURCE 1/2/3/C/L/S
-Select one item, RETURN

LOG CHANNELS (FFF-LLL)
-Enter First/Last—only if L is output source

OUTPUT DEVICES 1/2/M/G
-Select any, RETURN

OUTPUT MODE (D/A/O)
-Select any, RETURN

SUPPRESS LIMITS? (Yes/No)
-Yes or No, RETURN

SPRES IMM ALARMS? (Yes/No)
-Yes or No, RETURN

SUPPRESS MESSG? (Yes/No)
-Yes or No, RETURN

SCAN LABEL (Yes/No)
-Yes or No, RETURN

OUTPUT LABEL (.....)
-Assign up to 7 characters as output label.

When you program the Format function, you select what output devices are used to record different scans of data. The output source refers to the scan type (1, 2, 3, C) programmed in SCAN; L for log and S for Summary (defined under Summary function). The channels entered under Log Source here will be output when the system receives a LOG command. The output device to be used is chosen as:

1 -Serial Port 1
2 -Serial Port 2
M-Mag Tape
G-GPIB

The output mode for each scan type is individually selected allowing all data, all alarms or alarms once to be output. Immediate alarms and messages may be suppressed, and a scan label may be entered.

Function Five—TIME

Output to Display (-Response)

SET TIME (HR-MN-SC)
-Assign hour (0-23), minute (0-59), and second (0-59), RETURN

SET DATE (MO-DY-YR)
-Assign month (1-12), day (1-31), and year (0-99), RETURN

This function allows you to set real time or event time as the first item recorded at the beginning of each scan cycle. You assign time as hours (0-23), minutes (0-59), seconds (0-59), month (1-12), day (1-31), and year (0-99). Time is displayed and recorded in Gregorian format.

Function Six—SUMMARY

Output to Display (-Response)

SUMMARY TYPE (F/C/X/A/M/L/D)
-Select one, RETURN

CHANNELS (FFF-LLL)
-Channels and alarms require modifier—what channels

The Summary function allows the user to print a summary of his program. The output device for this information is selected in the Format function.

F -Table of Log Formats
C -Channel Programming
X -Lists all MX + B's
A -Setpoints assigned to specified channels
M-Alarm Messages
L -Alarm Limits
D-Deadbands

Function Seven—OPTIONS

Output to Display (-Response)

MESSAGE NO (NN) 01-40
-Select between 01 and 40, RETURN

MESSAGE (.....)
-Assign message—up to 13 characters, RETURN

LIMIT NO (NN) 01-99
-Select between 01 and 99, RETURN

LIMIT VALUE (+ NNNNNN H/L)
-Assign polarity, decimal function, and designate as High or Low limit region.

DEADBAND NO (NN) 01-10
-Select between 01-10, RETURN

DEADBAND VALUE (NNNNNN)
-Assign as decimal fraction, RETURN

SERIAL PORT (1/2)
-Select 1 or 2, RETURN

DATA FRAMES/LINE (NN)
-Assign 00 (continuous) to 99, RETURN

CARRIAGE RET? (Yes/No)
-Yes or No, RETURN

LINE FEED? (Yes/No)
-Yes or No, RETURN

END OF LINE CHAR (NN)
-Enter Hex Code

COMPRESSED FMT (Yes/No)
-Yes eliminates leading zeros

REMOTE CMD ENABLE (Yes/No)
-Yes enables remote CMD

The Options function is where you assign message numbers to actual messages, limit numbers to values and deadband numbers of values. You also use the Opt function to select the format for serial ports 1 and 2 and magnetic recording.

Input Specifications

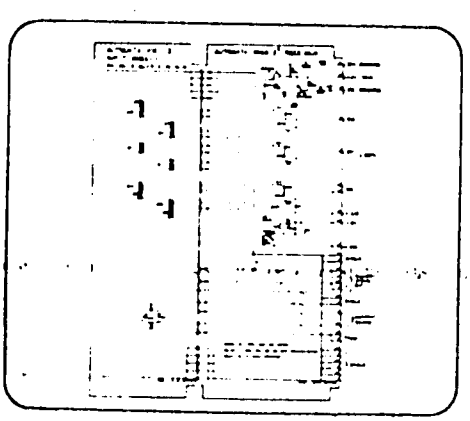
The Autodata Ten/4 input is designed for maximum versatility. The Autodata Ten/4 can handle both AC and DC voltages, DC millivolts, process current (0-1, 4-20, 10-50, 1-5 milliamps), thermocouples, RTD's, resistances and an assortment of digital inputs including pulse, BCD and frequency.

AUTOCAL and Auto Zero keep the Autodata Ten/4 accurate. Auto Zero is performed every 10 seconds. This allows the Autodata Ten/4 Integrating Digital Voltmeter (IDVM) to be fast while maintaining excellent zero stability. AUTOCAL provides recalibration to a National Bureau of Standards (NBS) traceable reference every 5 minutes. Added to Acurex's proven reed multiplexer design, this ensures extremely accurate data acquisition.

Noise rejection is an essential part of any measuring system. Noise is defined as an unwanted signal which may mask the presence of the desired signal if it is not rejected. Acurex's high common-mode rejection has been a standard in the Autodata instruments for 15 years. Common-mode rejection of 160 dB or 170 dB depending on speed selection in the A/D converter virtually eliminates noise.

Typical Measurement Error

Common Mode Voltage	Common Mode Rejection	Noise
120 Volts	160 dB	1.2 μV
12 Volts	160 dB	.12 μV
1 Volt	160 dB	.01 μV
120 Volts	170 dB	.4 μV
12 Volts	170 dB	04 μV
1 Volt	170 dB	003 μV



2-Wire Input and Mux

Input Options
DC Inputs

Four standard DC input ranges are provided:

0 to ± 50 mV with 1 μV resolution
0 to ± 500 mV with 10 μV resolution
0 to ± 5 V with .1 mV resolution
0 to ± 10 V with .2 mV resolution

All ranges above are with high resolution at 10 channels per second. For higher speed scanning, the resolution above is 5 microvolts, 50 microvolts, .5 millivolts, and 1 millivolt.

Current

Process current of 0 to 1 milliamp, 4 to 20 milliamps, 10 to 50 milliamps, and 1 to 5 milliamps is easily handled using either the current input module or by adding 25 ohm shunts to any voltage input card. The E/U conversions for current convert these inputs directly to 0 to 100% for convenience in scaling into engineering units. Scaling may be accomplished either through the use of the MX + B's or through the use of more complex Mini-MATHPAC™ functions. Process current may also be converted to analog output for control of other functions. Calculations performed on process current inputs may also be output on the analog output board.

Thermocouples

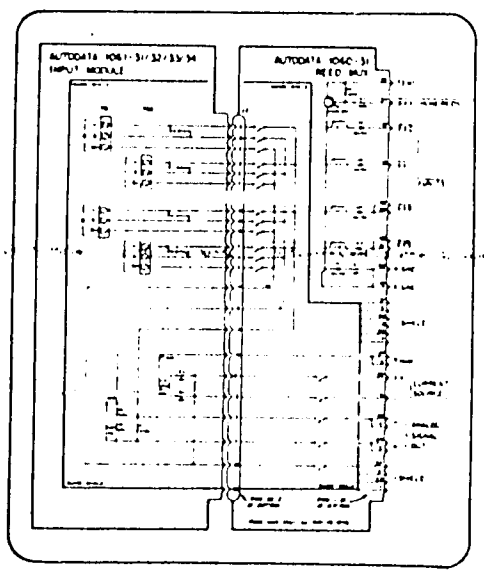
Acurex provides the 7 most common thermocouple linearizations as standard in every Autodata Ten/4. Only the isothermal thermocouple input board is required to use the thermocouple capability of the Acurex Autodata Ten/4. Linearizations for thermocouple types J, K, T, E, R, S, and B are included in every system. These are selectable as degrees C or degrees F. Thermocouple accuracy for various types of thermocouples is shown in the table below. Errors include the effect of cold junction as well as all system measurement errors and linearization errors.

Instrument Temp. 20° to 30°C		Error In Degrees			
Thermocouple	Measurement	Hi Res		Lo Res	
Type	Range (°C)	°C	°F	°C	°F
J	− 200 to − 100	0.4	0.7	1.1	1.5
	− 100 to 0	0.3	0.5	0.8	1.1
	0 to 400	0.4	0.5	0.8	1.1
	400 to 760	0.3	0.5	0.8	1.1
K	− 200 to − 100	0.5	0.9	1.3	1.9
	− 100 to 0	0.4	0.6	1.0	1.3
	0 to 400	0.3	0.5	0.9	1.2
	400 to 1370	0.4	0.7	1.0	1.2
T	− 200 to − 100	0.5	0.9	1.3	1.8
	− 100 to 0	0.4	0.6	1.0	1.4
	0 to 400	0.3	0.6	0.9	1.2
E	− 200 to − 100	0.5	0.8	1.1	1.6
	− 100 to 0	0.4	0.6	0.9	1.2
	0 to 800	0.3	0.6	0.9	1.3
	800 to 1000	0.6	1.1	1.2	1.7
R	0 to 400	1.2	2.1	2.5	4.5
	400 to 1665	0.7	1.3	1.7	3.1
S	0 to 400	1.1	2.0	2.4	4.3
	400 to 1064	0.8	1.2	1.7	3.1
	1064 to 1665	0.7	1.3	1.6	2.9
B	200 to 600	2.8	5.0	5.7	10.3
	600 to 1100	1.2	2.1	2.5	4.5
	1100 to 1820	0.8	1.2	2.0	3.5

Two-Wire Multiplexers

Two-wire multiplexers allow the connection of up to 20 input channels per card to the Autodata Ten/4. Two-wire multiplexers are available for thermocouple/volts and volts only. Lower common-mode rejection may be experienced with high source resistance transducers or extremely noisy locations. Two-wire multiplexers affect accuracy. Both voltage and temperature accuracy must be adjusted to reflect the larger number of channels being measured. The following derating parameters should be applied to 2-wire measurements.

Common Mode Rejection	Subtract	20 dB
Voltage	add	± 3 μV
Current	add	± .012%
Temperature	add	± .5°F



3-Wire Input and Mux

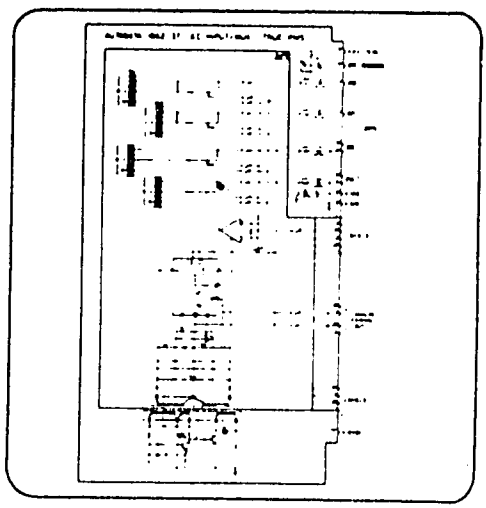
RTD

Five-wire multiplexers for resistance measurements can be made using the 5-wire mux card. The 5-wire resistance measurement makes possible switching of both the excitation and signal leads individually to each RTD, eliminating any problems with common-mode voltage interaction between the RTD's. A driven current source is used to excite the RTD's, thus problems with settling time are eliminated. Acurex 5-wire resistance measurements eliminate errors due to resistance and temperature coefficient of the leads. The switched current source makes possible precise temperature measurements that might otherwise be difficult due to the self-heating of the RTD. The RTD accuracy specifications are shown below.

Instrument Temp. 20° to 30°C		Error In Degrees			
RTD Type	Measurement Range (°C)	Hi Res °C	Hi Res °F	Lo Res °C	Lo Res °F
100 Ohm Pt = 00385	−200 to −100	0.2	0.4	0.9	1.1
	−100 to 500	0.3	0.6	1.0	1.3
	500 to 850	0.4	0.7	1.1	1.6
100 Ohm Pt = .003926	−200 to −100	0.2	0.4	0.9	1.1
	100 to 500	0.3	0.6	1.0	1.3
	500 to 850	0.4	0.7	1.1	1.6
10 Ohm Cu	−200 to −150	1.4	2.5	3.1	5.2

Resistance

The resistance inputs provide true 4-wire measurement of resistance. Resistance measurements are from 0 to 500, 0 to 5000 and 0 to 50,000 ohms full scale. Resolution is one part in 50,000 for high resolution, and one part in 10,000 for low resolution. Five-wire multiplexing provides switching excitation, signal and guard leads.



True RMS AC Inputs

AC Inputs

The AC input card consists of a 10 channel card which measures true RMS AC with a 60 cycle or 50 cycle period. A voltage divider, provided per channel, allows capability of intermixing voltage and current measurements on the same card.

Digital Inputs

Digital inputs may be connected to the Autodata Ten/4 in one of three ways: Contact Inputs, Pulse and BCD.

Contact Inputs

The analog inputs may be program look for an open or closed contact respond to that condition. In this ca contact inputs are intermixed with s ard analog channels.

Pulse Inputs

A special pulse input card provides accumulation, frequency, period, ar status for non-contact inputs (i.e., v ages). This card requires one I/O sl 5-15 channels of input. Versions are able with 5-, 10-, and 15-channel inp Low level pulse inputs are available on special order.

BCD Inputs

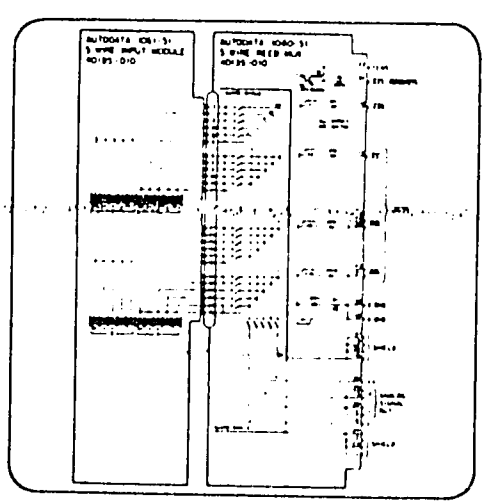
BCD inputs are available in a card t plugs into one of the I/O slots. There four BCD inputs per card. Each BCD input contains six digits, sign, and decimal point.

Remote Scanner

The Autodata 1016 Remote Scanner provides a remote housing for up to 3-wire channels or 200 2-wire chann This remote multiplexing in many ca saves money by allowing only one ar cable to be connected between the data Ten/4 Mainframe and Remote Sc up to 5,000 feet away. A control cabl also required to address the Scanne

Three-Wire Multiplexers

Three-wire multiplexers provide the lowest noise connection between the Autodata Ten/4 and external signal source. The high, low and shield are switched together to provide a fully shielded and guarded path between signal source and the datalogger measuring system. Three-wire multiplexers are available with process current inputs, DC inputs, thermocouple inputs and AC inputs.



5-Wire Input and Mux

Five-Wire Multiplexer

Five-wire multiplexers are used w resistance measurement is requ Both excitation and signal leads a switched along with the shield. Vo ta inputs may also be brought in on th 5-wire multiplexer board by simply n connecting the excitation leads.

Autodata Ten/4 Specifications

Dimensions
Bench model: 9.2" (23.37 cm) high, 17.75" (45.09 cm) wide, 22.75" (57.79 cm) deep.

Weight
Approximately 56 lbs (21.77 kg), dependent on options. Shipping weight adds approximately 20 lbs (9.8 kg).

Power Requirements
Operates on field selectable 115/230 VAC, 50 or 60 Hz. Draws less than 80 watts without options.

Power Line Range
88-109, 105-130, 193-238, or 210-260 VAC.

Temperature
Operating 0°C to + 50°C, Storage −20°C to + 65°C.

Relative Humidity
0% to 90%, non-condensing.

System Operating Altitude
Up to 10,000 feet minimum.

Clock
Battery backed to provide uninterrupted timekeeping during power interruption of up to six months.

Clock Output Format
Clock output is in Gregorian month, day, hours, minutes, seconds; i.e., 13:33:25 JUN 24, 1983.

Program Memory
All user entered programming variables stored in battery-protected RAM memory. Programs contained in this memory protected for a power outage of up to six months.

Data Buffer
Internal buffer provided for data storage during scanning.

I/O Option Capacity
Four slots for field-installable I/O options are available in the mainframe.

Digital Inputs
BCD and Pulse input options available. BCD is six digits plus sign and decimal point.

Channel Capacity
120 channels in mainframe using 2-wire multiplexers (60 channels with 3-wire). Multiplexers can be mixed as desired.

System Capacity
To 256 points with optional scanner housing.

Measurement Method
Patented V-F converter, true integrating, utilizing a standard charge dispenser and bipolar counter.

Zero Stability
Fully auto-zeroing; no zero calibration required.

Span Stability
Auto-Cal recalibrates the system automatically every 5 minutes.

Normal-Mode Rejection
Rejection of normal-mode electrical noise greater than 70 dB at power line frequency (50/60 Hz and harmonics).

Common-Mode Rejection
Rejection of common-mode electrical noise specified with up to 1000 ohms source unbalance given in Table A.

Warm-Up Time
One hour to full accuracy at calibration temperature (25°C).

Overall System Accuracy
Table A lists overall system measurement accuracy for voltage measurements. Included in the errors indicated are all system errors occurring between the voltage input termination on the input module and the digital readout occurring on the front panel. This is guaranteed performance for a time period of one year without recalibration.

Thermocouple Conformity
Better than 0.1°C.

Automatic Calibration
Totally guarded 10.0000V source periodically used for automatic calibration of IDVM without operator intervention. Calibration source traceable to NBS.

Table A
Autodata Ten/4 Input Specifications

		High Performance DVM	
Resolution		High	Low
Ranges		± 50mV	± 50mV
		± 500mV	± 500mV
		± 5V	± 5V
		± 10V	± 10V
Resolution (counts)		50,000	10,000
Other Inputs: T/C's		JKTRSEB	JKTRSEB
RTD's		100 Ω Pt.	100 Ω Pt.
		10 Ω Cu	10 Ω Cu
Integration Period		5	[illegible]
CRM (DC & 50/60Hz) (2- and 3-wire)		170dB	160dB
CMR (DC & 50/60Hz) (2-wire)		140dB	140dB
CMV (3- and 5-wire)		250V	250V
CMV (2-wire)		100V	100V
Speed (ch/sec) (60Hz)		10	20
Speed (ch/sec) (50Hz)		8	20
Voltage* Accuracy*	0% F.S.	± [illegible]	± .020%
	33% F.S.	± .01[illegible]	± .022%
	67% F.S.	± .013%	± .023%
	100% F.S.	± .015%	± .025%
	120% F.S.	± .01[illegible]	± .026%
Resistance* Accuracy*	0% F.S.	± .02[illegible]	± .030%
	100% F.S.	± .020%	± .030%
Temperature Stability		± 0[illegible] °C	± .002%/°C

*± 2.5 μV (.025 Ohms)

ACUREX Corporation

Autodata Division
485 Clyde Ave., Mt. View, CA 94042
(415) 964-3200 Telex: 34-6391

Acurex Corporation, Europe
58 rue Pottier
78150 Le Chesnay,
France
Phone: (333) 955 81 43
Telex: 696364BAB

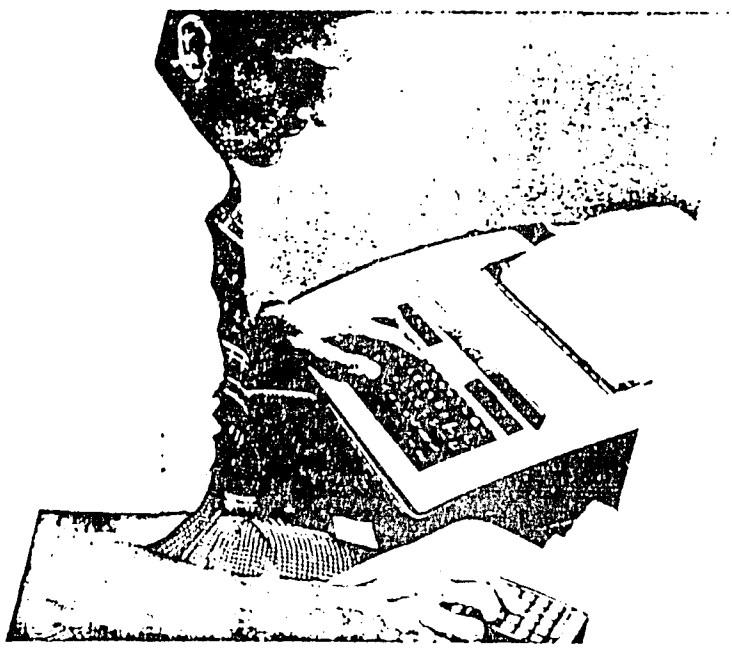
Acurex Far East, Inc.
Kyodo Building, Suite 47
4-2, 2-Chome, Hatchobori
Chuo-ku, Tokyo 104, Japan
Phone: 03-552-1231
Telex: (781) 28719

model 43 teleprinters for point-to-point systems

MODEL KSR - 4320 ABK
COST $1000

CARTON OF PAPER $47
1 DOZ. SPARE RIBBONS $89

SERIAL NO. 320-289544



features and selection guide

BASIC TERMINAL—STANDARD FEATURES

General

- **Transmission**
  Mode: Half- or Full-Duplex, operator selectable, over full-duplex switched network or point-to-point private-line facilities.
  Techniques: Asynchronous
  Speed: 110 or 300 bps
  Code: 8 level ASCII
  Parity: even or 8th bit Mark
- **Interface:** EIA RS232/DC Current (20-60 ma), TTL (digital), or FSK (integrated) 103-type data set—FCC Reg. No. AT793C-70162-DT-E.
- **Answer Back:** Optional, operator and on-line controllable.
- **Automatic Answer:** Manual or auto, with or without Answer-Back, operator controllable.
- **Diagnostics:** Printer self-test capability.
- **Configurations:** ASR (Automatic Send-Receive), KSR (Keyboard Send-Receive), RO (Receive-Only).

Printer

- **Print rate:** True 30-character-per-second throughput including carriage return.
- **Print line:**
  Tractor feed: 100 char/line at 10 char/inch (can be modified for 132 char/line, 13 char/inch)
  Pin feed: 132 char/line at 13 char/inch
  Friction feed: 80 char/line at 10 char/inch
- **Vertical spacing:** 6 lines/inch
- **Line feed:** Single
- **Paper handling:**
  Tractor feed: 3 to 12 inches wide.
  Has vertical "soft roll" feature and fine horizontal character positioning of up to approximately .200 inches.
  Pin feed: 12 inches wide
  Friction feed: 8½-inch wide 400-ft. roll.
- **Copies:**
  Tractor Feed: One original and up to three copies (depending upon paper/carbon weight)
  Pin Feed: Same as above
- **Printing technique:** 7 wide x 9 high dot matrix
- **Character set:** 94 up-low ASCII character set & parity error symbol.
- **Margins:** Left and right set and clear, keyboard and on-line selectable

Printer cont'd

- **Signal bell:** Activated before and at right margin during data entry and on receipt of BEL
- **Alarm:** Paper out (tractor and pin feed)
  Low paper (friction feed)
- **Last character visibility**
- **Line feeds at rate of 30 lines/sec**
- **Ribbon cartridge:** Three-million characters (nominal)—easy replacement

Keyboard

- Typewriter-like keyboard generates all 128 ASCII code combinations.
- Back Space, operator and on-line controllable
- Multiple-Key Rollover. 8-character burst buffer.
- Caps Lock, Repeat, Return, Line Feed, Shift and Control keys.

Punch and Reader (ASR or TSR)

- 10 or 30 characters per second
- 8-level, 1 in. fully perforated oiled paper tape
- Manual and Automatic Punch and Reader Controls
- **Punch Controls:** Off, On, Auto Start, Back-space, Blank feedout
- **Reader Controls:** Off, On, Auto/Start, Single Step/Skip, Tape Tight, Tangled, or Out
- Motor Control with motor start buffer
- 1000 ft. Paper Tape supply, oiled or non-oiled
- Chad Box

Electrical & Physical Facts

- **Imput Voltage:** 115 VAC @50/60 Hz (ASR, KSR, RO, TSR)
  115/230 VAC ±15% @ 50/60 (KSR's),
  115/240 VAC ±10% @ 50/60 (TSR's)
- **Power:** 75 watts maximum
- **Environmental Requirements:**
  Temperature—Operating +32 to 110°F
  Relative Humidity—5% to 95% (non-condensing)

Dimension & Weights (approx.)

	ASR	KSR	RO	TSR
Height:	10 in.	6 in.	6 in.	10 in.
Width:	27 in.	20 in.	20 in.	8 in.
Depth:	28 in.	27 in.	27 in.	28 in.
Weight:	52 lbs.	32 lbs.	20 lbs.	20 lbs.

add 2" to height for friction feed printer
add 3" to height for tractor feed printer

BUFFERED TERMINAL—STANDARD FEATURES

General

- **Transmission**
  Mode: Half- or Full-Duplex over point-to-point switched-network or private-line facilities
  Technique: Asynchronous
  Speeds: 110, 200, 300, 600, 1200 or 1800 bps
  Code: 8 level, ASCII
- **Communications Interface:** EIA-RS232C (requires full duplex modem) 103, 108, 202T or 212 type data sets Current 20/60 ma; requires 403103 EIA to Current Interface Converter
- **Parity:** Odd/Even/Mark/Space
- **Communication Function Controls:** Conversational or batch
- **Automatic answer:** Responds to incoming call while unattended
- **Answer back:** Up to 20 selectable characters (automatic operation optional)
- **Diagnostics:** Self-test capabilities are provided for each major component

Printer

- **Print rate:** 47 characters per second provides true 30-character-per-second throughput including carriage return
- **Print line:**
  Tractor feed: 100 char/line at 10 char/inch (can be modified for 132 char/line, 13 char/inch)
  Pin feed: 132 char/line at 13 char/inch
  Friction feed: 80 char/line at 10 char/inch
- **Vertical spacing:** 6 lines/inch
- **Line feed:** Single or double
- **Paper handling:**
  Tractor feed: 3 to 12 inches wide. Has vertical "soft roll" feature and fine horizontal character positioning of up to approximately .200 inches.
  Pin feed: 12 inches wide
  Friction feed: 8½-inch wide 400-ft roll
- **Top-of-form (form feed):** Any form length up to 22 inches, keyboard and on-line selectable
- **Copies:**
  Tractor feed: One original and up to three copies (depending upon paper/carbon weight)
  Pin feed: Same as above
- **Printing technique:** 7 wide x 9 high dot matrix
- **Character set:** 128 ASCII plus parity error symbol
- **Horizontal and vertical tabs:** Tab set and clear, keyboard and on-line selectable
- **Margins:** Left and right set and clear, keyboard and on-line selectable
- **Signal bell:** Activated before and at right margin during data entry and on receipt of BEL
- **Alarm:** Paper out (tractor and pin feed)
  Low paper (friction feed)
- **Ribbon cartridge:** Three-million characters (nominal)— easy replacement

Keyboard

- Typewriter-like keyboard generates all 128 ASCII code combinations
- Back Space, operator and on-line controllable
- N-Key Rollover: 8-character burst buffer
- Caps Lock, Repeat, Return, Line Feed, Shift and Control keys

Buffer

- **Buffer size:** 16K (16,000) characters
- **Send buffer:** Dynamically divided into edit buffer, to-be-sent buffer, and already-sent buffer
- **Receive Buffer:** Accepts all data from line, holds until printer becomes available
- **Six buffer controls:** Buffer Enter, String Enter, Insert, Send Ready, Message Clear and Receive Message Waiting

Electrical

- **Requirements:** 115VAC at 50/60 Hz:
  also available with 115/230 VAC, 50/60 Hz power supply
- **Power consumption:** 84 watts maximum
- **Environmental requirements:**
  Temperature — Operating +32 to 110°F
  Relative Humidity — 5% to 95% (non-condensing)

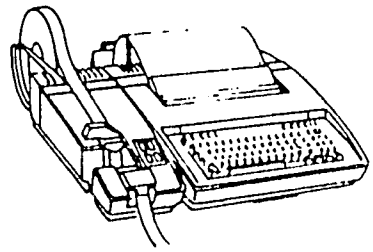
Dimensions & Weights (approx.)

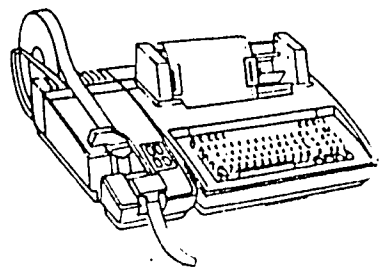
	Pin	Friction	Tractor
Height:	5[illegible] in.	7½ in	8[illegible] in.
Width:	[illegible] in.	20 in.	[illegible] in.
Depth:	21 in.	21 in.	21 in.
Weight:	31 lbs.	31 lbs.	35 lbs.

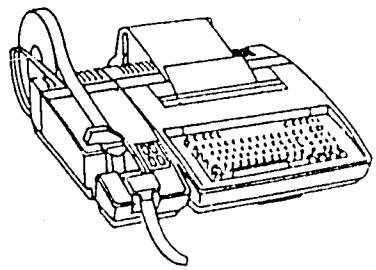
BASIC CONFIGURATIONS

4330 ASR (Automatic Send-Receive)

Interface	AC Power Supply 50/60 Hz	Printer	Punch & Reader	Catalog Number
EIA-RS232* or DC-20 to 60ma	115V	Pin Feed	Auto/Man'l	4330-2BCA
			Auto	4330-2BDA
		Friction Feed	Auto/Man'l	4330-2ACA
			Auto	4330-2ADA
		Tractor Feed	Auto/Man'l	4330-2CCA
			Auto	4330-2CDA
	115/230V ◆	Pin Feed	Auto/Man'l	4330-2BCQ
			Auto	4330-2BDQ
		Friction Feed	Auto/Man'l	4330-2ACQ
			Auto	4330-2ADQ
		Tractor Feed	Auto/Man'l	4330-2CCQ
			Auto	4330-2CDQ





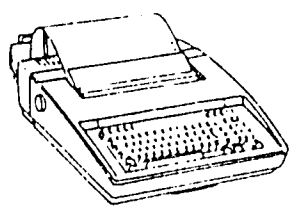


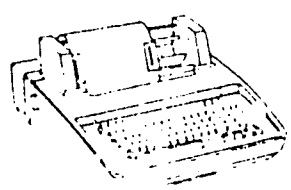
◆ KSR shipped as 230 VAC unit & TSR shipped as 115 VAC unit.

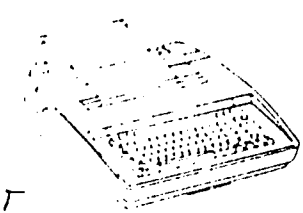
AC Power cord not included for KSR.

4320 KSR (Keyboard Send-Receive)

AC Power Supply 50/60 Hz	Interface	Printer	Catalog Number
115V	TTL-Serial	Pin Feed	4320AAA†
		Friction Feed	4320AAE†
		Tractor Feed	4320ABC†
	103-type Built-In Modem	Pin Feed	4320AAB
		Friction Feed	4320AAF
		Tractor Feed	4320ABB
	EIA-RS232* or DC-20 to 60ma	Pin Feed	4320AAK
		Friction Feed	4320AAL
		Tractor Feed	4320ABE
	Dual (Line + Aux.) each EIA* or DC	Pin Feed	4320AAH
		Friction Feed	4320AAJ
		Tractor Feed	4320ABH
115/230V ◆	TTL-Serial	Pin Feed	4320ABM
		Friction Feed	4320ABS
		Tractor Feed	4320ACK
	EIA-RS232* or DC-20 to 60ma	Pin Feed	4320ABK
		Friction Feed	4320ABP
		Tractor Feed	4320ACH







THIS IS UNIT SELECTED

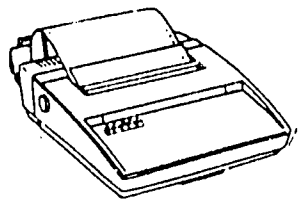
†Replace A, E or C at end of catalog number with U, V or G, respectively, if 410754 will be added to convert TTL to Dual EIA/DC interface.

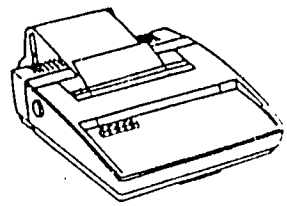
◆ Equipped with standard I.E.C. 3-pin receptacle and has fuse insert for European style fuse (5x 20 mm). Shipped with USA style fuse and 230 VAC power option.

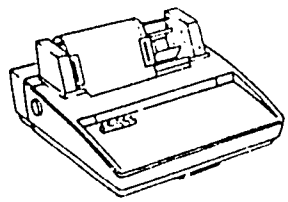
AC Power cord not included.

*Compatible with 103, 108-type data sets

4310 RO (Receive-Only)







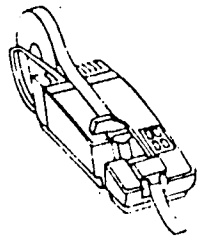
AC Power Supply 50/60 Hz	Interface	Printer	Catalog Number
115V	TTL-Serial	Pin Feed	4310AAA
		Friction Feed	4310AAE
		Tractor Feed	4310ABA
	103-type Built-In Modem	Pin Feed	4310AAB
		Friction Feed	4310AAF
		Tractor Feed	4310ABB
	EIA-RS232* or DC-20 to 60ma	Pin Feed	4310AAG
		Friction Feed	4310AAH
		Tractor Feed	4310ABC
115/230V ◆	TTL-Serial	Pin Feed	4310AAL
		Friction Feed	4310AAN
		Tractor Feed	4310ABD

◆ Equipped with standard I.E.C. 3-pin receptacle and has fuse insert for European style fuse (5x 20 mm). Shipped with USA style fuse and 230 VAC power option.

AC Power cord not included.

*Compatible with 103, 108-type data sets

4350 TSR (Tape Send Receive)†



AC Power Supply 50/60 Hz	Interface	Punch & Reader	Catalog Number
115V	Limited EIA	Auto Man'l	4350AAA
		Auto	4350AAC
115/240V**		Auto Man'l	4350AAD
		Auto	4350AAF

†A TSR plus a 430569 cable permits a dual interface KSR to be converted to an ASR.

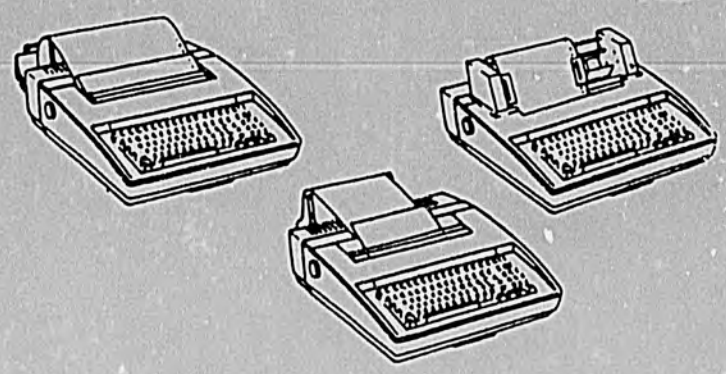
**Strap selectable for 115, 220, 230, 240 VAC operation. Equipped with standard I.E.C. 3-pin receptacle and detachable USA style 3-pin U-ground plug AC power cord. Refer to installation manual for 220/230/240 VAC options.

BUFFERED CONFIGURATIONS

4340 BSR (Buffer Send-Receive)

Interface	Buffer Size	Printer	Catalog Number
EIA-RS232*	16K	Pin Feed	4340BAB
		Friction Feed	4340BAD
		Tractor Feed	4340BAJ

*Compatible with 103, 108, 202T & 212-type data sets.



CUSTOMER ASSEMBLED TERMINALS

See "42/43 Customer Assembled Terminals" Features & Selection Guide (SD43-509) for 115/230VAC terminals.

ACCESSSORIES & OPTIONS for BASIC & BUFFERED Terminals

ASR Pedestal 430350
Includes AC power distribution panel and large chad box to replace smaller one supplied with ASR. Adds 25-in to terminal height & 24 lbs to weight

KSR/RO Pedestal 430311
Adds 25-in to terminal height & 22 lbs to weight

Copyholder (Pin or Friction-Feed Printer) 430310
Holds copy above print-out exit
Adds 12-in to terminal height

Paper Winder 430422
Winds up print-out as it comes from friction Feed printer. Handles up to 450 ft of single-ply paper. Adds 12-in to height. 115VAC @ 50/60 Hz, 45W (max.)

AC Distribution 430911
Provides 6 switch-controlled outlets for USA style 3-pin U-ground plugs from a single 6-ft power cord. Rated 12 amp., 125 V AC/DC.

PRINTER CONVERSION FROM TF TO FF 430903
Permits the customer to convert tractor feed terminals to friction feed. Applicable to all tractor feed terminals described in this document.

KSR to RO Conversion
Requires the following parts:
43K001AAA Keystrip
430251 Plate
430252 Plate
117608 Speed Nut, order 12

13 to 10 char/in Conversion or
10 to 13 char/in Conversion
See 50993S Specification.

ADDITIONAL ACCESSORIES & OPTIONS for BASIC Terminals

APL Conversion Kit 430899
Creates the APL font. Includes two special keytops and a set of stick-on labels. May be reprogrammed for other alternate fonts.

Top-of-Form Modification Kit 454668
Provides enhancements for basic tractor feed KPs and ROs.
Enhancements include Keyboard Programmable Options, Electric Top of Form, DC1/DC3 flow control, New Line on Line Feed, Double Line Feed, HT, VT, two separate answerback responses, TWX/DDD compatible, and nine PF keys.

Line Shunt Modification Kit 430647
When added to the 410755 Interface Card will shunt the current loop signal line if power is lost or removed from the teleprinter. Available October 1982.

Programmable Answer-Back Card 430900
Operator, on-line & auto-answer controllable. Includes unprogrammed PROM, available programmed from nearest Product Service Center at extra cost.

RO Conversion from Point-to-Point to Multi-Point Private-Line terminal 430910
Provides selective calling features as described in specification 50962S.

Built-In Modem Circuit Card 430750
Adds 103-type modem to TTL KSR and RO terminals.

EIA/DC Interface Circuit Card 410755
Adds EIA/Current Loop to TTL KSR and RO terminals.

Dual EIA/DC Interface Circuit Card 410754
Converts 4320AAU, AAV or ABG to
430AAH, AAJ or ABH, respectively

Interace Cables
EIA (Receptacle to Plug)
408065 (7 ft) 408067 (25 ft)
408066 (12 ft) 408068 (50 ft)

103 Built-In Modem to Modular Phone Cord
430581 (7 ft) 430583 (25 ft)
430582 (14 ft)

TSR to Dual Interface KSR cable 430569

AC Power Cord 412394 (7.5 ft)
One end has I.E.C. plug with socket contacts which mates with I.E.C. 320-type connector and the other end has a USA style 3-pin U-ground plug (NEMA 5-15P).

Spare Print Ribbons 430484
(6 pack of M43 ribbon cartridges)

DOCUMENTATION

TECHNICAL REFERENCES

SD42-401 Model 42 Buffered Teleprinters for Telex and Point-to-Point Systems (General Technical Reference)
SD43-403 Model 43 ASR/KSR/RO Data Terminals (General Technical Reference)
SD43-404 Model 43 BSR Data Terminal (General Technical Reference)

HOW TO OPERATE MANUALS

367 — 43 Teleprinter Basic KSR
372 — 43 Teleprinter Basic RO
386 — 43 Teleprinter Buffered KSR (Full Duplex Batch and Send/Receive)
420 — 42/43 Paper Tape Unit
441 — 43 Teleprinter Basic ASR

INSTALLATION AND ROUTINE SERVICING MANUALS

368 — 43 Teleprinter Basic KSR and ASR
373 — 43 Teleprinter Basic RO
421 — 42/43 Paper Tape Unit
451 — 43 Teleprinter Tabletop Buffered Terminals

SERVICE MANUALS

369 — 43 Teleprinter Basic KSR and RO
406 — 43 Teleprinter Buffered KSR Tabletop and Pedestal Based
422 — 42/43 Paper Tape Unit

REPAIR MANUALS

385 — Circuit Diagrams for components used in 42/43 and 45-30 CPS Character Printer Terminals and Associated Units
391 — 43 Teleprinter Basic KSR and RO w/o Internal Data Set
416 Product Support Manual (Model 42/43 cross reference to documentation and terminal components)
442 — 42/43 Paper Tape Unit
522 — TTL and SSI Logic Cards used in 42/43 and 45-30 CPS Character Printers
523 — Power Supplies used in 42/43 and 45-30 CPS Character Printer Terminals
525 — Keyboards used in 42/43 Basic Terminals
530 — SSI Keyboards used in 42/43 Buffered Terminals
533 — Parts — Enclosures, Paper Handling and Miscellaneous Accessories used with 42/43 and 45-30 CPS Character Printers
534 — Interfaces, Controllers and Modification Kit Circuit Cards Associated with 42/43 Terminals (includes AB, SCU, and brief repair of non-pedestal controllers)
539 — 42/43 and 45-30 CPS Character Printer Mechanisms

SHOP MANUALS

478 — Tabletop Buffered Controllers used in 42/43 Terminals
535 — Single Card Controllers used in 42/43 Basic Terminals

REGISTRATION INSTRUCTIONS

407 — 43 Teleprinter Registration Instructions for Sets w/Integrated Terminal Data Unit

WIRING DIAGRAM PKGS

494 RO
499 KSR
552 BSR
566 TSR

CIRCUIT DIAGRAMS

385 KSR

TELETYPE CORPORATION
GENERAL OFFICES: 5555 Touhy Avenue, Skokie, Illinois 60077 Telephone: (312) 982-2000
TWX: 910-223-3611 and TELEX: 25-4051 (both have 24 hour automatic answering service)

BROOKS

THE MEASURE OF EXCELLENCE

DESIGN SPECIFICATIONS

BROOKS FULL-VIEW* Flowmeters Models 1110 and 1140

April, 1982 (Supersedes issue dated Feb. '81)

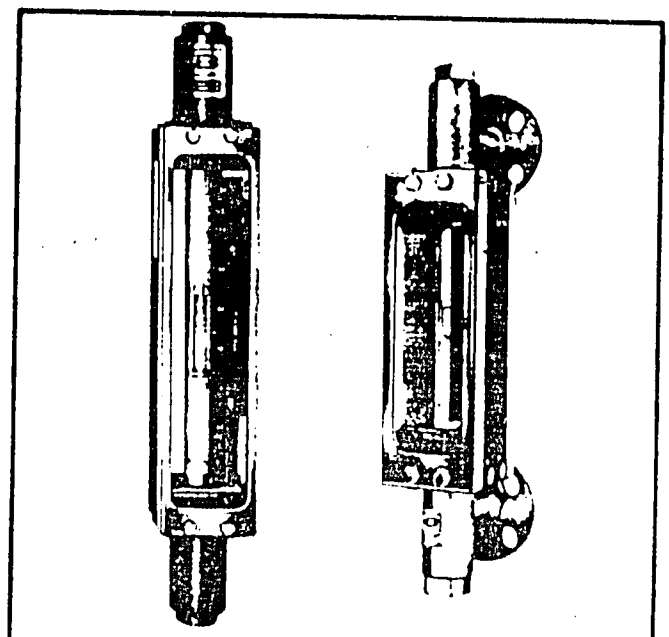
PART # 1114-R-9M-25-1
MODEL # 1114
TUBE # R-9M-25-1
FLOAT # 9-RS-33
SERIAL NO. 8308H70985

2.5 GPM

COST $507

Description

Brooks Full-View Flowmeters are intended for general in-line and bypass metering applications where operating conditions are within the limitations of glass metering tubes. A wide range of capacities and options is available. These packed-gland meters are constructed to withstand the stresses and vibrations inherent in industrial piping installations.



Model 1110 Full-View Flowmeter — Model 1140 Full-View Flowmeter

Design Features

- Dowel-pin, side plate construction
- Detachable or direct-fused flow scales
- Precision-bore, plain or ribbed borosilicate glass metering tubes
- Externally adjustable packing glands
- Connections rotatable 360° at 90° intervals
- Laminated safety glass shielding
- Ten-to-one rangeability
- Scale length of 127 mm, 150 mm, and 250 mm
- Standard floats are interchangeable in tubes of given flowmeter size
- Wide choice of float types and capacity ranges

Materials of Construction

METERING TUBES – Borosilicate glass

FLOATS–Sizes 2-6 (Spherical): Sapphire, Tantalum, Glass, Carboloy, 316 Stn. Stl.; Sizes 8-13: Standard - 316 Stn. Stl. Optional - Aluminum, Alloy 20, Teflon*, Hastelloy* B or C, Monel*, Nickel, PVC, 18-8 Stainless Steel, Titanium

GUIDE RODS & CARTRIDGES – Standard: 316 Stainless Steel, Optional: Hastelloy B or C

END FITTINGS – Monel, Hastelloy B or C, PVC, Brass, 316 Stainless Steel, Nickel, Steel, Kynar*

PACKING MATERIAL – Std.: Steel and Brass meters - Neoprene*, all others - Teflon; Optional: Teflon or Viton*

SIDE-PLATES – Std.: Aluminum; Optional: 18-8 Stn. Stl.

GLAND RINGS – Standard: Steel; Optional: 18-8 Stn. Stl.

SAFETY GLASS WINDOWS – Aluminum Frames

GLAND FOLLOWERS – Standard: Sizes 2-10- Aluminum, Sizes 12-13 - Steel; Optional: 18-8 Stainless Steel

BOLTS – 18-8 Stainless Steel

SIDE PLATE GASKETS – Anchorite

COATINGS (Optional) – PVC coating of external surfaces of end fittings, gland rings, and gland followers and both surfaces of side plates. (Window frames, bolts, and dowel pins not coated.)

FLOAT TYPES

TYPE RV – Rib guided
TYPE GV – Rod guided

Analogous in design to a sharp edge orifice. Gives most immunity to viscosity variations of the fluid being metered.

TYPE RS – Rib guided
TYPE GS – Rod guided

Analogous in design to a flow nozzle or venturi. Offers the maximum flow capacity in any given size flowmeter.

TYPE LJ Floats – used for extended capacity ranges; non-viscosity compensating

Other types of floats available for special applications.

*TRADEMARKS

Full-View	Brooks Instrument Div., Emerson Electric Co.
Hastelloy	Stellite Div., Cabot Corp.
Kel-F	3M Company
Kynar	Pennwalt Corp.
Monel	International Nickel Co.
Neoprene	E.I. DuPont de Nemours & Co.
Teflon	E.I. DuPont de Nemours & Co.
Viton	E.I. DuPont de Nemours & Co.

EMERSON

BROOKS INSTRUMENT DIVISION EMERSON ELECTRIC CO. HATFIELD, PENNSYLVANIA 19440
TELEPHONE: (215) 362-3500 TELEX: 846181

SCALES

Nominal Lengths – 127 mm, 150 mm, and 250 mm
Type – Standard: Engraved detachable metal plate. Optional: Engraved detachable plastic scale or scale fused on metering tube.
Graduations – Choice of direct reading, arbitrary millimeter or 0-100 linear with calibration curves, or percentage of maximum flow with factor tag.

PRESSURE DROP – Inquire at factory.

PERFORMANCE

Industrial Accuracy: ±2% of full scale from 100% to 10% of scale reading. Conforms to ISA R. P. 16.1, Spec. 2-S-10.
Calibrated Accuracy: ±1% of full scale from 100% to 10% of scale reading. Conforms to ISA R.P. 16.1, Spec. 1-S-10.
Repeatability: 0.5% full scale.

CONNECTIONS

Meter Size	Model 1110 Inlet & Outlet Horiz.(NPT)	Model 1114 Inlet & Outlet Vert. (NPT)	Model 1140 Inlet & Outlet Horiz.(FLG.)	Model 1144 Inlet & Outlet Vert. (FLG.)
2-6	1/4"	1/4"	1/2"	1/2"
7&8	1/2"	1/2"	1/2"	1/2"
9	3/4"	3/4"	1"	1"
10	3/4"	1"	1"	1"
12	1-1/2"	1-1/2"	1-1/2"	1-1/2"
13	1-1/2"	2"	2"	2"

RATINGS (Ribbed Tubes)

Meter Size	Max Pressure* (psig at 250°F, 121°C)	Max. Temp* Degrees F
2-4	500	250
6	450	
7	350	
8	300	
9	175	
10	100	
12	75	
13	100	

(Plain Taper Tubes with Rod Guided Floats)

Meter Size	Max. Pressure* (psig at 250°F, 121°C)	Max. Temp* Degrees F
8	500	250
9	500	
10	400	
12	300	
13	300	

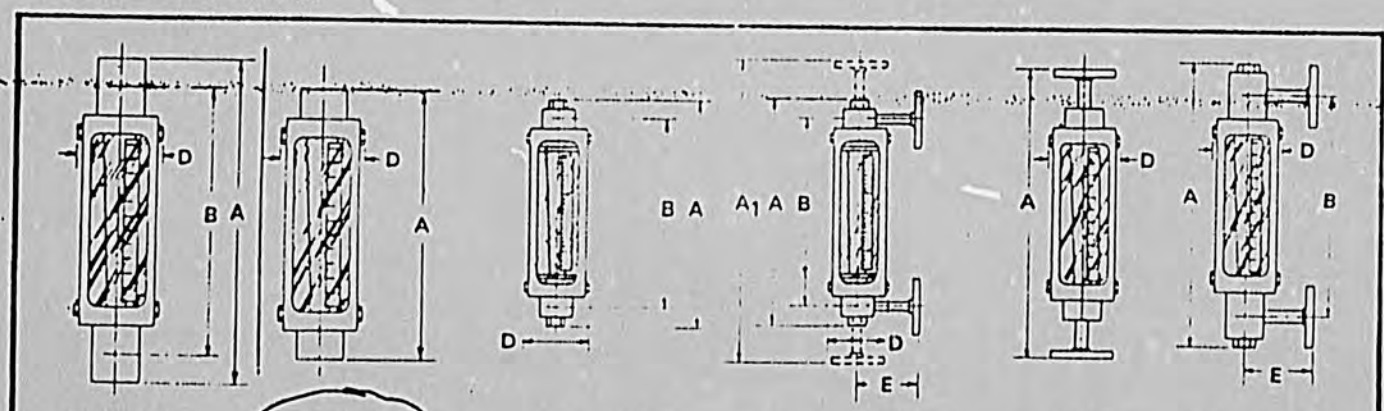
1. Pressure ratings are based on static pressure applicable at 250°F.
2. Caution: Do not use meters in excess of these pressures. Maximum fluid temperature should not exceed 250°F.
3. Fluid temperatures below 32°F will cause frosting of the glass metering tube. Please consult factory for applications below this temperature.
4. Warnings:
   a. For safety reasons, glass tubes cannot be supplied for caustic services.
   b. For hot water applications, maximum recommended operating temperature is 200°F.

*For pressure and temperature ratings on all PVC and Kynar or nonmetallic meters, consult factory.

Dimensions (For certified dimension prints, write to factory.)

Meter Size	Model 1110 & 1140 Nominal Scale Length 127 MM A	B	E	250 MM A	B	E	Model 1114 Nominal Scale Length 127 MM A	250 MM A	Model 1144 Nominal Scale Length 127 MM A	250 MM A	All Meters D
2-6*	10-1/8	8-19/32	3-1/2	15-1/8	13-19/32	3-1/2	9-5/8	14-5/8	14-7/8 A1 only	19-7/8 A1 only	2-7/16
7&8	15-3/8	11-1/2	3-1/2	20-3/8	[illegible]	3-1/2	12	17	17-7/8	22-7/8	3-1/4
9	17	12-1/2	4	22	17-1/2	4	12-1/4	17-1/4	17-3/4	22-3/4	3-3/4
10	17-7/8	12-1/2	4	22-7/8	17-1/2	4	12-1/4	17-1/4	17-1/2	22-1/2	4-7/16
12	20-1/8	15-1/2	5	25-1/8	20-1/2	5	15-7/8	20-7/8	21-3/8	26-3/8	4-7/16
13	21-1/4	15-1/2	5	26-1/4	20-1/2	5	15-1/8	20-1/8	20-5/8	25-5/8	4-7/8

*Also available in 150 mm scale length. Dimensions are identical to 127 mm scale length meters.
All dimensions in inches.



Capacities

It is important to note that other capacity ranges are obtainable. Specific information on special ranges and capacities can be obtained from your nearest Brooks technical sales representative or by writing directly to Brooks Instrument Division, Hatfield, Pennsylvania.

Table 1

150 mm scale, rib guide tubes, spherical floats

Meter Size	Tube No.	Float Material	Max. Flow Rate Water (cc/min.)	Max. Flow Rate Air
2	R-2-15-AAA	Glass	.537	49 cc/min
		Sapphire	1.05	77 cc/min
		Stainless Steel	2.49	146 cc/min
		Carboloy	4.90	245 cc/min
		Tantalum	5.47	270 cc/min
	R-2-15-AA	Glass	1.11	96 cc/min
		Sapphire	2.15	146 cc/min
		Stainless Steel	4.93	265 cc/min
		Carboloy	9.33	430 cc/min
		Tantalum	10.4	460 cc/min
	R-2-15-D	Glass	5.75	370 cc/min
		Sapphire	10.5	510 cc/min
		Stainless Steel	20.6	820 cc/min
		Carboloy	33.2	1220 cc/min
		Tantalum	35.9	1300 cc/min
	R-2-15-A	Glass	16.6	0.82 LPM
		Sapphire	26.3	1.08 LPM
		Stainless Steel	46.2	1.68 LPM
		Carboloy	70.8	2.40 LPM
		Tantalum	75.9	2.55 LPM
	R-2-15-B	Glass	52.8	2.35 LPM
		Sapphire	79.7	3.05 LPM
		Stainless Steel	133.	4.6 LPM
		Carboloy	199.	6.6 LPM
		Tantalum	212.	7.0 LPM
	R-2-15-C	Glass	84.6	3.8 LPM
		Sapphire	129.	5.0 LPM
		Stainless Steel	218.	7.6 LPM
		Carboloy	326.	10.4 LPM
		Tantalum	349.	11.0 LPM
6	R-6-15-A	Glass	200.	8.6 LPM
		Sapphire	297.	11.2 LPM
		Stainless Steel	493.	16.4 LPM
		Carboloy	726.	23.0 LPM
		Tantalum	772.	24.5 LPM
	R-6-15-B	Glass	573.	23.5 LPM
		Sapphire	851.	30 LPM
		Stainless Steel	1350.	43 LPM
		Carboloy	1950.	60 LPM
		Tantalum	2060.	64 LPM

Table 2

250 mm scale, rib guide tubes, spherical floats

Meter Size	Tube No.	Float Material	Maximum Flow Rate Water	Maximum Flow Rate Air
2	R-2-25-D	Glass	5.50 cc/min	366 cc/min
		Sapphire	10.1 cc/min	500 cc/min
		Stn. Stl.	19.8 cc/min	810 cc/min
		Carboloy	32.2 cc/min	1200 cc/min
		Tantalum	34.8 cc/min	1280 cc/min
	R-2-25-A	Glass	16.8 cc/min	0.84 LPM
		Sapphire	26.8 cc/min	1.11 LPM
		Stn. Stl.	46.5 cc/min	1.70 LPM
		Carboloy	71.5 cc/min	2.46 LPM
		Tantalum	77.0 cc/min	2.62 LPM
	R-2-25-B	Glass	49.0 cc/min	2.20 LPM
		Sapphire	74.5 cc/min	2.86 LPM
		Stn. Stl.	124 cc/min	4.3 LPM
		Carboloy	186 cc/min	6.2 LPM
		Tantalum	198 cc/min	6.6 LPM
	R-2-25-C	Glass	82 cc/min	3.78 LPM
		Sapphire	125 cc/min	4.95 LPM
		Stn. Stl.	212 cc/min	7.45 LPM
		Carboloy	318 cc/min	10.3 LPM
		Tantalum	342 cc/min	10.9 LPM
6	R-6-25-A	Glass	196 cc/min	8.6 LPM
		Sapphire	292 cc/min	11.0 LPM
		Stn. Stl.	485 cc/min	16.2 LPM
		Carboloy	715 cc/min	22.8 LPM
		Tantalum	760 cc/min	24.2 LPM
	R-6-25-B	Glass	550 cc/min	22.8 LPM
		Sapphire	810 cc/min	29.0 LPM
		Stn. Stl.	1300 cc/min	42.0 LPM
		Carboloy	1860 cc/min	58.5 LPM
		Tantalum	1980 cc/min	62.0 LPM
	R-6-M-25-1	Glass	275 cc/min	12.3 LPM
		Sapphire	412 cc/min	15.6 LPM
		Stn. Stl.	676 cc/min	22.8 LPM
		Tantalum	1087 cc/min	33.9 LPM
7	R-7-M-25-1	Glass	643 cc/min	26.2 LPM
		Stn. Stl.	1400 cc/min	46.5 LPM
		Monel	1485 cc/min	48.8 LPM

NOTE: All air flows are at 14.7 Psia and 70°F.

Warning

Glass metering tubes are designed for operation up to the maximum operating pressures and temperatures as specified herein. Due to the inherent brittle characteristics of glass and conditions beyond our control, tube breakage could result below specified operating conditions. Possible glass tube breakage represents a potential hazard to operating personnel; therefore, operator protection should be supplied where operating pressures may exceed 50 psig. A customer supplied safety shield constructed of 1/2-inch acrylic plastic may be used or the glass tube meter may be replaced with an all metal (armored) meter.

Capacities (Cont'd)

Table 3

250 mm scale, rib guide tubes, standard floats

Meter Size	Tube No.	Float No.	Maximum Flow Rate: Water GPM	Water LPM	Water Pressure Drop Inches, W.C.	Visc. Immunity Ceiling, Cs.**	Air SCFM	Air SLPM	Air Pressure Drop Inches, W.C.
7	R-7M-25-1	Glass	0.17	0.643	—	***	0.93	26.24	—
		Stn. Steel	0.37	1.400	—	***	1.64	46.54	—
		Monel	0.39	1.485	—	***	1.72	48.80	—
8	R-8M-25-2	8-RV-3	0.55	2.08	2	2.0	2.22	62.87	3
		8-RV-8	0.78	2.95	5	3.3	3.22	91.19	6
		8-RV-14	1.04	3.94	8	4.6	4.28	121.21	9
		8-RV-31*	1.50	5.68	17	6.0	6.12	173.32	19
		8-RS-8	1.00	3.79	6	1.7	4.18	118.38	7
		8-RS-14	1.32	5.00	11	1.8	5.48	155.19	12
		8-RS-31*	1.89	7.15	22	2.6	7.76	219.76	25
		8-LJ-48*	3.01	11.39	45	***	13.01	368.44	51
	R-8M-25-4	8-RV-3	0.78	2.95	4	2.0	3.17	89.77	4
		8-RV-8	1.09	4.13	7	3.7	4.45	126.02	8
		8-RV-14	1.45	5.49	12	5.4	5.88	166.52	14
		8-RV-31*	2.06	7.80	23	7.0	8.32	235.62	28
		8-RS-8	1.40	5.30	10	1.8	5.86	165.96	11
		8-RS-14	1.83	6.93	17	1.9	7.56	214.10	19
		8-RS-31*	2.59	9.80	33	3.1	10.66	301.89	37
		8-LJ-48	4.88	18.47	93	***	20.32	575.46	106
9	R-9M-25-1	9-RV-33	1.90	7.19	5	10.0	7.96	225.43	6
		9-RV-87*	3.08	11.66	12	15.0	12.56	355.70	14
		9-RS-33	2.52	9.54	6	2.3	10.46	296.23	7
		9-RS-87*	4.04	15.29	14	3.4	16.84	476.91	16
		9-LJ-160*	6.88	26.04	31	***	30.45	862.34	35
	R-9M-25-3	9-RV-33	2.53	9.58	6	11.0	10.45	295.94	7
		9-RV-87*	3.92	14.84	14	17.0	16.25	460.20	16
		9-RS-33	3.24	12.26	7	2.4	13.45	380.90	8
		9-RS-87*	5.12	19.38	17	3.5	21.20	600.38	20
		9-LJ-160*	9.65	36.53	43	***	44.18	1251.18	49
10	R-10M-25-1	10-RV-64	4.54	17.18	8	14.0	18.05	511.18	9
		10-RV-138*	6.42	24.30	17	22.0	26.60	753.31	19
		10-RS-64	5.64	21.35	10	3.0	23.65	669.77	12
		10-RS-138*	8.02	30.36	21	5.0	34.60	979.87	23
		10-LJ-238*	14.91	56.43	52	***	66.00	1869.12	59
	R-10M-25-3	10-RV-64	6.28	23.77	11	15.0	25.76	729.52	13
		10-RV-138*	8.84	33.46	23	23.0	36.10	1022.35	26
		10-RS-64	7.84	29.67	15	3.7	32.15	910.49	17
		10-RS-138*	10.93	41.37	29	5.5	45.90	1299.69	33
		10-LJ-238*	23.10	87.43	98	***	105.70	2993.42	112
12	R-12M-25-4	12-RV-221	9.33	35.31	8	28.0	37.81	1070.15	9
		12-RV-343*	11.71	44.32	12	35.0	47.12	1334.44	14
		12-RS-221	12.46	47.16	9	4.0	50.65	1434.41	10
		12-RS-343*	15.43	58.40	13	4.3	62.75	1777.08	15
		12-LJ-740*	30.00	113.55	31	***	123.30	3491.86	36
	R-12M-25-5	12-RV-221	17.21	65.14	10	29.0	70.80	2005.06	11
		12-RV-343*	20.95	79.30	15	36.0	86.45	2448.26	17
		12-RS-221	22.40	84.78	12	4.2	91.85	2601.19	14
		12-RS-343*	26.90	101.82	18	4.5	112.00	3171.84	20
		12-LJ-740*	67.60	255.83	65	***	299.50	8481.84	75
13	R-13M-25-1	13-RV-510	19.94	75.47	12	40.0	81.55	2309.50	14
		13-RV-760*	23.79	90.05	18	50.0	96.00	2718.72	20
		13-RS-510	26.89	101.78	15	7.3	108.00	3067.06	17
		13-RS-760*	31.86	120.55	21	9.0	131.00	3709.92	24
		13-LJ-1394*	54.60	206.66	46	***	—	—	—
	R-13M-25-3	13-RV-510	31.78	120.29	17	42.0	130.90	3707.09	19
		13-RV-760*	37.60	142.32	24	52.0	155.20	4395.27	27
		13-RS-510	42.52	160.94	23	7.6	176.60	5001.31	26
		13-RS-760*	49.55	187.55	32	9.3	217.70	6165.26	36
		13-LJ-1394*	98.60	373.20	92	***	—	—	—

* These floats are not recommended for gas service unless operating pressure (downstream) exceeds 30 psi.

** Viscosity immunity ceilings listed are for Stainless Steel floats only and fluid Sp. Gr. 1.0. For other fluid gravities, convert to sizing viscosity and use this value when comparing with values in table.

*** These floats are very sensitive to viscosity changes and do not offer any immunity to viscosity changes.

NOTE: All air flows are at 14.7 psia and 70°F.

Capacities (Cont'd)

Table 4

127 mm scale, rib guide tubes, standard floats

Meter Size	Tube No.	Float No.	Maximum Flow Rate						
			Water				Air		
			GPM	LPM	Pressure Drop Inches, W.C.	Visc. Immunity Ceiling, Cs.**	SCFM	SLPM	Pressure Drop Inches, W.C.
8	R-8M-127-1	8-RV-3	0.50	1.89	2	2.0	2.05	58.06	2
		8-RV-8	0.74	2.80	3	3.3	3.01	85.24	4
		8-RV-14	0.96	3.63	6	4.6	3.95	111.86	6
		8-RV-31*	1.38	5.22	11	6.0	5.60	158.59	13
		8-RS-8	0.92	3.48	4	1.7	3.84	108.75	4
		8-RS-14	1.22	4.62	6	1.8	5.03	142.45	7
		8-RS-31*	1.70	6.43	13	2.6	6.98	197.67	15
		8-LJ-48*	2.59	9.80	22	***	10.93	309.54	25
	R-8M-127-4	8-RV-3	0.72	2.73	2	2.0	2.94	83.26	2
		8-RV-8	1.02	3.86	4	3.7	4.19	118.66	5
		8-RV-14	1.34	5.07	7	5.4	5.46	154.63	8
		8-RV-31*	1.85	7.00	14	7.0	7.53	213.25	15
		8-RS-8	1.30	4.92	5	1.8	5.40	152.93	6
		8-RS-14	1.69	6.40	8	1.9	6.98	197.67	10
		8-RS-31*	2.30	8.71	16	3.1	9.45	267.62	18
		8-LJ-48*	4.40	16.65	35	***	18.10	512.59	40
9	R-9M-127-1	9-RV-33	1.70	6.43	4.6	10.0	7.00	198.24	6
		9-RV-87*	2.64	9.99	11.5	15.0	11.08	313.79	13
		9-RS-33	2.20	8.33	5.3	2.3	9.05	256.30	6
		9-RS-87*	3.46	13.10	13.0	3.4	14.40	407.81	15
		9-LJ-160*	5.91	22.37	26.6	***	26.03	737.17	31
	R-9M-127-3	9-RV-33	3.90	14.76	8.4	11.0	15.75	446.04	10
		9-RV-87*	5.55	21.01	18.1	17.0	23.30	659.86	21
		9-RS-33	4.90	18.55	10.8	2.4	20.35	576.31	13
		9-RS-87*	6.75	25.55	21.7	3.5	28.75	814.20	25
		9-LJ-160*	17.20	65.10	79.0	***	83.40	2361.89	90
10	R-10M-127-1	10-RV-64	4.28	16.20	7.0	14.0	17.90	506.93	8
		10-RV-138*	5.93	22.45	14.0	22.0	25.30	716.50	16
		10-RS-64	5.40	20.44	8.4	3.0	22.85	647.11	10
		10-RS-138*	7.41	28.05	16.2	5.0	31.50	892.08	19
		10-LJ-238*	13.65	51.67	36	***	57.90	1639.73	41
	R-10M-127-3	10-RV-64	6.02	22.79	9.2	15.0	24.33	689.03	11
		10-RV-138*	8.01	30.32	17.2	23.0	33.45	947.30	20
		10-RS-64	7.56	28.61	11.4	3.7	30.80	872.26	13
		10-RS-138*	9.94	37.62	21	5.5	41.53	1178.96	24
		10-LJ-238*	22.47	85.05	61	***	109.30	3095.38	70
12	R-12M-127-1	12-RV-221	8.60	32.55	8	26.0	[illegible]	[illegible]	9
		12-RV-343*	10.74	40.65	12	35.0	43.55	1233.34	14
		12-RS-221	11.49	43.49	8	4.0	47.10	1333.87	10
		12-RS-343*	13.97	52.88	13	4.3	56.70	1605.74	15
		12-LJ-740*	24.30	91.98	28	***	99.80	2826.34	32
	R-12M-127-3	12-RV-221	16.61	62.87	10	29.0	67.65	191[illegible].85	11
		12-RV-343*	19.68	74.49	14	36.0	80.30	227[illegible].10	17
		12-RS-221	21.83	82.63	12	4.2	89.70	2540.39	13
		12-RS-343*	24.72	93.57	16	4.5	101.80	2882.93	19
		12-LJ-740	72	272.52	57	***	....	....	....
13	R-13M-127-1	13-RV-510	19.28	72.97	12	40.0	78.25	2216.04	14
		13-RV-760*	22.90	86.68	17	50.0	92.80	2628.10	20
		13-RS-510	26.35	99.73	14	7.3	105.3[illegible]	299[illegible]	16
		13-RS-760*	31.30	118.47	20	9.0	126.10	3571.[illegible]	23
		13-LJ-1394*	47.45	179.60	38	***	....	....	....
	R-13M-127-3	13-RV-510	30.40	115.06	16	42.0	125.00	3540.[illegible]	18
		13-RV-760*	34.90	132.10	22	52.0	144.20	4083.74	25
		13-RS-510	41.30	156.32	20	7.6	175.25	4963.08	23
		13-RS-760*	46.50	176.00	27	9.3	199.80	565[illegible].34	31
		13-LJ-1394*	93.8	355.03	70	***	....	....	....

* These floats are not recommended for gas service unless operating pressure (downstream) exceeds 30 psi.

** Viscosity immunity ceilings listed are for Stainless Steel floats only and fluid Sp. Gr. 1.0. For other fluid gravities, convert to sizing viscosity and use this value when comparing with values in table.

*** These floats are very sensitive to viscosity changes and do not offer any immunity to viscosity changes.

NOTE: All air flows are at 14.7 psia and 70°F.

Table 5

250 mm scale, plain taper tubes, rod guided floats

Meter Size	Tube No.	Float No.	Maximum Flow Rate						
			Water				Air		
			GPM	LPM	Pressure Drop Inches, W.C.	Visc. Immunity Ceiling, Cs.****	SCFM	SLPM	Pressure Drop Inches, W.C.
8	8M-25-3	8-GV-7	1.18	4.47	11	4.7	4.82	136.50	12
		8-GV-12	1.56	5.90	19	6.2	6.40	181.25	21
		8-GV-26*	2.24	8.48	39	9.1	9.23	261.39	45
		8-GS-7	1.54	5.83	17	1.6	6.50	184.08	19
		8-GS-12	2.06	7.80	31	1.6	8.60	243.55	35
		8-GS-26*	2.96	11.20	64	1.7	12.45	352.58	74
		8-LG-27	3.84	14.53	106	***	---	---	---
		8-LG-28	5.33	20.17	202	***	---	---	---
		8-LG-37	6.40	24.22	293	***	---	---	---
9	9M-25-2	9-GV-29	2.30	8.71	8	10.1	9.66	273.57	10
		9-GV-75	3.90	14.76	23	16.3	16.40	464.45	26
		9-GS-29	3.23	12.23	13	1.8	13.53	383.17	15
		9-GS-75	5.22	19.76	34	2.1	21.60	611.71	38
		9-LG-60	7.02	26.57	52	***	---	---	---
		9-LG-88	8.91	33.72	81	***	---	---	---
		9-LG-124	11.00	41.64	121	***	---	---	---
10	10M-25-2	10-GV-54	5.60	21.20	22	13.0	23.52	666.09	25
		10-GV-119*	8.52	32.25	38	19.4	35.48	1004.79	43
		10-GS-54	7.84	29.67	48	1.7	33.12	937.96	55
		10-GS-119*	11.71	44.32	81	2.0	49.75	1408.92	93
		10-LG-191	16.00	60.56	146	***	---	---	---
		10-LG-113	19.14	72.44	194	***	---	---	---
		10-LG-164	25.20	95.38	327	***	---	---	---
		10-LG-194	31.39	118.81	493	***	---	---	---
12	12M-25-3	12-GV-201	11.44	43.30	15	26.7	48.00	1359.36	17
		12-GV-315*	14.43	54.62	23	33.3	60.25	1706.28	27
		12-GS-201	16.06	60.79	23	4.0	66.35	1879.03	27
		12-GS-315*	20.05	75.89	35	5.0	82.70	2342.06	41
		12-LG-391	36.58	138.46	94	***	---	---	---
		12-LG-490	43.90	166.16	131	***	---	---	---
		12-LG-461**	58.95	223.13	220	***	---	---	---
13	13M-25-2	13-GV-465	23.66	89.55	28	40.0	100.00	2832.00	32
		13-GV-696*	29.6	112.04	43	48.8	122.20	3460.70	49
		13-GS-465	33.31	126.08	47	6.0	139.00	3936.48	53
		13-GS-696*	41.50	157.08	71	7.3	177.10	5015.47	81
		13-LG-822	64.40	243.75	151	***	---	---	---
		13-LG-844	69.20	261.92	172	***	---	---	---
		13-LG-866**	85.60	324.00	252	***	---	---	---
		13-LG-950**	102.6[illegible]	[illegible].34	352	***	---	---	---
		13-LG-1402	118.00	446.65	464	***	---	---	---
		13-LG-1465	129.50	490.16	551	***	---	---	---

* These floats not recommended for gas service unless operating pressure (downstream) exceeds 30 psi.

** These floats do not provide a 10-1 flow range. Range will be 5-1 or better.

*** These floats are very sensitive to viscosity changes and do not offer any immunity to viscosity changes.

**** Viscosity immunity ceilings listed are for Stainless Steel floats only and fluid Sp. Gr. 1.0. For other fluid gravities, convert to sizing viscosity and use this value when comparing with values in table.

NOTE: All air flows are at 14.7 psia and 70°F.

Capacities (Cont'd)

Table 6

All types of extensions

Meter Size	Tube No.	Float Type	Stn. Stl. Float Weight (gms)*	Max. Flow Rate Water (GPM)	Max. Flow Rate Air (SCFM)
7	R-7 M-127-1	Not Std.	24	0.6	2.5
	R-7 M-127-1	Not Std.	90	2.0	8.0
8	R-8 M-127-1	AV	30	1.5	6.0
	R-8 M-127-1	AV	135	3.2	14.5
	R-8 M-127-1	AS	30	2.0	8.3
	R-8 M-127-1	AS	135	4.0	15.5
	R-8 M-127-4	AV	30	2.3	9.5
	R-8 M-127-4	AV	135	5.0	20.0
	R-8 M-127-4	AS	30	2.8	11.6
	R-8 M-127-4	AS	135	5.7	23.0
9	R-9 M-127-1	AV	60	2.8	11.6
	R-9 M-127-1	AV	190	4.5	18.0
	R-9 M-127-1	AS	60	3.8	15.0
	R-9 M-127-1	AS	190	6.0	25.0
	R-9 M-127-3	AV	60	6.3	26.0
	R-9 M-127-3	AV	190	8.5	35.0
	R-9 M-127-3	AS	60	8.5	35.0
	R-9 M-127-3	AS	190	12.0	50.0
10	R-10 M-127-1	AV	100	6.0	25.0
	R-10 M-127-1	AV	270	9.0	37.3
	R-10 M-127-1	AS	100	7.5	31.0
	R-10 M-127-1	AS	270	13.0	54.0
	R-10 M-127-3	AV	100	8.0	33.0
	R-10 M-127-3	AV	270	13.5	56.0
	R-10 M-127-3	AS	100	10.5	45.0
	R-10 M-127-3	AS	270	18.0	75.0
12	R-12 M-127-1	AV	285	11.0	45.0
	R-12 M-127-1	AV	453	15.0	60.0
	R-12 M-127-1	AS	285	14.0	60.0
	R-12 M-127-1	AS	453	20.0	83.0
	R-12 M-127-3	AV	285	22.0	90.0
	R-12 M-127-3	AV	453	28.0	120.0
	R-12 M-127-3	AS	285	30.0	124.0
	R-12 M-127-3	AS	453	38.0	158.0
13	R-13 M-127-1	AV	505	22.0	91.0
	R-13 M-127-1	AV	865	28.0	116.0
	R-13 M-127-1	AS	505	30.0	125.0
	R-13 M-127-1	AS	865	37.0	154.0
	R-13 M-127-3	AV	505	35.0	150.0
	R-13 M-127-3	AV	865	46.0	191.0
	R-13 M-127-3	AS	505	45.0	190.0
	[illegible]	[illegible]	865	60.0	250.0

NOTE: All air flows are at 14.7 psia and 70°F.

Table 7

Close-coupled instruments

Meter Size	Tube No.	Float Type	Stn. Stl. Float Weight (gms)*	Max. Flow Rates Water (GPM)	Max. Flow Rates Air (SCFM)
6	R-6 M-127-1	Non Std. V	5.4	0.30	1.2
	R-6 M-127-1	Non Std. S	12.0	0.45	2.0
7	R-7 M-127-1	Non Std. V	13.0	0.45	2.0
	R-7 M-127-1	Non Std. S	25.0	0.80	3.5
8	R-8 M-127-1	V	33	1.8	7.3
	R-8 M-127-1	V	48	2.6	10.6
	R-8 M-127-1	S	33	1.9	7.7
	R-8 M-127-1	S	48	2.7	11.0
	R-8 M-127-4	V	33	2.4	9.8
	R-8 M-127-4	V	48	3.3	13.5
	R-8 M-127-4	S	33	2.6	10.6
	R-8 M-127-4	S	48	3.5	14.3
9	R-9 M-127-1	V	90	3.4	14.1
	R-9 M-127-1	V	120	3.9	16.2
	R-9 M-127-1	S	90	3.6	14.9
	R-9 M-127-1	S	120	4.2	17.4
	R-9 M-127-3	V	90	6.9	28.5
	R-9 M-127-3	V	120	8.0	33.1
	R-9 M-127-3	S	90	7.4	30.6
	R-9 M-127-3	S	120	8.5	35.2
10	R-10 M-127-1	V	163	6.9	29
	R-10 M-127-1	V	219	8.5	35
	R-10 M-127-1	S	163	7.2	30
	R-10 M-127-1	S	219	9.0	37
	R-10 M-127-3	V	163	8.7	36
	R-10 M-127-3	V	219	10.9	45
	R-10 M-127-3	S	163	9.8	40
	R-10 M-127-3	S	219	12.2	50
12	R-12 M-127-1	V	330	10.4	43
	R-12 M-127-1	V	560	13.4	55
	R-12 M-127-1	S	330	13.5	56
	R-12 M-127-1	S	560	17.4	72
	R-12 M-127-3	V	330	19.0	79
	R-12 M-127-3	V	560	24.5	101
	R-12 M-127-3	S	330	24.5	101
	R-12 M-127-3	S	560	31.5	130
13	R-13 M-127-1	V	850	23.5	97
	R-13 M-127-1	V	1200	27.0	110
	R-13 M-127-1	S	850	31.0	128
	R-13 M-127-1	S	1200	36.0	148
	R-13 M-127-3	V	850	35.5	147
	R-13 M-127-3	V	1200	42.0	173
	R-13 M-127-3	S	850	45.5	188
	R-13 M-127-3	S	1200	54.0	220

*Meters having floats whose weight exceeds that given in the following table require a downstream operating pressure of 30 psig or more for satisfactory operation in gas service.

Meter Size	[illegible]	8	9	10	12	13
Stn. Stl. Float Weight (gms)	[illegible]	90	120	190	350	600

Approximate Weights

Meter Size	Model 1110 Meter Only	Model 1110 With Box and Packing	Model 1140 Meter Only	Model 1140 With Box and Packing
2-6	5 lbs.	6 lbs.	8 lbs.	10 lbs.
7 & 8	9 lbs.	12 lbs.	11 lbs.	13 lbs.
10	20 lbs.	25 lbs.	25 lbs.	29 lbs.
12	22 lbs.	26 lbs.	31 lbs.	35 lbs.
13	36 lbs.	40 lbs.	48 lbs.	52 lbs.

Optional Equipment

Mountings – Brackets for panel mounting.
Valves – Available for connection sizes 1/4" through 3/4" only. Horizontal stem in outlet or inlet and fitting sizes 2 through 10.
Flow Controller – Brass or 316 Stainless Steel, integrally piped to sizes 2-6.
Electrical Alarms – Integral (High Frequency) or Extension Type (Reed Switch)
Multi-Tube Construction – Sizes 2-6 only
Indicating Pneumatic Transmitter
Indicating Electrical Transmitter

Ordering Information

To order, please specify:

1. Complete flow metering data:
   - Type of fluid
   - Maximum, minimum, normal flows
   - Temperature, pressure
   - Viscosity, specific gravity
   - Maximum allowable pressure drop
2. Model number and size of flowmeter
3. Connection arrangement and orientation
4. Materials of construction
5. Scale data and float type required
6. Options if desired

Specifications subject to change without notice.

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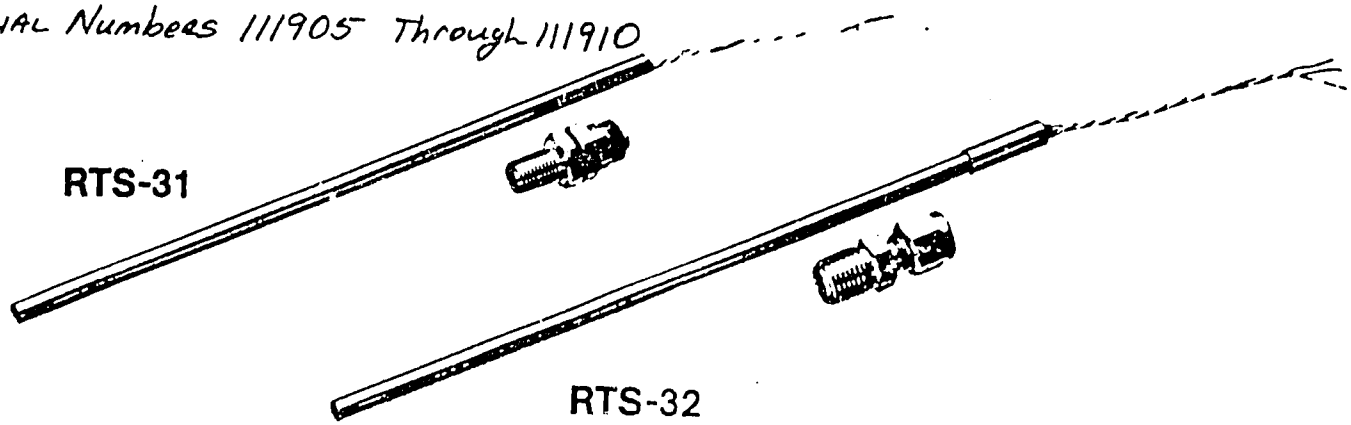
PRODUCT DATA

PLATINUM RESISTANCE TEMPERATURE SENSORS

RTS-31 & RTS-32

Medium Temperature Range
−200°C to +260°C
−320°F to +500°F

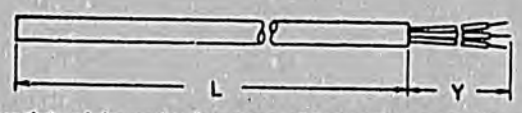
PART # RTS-32-A-100-A-8-4C-36
PRICE EACH: $60 ORDERED 6 = $360
SERIAL Numbers 111905 Through 111910



GENERAL PURPOSE PROBES
HEAVY DUTY SENSORS
LOW TO MEDIUM TEMPERATURE RANGE
STURDY LEAD ANCHOR
LONG TERM STABILITY
INTERCHANGEABILITY
INTERNATIONAL OR REFERENCE GRADE PLATINUM

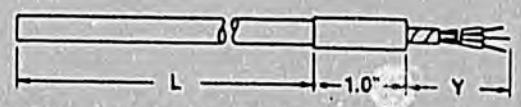
HY-CAL ENGINEERING
Santa Fe Springs, Ca. U.S.A. • (213) 6[illegible]-7785 • Telex [illegible]

RTS-31 GENERAL PURPOSE PLAIN RTD



Heavy duty plain probe for general industrial applications in fluid or air. Used with threaded fitting for some mounting arrangements.

RTS-32 GENERAL PURPOSE ADAPTER RTD



The adapter, added to the heavy duty plain probe, allows room to attach larger size leads or cables. Standard fittings may be used for mounting. Optional lead cable shown above.

PLATINUM RESISTANCE TEMPERATURE SENSORS

The Hy-Cal RTS-31 and RTS-32 Platinum Resistance Temperature Sensors have a record for precision and dependability. Designed for remote control monitoring and measurement of data in a low-medium temperature range, these sensors are suited for installation in different types of applications including building and plant temperature control, energy conservation, food processing and textile industries, automotive applications, machinery temperature control and in laboratories.

The unique strain-free and rugged construction of the RTS-31 and RTS-32 provide extremely dependable sensors. The probes are interchangeable and are available in International or Reference grade platinum.

The basic element is the well-proven Hy-Cal strain-free platinum wire wound sensor. The fully supported element has integral anchored leads that are isolated from mechanical strain, and shock or vibration effects.

With Teflon* leads, the probes are designed to give precision measurements over the temperature range of -200°C to +260°C. *Identical probes, models RTS-41 and RTS-42 have fiberglass leads to withstand a temperature range of -75°C to +500°C.*

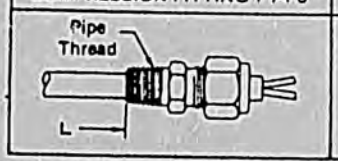
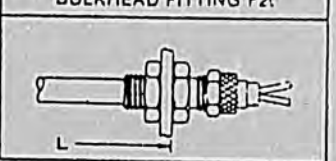
STURDY LEAD ANCHOR

To prevent breakage, lead wires are welded and anchored within the element. A thin outer ceramic tube covers the element and lead attachment, adding to the ruggedness of the lead anchor at this joint. Spacers of high purity alumina are used to separate the wires, avoiding short circuits. The element assembly is placed in a stainless steel sheath and the entire probe cavity packed with Magnesium Oxide to avoid vibration of the leads.

LONG TERM STABILITY

Stability of the sensors is obtained by proper selection of materials and a controlled annealing process. Only the most pure platinum wire and alumina offering matched thermal expansion are used in the sensors. These are assembled under clean room conditions to avoid contamination. After a proprietary refractory cement is used over the fine platinum wires to prevent thermal strain the sensor is annealed for maximum stability and sensitivity. This process is performed under strictly controlled procedures the key to Hy-Cal's selection as "Number One" by the customer. Request MTBF report.

MOUNTING HARDWARE

COMPRESSION FITTING F1-F6	BULKHEAD FITTING F20
	

Threaded compression fittings, F1 thru F6, or a bulkhead fitting, F-20, may be ordered to facilitate mounting the probe. Compression fittings are available in brass or stainless steel, 1/8", 1/4" or 1/2" NPT. When ordered with the probe, the factory will add necessary probe length to accommodate the fitting. Ferrule material should be specified: "N" = Neoprene (−40°F to +200°F) or "T" = Teflon (−300°F to +500°F).

*Trademark E.I. DuPont Co.

GENERAL SPECIFICATIONS

Temperature Range:	-200°C to +260°C, -320°F to +500°F
Sensing Element:	Platinum PT-385 0.00385 Ω / Ω /°C Platinum PT-392 0.00392 Ω / Ω /°C
Resistance at 0°C R_0:	100 ± 0.2Ω; 200 ± 0.4Ω; 500 ± 1Ω
Probe Body and Diameter:	SS body in standard dia. of 1/8", 3/16" and 1/4". Other dia. on order. Minimum length is 2".
Lead Wire:	2-, 3- or 4-wire lead configuration.
Lead Cable:	24 gage silver-coated stranded, copper with Teflon* insulation, shielded.
Pressure:	3000 psi
Recommended Current:	15 mA maximum, 1 to 5 mA preferable
Insulation Resistance:	50 Megohms minimum at 50 VDC
Time Constant:	1/8" dia. = 1.5 sec. 1/16" dia. = 3.0 sec. 1/4" dia. = 5.0 sec.

AVAILABLE OPTIONS

"POLYSEAL" -- An all-weather seal that provides a moisture-proof redundant seal to the lead exit. Order option X10 for underwater seal.

SILVER TIP — A silver or special copper alloy tip is used to generate a five-times faster response. It is recommended to improve the response where probes are installed in wells or in machined holes. Not available on 1/8" diameter.

CABLE LEAD WIRES — Available on the RTS-32 only, this option offers extra protection in damaging environments. Cables are 24 AWG silver coated stranded copper with Teflon* over each, tinned copper braid overall and Teflon overall. When cable leads are not specified, individual leads are 22 AWG Teflon insulated.

OFF-THE-SHELF

General purpose RTD probes of 100 ohm, PT-385 platinum are stocked in standard lengths. These are 1/4" diameter SS sheath with 3 foot 3-wire leads. Order RTS-31-A-100-C-"L"-3-36. Specify "L" length in inches for standard lengths of 4", 6", 8" and 12".

OTHER PRODUCTS

Hy-Cal has low, medium and high temperature probes in an extensive variety of configurations including threaded, reduced tip, spring loaded, surface sensors and gas and air probe assemblies.

Linearized RTD bridge amplifiers and 2-wire current transmitters are available to meet a variety of requirements. These are provided in single channel and multi-channel systems. Digital indicators for RTD input are available in single or multi-channel. Differential temperature transmitters and indicators are also standard products.

ORDERING INFORMATION

When ordering either the RTS-31 or the RTS-32 specify basic number, temperature coefficient, resistance at 0°C, sheath diameter, immersion length, lead wire configuration and length, and options. For detailed ordering information, see the latest RTS-31 and RTS-32 price list. Phone our Sales Department for further information on the complete temperature product line.

129-78-1
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HY-CAL ENGINEERING
12105 Los Nietos Rd. • Santa Fe Springs, Ca.-U.S.A.-90670 • (213) 698-7785 • Telex 67-4494

RADIATION SENSORS and APPLICATIONS

Model Number	Name	Picture Number	Type	Wavelength Range	Measurement	Typical Units Instantaneous Measurements	Typical Applications	Accessories 1/	Picture Number
LI-190SB	Quantum Sensor	1	Terrestrial Cosine Sensor	400-700 nm 2/	Photosynthetic Photon Flux Density (PPFD) 3/	$\mu E\ s^{-1}\ m^{-2}$ 4/	PPFD measurements in the field, growth chamber, greenhouse, phytotron. Studies concerning photosynthesis, plant growth & development, water relations, pathology, pollution, etc. in plant science, photobiology, biological and environmental sciences.	2003S Mounting & Leveling Fixture 2010S Miniature Shadow Band 2222SB Extension Cable	19 13
LI-191SB	Line Quantum Sensor	5	Terrestrial Line Sensor	400-700 nm	PPFD	$\mu E\ s^{-1}\ m^{-2}$	Spatially-averaged PPFD along 1 meter length: Plant canopy profiling studies, correlation between radiation interception and dry matter accumulation; same areas of applications as LI-190SB.	2222SB Extension Cable	
LI-229SB	Near Infrared Sensor	4	Terrestrial Cosine Sensor	745-815 nm	Near Infrared Irradiance	$W\ m^{-2}$ 5/	Near Infrared Irradiance: Some of the same applications as the LI-190SB.	Same as LI-190SB	
LI-190SEB	Photosynthetic Irradiance Sensor		Terrestrial Cosine Sensor	400-700 nm	Photosynthetic Irradiance (PI)	$W\ m^{-2}$	Radiant energy flux density in 400-700 nm waveband.	Same as LI-190SB	
LI-192SB	Underwater Quantum Sensor	7	Underwater Cosine Sensor 6/	400-700 nm	PPFD	$\mu E\ s^{-1}\ m^{-2}$	PPFD underwater: Productivity studies, vertical profiling and photosynthesis studies, etc. in oceanography, limnology, marine science, and photobiology.	2009S Lowering Frame 2222UWB Underwater Cable	17 18
LI-193SB	Spherical Quantum Sensor	6	Underwater Spherical Sensor (4π) 7/	400-700 nm	Photosynthetic Photon Flux Fluence Rate (PPFFR) 8/	$\mu E\ s^{-1}\ m^{-2}$	PPFFR underwater (PAR from all directions): Same applications as LI-192SB.	Same as LI-192SB	
LI-200SB	Pyranometer	2	Terrestrial Cosine Sensor	400-1100 nm 9/	Solar Irradiance	$W\ m^{-2}$	Solar Irradiance or Solar Energy: Energy assessment, monitoring, site evaluation, solar collector evaluation; meteorology, plant science, hydrology, irrigation scheduling, environmental science.	Same as LI-190SB	
LI-210SB	Photometric Sensor	3	Terrestrial Cosine Sensor	380-770 nm 9/	Illuminance	lux 9/	Illuminance: Indoor and outdoor lighting studies, illumination engineering, passive solar energy, architecture, and biological studies.	Same as LI-190SB	
LI-212SB	Underwater Photometric Sensor	8	Underwater Cosine Sensor 6/	380-770 nm 9/	Illuminance	lux	Underwater Illuminance: Biological and lighting studies.	Same as LI-192SB	

1/ Can also be used for atmospheric measurements.
2/ Photosynthetically Active Radiation (PAR).
3/ Also known as Quantum Flux Density.
4/ Also known as Quantum Scalar Irradiance.
5/ Spectral response follows the CIE Standard Observer Curve.
6/ Units currently in use are moles, einsteins, photons, and quanta. $1\ \mu mol\ s^{-1}m^{-2} = 1\ \mu E\ s^{-1}m^{-2} = 6.022 \cdot 10^{17}$ photons $s^{-1}m^{-2} = 6.022 \cdot 10^{17}$ quanta $s^{-1}m^{-2}$ (6,9,14).
7/ International System of Units (SI).
8/ A Millivolt Adapter is included with all sensors for direct mV output.
9/ Calibrated using Eppley PSP (for 285-2600 nm).

METERS, INTEGRATORS and ACCESSORIES

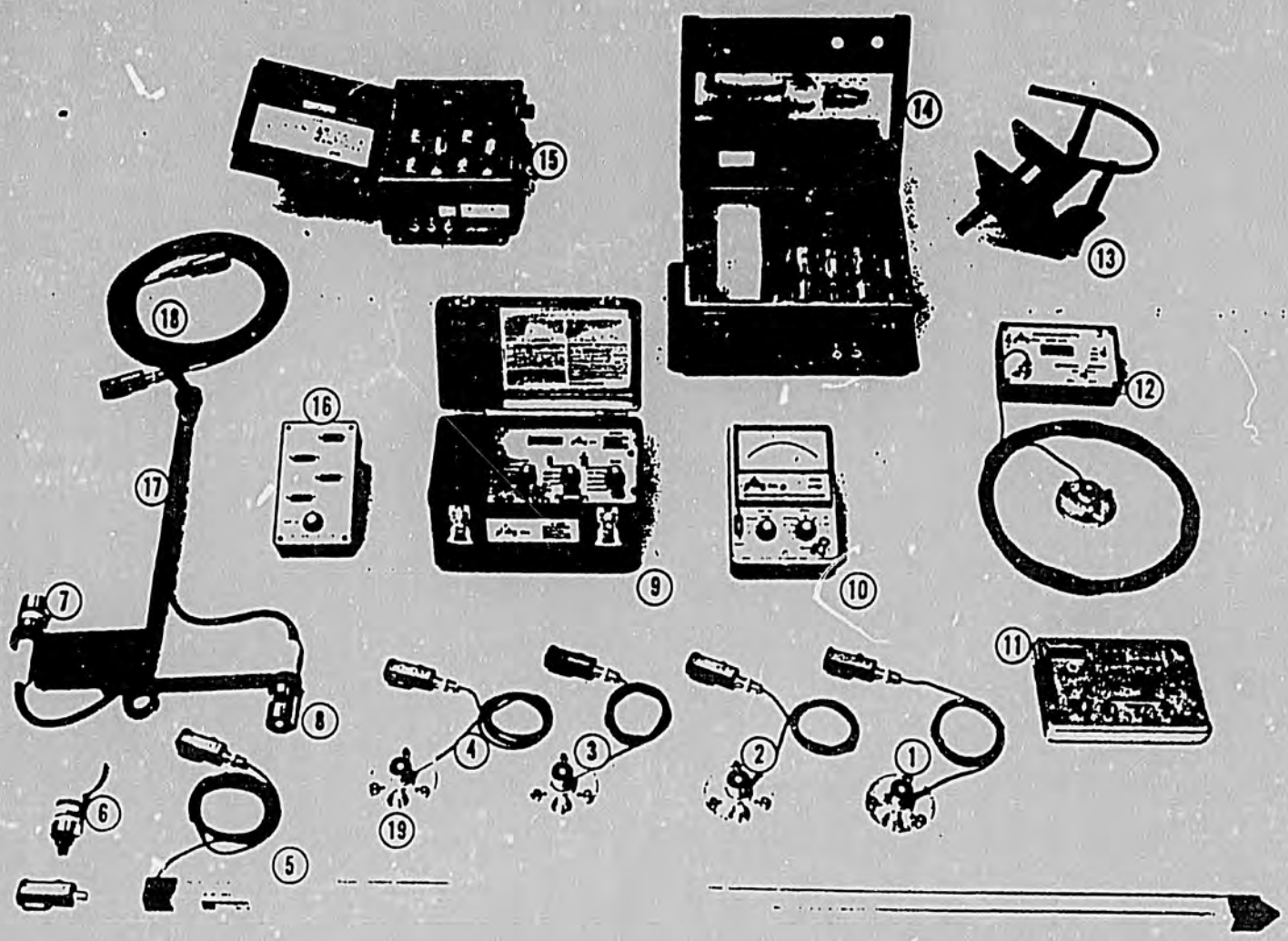
Model Number	Name	Picture Number	INSTANTANEOUS Range	INSTANTANEOUS Accuracy	INTEGRATED 1/ Integration Periods	INTEGRATED 1/ Range	Data Output	Power	Accessories
LI-188B	Integrating Quantum Radiometer Photometer	9	5 Ranges, low & high listed 1.999, 19.900 $\mu E\ s^{-1}m^{-2}$ 0.1999, 1.999 $W\ m^{-2}$ 1.999, 19.900 lux 1.999 mV, 19.99 V	± 0.5% full scale ± 1 digit (25°C) ± 1% full scale ± 1 digit (0 to 55 C)	1, 10, 100, 1000 seconds	5 Ranges, low & high listed 1.999, 19.990 $\mu E\ s^{-1}m^{-2}$ 0.1999, 1.999 $W\ m^{-2}$ 19.99, 199.900 lux 1.999 mV, 19.99 V	3½-digit LCD Analog (0 to 100 mV full scale any range)	Battery AC (optional)	SS-3 Sensor Selector 185PSA Power Supply (AC) 2223S Recorder Leads 2224SB Millivolt Leads 2225SB Integrator Leads
LI-185B	Quantum Radiometer Photometer	10	9 Ranges, low & high listed 3, 3 x 10³ $\mu E\ s^{-1}m^{-2}$ 0.3, 3 x 10³ $W\ m^{-2}$ 30, 3 x 10³ lux 3 mV, 30 V	± 1% full scale (0 to 55 C)			Meter Analog (0 to 100 mV full scale any range)	Battery AC (optional)	Same as LI-188B 2004-185 Carrying Case
LI-1776	Solar Meter/ Monitor		3072 $\mu E\ s^{-1}m^{-2}$ 3072 $W\ m^{-2}$ 974.1 BTU $ft^{-2}h^{-1}$ 307.2 klux (1000 lux) 30.72 mV	± 0.5% full scale ± 1 digit (25 C) ± 1% full scale ± 1 digit (0 to 55 C)	LI-1776/02A: 24 hours (others available) LI-1776/02A, LI-1776/02M or LI-1776/07: 7.5, 15, 30 minutes, 1, 2, 4, 8, 12, or 24 hours (user adjustable)	64,47.5 m^{-2} 9999 Wh m^{-2} 7792 BTU m^{-2} 999.9 klux h 99.99 mV h	Full 4-digit LCD Analog (instantaneous values) Cassette tape output LI-1776/02A, LI-1776/02M RS-232-C output to computer system: LI-1776/07	AC External battery Internal battery backup	1776-01 Millivolt Input Module 1776-06 Weatherproof Case 1600-04 Cassette Tape Recorder 1600-05 Cassette Tape Reader 2228S Millivolt Recorder Leads 2004-1776 Carrying Case 1776-08 External Battery Leads
LI-175	Solar Meter/ Integrator	12	2000 $W\ m^{-2}$ 634 BTU $ft^{-2}h^{-1}$	± 1% full scale ± 1 digit (25 C)	User timed	9999 Wh m^{-2} 9999 BTU ft^{-2}	Full 4-digit LCD	AC External battery Internal battery backup	1776-08 External Battery Leads
LI-510B	Integrator	15			User timed	9999 counts 2/	Full 4-digit LED	Battery	2225SB Integrator Leads 2226SB Integrator Millivolt Leads
LI-550B	Printing Integrator	14			1, 10 minutes 1, 24 hours	9999 counts 2/	Printer: 14 characters, 4 digit data print	Battery	2225SB Integrator Leads 2226SB Integrator Millivolt Leads

1/ See the individual instrument specifications for accuracy information.
2/ Count will depend on type of sensor and integration rate setting. Will not overrange for a full day's radiation.
3/ The appropriate sensor(s) must also be ordered (a pyranometer is included with the LI-175).

PART # LI-200SB-50 COST $215
" " 2003S MOUNTING FIXTURE COST $42
SERIAL NO. PY5418

Radiation Measurement—*A System to Meet Your Needs*

SENSORS, METERS, INTEGRATORS, ACCESSORIES



1. LI-190SB Quantum Sensor
2. LI-200SB Pyranometer Sensor
3. LI-210SB Photometric Sensor
4. LI-220SB Near Infrared Sensor
5. LI-191SB Line Quantum Sensor
6. LI-193SB Spherical Quantum Sensor
7. LI-192SB Underwater Quantum Sensor
8. LI-212SB Underwater Photometric Sensor
9. LI-188B Integrating Quantum/Radiometer/Photometer
10. LI-185B Quantum Radiometer Photometer
11. LI-1776 Solar Monitor
12. LI-176 Solar-Meter/Integrator System
13. 2010S Miniature Shadow Bar
14. LI-550B Printing Integrator
15. LI-510B Integrator
16. SS-3 Sensor Selector
17. 2009S Lowering Frame
18. 2222UWB Underwater Cable
19. 2003S Mounting and Leveling Fixture

LI-COR offers you a broad range of instruments to fit your particular applications for radiation measurement in the field or lab.

Several types of sensors are available for photosynthetically active radiation (both atmospheric and underwater), plus solar energy, illuminance, and near infrared radiation. Instantaneous or integrated measurements are provided when sensors are used with the appropriate LI-COR meter or integrator. Accessories are offered for the sensors and readouts to complete the system.

Comprehensive spectral measurement and analysis can be accomplished using the LI-1800 Portable Spectroradiometric Research System, or the LI-1800UW Underwater Spectroradiometer. Completely self-contained and weatherproof, the LI-1800 utilizes its own internal microcomputer and an external handheld terminal for control. A wide selection of accessories gives the LI-1800 added versatility and flexibility for numerous applications.

To select the instruments that best fit your requirements, refer to the tables on the next page.

CERTIFICATE of CALIBRATION
LI-COR PYRANOMETER SENSOR

Model Number: LI-200SB Pyranometer

Serial Number: PY5418 Date of Calibration: 12/16/83 By: JL

Output:* 50.9 microamps per 1000 watts m^2

Calconnector resistance for SENSOR (in air) 2818 ohms

Output:** 10.0 millivolts per 1000 watts m^{-2} when using millivolt adaptor.
3.15 millivolts per 100 BTU ft^{-2} h^{-1} when using millivolt adaptor.
Calconnector resistance for millivolt adaptor 196.5 ohms

The above sensor is supplied with a calibrated connector (calconnector) that has resistance values unique to that sensor. For that reason, the calconnector has a serial number that matches the serial number on the sensor. ALWAYS MAKE SURE THAT THE SENSOR IS USED WITH THE CALCONNECTOR THAT HAS THE SAME SERIAL NUMBER.

This feature allows the above sensor to be used with any LI-COR LI-185B, LI-188B, and LI-1776 without need for correction factors or recalibration of the readout instrument in order to obtain a direct readout.

**When using a sensor with a LI-COR LI-510B or LI-550B Integrator, the sensor's calibration constant as listed here must be used to determine the relationship between the sensor input and the counts recorded by the integrator. See sample calculations in the LI-510B, LI-550B manual for further instructions.*

***Each LI-COR sensor is provided with a millivolt adapter. There is also a resistance in the [illegible] that is sensed when the millivolt adapter is connected to the sensor to allow for direct millivolt output.*

IMPORTANT: Read the appropriate sensor manual before using this sensor.

IMPORTANT: It is recommended that sensors be recalibrated every two years.

Note: LI-COR Pyranometers are calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions. As of April 1, 1977, the calibration traceability of Eppley solar radiation measuring instruments has been changed from the International Pyrheliometric Scale of 1956 (IPS 1956) to the Absolute Scale (SI). This change, based on the results of IPC IV, is such that instruments calibrated in SI units (traceable to the World Radiometric Reference, WRR) yield irradiance values which are 2.1% higher than values which would be obtained using Eppley instruments calibrated previously and referenced to IPS. See the instruction manual for further details on calibration.

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Phone (402) 467-3576 / TWX 910-621-8116

APPENDIX 3
Sample Datalogger Output

KEY TO DATALOGGER OUTPUT

CHANNEL #	PARAMETER	QUANTITY	UNITS
000/071	T-IN	Collector Inlet Temp.	$^oC/^oF$
001/073	T-OUT	Collector Outlet Temp.	$^oC/^oF$
003/075	T-AMB	Ambient Temp.	$^oC/^oF$
010/076	WATTS/BTU	Solar Insolation	W/M^2 $BTU/HR/FT^2$
061/081	DT/I	Calculated*	$^oC\text{-}M^2/W$ $^oF\text{-}HR\text{-}FT^2/BTU$
066	EFF	Efficiency**	

* DT/I = (Tinlet - Tamb)/Insolation

** EFF = Instantaenous Efficiency
= Mc_p(Toutlet - Tinlet)/Indolation*Collector Area

m = 2.5[illegible] liters/minute (metric units)
= 0.65 gallons/minute (English units)

066	0.55395	EFF	071	[illegible]	T-IN	073	134.[illegible]	T-OT	075	[illegible]	T-AB	076	[illegible]	BTU	
081	0.27136	DT/I	085	0.55580	EFF										
12:03:26 NOV29,1984															
000	53.2278	T-IN	001	[illegible]	T-OUT	003	25.0016	T-AMB	010	607.585	WATTS	061	0.04630	DT/I	
066	0.53888	EFF	071	127.810	T-IN	073	134.532	T-OT	075	77.0029	T-AB	076	192.324	BTU	
081	0.26418	DT/I	085	0.54668	EFF										
12:04:56 NOV29,1984															
000	53.2707	T-IN	001	[illegible]	T-OUT	003	24.5735	T-AMB	010	611.791	WATTS	061	0.04615	DT/I	
066	0.54345	EFF	071	127.802	T-IN	073	134.802	T-OT	075	76.2332	T-AB	076	196.176	BTU	
081	0.26331	DT/I	085	0.54526	EFF										
12:06:26 NOV29,1984															
000	53.3775	T-IN	001	[illegible]	T-OUT	003	25.4298	T-AMB	010	613.664	WATTS	061	0.04545	DT/I	
066	0.53124	EFF	071	128.079	T-IN	073	134.763	T-OT	075	[illegible]	T-AB	076	193.990	BTU	
081	0.25932	DT/I	085	0.53601	EFF										
12:07:56 NOV29,1984															
000	53.2066	T-IN	001	[illegible]	T-OUT	003	25.9864	T-AMB	010	612.802	WATTS	061	0.04442	DT/I	
066	0.56521	EFF	071	127.222	T-IN	073	135.110	T-OT	075	[illegible]	T-AB	076	193.339	BTU	
081	0.25342	DT/I	085	0.58715	EFF										
12:09:26 NOV29,1984															
000	53.3775	T-IN	001	[illegible]	T-OUT	003	26.0934	T-AMB	010	614.204	WATTS	061	0.04442	DT/I	
066	0.55326	EFF	071	128.079	T-IN	073	135.033	T-OT	075	78.9642	T-AB	076	193.781	BTU	
081	0.25344	DT/I	085	0.55511	EFF										
12:10:56 NOV29,1984															
000	53.5322	T-IN	001	[illegible]	T-OUT	003	25.9269	T-AMB	010	621.526	WATTS	061	0.04420	DT/I	
066	0.52206	EFF	071	128.358	T-IN	073	135.042	T-OT	075	78.6634	T-AB	076	197.038	BTU	
081	0.25318	DT/I	085	0.52481	EFF										
12:12:26 NOV29,1984															
000	53.6391	T-IN	001	[illegible]	T-OUT	003	25.4273	T-AMB	010	615.152	WATTS	061	0.04427	DT/I	
066	0.53720	EFF	071	128.550	T-IN	073	135.543	T-OT	075	77.8591	T-AB	076	200.297	BTU	
081	0.25256	DT/I	085	0.53900	EFF										
12:13:56 NOV29,1984															
000	53.5963	T-IN	001	[illegible]	T-OUT	003	24.4497	T-AMB	010	613.447	WATTS	061	0.04598	DT/I	
066	0.56251	EFF	071	128.421	T-IN	073	135.774	T-OT	075	76.0095	T-AB	076	199.979	BTU	
081	0.26235	DT/I	085	0.56429	EFF										
12:15:26 NOV29,1984															
000	53.7032	T-IN	001	[illegible]	T-OUT	003	24.5568	T-AMB	010	634.012	WATTS	061	0.04592	DT/I	
066	0.54200	EFF	071	128.666	T-IN	073	135.697	T-OT	075	76.2022	T-AB	076	200.031	BTU	
081	0.26228	DT/I	085	0.54381	EFF										
12:16:56 NOV29,1984															
000	53.8100	T-IN	001	[illegible]	T-OUT	003	24.7494	T-AMB	010	615.652	WATTS	061	0.04565	DT/I	
066	0.53977	EFF	071	128.850	T-IN	073	135.890	T-OT	075	76.5476	T-AB	076	200.864	BTU	
081	0.26042	DT/I	085	0.54158	EFF										
12:18:26 NOV29,1984															
000	53.8941	T-IN	001	[illegible]	T-OUT	003	25.0663	T-AMB	010	611.365	WATTS	061	0.04713	DT/I	
066	0.53643	EFF	071	128.923	T-IN	073	135.697	T-OT	075	77.0114	T-AB	076	193.264	BTU	
081	0.26887	DT/I	085	[illegible]	EFF										
12:19:56 NOV29,1984															
000	54.0024	T-IN	001	[illegible]	T-OUT	003	25.5844	T-AMB	010	611.740	WATTS	061	0.04645	DT/I	
066	0.52179	EFF	071	[illegible]	T-IN	073	135.736	T-OT	075	78.0514	T-AB	076	193.004	BTU	
081	0.26503	DT/I	085	[illegible]	EFF										
12:21:26 NOV29,1984															

000	54.0503	T-IN	001	58.5002	T-OUT	003	25.[illegible]	T-AMB	[illegible]	[illegible]	[illegible]	061	[illegible]	[illegible]	
066	0.57136	EFF	071	129.291	T-IN	073	136.400	T-OT	075	78.5384	T-AB	076	191.862	BTU	
081	0.26400	DT/I	085	0.5732[illegible]	EFF										
12:22:56 NOV29,1984															
000	54.1352	T-IN	001	58.1072	T-OUT	003	25.4820	T-AMB	010	608.533	WATTS	061	0.04709	DT/I	
066	0.57409	EFF	071	129.444	T-IN	073	136.593	T-OT	075	77.8676	T-AB	076	191.992	BTU	
081	0.2682[illegible]	DT/I	085	0.57601	EFF										
12:24:26 NOV29,1984															
000	54.0503	T-IN	001	58.1214	T-OUT	003	25.6951	T-AMB	010	601.171	WATTS	061	0.04716	DT/I	
066	0.60300	EFF	071	129.291	T-IN	073	136.708	T-OT	075	78.2530	T-AB	076	189.676	BTU	
081	0.26908	DT/I	085	0.60501	EFF										
12:25:56 NOV29,1984															
000	54.1947	T-IN	001	57.8665	T-OUT	003	26.0140	T-AMB	010	606.548	WATTS	061	0.04647	DT/I	
066	0.53295	EFF	071	129.556	T-IN	073	136.160	T-OT	075	78.8611	T-AB	076	191.208	BTU	
081	0.26510	DT/I	085	0.53473	EFF										
12:27:26 NOV29,1984															
000	54.3229	T-IN	001	58.0177	T-OUT	003	26.9546	T-AMB	010	612.612	WATTS	061	0.04466	DT/I	
066	0.53324	EFF	071	129.281	T-IN	073	136.468	T-OT	075	80.5131	T-AB	076	193.342	BTU	
081	0.25480	DT/I	085	0.5350[illegible]	EFF										
12:28:56 NOV29,1984															
000	54.3015	T-IN	001	57.9735	T-OUT	003	27.2543	T-AMB	010	617.432	WATTS	061	0.04381	DT/I	
066	0.52315	EFF	071	129.243	T-IN	073	136.352	T-OT	075	81.0577	T-AB	076	194.800	BTU	
081	0.24992	DT/I	085	0.52490	EFF										
12:30:26 NOV29,1984															
000	54.3495	T-IN	001	58.0644	T-OUT	003	26.5953	T-AMB	010	609.514	WATTS	061	0.04621	DT/I	
066	0.54409	EFF	071	129.[illegible]	T-IN	073	136.516	T-OT	075	79.8716	T-AB	076	189.494	BTU	
081	0.26364	DT/I	085	0.54590	EFF										
12:31:56 NOV29,1984															
000	54.4135	T-IN	001	[illegible]	T-OUT	003	26.5077	T-AMB	010	595.004	WATTS	061	0.04690	DT/I	
066	0.55240	EFF	071	129.944	T-IN	073	136.670	T-OT	075	79.2174	T-AB	076	187.724	BTU	
081	0.26756	DT/I	085	0.55424	EFF										
12:33:26 NOV29,1984															
000	54.5417	T-IN	001	58.0425	T-OUT	003	25.5677	T-AMB	010	573.552	WATTS	061	0.05052	DT/I	
066	0.53698	EFF	071	130.125	T-IN	073	136.477	T-OT	075	78.0318	T-AB	076	180.957	BTU	
081	0.28821	DT/I	085	0.5382[illegible]	EFF										
12:34:14 NOV29,1984															
000	54.5845	T-IN	001	57.9[illegible]	T-OUT	003	25.1813	T-AMB	010	574.[illegible]	WATTS	061	0.05116	DT/I	
066	0.51953	EFF	071	130.[illegible]	T-IN	073	136.362	T-OT	[illegible]	[illegible]	T-AB	076	181.321	BTU	
081	0.29188	DT/I	085	0.521[illegible]	EFF										
12:34:39 NOV29,1984															
000	54.5417	T-IN	001	[illegible]	T-OUT	003	25.3984	T-AMB	010	558.[illegible]	WATTS	061	0.05129	DT/I	
066	0.53203	EFF	071	130.1[illegible]	T-IN	073	136.362	T-OT	[illegible]	77.2135	T-AB	076	179.291	BTU	
081	0.29251	DT/I	085	0.5318[illegible]	EFF										
12:34:56 NOV29,1984															
000	54.541[illegible]	T-IN	[illegible]	58.0[illegible]	T-OUT	003	25.6105	T-AMB	010	5[illegible]	WATTS	061	0.05091	DT/I	
066	0.51534	EFF	[illegible]	130.1[illegible]	T-IN	073	136.430	T-OT	075	78.0987	T-AB	076	179.291	BTU	
081	0.29046	DT/I	[illegible]	0.5[illegible]	EFF										
12:36:11 NOV29,1984															
000	54.62[illegible]	T-IN	[illegible]	58.0644	T-OUT	003	25.8[illegible]	T-AMB	010	5[illegible]	WATTS	061	0.05017	DT/I	
066	0.5[illegible]	EFF	071	130.329	T-IN	073	136.516	T-OT	075	78.4842	T-AB	076	181.139	BTU	
081	0.28[illegible]	DT/I	[illegible]	0.5[illegible]	EFF										

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12:36:13 N0029,1984
000    54.6058  T-IN    001    58.0644  T-OUT   003    25.5463  T-AMB   010    522.072  WATTS   061    0.05080 DT/I
066     0.53181 EFF    071   130.290   T-IN    073   136.516   T-OUT   075    27.9833  T-AB    076   180.489  BTU
081     0.28981 DT/I   085     0.53154 EFF
12:37:56 N0029,1984
000    54.6486  T-IN    001    58.0644  T-OUT   003    25.2175  T-AMB   010    559.192  WATTS   061    0.05084 DT/I
066     0.52798 EFF    071   130.367   T-IN    073   136.516   T-OUT   075    28.2915  T-AB    076   179.552  BTU
081     0.29003 DT/I   085     0.52974 EFF
12:39:28 N0029,1984
000    54.7340  T-IN    001    58.0427  T-OUT   003    26.0382  T-AMB   010    557.022  WATTS   061    0.05198 DT/I
066     0.52228 EFF    071   130.571   T-IN    073   135.427   T-OUT   075    28.8676  T-AB    076   174.164  BTU
081     0.29652 DT/I   085     0.52[illegible] EFF
****
13:02:27 N0029,1984
000    55.0332  T-IN    001    57.5911  T-OUT   003    24.5042  T-AMB   010    464.009  WATTS   061    0.06558 DT/I
066     0.48536 EFF    071   131.060   T-IN    073   135.668   T-OUT   075    26.2026  T-AB    076   146.395  BTU
081     0.37414 DT/I   085     0.48696 EFF
13:03:57 N0029,1984
000    55.0546  T-IN    001    57.5147  T-OUT   003    24.5186  T-AMB   010    464.072  WATTS   061    0.06580 DT/I
066     0.48528 EFF    071   131.078   T-IN    073   135.707   T-OUT   075    26.1355  T-AB    076   146.421  BTU
081     0.37539 DT/I   085     0.[illegible] EFF
13:05:27 N0029,1984
000    55.1291  T-IN    001    57.[illegible]  T-OUT   003    24.6137  T-AMB   010    441.381  WATTS   061    0.06852 DT/I
066     0.50148 EFF    071   131.212   T-IN    073   135.803   T-OUT   075    26.3946  T-AB    076   140.518  BTU
081     0.39090 DT/I   085     0.50115 EFF
13:06:57 N0029,1984
000    55.1291  T-IN    [illegible]  T-OUT   003    24.8270  T-AMB   010    441.422  WATTS   061    0.06865 DT/I
066     0.48891 EFF    [illegible]  T-IN    073   135.649   T-OUT   075    26.6900  T-AB    076   139.268  BTU
081     0.39164 DT/I   [illegible] EFF
13:08:27 N0029,1984
000    55.[illegible]  T-IN    [illegible]  T-OUT   003    24.7849  T-AMB   010    444.[illegible]  WATTS   061    0.06826 DT/I
066     0.49076 EFF    [illegible]  T-IN    073   135.649   T-OUT   075    26.6129  T-AB    076   140.153  BTU
081     0.38944 DT/I   085     0.49150 EFF
13:09:57 N0029,1984
000    55.[illegible]  T-IN    [illegible]  T-OUT   003    25.1031  T-AMB   010    444.721  WATTS   061    0.06770 DT/I
066     [illegible] EFF    131.186   T-IN    073   135.687   T-OUT   075    27.1909  T-AB    076   140.310  BTU
081     [illegible] DT/I   085     0.47420 EFF
13:11:27 N0029,1984
000    55.2[illegible]  T-IN    [illegible]  T-OUT   003    25.0507  T-AMB   010    435.650  WATTS   061    0.06734 DT/I
066     0.4[illegible] EFF    131.454   T-IN    073   135.870   T-OUT   075    28.5312  T-AB    076   137.757  BTU
081     0.[illegible] DT/I   085     0.49590 EFF
13:12:57 N0029,1984
000    55.2735  T-IN    [illegible]  T-OUT   003    25.2941  T-AMB   010    424.843  WATTS   061    0.07073 DT/I
066     0.49147 EFF    071   131.49[illegible]  T-IN    073   135.755   T-OUT   075    27.[illegible]93  T-AB    076   133.723  BTU
081     0.40354 DT/I   085     0.49311 EFF
13:14:27 N0029,1984
000    55.1606  T-IN    001    57.6629  T-OUT   003    24.8873  T-AMB   010    440.542  WATTS   061    0.06876 DT/I
066     0.49[illegible] EFF    071   131.300   T-IN    073   135.793   T-OUT   075    26.7971  T-AB    076   138.928  BTU
081     0.39231 DT/I   085     0.50034 EFF
13:15:57 N0029,1984
000    55.0811  T-IN    001    57.5[illegible]  T-OUT   003    24.1[illegible]  T-AMB   010    435.[illegible]  WATTS   061    0.07038 DT/I
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066	0.44465	EFF	071	[illegible]	T-IN	073	135.56[illegible]	T-OT	075	[illegible]	T-AB	076	[illegible]	BTU	
081	0.40155	DT/I	085	0.44630	EFF										
13:16:51 NOV29,1984															
000	55.0384	T-IN	[illegible]	[illegible]	T-OUT	003	24.3072	T-AMB	010	434.[illegible]	WATTS	061	0.07034	DT/I	
066	0.42623	EFF	[illegible]	131.069	T-IN	073	135.331	T-OT	075	[illegible]	T-AB	076	137.835	BTU	
081	0.40130	DT/I	[illegible]	[illegible]	EFF										
13:17:27 NOV29,1984															
000	55.0511	T-IN	[illegible]	[illegible]	T-OUT	003	24.4005	T-AMB	010	434.[illegible]	WATTS	061	0.07047	DT/I	
066	0.46663	EFF	[illegible]	[illegible]	T-IN	073	135.292	T-OT	075	[illegible]	T-AB	076	137.002	BTU	
081	0.40205	DT/I	[illegible]	[illegible]	EFF										
13:18:57 NOV 27,1984															
000	55.1025	T-IN	[illegible]	[illegible]	T-OUT	003	24.5019	T-AMB	010	445.[illegible]	WATTS	061	0.06873	DT/I	
066	0.45515	EFF	[illegible]	131.185	T-IN	073	135.331	T-OT	075	[illegible]	T-AB	076	140.463	BTU	
081	0.[illegible]	DT/I	[illegible]	0.45667	EFF										
13:20:27 NOV [illegible],1984															
[illegible]	55.[illegible]	T-IN	[illegible]	[illegible]	T-OUT	003	24.3567	T-AMB	010	446.[illegible]	WATTS	061	0.06886	DT/I	
[illegible]	[illegible]	[illegible]	[illegible]	131.[illegible]	T-IN	073	135.494	T-OT	075	[illegible]	T-AB	076	140.986	BTU	
081	0.39286	DT/I	[illegible]	0.4[illegible]	EFF										
13:21:57 NOV [illegible],1984															
000	55.[illegible]	T-IN	[illegible]	[illegible]	T-OUT	003	24.3741	T-AMB	010	44[illegible]	WATTS	061	0.06989	DT/I	
066	0.45529	EFF	[illegible]	131.[illegible]	T-IN	073	135.329	T-OT	075	[illegible]	T-AB	076	138.904	BTU	
081	0.39822	DT/I	[illegible]	0.45[illegible]	EFF										
13:23:27 NOV27,1984															
000	55.2360	T-IN	[illegible]	[illegible]	T-OUT	003	24.5700	T-AMB	010	44[illegible]	WATTS	061	0.06892	DT/I	
066	0.44697	EFF	071	131.425	T-IN	073	135.494	T-OT	075	[illegible]	T-AB	076	140.388	BTU	
081	0.39318	DT/I	085	0.44846	EFF										
13:23:51 NOV29,1984															
000	55.1932	T-IN	001	52.5612	T-OUT	003	24.2471	T-AMB	010	43[illegible]	WATTS	061	0.06875	DT/I	
066	0.47030	EFF	071	131.348	T-IN	073	135.610	T-OT	075	[illegible]	T-AB	076	139.737	BTU	
081	0.39225	DT/I	085	0.47182	EFF										
13:24:57 NOV29,1984															
000	55.1291	T-IN	001	52.5392	T-OUT	003	24.6[illegible]	T-AMB	010	438.[illegible]	WATTS	061	0.06941	DT/I	
066	0.48332	EFF	071	131.212	T-IN	073	135.572	T-OT	075	[illegible]	T-AB	076	138.410	BTU	
081	0.39602	DT/I	085	0.48498	EFF										
13:26:27 NOV29,1984															
000	55.1291	T-IN	001	52.4[illegible]	T-OUT	003	24.5922	T-AMB	010	441.139	WATTS	061	0.06919	DT/I	
[illegible]	0.46[illegible]	EFF	071	131.232	T-IN	073	135.456	T-OT	075	[illegible]	T-AB	076	139.242	BTU	
081	0.39475	DT/I	085	0.46923	EFF										
13:27:57 NOV29,1984															
000	55.2360	T-IN	001	52.6039	T-OUT	003	24.2[illegible]	T-AMB	010	4[illegible]	WATTS	061	0.06659	DT/I	
066	0.45456	EFF	071	131.425	T-IN	073	135.687	T-OT	075	[illegible]	T-AB	076	144.578	BTU	
081	0.37992	DT/I	085	0.45608	EFF										
13:29:27 NOV29,1984															
000	55.2360	T-IN	001	[illegible]	T-OUT	003	24.6279	T-AMB	010	4[illegible]	WATTS	061	0.06691	DT/I	
066	0.48910	EFF	071	131.425	T-IN	073	135.995	T-OT	075	[illegible]	T-AB	076	144.083	BTU	
081	0.38176	DT/I	085	0.49074	EFF										
13:30:57 NOV29,1984															
000	55.2411	T-IN	001	52.7[illegible]	T-OUT	003	24.7896	T-AMB	010	4[illegible]	WATTS	061	0.06734	DT/I	
066	0.48561	EFF	071	131.434	T-IN	073	135.928	T-OT	075	[illegible]	T-AB	076	142.680	BTU	
081	0.38416	DT/I	085	0.4[illegible]23	EFF										

[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00125	BTU/I
[illegible]	0.[illegible]	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	[illegible]	BTU
[illegible]	0.00[illegible]05	BTU/I	[illegible]	[illegible]	EFF									
11:49:55	NOV30,1984													
[illegible]	26.5916	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00195	BTU/I
[illegible]	0.69051	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	278.187	BTU
[illegible]	0.01120	BTU/I	[illegible]	[illegible]	EFF									
12:50:20	NOV30,1984													
[illegible]	26.6110	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00200	BTU/I
[illegible]	0.70054	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	[illegible]	BTU
[illegible]	0.01143	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	26.[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00162	BTU/I
[illegible]	0.71186	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	[illegible]	BTU
[illegible]	0.00[illegible]5	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	26.8654	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00195	BTU/I
[illegible]	0.72119	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	269.705	BTU
[illegible]	0.00[illegible]3	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	27.0190	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00086	BTU/I
[illegible]	0.70652	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	279.567	BTU
[illegible]	0.00493	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.15[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00089	BTU/I
[illegible]	0.71[illegible]00	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	280.719	BTU
[illegible]	0.00505	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.2569	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00114	BTU/I
[illegible]	0.70981	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	284.102	BTU
[illegible]	0.00648	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.4084	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00148	BTU/I
[illegible]	0.72661	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	277.543	BTU
[illegible]	0.00844	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.5627	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00115	BTU/I
[illegible]	0.73192	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	275.544	BTU
[illegible]	0.00626	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.6909	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00114	BTU/I
[illegible]	0.72248	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	281.441	BTU
[illegible]	0.00651	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.7978	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00156	BTU/I
[illegible]	0.73549	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	277.959	BTU
[illegible]	0.00691	BTU/I	[illegible]	[illegible]	EFF									
[illegible]	NOV30,1984													
[illegible]	22.9200	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-GAS	[illegible]	[illegible]	WATTS	[illegible]	0.00231	BTU/I
[illegible]	0.81846	EFF	[illegible]	[illegible]	T-IN	[illegible]	[illegible]	T-OUT	[illegible]	[illegible]	T-AB	[illegible]	229.732	BTU

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064	0.01320 DT/I	065	[illegible] EFF														
12:06:25 NOV30,1984																	
000	26.0494 T-IN	001	34.9733 T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00196 DT/I						
066	0.66617 EFF	071	82.4[illegible] T-IN	073	94.9539	T-OUT	075	[illegible]	T-AR	076	268.569 BTU						
081	0.01118 DT/I	085	0.00840 EFF														
12:07:55 NOV30,1984																	
000	26.1349 T-IN	001	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00171 DT/I						
066	0.72426 EFF	071	82.6[illegible] T-IN	073	96.1482	T-OUT	075	[illegible]	T-AR	076	287.511 BTU						
081	0.00974 DT/I	085	0.[illegible] EFF														
12:09:25 NOV30,1984																	
000	26.2418 T-IN	001	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00267 DT/I						
066	0.74249 EFF	071	82.8[illegible] T-IN	073	96.3407	T-OUT	075	[illegible]	T-AR	076	280.456 BTU						
081	0.01521 DT/I	085	0.[illegible] EFF														
12:10:55 NOV30,1984																	
000	26.4222 T-IN	001	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00261 DT/I						
066	0.72981 EFF	071	83.1[illegible] T-IN	073	96.[illegible]	T-OUT	075	[illegible]	T-AR	076	286.167 BTU						
081	0.01490 DT/I	085	0.[illegible]224 EFF														
12:12:25 NOV30,1984																	
000	26.5932 T-IN	001	[illegible] T-OUT	003	26.[illegible]	T-HR	010	[illegible]	WATTS	061	0.00232 DT/I						
066	0.74884 EFF	071	83.46[illegible] T-IN	073	96.8573	T-OUT	075	[illegible]	T-AR	076	275.231 BTU						
081	0.01323 DT/I	085	[illegible] EFF														
12:13:55 NOV30,1984																	
000	26.7000 T-IN	001	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00341 DT/I						
066	0.80876 EFF	071	83.[illegible] T-IN	073	96.2814	T-OUT	075	[illegible]	T-AR	076	240.620 BTU						
081	0.01948 DT/I	085	0.01146 EFF														
12:15:25 NOV30,1984																	
000	26.8496 T-IN	[illegible]	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00468 DT/I						
066	0.80487 EFF	[illegible]	[illegible] T-IN	073	95.5829	T-OUT	075	[illegible]	T-AR	076	223.338 BTU						
081	0.0[illegible] DT/I	[illegible]	[illegible] EFF														
12:16:55 NOV30,1984																	
000	28.9137 T-IN	[illegible]	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00598 DT/I						
066	0.74405 EFF	071	[illegible] T-IN	073	94.91[illegible]	T-OUT	075	[illegible]	T-AR	076	215.628 BTU						
081	0.03410 DT/I	085	[illegible] EFF														
12:18:25 NOV30,1984																	
000	29.0633 T-IN	[illegible]	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00496 DT/I						
066	0.70723 EFF	[illegible]	[illegible] T-IN	073	96.[illegible]	T-OUT	075	[illegible]	T-AR	076	271.827 BTU						
081	0.02603 DT/I	085	0.[illegible] EFF														
12:19:55 NOV30,1984																	
000	29.1701 T-IN	001	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	WATTS	061	0.00419 DT/I						
066	0.74440 EFF	071	[illegible] T-IN	073	[illegible]	T-OUT	075	[illegible]	T-AR	076	274.221 BTU						
081	0.02141 DT/I	085	0.[illegible] EFF														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WATTS	061	0.00394 DT/I						
[illegible]	29.3197 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T-AR	076	266.751 BTU						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
081	[illegible]	[illegible]	[illegible] EFF														
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WATTS	061	0.00373 DT/I						
[illegible]	29.4952 [illegible]	[illegible]	[illegible] T-OUT	003	[illegible]	T-HR	010	[illegible]	T-AR	076	258.501 BTU						
[illegible]	[illegible]	[illegible]	[illegible] T-IN	073	[illegible]	T-OUT	075	[illegible]									
[illegible]	[illegible]	085	[illegible] EFF														
[illegible]	[illegible]	[illegible]	[illegible] T-OUT	003	[illegible]	T-HR	[illegible]	[illegible]	WATTS	061	[illegible] DT/I						
[illegible]	29.5545 [illegible]	[illegible]	[illegible]														

BOB WILLIAMS CO. INC.

000	[illegible]	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	[illegible]	WATTS	061	[illegible]	DT/I	
066	0.47897	EFF	071	131.511	T-IN	073	135.887	T-OT	075	76.1990	T-AB	076	140.936	BTU	
081	0.39111	DT/I	085	0.48052	EFF										
13:13:[illegible] NOV29,1984															
000	[illegible]	T-IN	001	[illegible]	T-OUT	003	24.9509	T-AMB	010	439.036	WATTS	061	[illegible]	DT/I	
066	0.47442	EFF	071	131.472	T-IN	073	135.235	T-OT	075	76.9295	T-AB	076	138.516	BTU	
081	0.39327	DT/I	085	0.47606	EFF										
13:35:[illegible] NOV29,1984															
000	55.3693	T-IN	001	[illegible]	T-OUT	003	25.1964	T-AMB	010	439.201	WATTS	061	0.06870	DT/I	
066	0.45289	EFF	071	131.665	T-IN	073	135.235	T-OT	075	77.3535	T-AB	076	138.368	BTU	
081	0.39195	DT/I	085	0.45441	EFF										
13:36:57 NOV29,1984															
000	55.3479	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	[illegible]	WATTS	061	0.07085	DT/I	
066	0.49347	EFF	071	131.626	T-IN	073	135.966	T-OT	075	76.8140	T-AB	076	135.601	BTU	
081	0.40422	DT/I	085	0.49511	EFF										
13:38:27 NOV29,1984															
000	55.3479	T-IN	001	[illegible]	T-OUT	003	24.6826	T-AMB	010	421.012	WATTS	061	0.07249	DT/I	
066	0.46575	EFF	071	131.626	T-IN	073	135.658	T-OT	075	[illegible]	T-AB	076	133.467	BTU	
081	0.41357	DT/I	085	0.46730	EFF										
13:39:57 NOV29,1984															
000	55.4548	T-IN	001	57.5450	T-OUT	003	[illegible]	T-AMB	010	421.548	WATTS	061	[illegible]	DT/I	
066	0.43615	EFF	071	131.819	T-IN	073	135.581	T-OT	075	[illegible]	T-AB	076	132.998	BTU	
081	0.40720	DT/I	085	0.43761	EFF										
13:40:4[illegible] NOV29,1984															
000	55.4976	T-IN	001	[illegible]	T-OUT	003	25.4105	T-AMB	010	419.815	WATTS	061	0.07167	DT/I	
066	0.44246	EFF	071	131.875	T-IN	073	135.696	T-OT	075	[illegible]	T-AB	076	132.452	BTU	
081	0.40888	DT/I	085	0.44393	EFF										
13:41:2[illegible] NOV29,1984															
000	55.4120	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	[illegible]	WATTS	061	0.07193	DT/I	
066	0.45785	EFF	071	131.242	T-IN	073	135.698	T-OT	075	[illegible]	T-AB	076	133.180	BTU	
081	0.41041	DT/I	085	0.45938	EFF										
13:42:5[illegible] NOV29,1984															
000	55.3052	T-IN	001	[illegible]	T-OUT	003	24.1820	T-AMB	010	420.963	WATTS	061	0.07361	DT/I	
066	0.47352	EFF	071	131.549	T-IN	073	135.619	T-OT	075	[illegible]	T-AB	076	132.530	BTU	
081	0.41998	DT/I	085	0.47510	EFF										
13:44:2[illegible] NOV29,1984															
000	55.3907	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	413.875	WATTS	061	0.07373	DT/I	
066	0.42603	EFF	071	131.703	T-IN	073	135.311	T-OT	075	[illegible]	T-AB	076	130.578	BTU	
081	0.42065	DT/I	085	0.42245	EFF										
13:45:57 NOV29,1984															
000	55.3745	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	413.800	WATTS	061	0.07421	DT/I	
066	0.46250	EFF	071	131.674	T-IN	073	135.570	T-OT	075	[illegible]	T-AB	076	130.554	BTU	
081	0.42339	DT/I	085	0.46404	EFF										
13:47:2[illegible] NOV29,1984															
000	55.4387	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	[illegible]	WATTS	061	0.07530	DT/I	
066	0.43356	EFF	071	131.790	T-IN	073	135.398	T-OT	075	[illegible]	T-AB	076	128.315	BTU	
081	0.42958	DT/I	085	0.43500	EFF										
13:48:10 NOV29,1984															
000	55.4814	T-IN	001	[illegible]	T-OUT	003	[illegible]	T-AMB	010	[illegible]	WATTS	061	0.07572	DT/I	10 point
066	0.43016	EFF	071	131.866	T-IN	073	135.436	T-OT	075	[illegible]	T-AB	076	127.951	BTU	
081	0.43200	DT/I	085	0.43160	EFF										