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COLLATION OF QUARTERLY REPORTS ON AIR FLAT PLATE COLLECTORS

Prepared by

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This work was done under the technical supervision of Mr. John Caudle, Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report is a collection of quarterly reports on the Solar II Air Flat Plate Collectors. The work covers the development and fabrication of a prototype air flat plate collector subsystem containing 320 square feet of collector area. Three instrumented panels were completely assembled with glazing and insulation. Manufacture of the last seven prototype collectors was conpleted in October 1977.

A summary table of contents lists each Quarterly Report with an individual Table of Contents.

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PREFACE

This report is a collation of quarterly reports on the Solar II Air Flat Plate Collectors. The work covers development and fabrication of a prototype air flat plate collector subsystem containing 320 square feet (10-4' X 8' panels) of collector area. Three (instrumented) panels were completely assembled with glazing and insulation. Manufacturing of the last seven prototype collectors was completed in October, 1977.

A summary table of contents follows this introduction. It lists each Quarterly Report with an individual Table of Contents. The first three Quarterly Reports' pages were renumbered using a roman number "I" followed by an arabic number "2". Hence, in this example, I-2 is the second page of the First Quarterly Report.

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FIRST QUARTERLY REPORT

AIR FLAT PLATE COLLECTOR

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT No. NAS8-32261

February 1, 1977

Life Sciences Engineering
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Morrison, Colorado 80465

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PART I SUMMARY

1. Introduction

The Development Phase of the Air Flat Plate Collector during the First Quarter is described in detail in subsequent parts of this report.

2. Summary

2.1 Contract - No changes have been requested.

3. Schedules

3.1 The Development Plan schedule indicated the Preliminary Design Review occurred on schedule. The Quarterly Review was approximately 2 weeks ahead of schedule.

3.2 The Verification Plan Test Program indicated the Test Program was approximately 2 weeks behind schedule. Life Sciences Engineering expects to be back on schedule within 2 to 3 months by developing: one additional SC4X8 test collector, a 'final-configuration' preproduction SC4X8 collector, and 2 spare SC22X48 test collectors. These additional test collectors will permit rapid change over to the next configuration while the other collectors are in testing.

4. Technical Performance

4.1 A monthly description of the work activities was provided.

4.2 Forecast of activities to complete tasks included the fabrication of a SC4X8 collector that meets baseline and Thermal Analysis specifications. The Test Program and activities were identified for the Prototype Design Review.

4.4 Data - A limited amount of data was taken due to: an excessive number of cloudy days, changing collector spacing, late deliveries of materials and illness.

Data analysis of the baseline collector indicated an average efficiency for the 3½ hour test on January 30th was 57.6% and 17,442 Btu were transferred to the air.

PART II CONTRACT

1. Changes Requested

No requests for changes have been submitted. However the following revisions were made.

1.1 Subsystem Performance Identification SHC-3058

1.1.1 Identification was supplied for the Installation, Operation and Maintenance Manual as SHC-3070.

1.1.2 This specification was modified when the SC4X8 collector was selected rather than the SC4X10 collector on which the proposal specifications were based. These modifications included:

Three 32 square foot collectors instead of three 4o square foot collectors

14,400 Btu/Hr for the SC4X8 versus 18,000 Btu/Hr for the SC4X10

1.1.3 It should be noted that neither the air exit temperature nor the air flow rate were changed. This neglect to change the air exit temperature on our part made the design goal of 130°F average air temperature output for the SC4X10 collector unrealistic for the SC4X8 collector. Life Sciences Engineering is preparing additional analyses to define a realistic average air temperature output for an air inlet temperature of 70°F based on the reduced absorber panel area.

1.2 The Development Plan, SHC-3059 was revised to reflect changes in the schedule.

PART III SCHEDULE

1. Schedule

1.1 Verification Plan Test Program

Figure 3-1 Verification Plan Test Program shows the actual schedule is approximately 2 weeks behind schedule. Lack of clear skies, late delivery of equipment and illness have previously been reported as the primary causes. However, the multiple testing capability of the 3 test cells of the Test Facility are expected to make up for the last two weeks. Automatic data collection planned for March will also improve operations.

1.2 Development Plan

Figure 3-2 Development Plan Schedule shows that the scheduled program activities have occurred on time. The First Quarterly Review is approximately two weeks ahead of schedule.

1.3 Schedule Recovery Plan

The addition of Dr. Charles Murrish to Life Sciences Engineering will provide direction and expertise to expedite selection, installation and data processing systems.

A minimum of one additional test collector will be built concurrent with the building of a 'final configured' preproduction collector. This development test collector will allow Life Sciences Engineering the testing in stages by adding one improvement at a time and recording the effects of performance.

The 'final configured' preproduction collector will be fabricated to address manufacturing procedures, process controls and insulation techniques for 'all-up-build' and backup support for the test program. Meanwhile, the test program will be speeded up by modifying the SC22X48 collectors to baseline and thermal analysis requirements with the capability of rapidly changing absorber panels. The test program was designed to use four SC22X48 collectors to compare absorber coatings, glazings and combinations of absorber coatings and glazings. These collectors are much lighter in weight and easier to handle which will reduce test change time and personnel time. Two spare SC22X48 collectors will also be used in the development and testing by being set up for the next test while the other collectors are in testing. These spare collectors will also be used in developing installation techniques and installation drawings for the preparation of the Installation, Operation and Maintenance (IOM) Manual.

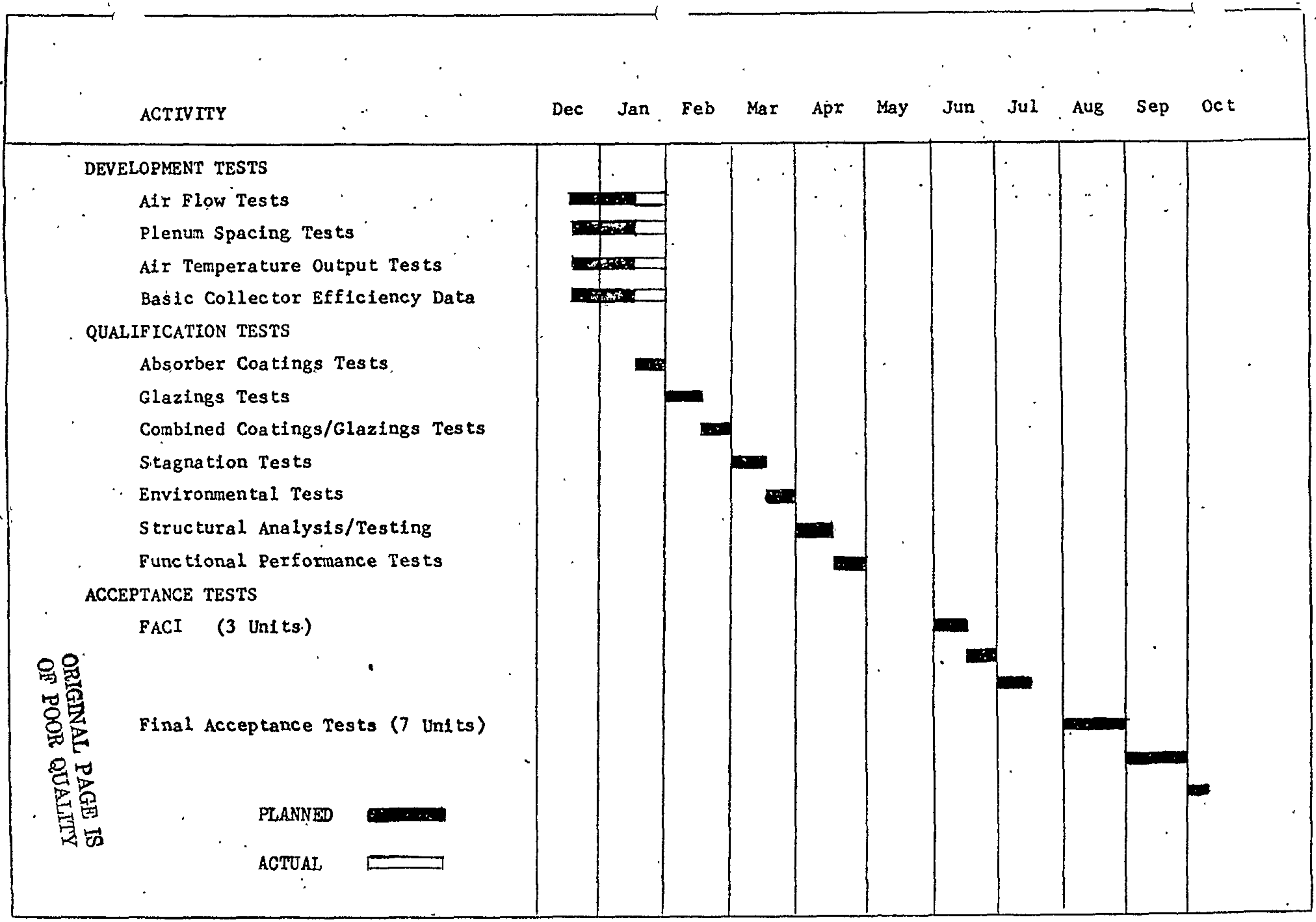

Figure 3-1 VERIFICATION PLAN TEST PROGRAM

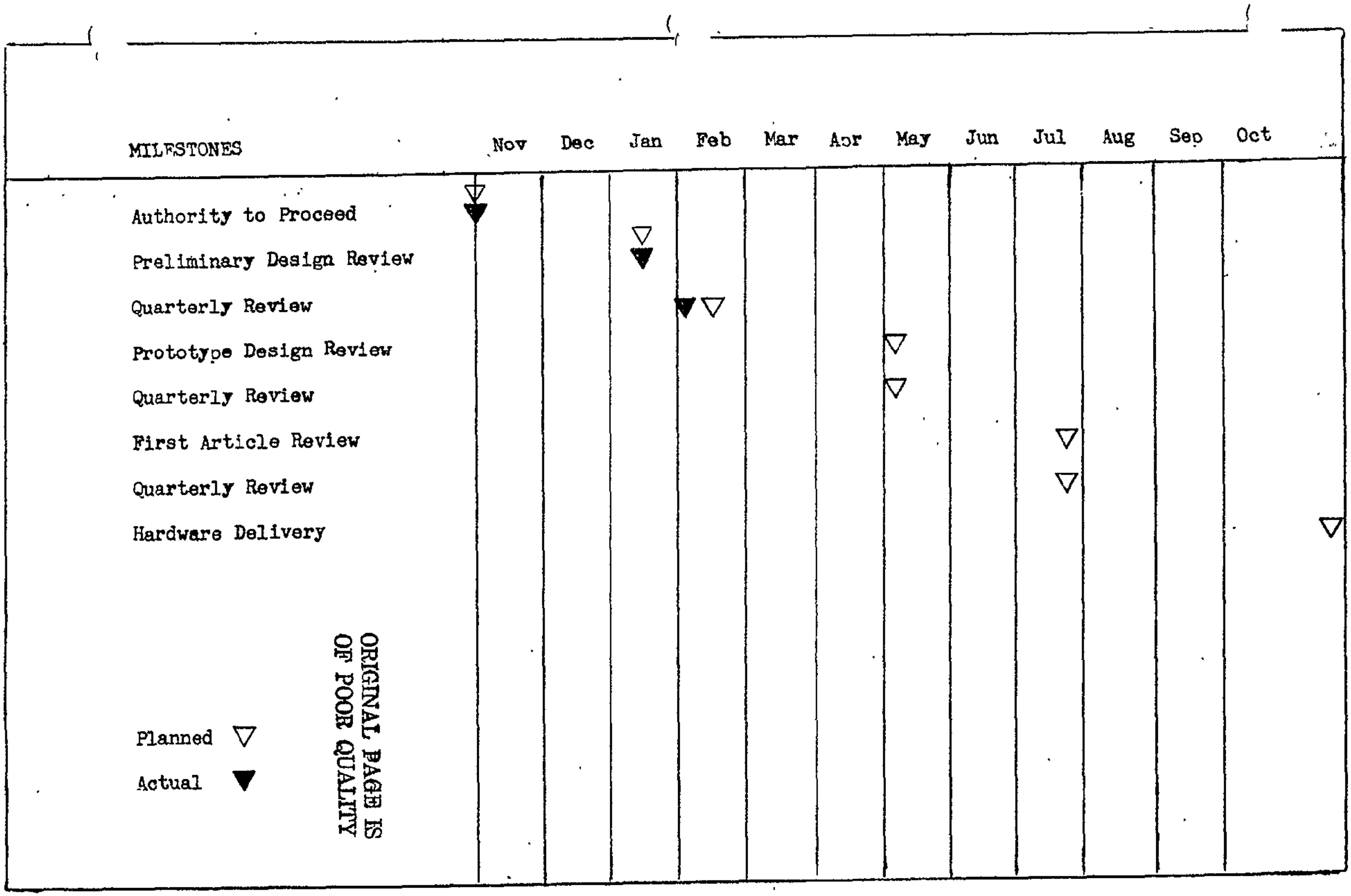

Figure 3-2 Development Plan

PART IV Technical Performance

1. General Description of Work Accomplished During the Quarter

1.1 November

The first month's work activities included:

Design Specification Review

Thomas Meter Checkout

Blower Motor Flow Rate

Verification Plan

Safety Hazard Analysis

Test Facility Checkout

Data Collection System

Component/Material Availability

The Thomas Meter and manometer air flow testing indicated that the blower motor would have to be changed to a variable speed motor in order to use more than one test cell at a time.

Component and material availability investigations indicated that the Minco thermal resistor would be 5 to 6 weeks late. Copper constantum thermocouple wire was therefore obtained and thermocouples would be used until the thermal resistor arrived. (It finally arrived 2 months late.) The first aluminum solder was found unsatisfactory.

Numerous mini-computer companies were contacted and their mini-computer characteristics and brochures were reviewed.

1.2 December

The second month's work activities included:

One SC4X8 Test Collector for Test Cell No. 1

Two SC22X48 Test Collectors

Two Thomas Meters for Test Cells No. 1 and 2

Preliminary Design Review Data Packages

Data Collection System

The late delivery of the Solarsorb paint delayed fabrication of the SC4X8 and two SC22X48 test collectors. The SC4X8 Test Collector was installed on the last day of December in test cell #1. Only preliminary air flow test data was obtained for the 1 inch plenum spacing.

Two Thomas Meters were built for test cells 1 and 2.

The Preliminary Design Review Data package was completed and consisted of:

Safety Hazard Analysis

Structural Analysis

Thermal Analysis

Verification Plan, SHC-3071

Drawing List, Standards and Symbology

Proposed Special Handling, Installation and Maintenance Tools

List of Data Recommended for the Prototype Design Review

Prototype Drawings

1.3 January

The third month's work activities included:

SC4X8 Test Collector Data

Preliminary Design Review

Glass Stress Analysis

Thomas Meters Installed

Instrumentation

Installed Air Flow Test Probe Sections

Quality Assurance Plan

SC22X48 Test Collector Development

Two air flow test probe sections were installed in Test Cell 1 above and below the collector. Each section has identical holes to test the distribution of air flow across the top and bottom of the collector.

Limited test data was taken on the SC4X8 Test Collector due to the lack of clear days. Test data was taken on the 1" plenum size. The Test Collector was removed and the plenum size was reduced to 5/8". A second set of data was taken at the 5/8" plenum spacing. The Test Collector was removed, the plenum spacing changed to 1/2" and test data was taken on January 30 and 31. Analysis of the data is given in Section 4.

Instrumentation: The Micro Tector Electronic Hook Gage with kiel probes was used to check the air flow across the entrance to the collector plenum. The flow varied by .001 between each of 3 test holes (a center hole and two holes half way to the sides). The second air flow test probe section was installed during the last week of the month. No tests were made to determine pressure drop across the length of the collector for the ½" plenum spacing.

The two Thomas Meter ducts were installed. During installation of test cell #2 ducting, one copper wire was broken and was repaired. The design for automatic operation of the Thomas Meters was found to require additional work. The existing copper wire sensors do not have sufficient sensitivity and nickel wire or thermocouples will be tested.

The Photovoltaic Pyranometer was used to collect data. One problem is that Rho Sigma failed to provide a meter and calibration for operation at a 60° angle to the horizon. The company has been asked to either replace the unit, recalibrate it or send us a calibration chart.

In general, instrumentation will be recorded by the data collection system but we plan to be able to read all instrumentation directly when problems arise.

Preliminary Design Review: Four Review Item Discrepancies were received and answered. Minutes of the Preliminary Design Review were typed and distributed. A Glass Stress Analysis was requested. A baseline drawing for the Air Flat Plate Collector was established as defined in SKSC4X8200-X.

Glass Stress Analysis: Further glass stress analysis recommended to Life Sciences Engineering use one cross member to support 5/32" glass in two ≈46" x≈46" sheets.

Quality Assurance Plan: The Quality Assurance Plan was completed on January 29th. In a telecon with the Technical Manager, the Quality Assurance Plan was retained for possible review at the Quarterly Review.

SC22X48 Test Collector Development: One of the four SC22X48 Test Collectors was modified for the installation of a heat transfer corrugated sheet which fits in the plenum spacing. This unit and the others will be modified to the ½" plenum spacing and tested in February.

2. Forecast of Activities to Complete Tasks

2.1 The SC22X48 Test Collectors will be reworked to the baseline plenum ½" spacing. They will be installed in Test Cell 2 early in February for the start of the testing program.

2.2 A second SC4X8 Test Collector will be fabricated to baseline specifications including Sunadex glass, improved solarsorb paint application, and an improved panel retention technique with longitudinal structur al support to maintain the ½" plenum spacing. Full testing will commence on this unit as soon as possible.

2.3 Continued testing of the current SC4X8 test collector in test cell 3 is planned to see the improvement in performance when changes are made including:

Insulation of the sides of the collector

Insulation of the top outer edges of the ends of the collector

Addition of "U" channels in the air plenum for improved heat transfer

Paint the inner sides of the collector

Changes in air flow rate

2.4 Further development of techniques for installation of the SC4X8 collector and prepare Installation Drawings.

2.5 Development of the Installation, Operation and Maintenance (IOM) Manual.

2.6 Continue the test program taking data on all units under test in the three test cells.

2.7 Complete the data collection system, design, install and collect data.

2.8 Make final decision on the mini-computer, purchase and use to analyze the data.

2.9 Preparation of a Spare Parts list.

2.10 Prepare schematics, engineering drawings, functional description and test data for the Prototype Design Review sufficient to evaluate the development effort. A finished set of 'shop drawings' will also be prepared.

2.11 Prepare a Certification Test Request for Proposal for sub-contractors to bid.

3. Identification of Major Problem Areas

3.1 The test data obtained on the SC4X8 collector when it was reworked to the 1/2" plenum spacing showed an average change of 40° F between input air and the exit air temperatures. A number of explanations are provided and there are probably multiple factors involved.

3.2 The current SC4X8 test collector is not in exact agreement with our Thermal Analysis. Life Sciences Engineering plans to fabricate an additional SC4X8 test collector that will meet baseline requirements and the thermal analysis requirements including:

Sunadex glass
Insulation
Full plenum interior painting with high emissivity black paint
New absorber panel retention technique
Longitudinal supports to maintain the ½" plenum spacing.

3.3 The design goal of 60°F average output air temperature increase for the SC4X10 collector was not achieved by the SC4X8 collector. As described in paragraph 1.1.2, the ratio that changed the 18,000 Btu/Hr to 14,400 Btu/Hr probably should have been applied to the 60°F design goal for the average output air temperature. An analysis is in preparation to verify this.

3.4 Additional instrumentation will be installed to provide data on weather, automatic monitoring of flow rates, thermocouples and thermal resistors on test units.

4. Data

Data was collected on January 16th with the plenum spacing at one inch. The plenum spacing was changed on January 23 to 5/8". On January 27th the plenum spacing was changed to ½".

The data taken on January 16th was considered preliminary as there was insufficient longitudinal support to assure maintenance of the 1" spacing.

The following code information is supplied for interpretation of the data:

#1 Air outlet thermocouple

#2 Thermocouple on inside of absorber plate ≈30" from top at center

#3 Thermocouple on inside of absorber plate ≈30" from bottom at center

#4 Thermocouple on inside of absorber plate at center

#5 Thermocouple on inside of absorber plate 16" from side in line with #4

T in Air inlet temperature

OAT Outside air temperature

4.1. Data Reduction

Data taken on January 30, 1977 was reduced to show solar input to the collector, heat transferred from the collector by the air flow, and the overall efficiency. The entire test was conducted holding one value of air flow. Air flow was derived from the velocity head of 0.032 in. H_2O occurring in the 9/16" by 45½" pressure test section near the entrance to the collector. With an air density of 0.062 lb/ft^3 the velocity in this section was 790 fpm. With a cross section of 0.178 ft^2 this results in a flow of 140.4 CFM, or a mass flow rate of 522 lb/hr.

Insolation was measured with a RHO SIGMA RS1008 photovoltaic pyranometer mounted in the plane of the collector. Calibration is such that insolation is given by the expression:

$$I = mV \times \frac{100}{149.4} \text{ Btu/Hr ft}^2$$

The net aperature area for solar insolation is:

$$\frac{46\frac{1}{2}" \times 94"}{144} = 30.35 \text{ ft}^2$$

The test ran for 3½ hours. During that time the integrated insolation was 30277.6 Btu and the heat transferred to the air was 17,442 Btu giving an average efficiency for the test period of 57.6%. The computation for each time increment are shown in Table 4.1.

Air flow in these tests was based upon measurements of velocity head. The Dwyer Model 1430 Micro Tector Electronic Hook Gage was used to measure the differential between total head taken by kiel probes and static head from a wall orifice. Similar tests are planned using the Thomas Meter to measure air flow.

TIME	I Btu/hr ft^2	INPUT But/hr	AIR FLOW Lb/hr	Δ T	OUTPUT Btu/hr	EFFICIENCY %
11:16	287.8	8735	522	39.3	4927	56.4
11:26	284.5	8635	522	38.2	4790	55.5
11:36	267.7	8125	522	38.2	4827	59.4
11:46	294.5	8938	522	39.7	4977	55.7
11:56	294.5	8938	522	40.3	5052	56.5
12:06	294.5	8938	522	39.8	4990	55.8
12:16	294.5	8938	522	39.4	4940	55.3
12:26	294.5	8938	522	39.5	4953	55.4
12:36	294.5	8938	522	39.0	4889	54.7
12:46	294.5	8938	522	39.5	4953	55.4
13:06	294.5	8938	522	40.7	5103	57.1
13:16	294.5	8938	522	43.5	5453	61.0
13:26	293.2	8899	522	44.2	5542	62.3
13:36	287.8	8735	522	41.1	5153	59.0
13:46	284.5	8635	522	40.8	5115	59.2
13:56	281.1	8531	522	39.8	4990	58.5
14:06	281.1	8531	522	39.7	4977	58.3
14:16	274.4	8328	522	39.3	4927	59.2
14:26	267.7	8125	522	38.2	4790	58.9
14:36	264.4	8025	522	37.2	4664	58.1
14:46	261.0	7921	522	37.0	4639	58.6

Table 4.1 TEST DATA REDUCTION (Jan. 30, 1977 Data)

TIME	FLOW RATE	#1	#2	#3	#4	#5	T IN	OAT	INSOL.
1223	(max.) .05"	125	108	101.5	112.5	112	49	43	.438
1253	zero	144	221	199	221	199	58	46	.440
1315	.008" (120CFM)	97	180.5	165.5	185.5	71.2	53	47.5	.445
1327	240CFM	78.5	130.1	120.1	133	128	51	46	.425
1337	180CFM	85.8	140.2	128.6	142	133.1	51	47	.435

Note: This test was performed with the plenum spacing at 1 inch. Pressure drop for the 1 inch spacing was less than 0.1 inches of water.

Test Date: January 16, 1977

Test Cell No. 1

TEST REPORT

TIME	FLOW	#1	#2	#3	#4	#5	T IN	OAT	INSOL.
1311	120CFM	101	131	116	132	100.8	61	41	.4
1315	120CFM	103.5	131.5	115	125	117.8	61	41.5	.36
1318	120CFM	99.3	130	115	123.4	115.6	62	42	.35
1332	120CFM	87.6	124	110.9	122.9	109	63	42	.32
1340	120CFM	82.4	106.6	97.5	101.4	95	62	42	.2

Note: This test was performed with the plenum spacing at 5/8".

Test Date: January 23, 1977

Test Cell No. 1

TEST REPORT

TIME	FLOW	#1	#2	#3	#4	#5	T IN	OAT	INSOL.
1400	120 CFM*	111.8	158.6	142.5	152.9	138.7	62	40.5	.41
1423	"	109.9	153.6	138.6	146.5	133.7	65	42	.395
1434	"	104.4	149.8	134.3	143.4	123.8	57.5	42	.365
1440	"	102.6	148.8	131.7	140	120	56	42	.34
1517	"	88.	108.8	105.4	117.9	92.9	50	40	.22
1525	"	84.6	106.6	100.5	113.2	92.6	48	40	.21

Note: This test was performed with the plenum spacing at ½ inch.

* On Feb.4, the Pressure Test Fixture was remeasured and found to have a 9/16" spacing which resulted in a flow rate of 140.4CFM.

SECOND QUARTERLY REPORT

AIR FLAT PLATE COLLECTOR

TO

NATIONAL AERONAUTICS & SPACE ADMINISTRATION

NAS 8-32261

MAY 1, 1977

Life Sciences Engineering

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Morrison, Colorado 80465

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TABLE OF FIGURES AND TABLES

PART I SUMMARY

1. Introduction

The Development Phase of the Air Flat Plate Collector during the Second Quarter is described in the subsequent parts of this report.

2. Summary

2.1 Contract

No changes have been formally submitted. However, an Engineering Analysis of the Temperature Specification for the Air Flat Plate Collector was submitted on March 31, 1977. This engineering analyses was expected to be the basis of a change proposal for the outlet temperatures specification.

3. Schedule

3.1 Development Plan

The Development Plan, Figure 3-2, indicated that the Prototype Design Review was rescheduled to June 7, 1977 because of testing delays due to late shipment of the Sunadex glass and paint peeling problems. A proposed schedule of dates following the Prototype Design Review was included.

3.2 Verification Plan

The Verification Plan Test Program, Figure 3-1, indicated a one month delay in the glazing tests. The test schedule was revised when it became evident the Sunadex glass would be late. This permitted 2 month stagnation testing which revealed Solarsorb paint peeling. A proposed reschedule of the test program was included in Figure 3-1.

4. Technical Performance

4.1 Performance Tests

Performance data was collected, reduced and analyzed. Average efficiency for each test was plotted on Figure 4-1.

4.2 Stagnation Tests

Stagnation testing was performed on the on SC4X8 (4 months) and the four SC22X48 test collectors (2 months). After 2 months the Solarsorb paint began to peel. The Nextel paint on two SC22X48 test collectors did not peel. The peeling was considered to be an etching/application problem and not necessarily the fault of the Solarsorb paint.

4.3 Absorber Paint Tests

The Solarsorb paint was compared with the Nextel paint and a very slight advantage in thermal absorbtivity was found for the Solorsorb paint. The Solarsorb paint thickness was estimated at twice the recommended coating. Hence, Solarsorb may be more efficient than indicated by the tests. However, the Solarsorb manufacturer recently reported peeling of their test collector in Pennsylvania at -20°F. Since our Nextel test collector has experienced -20°F temperatures without peeling, it is recommended for the Prototype collectors.

4.4 Air Flow Tests and Analysis

The Dwyer Micro Tector Hook Gage was used to verify the Thomas Meter development for low air flows. The Thomas meter will be automated to the data collection system and used in future data testing. The Dwyer Micro Tector Hook Gage is an accurate laboratory instrument, but is not capable of automatically monitoring air flows to three test cells.

4.5 Description of Activities

A description of monthly activities was provided.

4.6 Forecast of Activities to Complete Tasks

A forecast of the activities required to complete the tasks that are underway is provided, and an approximate completion date is given.

4.7 Identification of Major Problem Areas

Two major problems were discussed, shipping delays and paint peeling. The paint peeling problem was resolved. Early approval of long lead items for the Prototype Collector was requested.

PART II CONTRACT

1. Changes Requested

1.1 Engineering Change Proposal

No requests for official changes have been submitted. However, an Engineering Change Proposal is in preparation which changes outlet temperatures specifications. Currently an outlet temperature of 130°F corresponds to an inlet temperature of 70°F and 180°F for an inlet temperature of 140°F. The proposed temperature specification change is: 120°F for an inlet temperature of 70°F and 172°F for an inlet temperature of 140°F.

1.2 Prototype Design Review

The Prototype Design Review was rescheduled for June 7th to complete testing of the glazing and analyze results.

PART III SCHEDULE

1. Schedule

1.1 Verification Plan Test Program

The Verification Plan Test Program as show on Figure3-1, shows the actual schedule to be 1 month behind schedule. Late delivery of the Sunadex Glass and peeling of the Solarsorb paint were the primary causes of the delay. The glazing tests will be completed in the month of May. A proposed reschedule of the Verification Plan Test Program was included.

1.2 Development Plan

Figure 3-2, the Development Plan, shows the change in the Prototype Design Review from May 3rd to June 7th. This change in the PDR will reflect changes in subsequent milestones. A proposed reschedule of milestone indicates that the last 7 prototype collectors can be delivered by the end of October.

Figure 3-2 also shows that the absorber coatings and stagnation tests were run over a much longer time interval than originally scheduled. This 2 month test period for the SC22X48 collectors painted with Solarsorb revealed the peeling problem.

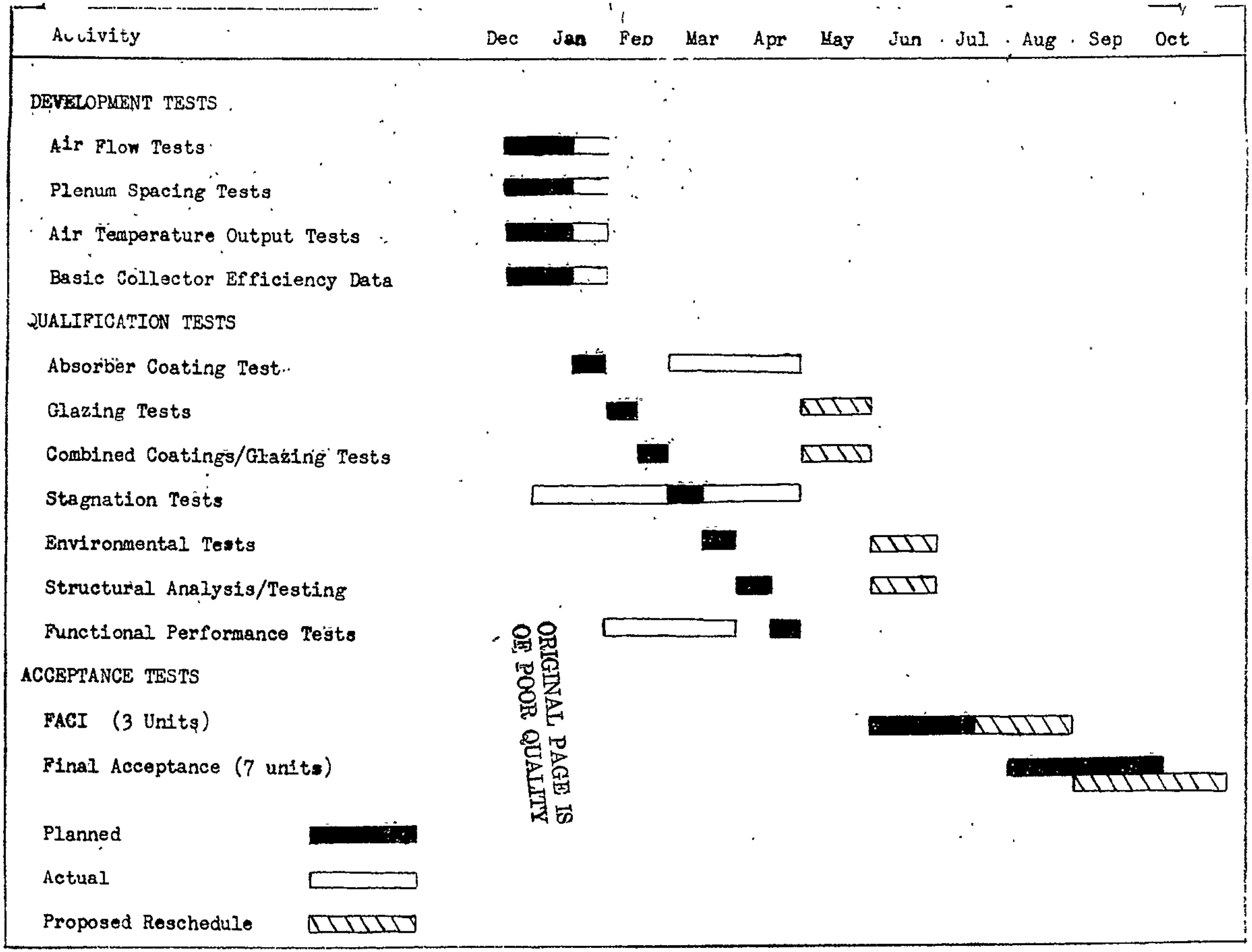

Figure 3-1 VERIFICATION PLAN TESTING

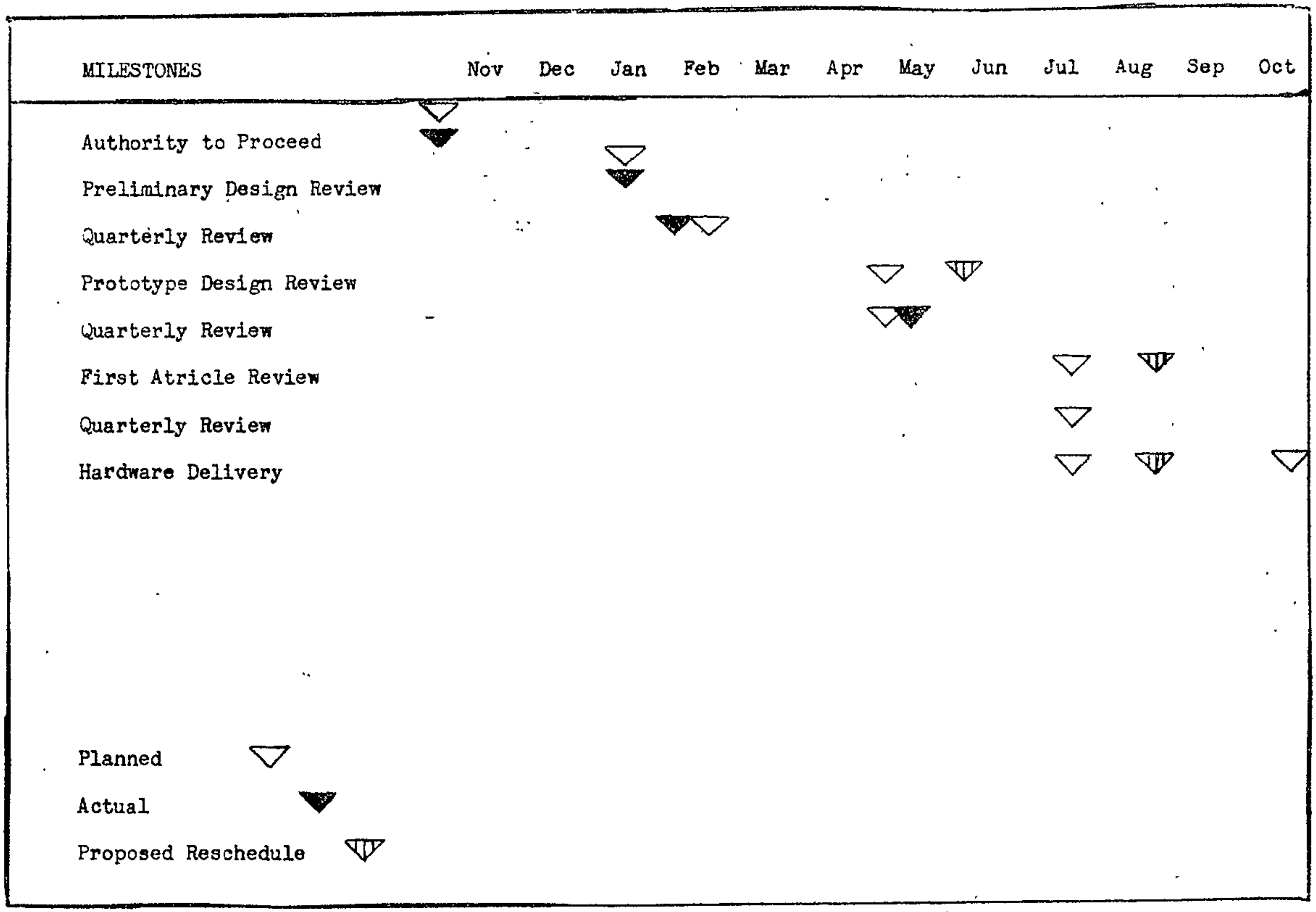

Figure 3-2 Development Plan

4. Data

Several types of tests were run during the Quarter: performance tests, air flow, paint comparison tests and stagnation tests. As described in section 4.1 to 4.3 only the glazing tests were not run due to the late arrival of the Sunadex glass.

4.1 Performance Data

All performance data was collected on the SC4X8 collector with the plenum spacing set at ½" per the baseline configuration. The collector cross section was 0.178 ft^2. Insolation was measured with a Rho Sigma Photovoltaic pyranometer mounted in the plane of the collector. It was calibrated at 149.4 mv = 100 Btu/ft^2. Thermocouple data was measured with a Doric Trendicator. Air flow was measured with the Dwyer Micro Tector Hook Gage as the primary standard while testing of the Thomas Meter continued. Air flow was measured at the pressure test unit located at the entrance to the collector. The SC4X8 aperture was 30.35 ft^2.

4.1.1 Data Reduction

4.1.2 February Performance Data Analysis

Data taken on February 13th and 17th, 1977, is shown displayed in Table 4.1. This data was reduced as shown in Table 4.2. Preparation for the test began at 1330 when the blower motor was started. After temperatures stabilized, two sets of data were taken when the skies became 85% overcast. The 61.3% average efficiency for February 13th data is plotted on Figure 4.1. Preparation for the February 17th data began at 1130 with the start of the blower motor. A thin layer of high clouds covered the skies which cleared by 1330. One and one half hours of data were collected with an average efficiency of 64.3%. The integrated insolation was 13,695 Btu and heat transferred to the air was 8,806.2 Btu. The average input air temperature to the collector was 70°F.

TIME	INSOL mv.	INPUT TEMP °F	OUTPUT TEMP °F	AMBIENT TEMP °F	AIR FLOW CFM
1345	420	69.0	120.0	56.0	113.6
1355	430	71.0	124.2	55.0	113.6
1405	420	72.0	125.2	54.5	113.6
1415	430	72.0	124.7	55.0	113.6
1425	425	72.0	125.4	55.5	113.6
1435	400	72.0	125.0	54.5	113.6
1445	400	71.5	123.0	54.5	113.6
1455	400	71.0	123.7	56.0	113.6
1505	360	70.0	119.4	54.0	113.6
1515	360	69.5	117.9	52.0	113.6
TEST DATA (Taken February 17, 1977)					
1430	420	64.0	113.0	54.0	121.5
1445	380	64.0	107.5	53.0	121.5
TEST DATA (Taken February 13, 1977)					

Table 4.1, TEST DATA (Taken February 13 & 17, 1977)

TIME	I Btu/hr-ft^2	INPUT Btu/hr	AIR FLOW Lb/hr	ΔT	OUTPUT Btu/hr	EFFICIENCY %
1345	281.1	8531.4	422.6	51.0	5172.6	60.6
1355	287.8	8734.7	422.6	55.2	5598.6	64.1
1405	281.1	8531.4	422.6	53.2	5395.8	63.2
1415	287.8	8734.7	422.6	52.7	5345.0	61.2
1425	284.5	8634.6	422.6	53.4	5416.0	62.7
1435	267.7	8124.7	422.6	53.0	5375.5	66.2
1445	267.7	8124.7	422.6	51.5	5223.3	64.3
1455	267.7	8124.7	422.6	52.7	5345.0	65.8
1505	241.0	7314.4	422.6	49.4	5010.3	68.5
1515	241.0	7314.4	422.6	48.4	4949.5	67.7
TEST DATA REDUCTION (February 17, 1977)						
1430	280.9	8526.4	452.1	49.0	5316.8	62.4
1445	254.2	7714.4	452.1	43.5	4720.0	61.2
TEST DATA REDUCTION (February 13, 1977)						

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Table 4.2, TEST DATA REDUCTION (February 13 & 17, 1977)

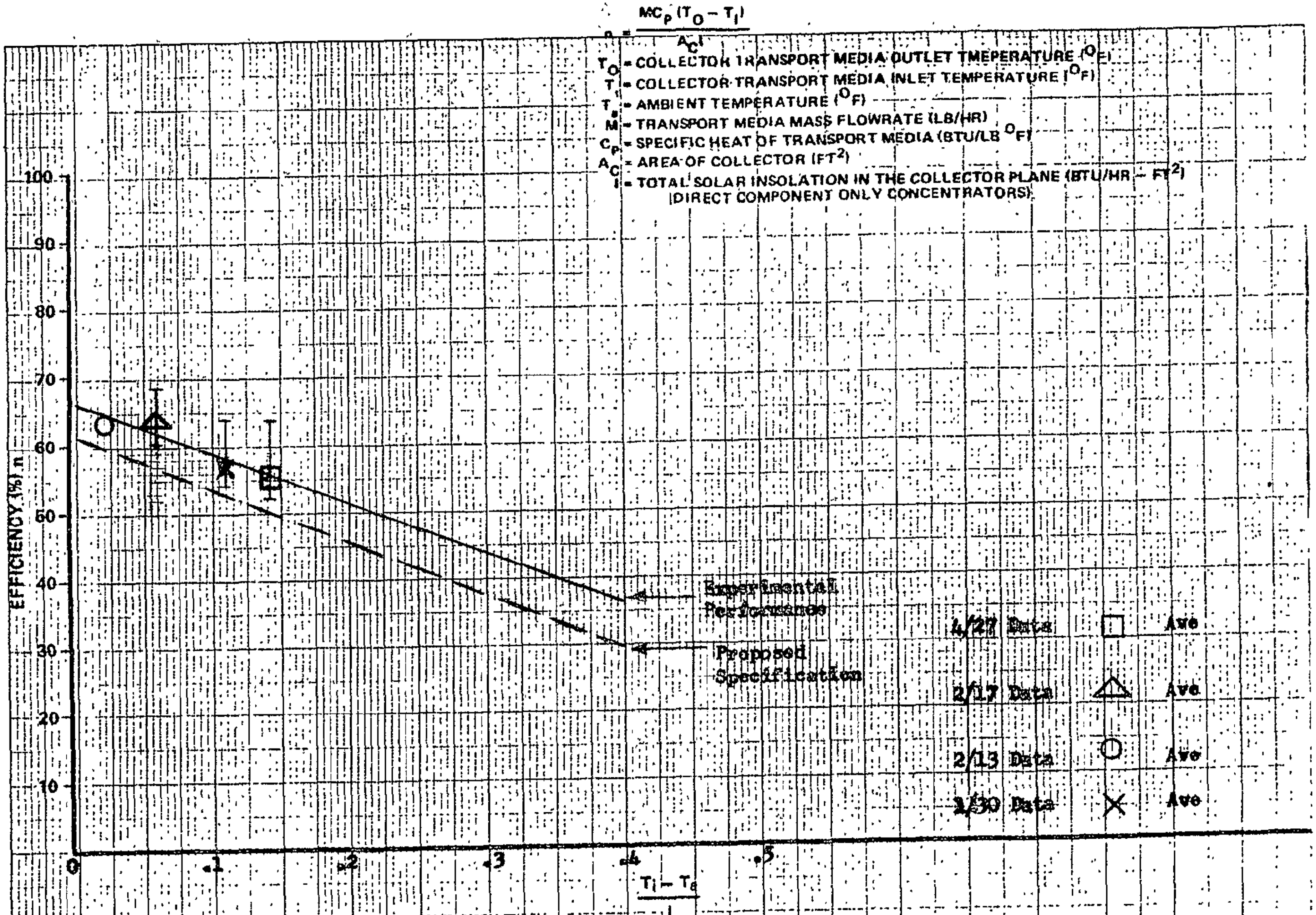

FIGURE 1 EFFICIENCY AS A FUNCTION OF OPERATING CONDITIONS

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4.1.3 March Performance Data Analysis

The data compiled in March 27, 1977 is presented in Table 4.3 and the reduction of this data shown in Table 4.4. The testing started with the starting of the blower motor at 1230. Two hours of data were collected with the average input temperature at 94.8°F. The integrated insolation for this period was 14,850 Btu and heat transferred to the air was 8,417.3 for an average efficiency of 56.7%.

....4 Efficiency Analysis

The above average efficiencies were plotted on Figure 4.1, Efficiency As A Function of Operating Conditions. Data from January 30th was also plotted. A curve was then drawn for the best fit for the plots of average efficiencies. The deviation of the individual data from the mean efficiencies is also plotted. This curve and these plots fit the Revised Engineering Analysis of the Temperature Specification for Air Flat Plate Collector dated May 5, 1977.

4.2 Stagnation Testing

Stagnation testing began on January 1st on the SC4X8 collector in Test Cell No. 3. During January and February, stagnation testing consisted of blower off condition with just stack air flow in the collector plenum. On March 5th a paint peeling appeared in the lower right quadrant of this collector about 2"x 6" in size. Closer examination of the absorber panel revealed fine, hair line cracks in the Solarsorb paint. On the following Saturday a narrow streak appeared in the upper left quadrant showing more peeling.

4.2.1 Analysis of Peeling Problem

Test reports of sample paint coupon by NASA found an "a" of 0.92 and an "e" of 0.83. This indicated the Solarsorb was applied 2 or 3 times thicker than the desired 1 mil thickness. In reviewing the paint method, the manufacturer,

TIME	INSOL. mv.	INPUT TEMP °F	OUTPUT TEMP °F	AMBIENT TEMP °F	AIR FLOW CFM
1410	400	99.0	147.6	64.6	127.5
1420	399	98.3	140.9	63.7	127.5
1430	388	97.3	136.4	65.4	127.5
1440	380	96.2	133.7	65.3	127.5
1450	377	94.3	131.2	63.7	130.0
1500	365	95.0	130.0	63.7	130.0
1510	350	95.6	127.6	64.7	130.0
1520	330	94.6	127.4	64.5	117.7
1530	315	84.6	126.2	64.3	117.7
1540	290	93.5	124.9	64.6	117.7
1550	280	92.6	123.2	64.2	117.7
1600	265	91.4	122.5	63.0	117.7
1610	250	89.5	117.7	64.0	111.0

Table4.3, TEST DATA (March 27, 1977)

TIME	I Btu/hr-ft^2	INPUT Btu/hr	AIR FLOW Lb/hr	Δ T	OUTPUT Btu/hr	EFFICIENCY %
1410	267.6	8120.0	474.3	48.6	5532.4	68.1
1420	266.8	8100.0	474.3	42.6	4849.2	59.9
1430	254.5	7876.8	474/3	39.1	4450.8	57.6
1440	254.2	7714.4	474.3	37.5	4268.7	55.3
1450	252.2	7653.5	483.6	36.9	4282.8	56.0
1500	244.2	7409.9	483.6	35.0	4062.2	54.8
1510	234.2	7105.4	483.6	32.0	3714.0	52.3
1520	220.7	6699.3	437.8	32.8	3446.4	51.5
1530	210.7	6394.8	437.8	31.6	3320.3	51.9
1540	194.0	5887.3	437.8	31.4	3299.3	56.0
1550	187.3	5684.2	437.8	30.6	3215.2	56.6
1600	177.3	5379.8	437.8	31.1	3267.7	60.7
1610	16712	5075.3	412.9	28.2	2794.5	55.1

Table 4.4,TEST DATA REDUCTION (March 27, 1977)

J. Caldwell Sr., gave 2 methods of applying the Solarsorb.

(1) Degrease and etch the panel; then paint with Solarsorb using xylene for thinning.

(2) Degrease and add the phosphoric acid for etching to the Solarsorb paint.

Unfortunately, Quality Control manager selected the second procedure. The phosphoric acid in the paint was not strong enough to etch but simply used to improve adherence. As a result the paint peeled. All Solarsorb Panels were found to have the same problem. Peeling begins after 2 months of stagnation conditions (with some stack flow).

4.2.2 Correcting Action

All Solarsorb panels were taken out in late April and the remaining paint removed. A special buffered hydroxide solution has been purchased to properly etch the absorber panels. Following etching, the panels are to be cleaned and washed. New instructions from the manufacturer now include a "wash undercoat paint" followed in a few days by the Solarsorb coating. The one mil thickness can be estimated by noting when Solarsorb coating changes from brown to black as the paint thickness builds up. Stagnation tests were also part of the absorber paint tests.

4.3 Absorber Paint Tests

Comparison tests were performed between the Solarsorb paint # C-1077-3/66, supplied by Caldwell Chemical coatings and for the Nextel Velvet coatings 101-C10 supplied by 3M, in order to determine their respective heat absorption properties. Temperature measurements were made using a thermocouple fastened to the back side and directly in the center of each coated absorber plate. Instantaneous insolation measurements were taken with a pyranometer at the end of test intervals. A heat absorption index, ξ_i, was developed for each paint under different testing conditions where ξ_i is the ratio of the average absorber plate temperatures to the average insolations for the combined tests. Thus,

$$\xi_i = \frac{T_i \text{ ave}}{I \text{ ave}}, \qquad 4.1$$

where T_i is the plate temperature and the subscript stands for collectors 1-4. Collectors 1 and 2 were coated with Nextel and set in series so that air flow was from 1 to 2. Similarly, collectors 3 and 4 were coated with Solarsorb and set in series such that the air flows from 3 to 4.

4.3.1 Flow Tests

The paints were first tested with a flow of air behind the absorber panel. This experiment was carried out over a one week period from March 30 to April 5. Data taken on two different days is displayed in Table 4.5 and is considered representative of the rest of the air flow data. These tests were taken in the sequence shown by switching the air flow back and forth between sets of collectors of different paint samples at 10 minute intervals. This accounts for the difference in insolation measurements. The data in Table 4.5 shows that a slight advantage is found with the Solarsorb coating. It is expected that this advantage will be futher increased for the new Solarsorb coated absorber plates since a better method of application is being used.

4.3.2 Stagnation Tests

The second set of tests were performed under stagnation conditions. Approximately two months of stagnation condition (with stack flow) were allowed and thermal tests were taken at various times during this period. Data from two representative days is displayed in Table 4.6. Very little change appeared in the absorption properties of either paint over this long stagnation period. The Solarsorb coated collectors were again shown to slightly have better heat absorption properties as compared to the Nextel, though the Solarsorb showed

Paint Comparison Tests with Air Flow

3-31-77	Nextel T_1 °F	Nextel T_2 °F	Nextel I Btuh/ft^2	Solarsorb T_3	Solarsorb T_4	Solarsorb I Btuh/ft^2
1.	118.4	140.0	267.7	121.9	149.7	281.1
2.	119.0	140.0	301.2	121.2	148.0	281.1
3.	121.6	144.0	267.7	120.1	144.2	274.4
4.	123.0	146.0	269.1	121.9	143.4	264.4
5.	125.8	151.0	275.8	122.3	144.4	277.8
Averages	121.56	144.2	276.3	121.4	145.9	275.8
ξ_i	0.44	0.55		0.44	0.53	

4-5-77	Nextel T_1	Nextel T_2	Nextel I	Solarsorb T_3	Solarsorb T_4	Solarsorb I
1.	119.5	145.1	281.1	116.0	140.0	267.7
2.	118.0	144.3	282.5	117.0	141.7	271.1
3.	120.6	147.8	281.1	118.6	142.5	271.1
4.	115.1	144.7	281.1	119.5	143.6	274.4
5.	120.8	148.2	281.4	121.4	145.7	277.8
Averages	118.8	146.0		118.6	142.7	270.4
ξ_i	0.42	0.52		0.439	0.53	

Table 4.5

Paint Comparison Tests Under Stagnation

4-6-77

	NEXTEL		SOLARSORB		
Data Point	T_1 DEG. F	T_2 DEG. F	T_3 DEG.F	T_4 DEG. F	I BTU/hr-ft^2
1.	152.4	169.4	158.2	178.0	197.5
2.	169.0	195.0	176.1	203.1	214.2
3.	185.2	220.4	189.8	227.8	241.0
4.	195.2	240.4	201.7	247.6	261.0
5.	209.3	256.0	214.3	261.5	267.7
6.	212.3	267.2	216.9	272.3	267.7
7.	216.2	274.4	221.6	278.4	274.4
8.	211.0	276.2	219.8	280.5	274.4
9.	213.8	275.4	215.7	279.3	271.1
10.	210.6	272.1	215.6	276.6	269.1
Average	198.65	249.3	203.6	254.6	254.0
ξ_i	0.782	0.981	0.802	1.002	——

Table 4.6 a

Paint Comparison Tests Under Stagnation

4-22-77

	NEXTEL		SOLARSORB		
Data Point	T_1 DEG. F	T_2 DEG. F	T_3 DEG. F	T_4 DEG. F	I BTU/hr-ft^2
1.	199.7	237.1	202.0	240.0	267.7
2.	209.8	249.9	213.5	252.4	267.7
3.	208.8	254.0	212.0	256.6	267.7
4.	209.4	255.9	210.6	258.4	264.4
5.	210.2	258.0	213.4	260.4	264.4
6.	208.4	258.6	211.4	260.8	261.0
7.	204.3	256.2	205.5	258.1	257.7
8.	201.6	254.1	204.5	255.3	254.3
9.	195.0	249.0	198.2	250.0	247.7
10.	189.9	243.2	191.0	244.2	237.6
Average	201.78	250.3	204.1	252.3	256.16
ξ_i	0.788	0.977	0.797	0.985	———

Table 4.6 b

signs of cracking and peeling. Corrective action to the peeling problem is discussed in section 4.2.2. Since the Solarsorb coating is estimated at twice the recommended thickness the Solarsorb may be even more efficient than the tests indicate. However, the Solarsorb manufacturer recently reported peeling of their test collector in Pennsylvania at -20°F. Since our Nextel test collector has experienced -20°F temperatures without peeling, it is recommended for the Prototype Collectors.

4.4 Air Flow Tests & Analysis

The Solar Collectors built by Life Science Engineering can be used with air flow rates in the range of from 50 to 1000 CFM. Expected air flow testing will range from 100 to 240 CFM. Air flows in this range have been recognized as being extremely difficult to measure. Two instruments were used to measure the air flow.

The Dwyer Micro Tector Hook Gage is proven to be an extremely accurate laboratory instrument and was used as a standard for calibration. However, this instrument cound not be used in our electronic data collection system to automatically measure air flows to three test cells. Also, it was found when field tested that the Hook Gage was affected by weather conditions such as exposure to the sun and wind pressure on plastic tubing. The Hook Gage must be stored inside so the fluid will not freeze. A stabilization period is required when it is brought outside for testing.

A Thomas Meter was developed in order to have a system that could be used in conjunction with a digital recorder. Modifications to the Thomas Meter were made and good correspondence was achieved between the measurements of the two instruments.

4.4.1 Thomas Meter Development

A Thomas Meter was originally constructed using two fine copper filaments, placed in the air flow path on either side of a nichrome heating filamenttation. The temperature rise of the air passing through the heating filament was to be measured by a bridge circuit which detected the change in the resistance of the copper filament on the downstream side of the heater. Because of instrumentation difficulties, the sensitivity of this method was low.

The Thomas Meter was then modified by replacing the copper filaments with thermopiles constructed of six couples of copper constantan thermocouple wire. Prior to the introduction of electrical power to the nichrome heating filament, the temperature of the air passing through the meter was measured by means of a Doric Trendicator. Power was then applied to the nichrome filament. The power dissipated in the filament was measured by a Simpson Model 79 Wattmeter with a range of 300 watts. The Doric Trendicator was then used to measure the change in temperature between the two thermopiles. The temperature change is arrived at as follows:

$$\Delta T_{\text{Across Thermopile}} = \frac{\text{Thermopile Reading } ^{o}F - \text{Initial Temperature } ^{o}F}{\text{Number of Thermocouple Junctions}} \quad 4.2.$$

Tests were run on February 12, 1977 with two different air flows and various increments of power supplied to the heater up to 300 watts. The scatter obtained is shown by the points plotted in Figure 4.2. This plot shows that the relationship between ΔT and power to the heater is essentially a straight line relationship. The tabulation of this data is given in Table 4.7.

Air flow is then derived from ΔT and power supplied by the following relationship:

$$\text{Flow rate, CFM} = \frac{\text{Power x 3.413 Btuh/Watt}}{\Delta T \text{ x } C_p \text{ x 60 min/hr x density}}$$

This may be simplified for the specific conditions of this test to:

$$\text{Flow rate, CFM} = \frac{\text{3.823 x Power (Watts)}}{\Delta T} \quad 4.3$$

The ducting containing the Thomas Meter was then connected to the collector system which introducted restrictions to the air flow on February 17, 1977 and additional tests were conducted. This resulted in a greater temperature rise for a lower value of power. The flow rate tabulation is shown in Table 4.7 and designated as Flow C.

During testing, variations were found in the power as shown by slow variations in the Wattmeter. Control of the input power was obtained by the addition of a Variac.

4.4.2 Ice Bath

The original data showed that small fluctuations of the order of 3 % in ΔT caused changes of up to 15 % variation in the CFM calculation. It was decided that an absolute reference junction was needed for measurement of ΔT. This was accomplished by removing the upstream thermopile from the plenum and placing it in an ice bath. The collectors remained connected for the rest of the flow measurements. On February 20th three tests with the ice bath were carried out in conjunction with the Hook Gage. The data was taken for 50 watt increments in the applied power up to a 300 watt maximum value. An air flow was selected and two successive tests were made and compared to the Hook Gage readings. For the third test the air flow was increased and the test was repeated. ΔT and air flow rates were calculated using equation 4.2 and 4.3 respectively and the results are tabulated in Table 4.8. A plot showing the variation of ΔT with applied power is illustrated for each test in Figure 4.3. A straight line relationship is again obtained. The deviation of ΔT from the curve using the ice bath is seen to be condiderably less than the deviation with the ambient air reference.

An examination of Figure 4.3 shows a small difference in the slopes of the two curves for the first two tests. Part of this is attributed to the change in

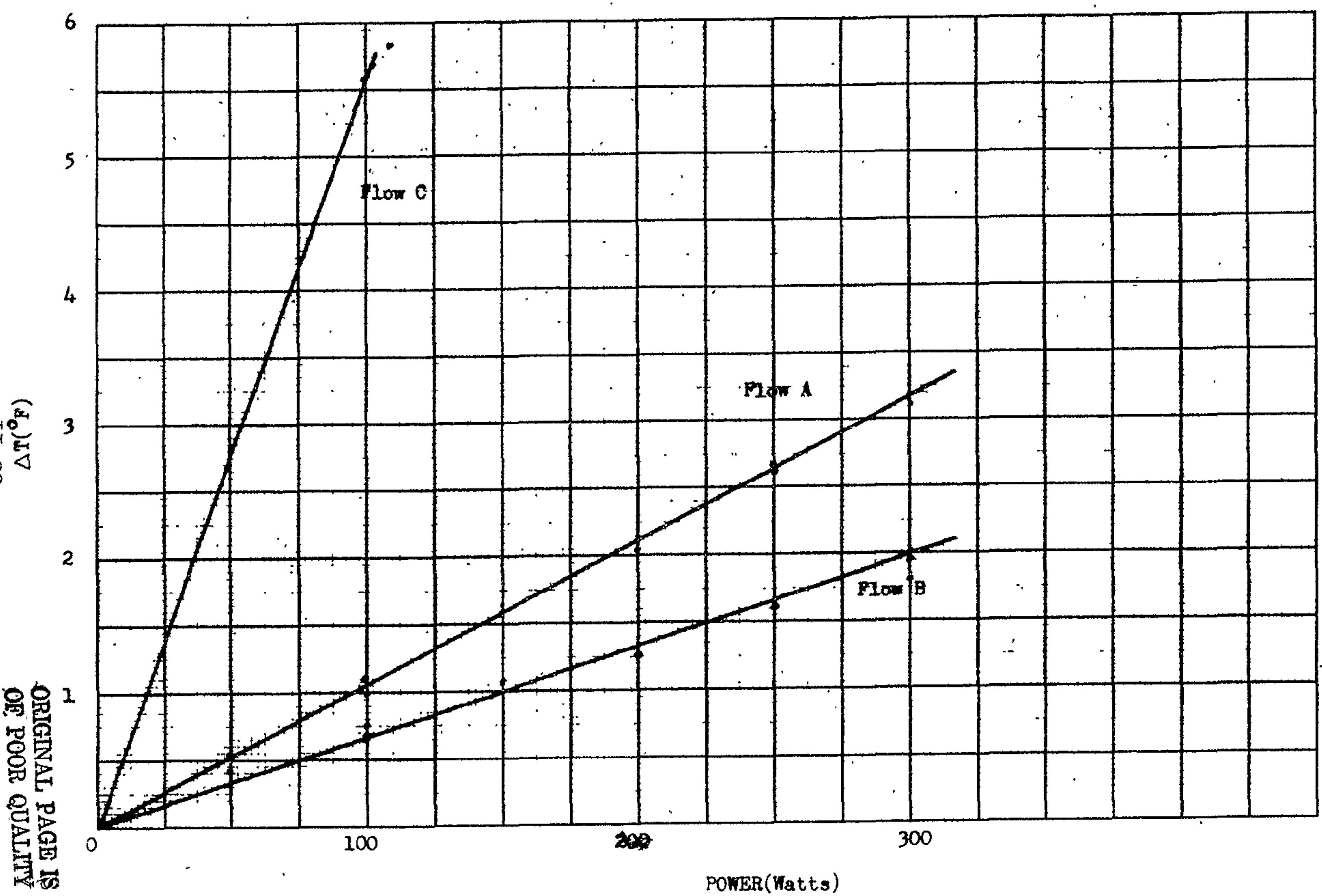

Figure 4.2 Thomas Meter Power – Temperature Relationship

Table 4.7 Thomas Meter Flow Tabulations

	Watts	Degree Differential	ΔT	CFM
Flow A	0	0	——	——
	50	3.30	0.55	347
	100	6.00	1.00	382
	150	9.60	1.60	358
	200	12.30	2.05	372
	250	16.20	2.70	363
	300	18.80	3.13	366
	250	16.00	2.67	353
	200	12.80	2.13	358
	150	9.90	1.65	347
	100	6.80	1.13	338
Flow B	0	0	——	——
	300	10.90	1.82	630
	200	7.70	1.28	597
	100	4.20	0.70	546
	150	6.50	1.08	531
	100	4.60	0.77	496
	50	2.80	0.47	406
	200	7.60	1.27	585
	250	9.80	1.63	587
	300	11.70	1.95	
Flow C	100	30.60	5.10	75
	102	34.40	5.73	68
	105	38.20	6.37	63
	108	39.30	6.55	63

	Time	Power (Watts)	T	Thomas Meter (CFM)	Hook Gage (CFM)
Test 1.	1410	0	---	---	120.3
	1411	103	3.13	126	
	1412	150	4.40	130	
	1413	200	5.90	129	
	1414	250	7.55	126	
	1415	300	8.90	129	
	1417	250	7.60	125	
	1418	200	6.08	126	
	1419	200	6.05	126	
	1420,	150	4.63	124	116
			Average	126	
Test 2.	1437	100	3.15	121	
	1437	150	4.70	122	
	1440	150	4.68	122	
	1442	200	6.10	125	124
	1443	250	7.65	125	
	1444	300	9.18	125	
	1445	250	7.83	122	125
	1449	150	4.80	120	
	1453	100	3.13	122	
			Average	123	

Table 4.8 Thomas Meter Performance Data Using Ice Bath
(Continued on following page)

Test 3

Time	Watts	T	CFM(Thomas Meter)	CFM(Hook Gage)
1510	200	4.83	158.2	160.7
1511	300	7.33	156.3	
1512	300	7.33	156.3	
1514	200	4.90	155.9	
1515	150	3.80	150.8	156.9
		Average	155.5	

Table 4.8 Thomas Meter Performance Data Using Ice Bath (Conclusion, of Table 4.8)

Ice Bath Data

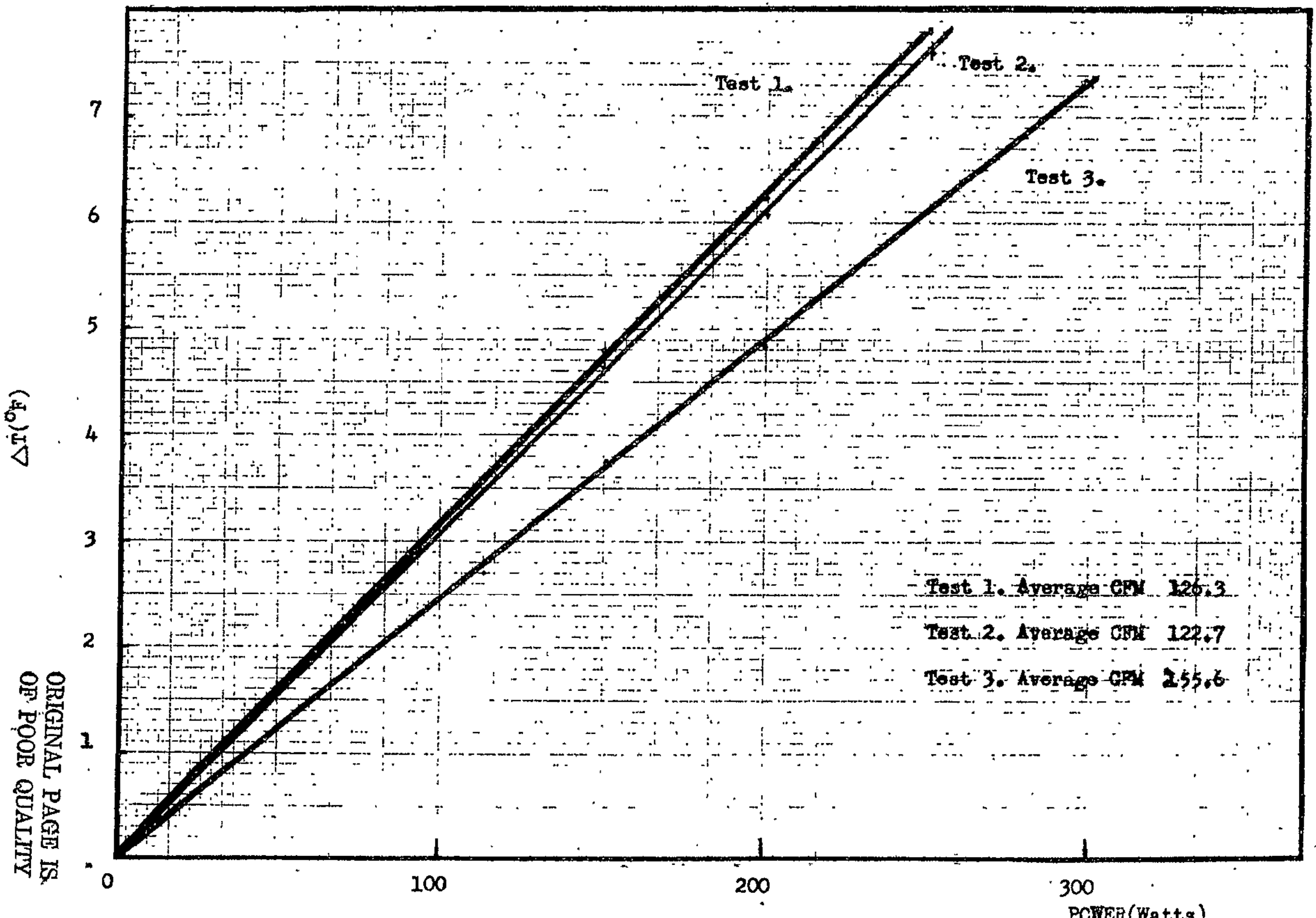

Figure 4.3 Thomas Meter Power - Temperature Relationship
With Ice Bath Reference

air density due to increases in the inlet air temperature which causes a change in the flow rate.

Variation in the air flow rate for each test are within ±3% of the mean. The comparison between the Thomas Meter and the Hook Gage in each of the three tests exhibited an average of 3 % difference which is considered satisfactory.

4.4.3 Testing Difficulties

When subsequent testing with other collectors was made in March it was found that the above results were not reproducible. The response of the Hook Gage and thermopiles was not linear with linear changes in the air flow rates. This was attributed in part to air leaks in the plenum caused by changing collectors. These were repaired and a better response was observed, though it was not as good as previously. The reason for this poor agreement of results was discovered when it was noticed that tests run with a single thermocouple in place of the thermopile displayed good comparison with the Hook Gage. This led to the discovery of a malfunction in one of the couples of the thermopile. Correction of this couple resulted in again obtaining reliable data. It was found that a small error was still being introduced into the system because of a temperature stratification in the ice bath. It became necessary to either agitate the ice bath vessel regularly or place another reference thermopile in the ice bath and take temperature readings at each data point.

4.4.4 Thermocouple versus Thermopile Testing

Additional testing was performed with the Thomas Meter. Comparison tests between a single thermocouple and the Hook Gage, and between the thermocouple and the six couple thermopile. During these tests the air flow rates were varied from 80 to 180 CFM and the power ranged between 100 to 200 watts to determine if there exists an optimum air flow regime for the Thomas Meter testing. It was found that good correspondence between Thomas Meter and Hook Gage

Blower RPM	Power Watts	Flow 1 (CFM) Thermocouple	Flow 2 (CFM) Thermopile	Flow 1 / Flow 2
steady	100	159	155	0.97
steady	100	159	154	.97
decrease	100	116	117	1.01
steady	100	116	117	1.01
decrease	100	80	83	1.02
steady	100	80	82	1.03
increase	100	106	108	1.01
steady	100	109	106	.97
increase	150	147	149	1.01
steady	150	147	149	1.01
steady	150	147	151	1.03

Table 4.9, Flow Measurements Using Thermocouple Versus 6 Couple Thermopile

Blower RPM	Power Watts	Flow 1 (CFM) Thermocouple	Flow 3 (CFM) Hook Gage	Flow 1 / Flow 3
increasing	98	76	73	1.04
increasing	98	105	102	1.03
increasing	98	121	122	.99
increasing	98	129	131	.98
increasing	98	161	157	1.02
decreasing	150	148	161	.92
decreasing	150	138	140	.98
decreasing	150	108	127	.85
decreasing	150	99	108	.91
decreasing	150	85	99	.86
increasing	200	101	116	.87
increasing	200	113	131	.86
increasing	200	127	145	.88
increasing	200	152	159	.96
decreasing	150	135	147	.91
decreasing	150	128	142	.90
decreasing	155	113	126	.89
decreasing	155	91	111	.81
steady	102	109	116	.94
steady	150	104	122	.85
steady	200	102	122	.84

Table 4.10 Air Flow Measurements Using Thermocouple Versus Dwyer Micro Tector Hook Gage. (April 22, 1977)

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reading was found over the whole range of air flows. The six couple thermopile proved to be only slightly better for measuring air flows than the thermocouple. The results of these tests are shown in Table 4.9 and 4.10 .

4.5 General Description of Work Accomplished During the Quarter

4.5.1 February

Test Collector

Four SC22X48 Test Collectors' plenum chambers were reworked to the PDR baseline specification. A 1/32 " teflon strip was placed between the absorber panel and the U Channel. This was developed to improve motion due to expansion of the absorber panel. The absorber panel was provided with elongated holes for rivets. Interconnecting units were developed for these SC22X48 panels. Transmissivity data was taken on the collector glazings.

Test Facility

Test Cell No. 2 was modified for installation of the four SC22X48 test collectors. An air flow director was installed to direct air from one set of vertical panels to the other.

The Test Station was developed on the east wall of the Test Facility. A Doric Trendicator, Wattmeter, Solar Pyranometer and Variac were installed. Six additional thermocouples were added to the SC4X8 pressure test units to monitor input/output temperatures. Eight thermocouples were added to Test Cell No. 2 for input/output temperature monitoring.

Data Collection System

Several data loggers and mini computers were investigated. Two data loggers were followed up. It was tentatively decided a mini computer would not be essential to the program.

Test Data

Due to poor weather only a few days of data were taken after side insulation was installed on the SC4X8 collector.

The Thomas Meter copper wire sensing elements were replaced with a thermopile as the copper wire did not have the required sensitivity. Initial comparative tests between the Thomas Meter and the Dwyer Micro Tector Hook Gage were in good agreement.

4.5.2 March

Test Collectors

Prior to installing the four SC22X48 test collectors, two thermocouples had to be replaced. They were fixed with epoxy and then covered with RTV. Pressure test units were fabricated and installed above and below the other two sets of collectors.

Test Facility

Test Cell No. 2 Thomas Meter outlet ducting was reworked for alternate equal flow to the two sets of collectors.

SC4X8 Test Data

Test data was obtained on the SC4X8 collector through March 27th. The collector was in stagnation testing (with stack flow) from installation. On March 5th a 2"X4" peeling spot appeared. On closer examination, there were also hair line cracks which the Solarsorb manufacturer indicated was due to over spraying.

Performance test data was taken on several days at 70°F inlet temperature. On March 27th, a 95°F average inlet temperature was used.

SC22X48 Collectors

The four SC22X48 test collectors were in stagnation testing since early March. Preliminary data indicated little temperature difference between the Solarsorb and Nextel paints.

Data Collection System

A letter was sent to the Technical Manager requesting concurrence to purchase a Doric Digitrend 220 data logger. Concurrence was given by the Technical Manager in a telcon.

The Life Sciences Engineering staff decided a mini computer was not necessary at this time.

Specification Review

The thermal specification for 130°F (for an inlet of 70°F) and 180°F (for an inlet of 140°F) was analyzed because performance data was not meeting specification data. It was found that the 130°F/180°F specifications were developed for the original 4' x 10' collector. An Engineering Analysis of the Thermal temperature Specification used theoretical tables and curves to indicate what could be expected for specific flow rates. A recommendation was made to change the specification air outlet temperatures to 120°F & 172°F.

4.5.3 April

SC22X48 Test Collectors

After two months of stagnation testing, mainly with stack flow, both Solarsorb coated absorber panels showed a few peeling spots. Further discussions with the Solarsorb manufacturer indicate that putting phosphoric acid in the Solarsorb paint was insufficient to properly etch these panels. Late in April, the panels were removed and dismantled. The Solarsorb paint was removed with paint remover and the panels were reworked.

Total stagnation testing was performed on two days about a week apart. This test was combined with absorber paint testing. The results of the stagnation tests indicate that the Solarsorb had slightly better thermal absorption properties. The Nextel paint withstood the severe conditions without noticeable change while the Solarsorb paint showed peeling. However, the absorber panels were not etched for the Solarsorb so that the tests were not considered fair to Solarsorb and will be resumed in May.

SC4X8 Test Collector

After March 27th, testing on the SC4X8 Test Collector was halted due to the continued peeling of the paint. The collector will be reworked as soon as the Sunadex glass is delivered.

Test Facility

During testing of the SC4X8 and SC22X48 panels, discrepancies in air flow were found. Considerable work was done in locating the leaks and caulking and foaming these areas.

The Thomas Meter was tested under a series of air flows for different applied power to the heater filament. The data indicates that the meter is not dependent on a particular heater wattage and the data is repeatable within limits of the thermocouples and the Doric Trendicator.

New SC4X8 Test Collector

A new SC4X8 Test Collector has been fabricated to baseline specifications and to prepare the manufacturing drawings. This collector has a center crossbrace for two 4' x 4' Sunadex glass glazings. The absorber panel was designed to float within the collector to prevent stresses. This new design was based on our stress analysis entitled, Absorber Paneling Stiffening and Attachment to Frame Conclusions and Glass Stress Conclusions. A crossbrace located in the center of the collector not only supports two glass sheets, but also supports the absorber panel and the side frame. The absorber panel is only attached to the crossbrace to provide for its expansion and contraction. It is often referred to as a floating absorber panel.

4.6 Forcast of Activities to Complete Tasks

4.6.1 The following activities are forcast for the month of May which are required for the Prototype Design Review.

Glazing tests will be completed in May with Sunadex glass compared with regular glass in 2 sets of SC22X48 collectors all with Nextel painted absorber panels.

4.6.2 The second SC4X8 Test Collector fabrication will be completed in May to baseline specifications and thermal analysis requirements. This test collector will be used to complete manufacturing drawings and procedure by mid-May. This will be the first unit to have the center crossbrace. Testing of this unit will begin late in May.

4.6.3 Installation drawings will be developed using two spare test collectors during May.

4.6.4 The data collection system delivery is expected in May. It will be installed checked out and used for data collection by June.

4.6.5 The Installation, Operation and Maintence Manual will be complated in May.

4.6.6 The Certification Plan willbe based on the Verification Plan. Specific Qual Unit testing has been prepared for incorporation into the Certification Plan.

4.6.7 The Spare Parts List and function description of the SC4X8 collector will be completed for the Prototype Design Review.

4.6.8 Review the Revised Engineering Analysis of the Temperature Specification, in Huntsville May 24th.

4.7 Identification of the Major problem Areas.

4.7.1 Shipping of components and materials has been a continuing problem. The Sunadex glass took 1½ months. Extrusions may take four weeks.

Approval is requested to order the Sunadex glass and end section extrusion as soon as possible as consistant with the Prototype Design Review procedures.

4.7.2 The Solarsorb paint peeling was primarily due to poor directions from the manufacturer for absorber panel preperation. A complete procedure has been prepared to properly clean, etch,and desmut each absorber panel prior to painting. The entire procedure will be tested by mid-May.

THIRD QUARTERLY REPORT

AIR FLAT PLATE COLLECTOR

TO

NATIONAL AERONAUTICS & SPACE ADMINISTRATION

NAS8-32261

JULY 31, 1977

Life Sciences Engineering
Rt. 1, Box 746
Morrison, Colorado 80465

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Part I Summary

1. Introduction

This third quarter was the Final Developmental Phase of the Air Flat Plate Collector and Manufacturing preparations which are described in the subsequent parts of this report.

2. Summary

2.1. Contract

An Engineering change proposal was submitted and approved for changing the air outlet temperature specifications.

3. Schedule

A proposed schedule for manufacturing was given along with completion dates.

4. Technical Performance

4.1. Data Analysis

Glazing performance data was collected, reduced and analyzed and the results were tabulated.

4.2. Glazing Tests

Stagnation and Performance Testing was performed on the Sunadex glazing and compared to normal glass.

4.3. Back Panel Testing

Stagnation and Performance Testing was performed on bare panels and compared to back panels with flat black coatings.

4.4. Heat Transfer Testing

Preliminary Testing was performed on the SC4X8 absorber panel to deterimine the heat transfer properties between the absorber and U-channel stiffeners.

4.5. Description of Activities

A description of monthly activities was provided.

4.6. Forecast of Activities to Complete Tasks

A Forecast of Activities required to complete manufacturing of the first eleven SC4X8 collectors were provided and an approximate completion date was given.

4.7. Major Problem Area

Shipping delays were discussed and expected arrival times were given. This also required changes to the production schedule.

PART II CONTRACT

2. Changes Requested

2.1 Engineering Change Proposal

An Engineering Change Proposal titled, "Heating Capacity Air Exit Temperatures," Program Control Number AH-00274 was submitted on May 13, 1977. The ECP was approved by CCBD 301-77-0144 as stated in Amendment/Modification No. 4. This ECP changed the Subsystem Performance output: from 130°F to 120°F for a 70°F inlet air temperature, and from 180°F to 172°F output for a 140°F inlet air temperature. The graph of Efficiency as a Function of Operating Conditions was changed to include the above performance changes.

2.2 Prototype Design Review

The Prototype Design Review corrected 13 Review Item Discrepancies. On June 24th, the Technical Manager closed all RIDs and directed Life Sciences Engineering to proceed with fabrication of the Prototype Collectors.

PART III SCHEDULE

3. Schedule

3.1 Verification Plan Test Program

The Verification Plan Test Program was revised as shown in Figure 3-1. The Glazings Tests and Combined Coatings/Glazings Tests occurred in late May and June. Additional stagnation tests were added in June with the Combined Coatings/Glazings Tests. The Environmental Tests and Structural Analysis/Testing were transferred as part of the Certification Tests to August. This was necessary as materials for the Qualification Unit and Prototype Collectors could not be ordered until the end of June. An additional Functional Performance Test was included as it was part of the Certification Test.

Acceptance Tests for the first three (FACI) Prototype Collectors was proposed for mid-September. Acceptance Tests for the remaining 7 Prototype Collectors was proposed for mid-October.

3.2 Development Plan

The Development Plan, Figure 3-2, was simplified by listing all Quarterly Reviews on one line. The First Article Review was proposed for mid-September. Hardware delivery for the first 3 Prototype Collectors was rescheduled for late September. The Prototype Review was completed on June 24th.

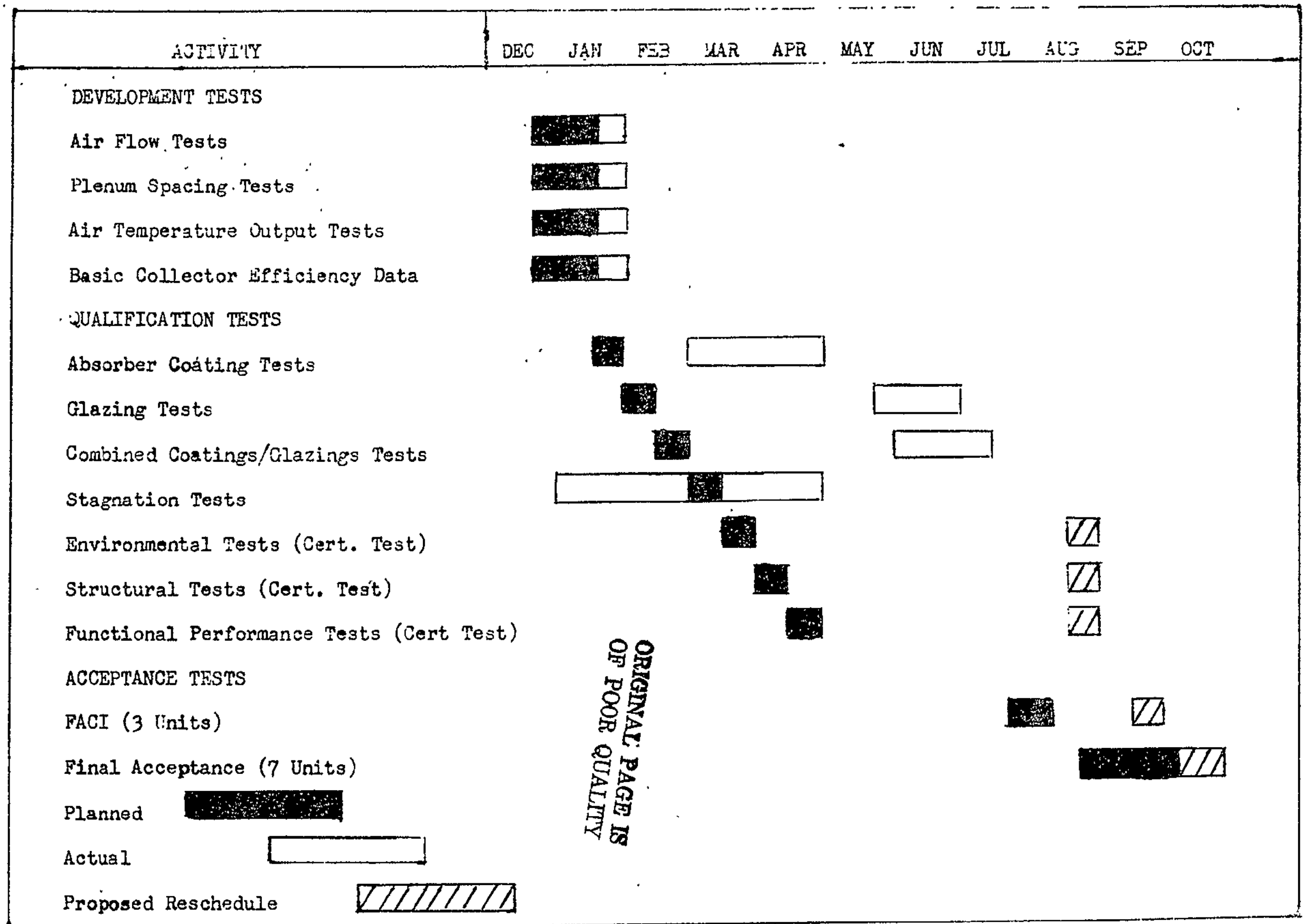

Figure 3-1 VERIFICATION PLAN TESTING

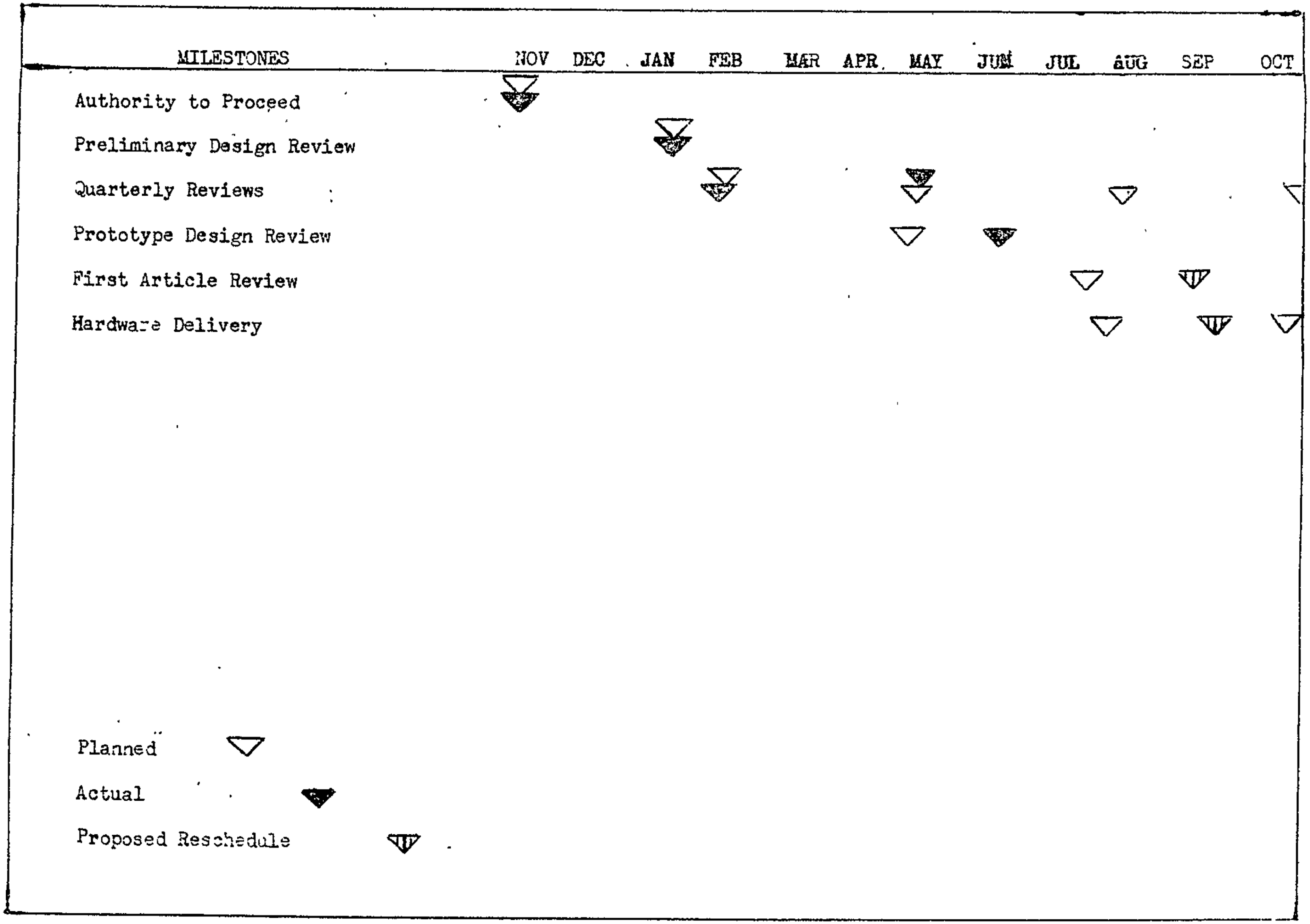

Figure 3-2 DEVELOPMENT PLAN

PART IV TECHNICAL PERFORMANCE

. Data

Testing began in this Quarter with the glazing tests for Sunadex glass on May 22. These tests continued into June. In July tests were made to determine if there was an advantage or disadvantage in painting the inside portion of the back panel. Preliminary tests were also made in July to determine if there was good heat transfer between the 4'x8' absorber panel and the U channel stiffeners riveted to the back of the absorber.

4.1 Data Analysis

Data taken during the glazing stagnation tests was recorded with the Doric Trendicator. In early June the Digitrend Data Logger was installed and checked out and all subsequent data was recorded with this instrument where possible. The Doric Trendicator was used in the heat transfer tests with 4'x8' absorber panel and is presently being used to monitor outgasing tests made with an 18"x18" small test fixture. Insolation testing through the middle of July was taken with the new Rho Sigma Pyranometer. The subsequent degradation of two Rho Sigmas prompted Life Sciences to order the Epply PSP Spectral Pyranometer which was delivered after mid-July. Air flow testing was made with the Thomas Meter and checked periodically with the Dwyer Micro Tector Hook Gage.

4.2 Glazing Tests

Stagnation and performance testing began on May 22nd right after the Sunadex glazing arrived. The first results were considered unsatisfactory due to the partial failure of the Rho Sigma Pyranometer. Upon replacing the Rho Sigma good results followed.

4.2.1 Stagnation Testing

On May 27th stagnation testing occurred. The East cell at the test facility was composed of two series 22"x48" Test Collectors each having a Sundex glazing. The West cell was identical except the glazing was of plain glass. The day was clear and wind speed was considered negligible. Readings were taken at 15 minute intervals. The results are recorded in Table 4-1. These results show that during stagnation the lower collector in the East cell utilizing the sundex glazing was consistently 2°F hotter than the normal glazing. The upper collector of the East cell held a consistent 6° advantage over the plain glass cell.

4.2.2 Performance Testing

Testing was halted the first week of June until the Digitrend Data Logger was installed, and checked out. Several days of glazing tests followed with the blower on. Representative data was taken on June 14th. The day was clear with a negligible wind factor. A few clouds formed in the late afternoon giving variations in the insolation readings. The results are recorded in Table 4-2. Air flow in each cell was monitored separately and stayed consistently within 2 or 3% of each other as the blower RPM'S were varied. The efficiency calculations show an enhancement in the BTU output for the Sundex glazing of from 10 to 18% over that of normal glass depending on the volume of air flow. Further testing is planned to verify this initial data, in September and October.

4.3 Back Panel Coating tests

Testing resumed July 20th. The East and West test cells were supplied with identically constructed test collectors, each having Sundex glazings. The only difference in the collectors was that the inside

SUNADEX GLAZING STAGNATION DATA *

Insolation	Ambient Temperature °F	Sunadex Lower Collectors °F	Sunadex Upper Collectors °F	Normal Lower Collectors °F	Normal Upper Collectors °F
246	72	223	243	220	236
248	72	229	251	227	244
254	74	234	256	232	250
255	75	237	261	236	254
257	76	242	266	240	259
261	77	245	269	243	263
261	77	246	271	245	265
257	77	246	272	245	265
257	78	245	272	244	265
254	78	243	270	243	264
250	80	242	269	241	263
246	79	239	266	238	260
243	79	235	262	235	257
235	80	231	257	230	252
228	80	225	252	225	247

* Data was taken at 15 minute intervals

Table 4-1 (May 27, 1977)

SUNADEX GLAZING PERFORMANCE TEST *

		Sunadex glass				Normal glass			
Insolation	Ambient	Inlet Temperature	Outlet Temperature	CFM	Efficiency	Inlet Temperature	Outlet Temperature	CFM	Efficiency
265	88	95	145	57	71	94	134	54	54
267	89	96	148	57	73	95	136	54	56
266	89	97	150	53	69	96	139	51	53
266	90	98	151	53	70	97	140	51	54
265	90	99	152	53	71	98	141	50	53
266	91	100	153	56	73	99	141	52	54
262	90	101	153	54	71	100	141	52	54
261	92	102	153	55	71	101	141	52	54
258	92	103	153	55	72	102	141	52	53
252	92	103	152	55	69	102	140	52	52
232	94	103	150	55	74	102	139	52	54

* Data was taken at 15 minute intervals

Table 4-2 (June 14, 1977)

of the East collectors had a flat black coating and the West cell collectors had bare aluminum back panels.

4.3.1 Stagnation Testing

The testing results taken on July 20th are tabulated in Table 4-3 and show that no consistent advantage is given to either test cell and that in most cases the results are nearly identical.

4.3.2 Performance Testing

Air flow testing began July 27th and results are tabulated in Table 4-4. The efficiency calculations again show that no significant advantage exists for the coated back panel, but the sky had been partly cloudy to overcast since testing began so that additional testing is required.

4.4 Heat Transfer Between Absorber Panel and Stiffeners

Concern has been raised over the heat transfer between the absorber panel and the U-channel stiffeners riveted to the back of the absorber so that for cases of thermal shock to the collector, the absorber panel would have room to expand without buckling. A worst case condition was investigated in which the collector was assumed below zero at night and an early morning sun was suddenly exposed to the collector. Heat transfer between the absorber and U-channel was assumed to be poor and a possible temperature difference of 120°F was arrived at. On the basis of this, a 1/4"x5/32" obround rivet hole was arrived at, giving the length of the absorber sheet 1/8" on each end to expand without buckling.

Preliminary testing was performed without air flow on the Manufacturing Mock-up test collector. The absorber panel temperature was monitored in the position required by the specifications. One U-channel temperature was monitored directly on the end rivet nearest

COATED VERSUS UNCOATED BACK PANEL DATA

UNDER STAGNATION *

	Uncoated			Coated		
Insolation**	Top T.C. °F	Center T.C. °F	Side T.C. °F	Top T.C. °F	Center T.C. °F	Side T.C. °F
270	254	247	243	251	246	242
272	260	253	248	258	252	249
273	264	256	251	262	256	254
280	270	262	257	270	264	262
275	273	264	259	273	266	266
277	274	265	259	274	267	267
275	271	263	256	272	265	266
275	252	245	236	252	246	246
275	264	254	248	263	256	258
271	262	252	245	261	253	256
268	258	251	242	258	250	254
265	253	248	237	254	246	250
257	248	241	232	248	241	245
250	240	232	224	240	233	237

* Data was taken at 15 minute intervals.

** Results tabulated on the upper collectors of each cell.

Table 4-3 (July 20, 1977)

	UNCOATED			COATED		
INSOLATION	CFM	T	EFF	CFM	T	EFF
208	48	15	26	45	16	20
231	48	19	24	45	20	24
262	45	26	27	42	30	29
254	45	26	28	42	30	30
215	52	25	37	48	28	38
258	52	24	29	48	27	30
279	52	30	34	48	34	34
263	60	31	43	55	30	38
277	60	30	40	55	33	40
260	44	29	30	40	28	40
245	44	30	33	40	30	30

Table 4-4 COATED VERSUS UNCOATED BACK PANELS WITH AIR FLOW (July 27,1977)

the top of the absorber. On the opposite U-channel, a thermocouple was placed between the top two rivets. The sheet was allowed to come to equilibrium indoors and then taken outside and set perpendicular to bright sunshine. Temperature increases were monitored by the Doric Trendicator at one minute intervals. The results are displayed in Table 4-5. Note that the temperature lag of the U-channel hits its peak in 2 to 3 minutes and that the rates of temperature increase thereafter, are approximately the same for the absorber panel and the U-channel until equilibrium is approached when the U-channel temperature approaches that of the absorber panel. Visual inspection of the absorber during the test found no buckling. This indicated that heat transfer was much better than previously believed and the existing 1/4"x5/16" obround rivet holes were more than adequate for any conditions of thermal shock found in the United States.

4.5 General Description of Work Accomplished during the Quarter

May

Test Collectors

Two SC22X48 Test Collectors were reworked for the Glazing Tests by replacing the plain glass with Sunadex glass. Initial data was taken on May 22nd. which compared the Sunadex performance against plain glass performance.

Data Collection System

The wind direction and speed instrument was received and installed on May 27th. The Digitrend Data Logger arrived on May 31st and was installed during the first week in June.

Design Changes

A Revised Engineering Analysis of the Temperature Specification for the Air Flat Plate Collector was prepared and became the basis for the Engineering Change Proposal described in Section II.

HEAT TRANSFER TESTING BETWEEN ABSORBER AND STIFFENERS

Time	Top T.C.	Center T.C.	Bottom T.C.	Side T.C.	U Channel on Rivets	U Channel between Rivets
* 1300	90	90	90	90	90	92
** 1305	99	101	100	101	97	97
1306	113	114	113	114	104	102
1307	118	118	117	119	108	109
1308	126	127	129	126	116	114
1309	130	132	130	133	121	115
1310	132	133	132	134	124	118
1311	133	135	133	136	124	118
1313	135	137	134	140	125	124
1315	140	139	138	141	126	126
1317	144	144	141	145	128	130
1319	147	145	145	150	130	133
***1330	161	159	158	161	149	148
1400	160	158	158	158	150	148

* Equilibrium reached indoors

** Sudden exposure to sunlight (no glazing)

*** Equilibrium

Table 4-5 (July 26, 1977)

Quarterly Report

The Second Quarterly Report for the second 3 month period was submitted. This report contained all of the test data except the May 22nd. Glazings Test.

Technical Conference

A technical conference was held on May 24th. The SC4X8 drawings were reviewed and additional drawings were requested. A number of recommendations and suggestions were made. The thermal analysis was reviewed. Additional reports submitted included: Installation, Operations and Maintenance Manual, Spare Parts List, Functional Description and the Certification Plan.

June

Test Collectors

Additional Glazings Tests were performed on the SC22X48 Test Collectors. The Sunadex glazing yielded efficiencies up to 20% higher than the normal glass during air flow tests.

Test Facility

The Digitrend Data Logger was installed and checked out during the first week in June. A tachometer was attached to the blower motor to monitor RPM's.

A false ceiling was installed in the test facility to serve as a common ducting to return collector heated air to the blower motor to provide for higher input air temperatures from 120°F to 140°F. A monitor was placed on the line voltage to measure its variations. Dry and wet bulb thermocouples were installed in the duct and test facility for measuring relative humidity at each location.

The data system is now monitoring: humidity, ambient air temperature, wind direction and velocity, solar radiation, input line voltage, absorber panel temperatures, input-output air temperatures, blower RPM's and Thomas Meter air flow data.

Prototype Design Review Summary

Thirteen Review Item Discrepancies (7LS5 through 7LS17) were received during the first week of June and responses were completed by the end of the following week. All RID's were closed on June 24th. and Life Sciences Engineering was directed to proceed with the fabrication of the Prototype Collectors. A number of changes were made in the collector design by the RID's and drawings were changed accordingly.

Manufacturing Preparation

Orders were placed for the special extrusions and the Sunadex glass in late June. A 5 ton punch press was obtained. Four miter vises were obtained to hold the aluminum outer glazing H-bar frame during its fabrication and for Tedlar installation. Tanks for etching and cleaning were obtained and insulated. A heating system was developed to hold the solutions at the proper operating temperatures. Negotiations were completed for the manufacturing facility which has 1800 square feet of work area. A test fixture, 18"x18" was constructed to test the outgasing properties of certain adhesives and silicone rubber strips used in the SC4X8 Prototype Collectors.

Certification Document

A Certification Document was started in June to accompany the Certification Plan. It will contain data and signature pages for each item in the Certification Plan.

July

Manufacturing Preparation

The etching and cleaning tanks were completed in early July and four 22"x48" panels and one 4'x8' panel were successfully etched and painted. Safety procedures were added to the existing specification.

A competent welder was found who will make the welds for the collector frame. A welding jig was designed to hold the frame while it is being welded.

In assembling the manufacturing mock-up collector, a number of procedure changes were made. The absorber panel and stiffeners will be riveted together prior to painting. The rivet back-up plate or washer will be installed with the rounded side down and temporarily shimmed with a .001 shim during installation. This shim will also be used to provide spacing between the 5/8"x5/8"x1/8" U-channel and the absorber panel to provide for the floating motion of the absorber panel.

In ordering the aluminum, companies were not able to supply the 4'x8' aluminum sheet .032 thickness in the 3003-H34 specification but were able to supply it in the 5005-H34 specification. No significant changes are expected from this substitution.

The 18"x18" test fixture was mounted on the manufacturing facility roof and connected to the Doric Trendicator. Outgasing tests of the silicone RTV 732 will be performed during the first week in August.

Manufacturing Facility Preparation

Manufacturing equipment was transferred to the Manufacturing Facility on July 9th. Lighting, coolers and fans were installed for better working conditions. Working tables were constructed for assembling the collectors, the punch press and power saws. A heater control panel was designed, developed and installed to supply electrical power to the etching and cleaning tanks' heaters. Storage racks and shelves were made to hold the raw materials and supplies for assembling the collectors.

4.6 Forecast of Activities

The following activities were forecast for the month of August which are primarily required for completion of the Certification Test.

4.6.1 The Manufacturing Mock-up will be completed and templates developed from the mock-up for mass producing subsequent collectors.

4.6.2 The Qualification Unit will be fabricated upon completion of the templates.

4.6.3 The Certification Testing will proceed from Performance Testing through structural testing. An Architectural Engineer will review drawings in support of the Certification Agency.

4.6.4 The Design Brochure will be completed by the end of August.

4.6.5 Components for the first three Prototype Collectors will be made in August. Assembly of the components is planned for the first week in September. FACI is proposed for September 15th.

4.7 Major Problem Areas

Orders were placed for all components during the last week in June and first week in July. Several companies had back logs of orders resulting in shipping delays that subsequently delayed the proposed fabrication of the deliverable Prototype Collectors. The Certification Test is now scheduled for the last week in August. Delayed materials included the Sunadex glass and the plastic U-channel. Most of the materials were availablefor going ahead with fabrication of the Manufacturing Mock-up and the Qualifacation Unit. Fabrication of the Qualification Unit is expected to be completed by mid-August.

The National Aeronautics and Space Administration research studies on Tedlar are needed to support the Certification Test.

FOURTH QUARTERLY REPORT

AIR FLAT PLATE COLLECTOR

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NAS8-32261

OCTOBER 31. 1977

LIFE SCIENCES ENGINEERING

Rt. 1, Box 746

Morrison, Colorado 80465

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PART I SUMMARY

1. Introduction

During the Fourth Quarter, the Manufacturing Mockup, Qual Unit and ten Prototype Solar II Collectors were fabricated and tested as described in subsequent parts of this report.

2. Summary

2.1. Contract

The Certification Test was completed and monitored by the Certification Agent on both Performance and Structural Tests.

2.2. First Article Configuration Inspection and Acceptance Test I

The First Article Configuration Inspection for serial number LSE4x8-00-002 and 003 were completed on October 6th.

2.3. Acceptance Test II

Acceptance Test II was completed on November 4th for serial numbers LSE4x8-00-004 through -010.

3. Schedule

The Schedule in Part III reflects the actual schedule for the completion of the contract.

4. Technical Performance

4.1. Data

Extensive Data was obtained on the Mockup Unit, the Qual Unit and the first 3 Prototype Collectors during this quarter. While the data indicated performance was above the Specification Curve, stray noise made the efficiencies excessively high.

4.2. Certification Structural Testing

All structural tests in the Certification Test Plan were satisfactorily completed.

4.3. Test Facility

The stray noise problem was found to be a grounding/shielding problem in the Thomas Meter which was corrected. Glazing tests which were originally performed in July were repeated to compare the efficiences of Sunadex versus plain glass as an inner glazing.

4.4. General Description of Work Accomplished

A general description of the work was provided for each month of the Quarter.

PART II CONTRACT

1. Changes Requested

No requests for changes were submitted during this quarter.

1.1 Certification Test

The Certification Test for the Qualification Unit was begun September 3rd. with Performance Tests and completed on September 30th. with Structural Tests. A summary is provided in the Technical Performance Section.

1.2 First Article Configuration Inspection and Acceptance Test I

The First Article Configuration Inspection was held on October 6th. This inspection included a review of the Certification Test Report, the FACI for serial number LSE4X8-00-001, and Acceptance Test Reviews of Solar II Collectors, serial numbers LSE4X8-00-002 and LSE4X8-00-003. These collectors were shipped on October 31st.

1.3 Acceptance Test II

A second Acceptance Test was held on November 4th. for the remaining 7 Solar II Collectors, serial numbers LSE4X8-00-004 through LSE4X8-00-010. Upon completion of the Acceptance Test, the Solar II Collectors were boxed and shipped on November 7th.

PART III SCHEDULE

3. Schedule

3.1 Verification Plan Test Program

The Verification Plan Test Program was revised to reflect the actual testing as shown in Figure 3-1. The Certification Test began with Performance Tests on September 3rd and Structural Tests were run on September 28th. Additional Performance Tests were run between September 14th and November 4th to locate an intermittant noise problem that appeared during high temperature testing. Performance Tests run on November 3rd. and 4th. verified an intermittant thermocouple problem had been corrected. A Verification Test Summary was prepared for the FACI to indicate the status of the Test Program prior to Certification Test.

Acceptance Tests for the first three Prototype Collectors occurred during FACI on October 6th. Acceptance Test for the remaining seven Prototype Collectors was completed on November 4th.

3.2 Development Plan

The Development Plan shows the final planned versus actual milestones in Figure 3-2. The first three Prototype Collectors were shipped on October 31st., and the remaining seven Prototype Collectors were shipped on November 7th.

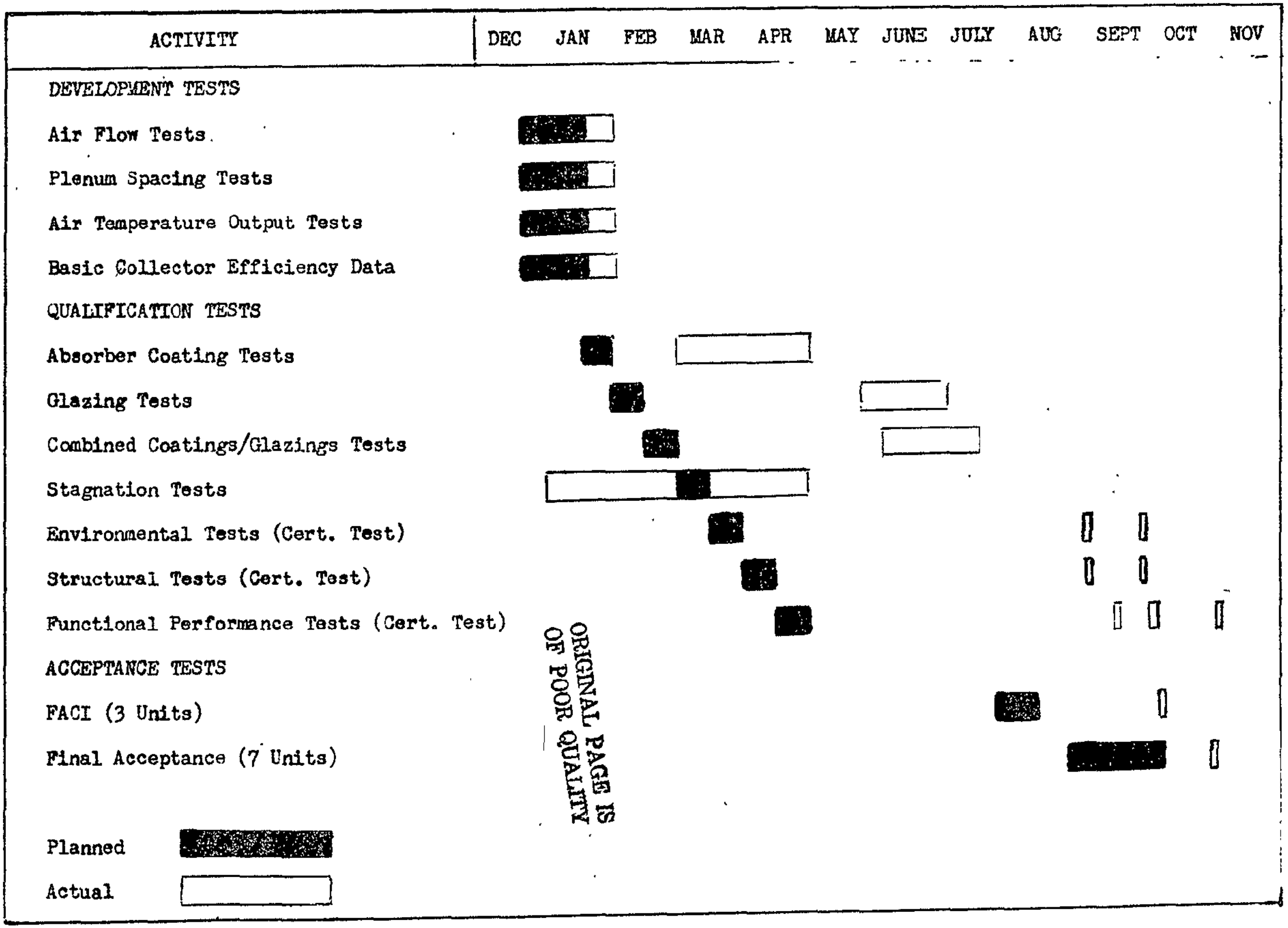

Figure 3-1, VERIFICATION PLAN TESTING

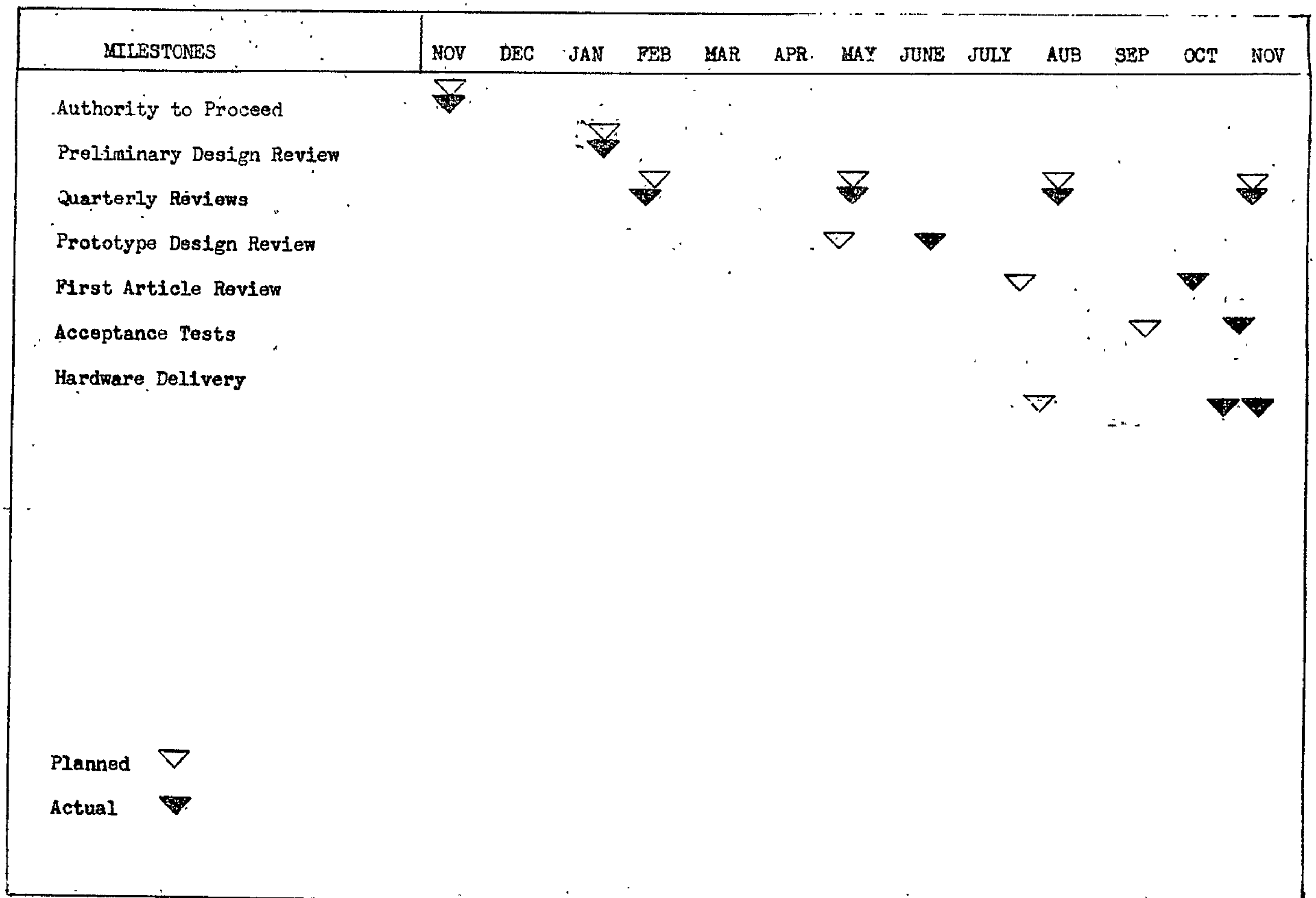

Figure 3-2, DEVELOPMENT PLAN

Part IV Technical Performance

4.1 Data

Extensive testing of the collectors was carried out this Quarter. The Manufacturing Mockup was tested for preliminary performance and stagnation data, and for structural integrity as preparation for Certification Test. The Certification Test was run on the Qualification Unit according to Certification Test Plan. Certification data was taken at three input temperatures. Stagnation data was obtained, and extensive structural testing was performed. Each of these tests was monitored by the Certification Agent, J. Pals of Intermountain Inspection Co. Performance testing was then carried out on the first three deliverable units; #LSE 4x8-00-001 through -003 to assure that baseline performanse specifications were met. July glazing tests were repeated to determine the advantage of Sunadex glass over plain glass.

4.1.1 Performance Data

Data on all LSE 4x8 collectors was taken at the test facility using the same testing cell and our standard testing and recording equipment. Temperatures of the absorber panels were measured with thermocouples for the Mockup and Qual units and with Minco Thermal Resistors for LSE 4x8-00-001 through -003 collectors.

4.112 Performance Data for Manufacturing Mockup.

The Manufacturing Mockup was finished in August. The purposes of the Mockup were: 1., to develop manufacturing proceedures, 2., to develop Certification Test procedures, and 3., to obtain preliminary performance data.

The Mockup performance data was found to be in error due to a faulty end connector design. The end connector was re-designed for all subsequent units to permit better air flow. Mockup stagnation tests found absorber temperatures in excess of 350°F for insolation near 300 BTUH/ft^2. The inner Sunadex glazing reached a temperature of 255°F and the H-bar flange at the bottom of the collector reached 196°F. After the end connector was redesigned, the pressure drop across the collector was .1 inches or less of water at 120 CFM of air flow.

.1.3 Performance and Stagnation Data for the Qualification unit

Performance and stagnation data were taken on the Qual unit. The testing of this collector was monitored by the Certification Agent. The performance curve and the specification curve per ECP # CCBD 301-77-0144 are plotted in Figure 1. The Qual Unit performance is well above the Specification Curve. Performance data is shown in Tables 1, 2, and 3.

Certain misleading data points have been deleted from these tables. One such "wild" point underlined in Table 3 and plotted in Figure 1. This point was the result of a momentary cloud cover which caused a large drop in insolation resulting in a large increase in efficiency.

In Figure 1, some variations in the data points were observed to become more pronounced as the air temperature increased. These variations were due to the inherent turbulence in the air duct where the Thomas Meter is located. The forced convection heat transfer coefficient between the air stream and the thermopile is a function of the intensity of the turbulence and the temperature of the air stream. Such variations can be greatly reduced by constructing a special air duct that exhibits laminar flow where the Thomas Meter is located.

Stagnation data is displayed in Table 4. In Figure 2 a curve of Air Flow Rate through the Collector Versus Pressure Drop across the collector is drawn showing that at 120 CFM the pressure drop across the collector is less than .1 inches of water which concurs with the pressure drop requirement.

4.1.4 Performance Data for # LSE 4x8-00-001 through -003

In order to assure that the first three deliverable units exhibited efficiencies equivalent to the Qual unit, performance data was recorded. The 70°F air input data for collectors -001 through -003 is given in Tables 5, 6, and 7 respectively.

4.2 The Certification Test's Structural Testing

The structural testing of the Qual unit required in the Certification Test Plan was succesfully performed as follows. A drop test and racking test of the collector simulated handling and shipping stresses. A Maximum Load Test with 16 lbs/ft^2 of water on the Qual unit was designed to simulate wind, snow and ice loads. The Tedlar Water Load Test assured that under moderately heavy wind, snow or ice loads, the Tedlar would not be permenantly deformed or torn etc. The Tedlar Air Leak Test assured that pinholes did not form in the Tedlar after several weeks of use. The Flutter Test was performed to measure Tedlar flutter under wind gusts. A Plenum Pressurization Test assured that no permanent deformation was observed when the plenum chamber was pressurized well above the normal operating pressures. For full Certification Test data refer to the Certification Test Report.

C-2

Performance Test #LSE 4x8 Qual

Ambient Air to Inlet

Time	Flow CFM	Insolation BTUH/ft^2	Ambient Air °F	RH %	Inlet Air °F	Outlet Air °F	TC#1 °F	TC#2 °F	TC#3 °F	TC#4 °F	Efficiency % Total Area
1145	120	280	72	40	80	137	183	208	160	177	69
1200	124	290	73	44	82	142	187	214	163	181	72
1230	127	306	74	40	83	145	196	223	167	190	72
1315	115	316	76	37	85	153	201	227	175	197	69
1330	116	318	76	35	84	153	200	227	174	198	70
1345	116	317	75	34	83	152	199	226	172	197	71
1400	114	317	77	36	83	152	200	225	172	198	69
1415	116	311	77	40	84	152	199	225	171	198	71
1430	112	305	76	36	83	151	196	221	168	195	70

Table 4.1 Low Temperature Performance Data September 14, 1977

Performance Test Serial # LSE 4x8-Quad

Recirculated Input Air

Time	Flow CFM	Insolation BTU/ft²	Ambient Air °F	RH %	Inlet Air °F	Outlet Air °F	Thermo couple#1	Thermo couple#2	Thermo couple#3	Thermo couple#4	Efficiency Gross Area %
12:20	128	328	82	40	94	158	199	225	172	197	69
12:25	117	324	82	"	95	158	200	226	173	198	65
12:30	121	330	82	"	95	159	201	227	174	199	66
12:40	118	323	81	"	96	160	201	227	174	200	65
12:50	116	321	81	36	97	160	201	227	174	200	64
13:00	116	317	81	"	98	160	201	226	174	200	64
13:10	124	312	81	"	98	159	198	223	170	198	68
13:45	116	232	81	"	97	145	175	194	154	175	68

Table 4.2. Intermediate Temperature Performance Data November 3, 1977

Performance Test LSE 4x8 Qual

High Temperature Input

Time	Flow CFM	Insolation BTU/ft^2	Ambient Air °F	RH %	Inlet Air °F	Outlet Air °F	Thermo couple#1	Thermo couple#2	Thermo couple#3	Thermo couple#4	Efficiency Gross Area %
1245	117	348	68	43	127	182	228	250	200	220	52
1255	117	325	69	"	129	182	228	250	201	223	54
1305	119	313	72	"	129	182	222	243	198	219	55
1325	111	159	71	"	128	160	176	187	160	170	62
1335	120	222	72	37	128	162	188	201	172	187	53
1355	122	289	72	"	129	170	209	226	189	203	48
1405	114	292	73	29	130	174	215	231	190	209	48
1415	118	278	73	"	130	175	211	227	185	208	52
1425	114	262	74	27	132	175	210	225	185	207	53
1435	107	249	73	"	132	174	207	223	181	204	51

Table 4.3. High Temperature Performance Data November 4, 1977

STAGNATION TEST SERIAL #LSE 4x8 QUAL

Time	Insolation BTUH/ft^2	Ambient °F	TC #1 °F	TC #2 °F	TC #3 °F	TC # 4 °F
1420	288	87	271	292	259	266
1430	281	88	282	301	266	277
1440	233	88	288	309	269	286
1450	186	88	270	283	236	268
1500	78	88	234	244	195	236
1510	59	88	218	226	178	220

September 3, 1977

Harry R. Nuce
Colo #5674

Table 4.4 Stagnation Data September 3, 1977

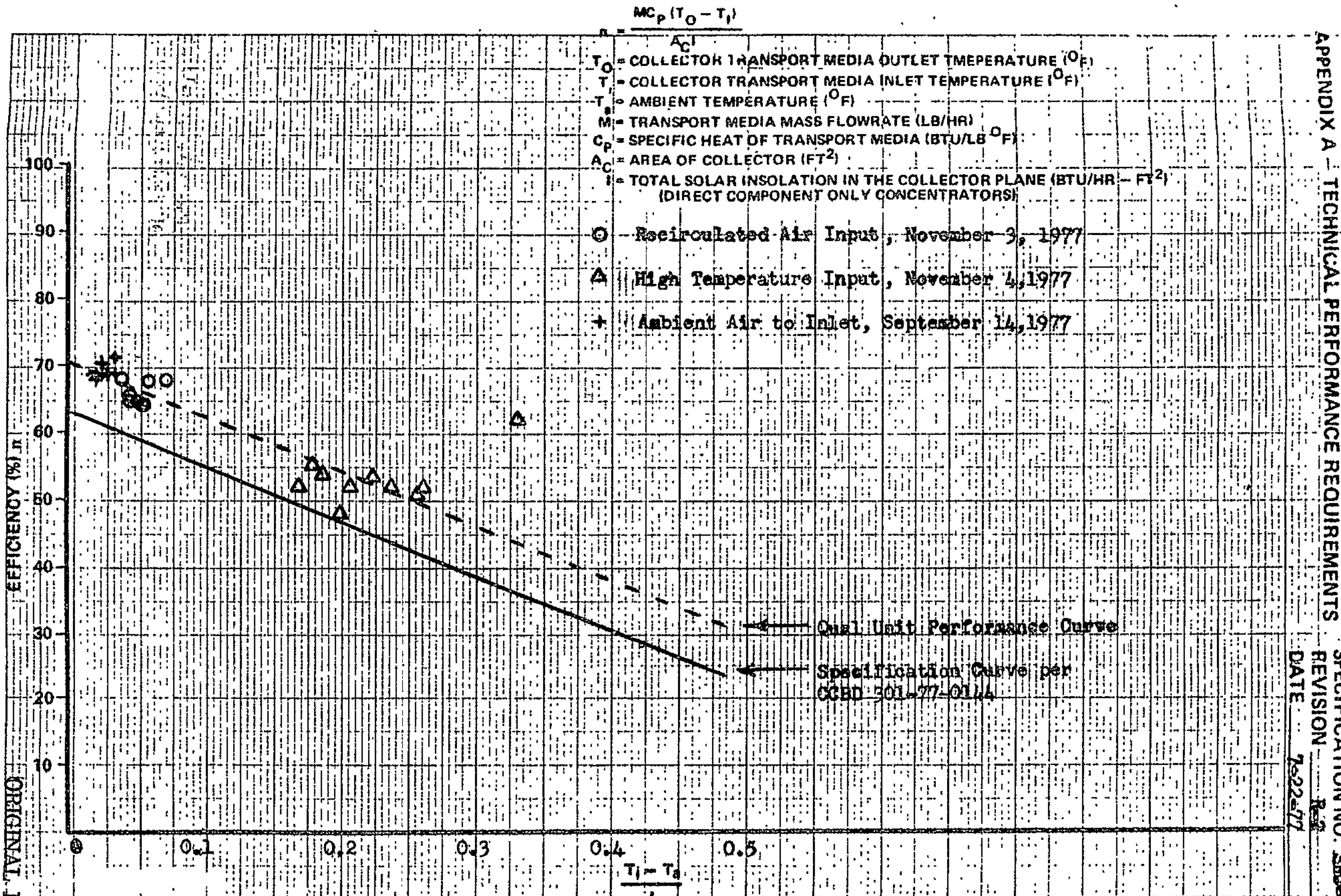

FIGURE 4.1 EFFICIENCY AS A FUNCTION OF OPERATING CONDITIONS
PERFORMANCE MUST BE ABOVE LINE

ORIGINAL PAGE IS OF POOR QUALITY

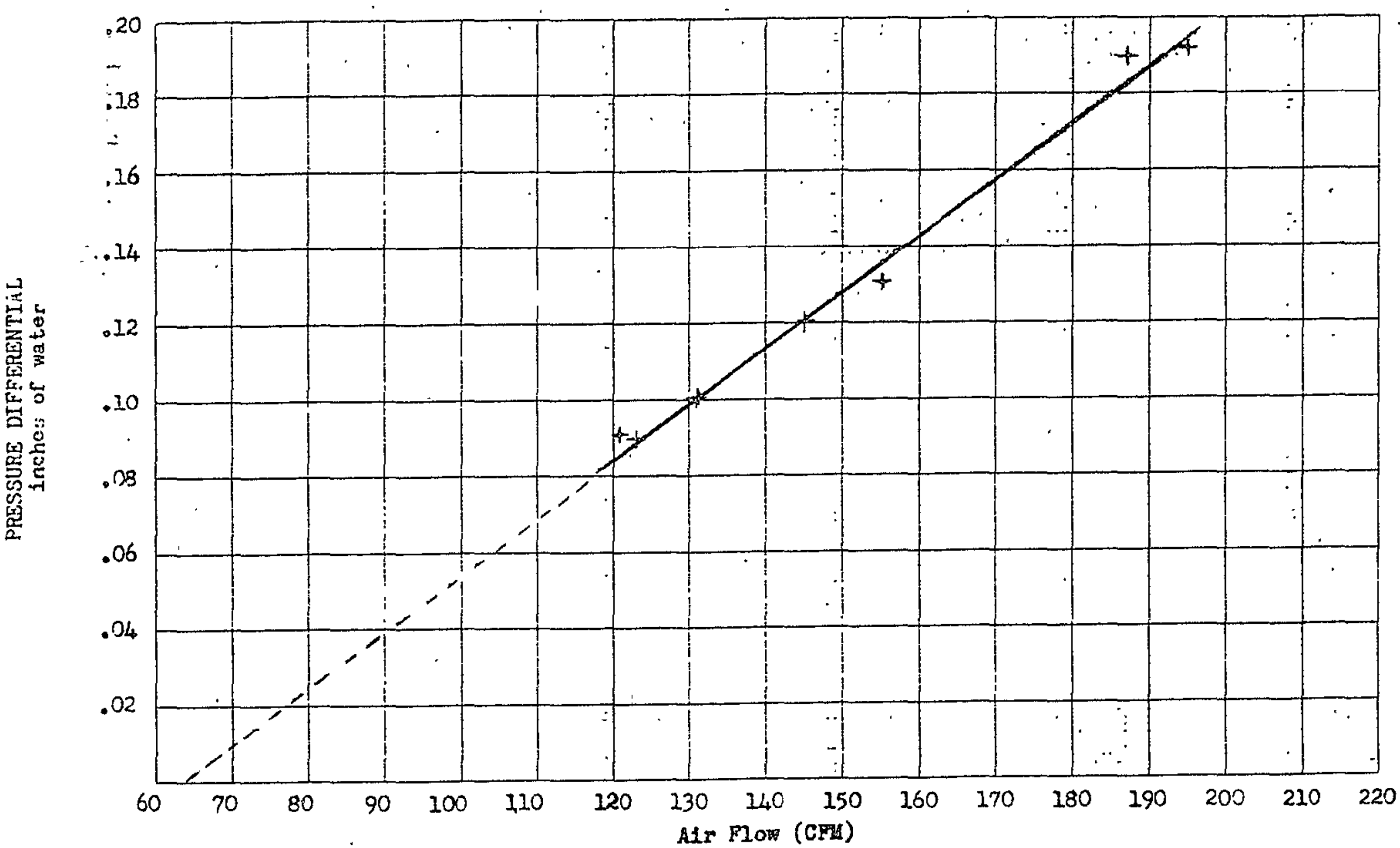

Figure 4.2 Pressure Differential Across the Collector versus Air Flow Rate

Harry R Nuce
Colo #567

Performance Test Serial # LSE 4x8-00-001

Time	Flow CFM	Insolation BTUH/ft^2	Ambient Air°F	Rh %	Inlet Air°F	Outlet Air °F	RTD#1 °F	RTD#2 °F	RTD#3 °F	RTD#4 °F	Efficiency Total Area %
1030	128	183	60	27	65	101	141	154	124	125	71
1045	126	211	60	"	65	105	137	150	119	125	66
1100	125	261	60	"	67	116	159	175	136	143	66
1115	131	277	60	"	66	122	166	182	137	149	73
1130	126	288	59	"	65	125	170	187	146	154	73
1145	125	297	58	"	65	129	175	192	150	159	73

Table 4.5 Low Temperature Performance Data for LSE4x8-00-001 September 23,1977

Performance Test Serial # LSE 4x8-00-002

Time	Flow CFM	Insolation BTUH/ft^2	Ambient Air ^oF	RH %	Inlet Air ^oF	Outlet Air ^oF	RTD#1 ^oF	RTD#2 ^oF	RTD#3 ^oF	RTD#4 ^oF	Efficiency % Total Area
1100	122	256	72	40	76	125	160	180	151	166	65
1115	120	272	73	"	78	128	165	185	158	172	62
1130	123	285	75	"	80	133	171	191	163	179	64
1145	124	295	75	"	81	136	175	195	167	184	66
Blower RPM's increased											
1215	158	310	76	"	81	135	168	186	160	172	75
1245	152	219	77	"	82	136	171	189	164	173	72
1300	146	323	78	"	83	138	172	190	165	174	70
1330	154	319	80	"	83	137	167	187	161	169	74

Table 4.6 Low Temperature Performance Data for LSE 4x8-00-002

Performance Test Serial #LSE 4x8-00-003

Time	Flow CFM	Insolation BTUH/ft^2	Ambient Air °F	RH %	Inlet Air °F	Outlet Air °F	RTD#1 °F	RTD#2 °F	RTD#3 °F	RTD#4 °F	Efficiency % Total Area
1100	136	263	73	37	79	128	161	184	152	153	71
1115	132	278	74	"	80	133	167	193	158	160	71
1130	132	289	75	"	81	137	172	199	163	166	72
1145	129	300	76	"	82	141	176	203	166	170	71
1200	133	299	76	"	82	141	176	202	165	171	73
1215	132	299	77	"	83	139	171	194	158	167	71
1230	128	308	78	"	83	144	181	209	171	179	72
1245	128	308	78	"	83	146	185	215	175	183	72
1300	131	337	79	"	84	150	187	219	177	186	72

Table 4.7 Low Temperature Data for LSE 4x8-00-003

4.3 Test Facility

The first set of high temperature data was considered suspect. The flow rate was well above the 120 CFM. At elevated temperatures the flow rate had questionably large fluctuations. The performance testing at elevated temperatures was repeated and data was still considered suspect due to large variations in flow.

The operation of the Thomas Meter was checked out. A stray 50 microvolt signal was present at zero flow conditions. All system grounds and appropriate shielding of suspect wiring was rechecked and the stray field pickup was eliminated.

Futher investigation showed that the zero reading from the thermopile of the Thomas Meter did not vary linearly with temperature. It was found that the 12 seemingly identical thermocouples making up the thermopile each had slightly different output variations at different temperatures causing the thermopile zero to drift almost 200 microvolts at high temperatures.

An alternate method of measuring the thermopile data was to connect the thermocouples on each end of the Thomas Meter in parallel which averaged out the temperature dependent variations. Also, the thermopile zero was checked prior to acquiring each data point. The data in Section 4.1.3 was a rerun of high temperature and intermediate input air temperature data.

4.3.1. Glazing Test

Glazing Tests were originally performed in July to compare the efficiencies of Sunadex versus ordinary window glass when used as an inner glazing. LSE reported preliminary data that gave Sunadex glass a 10 to 18% advantage over plain glass. This was considered preliminary since our Test Facility had air flow problems between the two test cells. Originally, two different sets of 2'X 4' test collectors placed in series was used. Each set of collectors was placed in a separate test cell and had one of the different glazings. When the tests were rerun, only one set of collectors was used. After the plain glass glazing was tested, it was replaced with Sunadex without removing the collectors from the test cell. Air flow in the cell was kept constant between each test. Results of the test showed that when the collectors had the Sunadex glazing they exhibited an 11% enhancement in heat output than when the same collectors supported the plain glass glazing. This was expected since the Sunadex glass transmitted 10% more sunlight than the plain glass. The comparison data for this test is displayed in Table 8. $\frac{\Delta T}{I}$ is given for each point, since,

$$\text{Efficiency} \approx K \frac{\Delta T}{I}$$

where ΔT is the temperature increase of the air across the collector, I is the insolation and K is a constant for this test.

GLAZING COMPARISON TEST

Plain Glass				Sunadex			
Insolation BTUH/ft^2	Inlet Air ^oF	Outlet Air ^oF	$\frac{\Delta T}{I}$	Insolation BTUH/ft^2	Inlet Air ^oF	Outlet Air ^oF	$\frac{\Delta T}{I}$
261	81	142	.234	259	66	128	.241
262	81	141	.230	258	66	128	.240
249	80	139	.237	249	66	127	.244
247	80	139	.237	222	66	125	.263
265	81	139	.220	210	66	123	.267
266	80	139	.218	225	66	120	.239

Average $\frac{\Delta T}{I}$ = .226

Average $\frac{\Delta T}{I}$ = .256

Reading Taken on 5 Minute Intervals

Table 4.8 Inner Glazing Test Between Sunadex and Plain Glass

4.4 General Description of Work Accomplished during the Quarter

4.4.1 August

Manufacturing Mockup

Two difficulties were found in assembling and testing the Mockup. First, it was difficult to install the 5/32" Sunadex glass in the H-bar center support. The channel in the H-bar was too narrow for the glass and silicone rubber U-channel. A new H-bar was obtained with a 0.003" larger channel and the glass with the silicone rubber U-channel fit in smoothly. The second problem was the collector input/output End Connector that was found to be too weak and it partially closed in the opening. This was corrected in the Qual unit. Reliable Stagnation data was collected on the Mockup.

Qualification Unit

The Qualification Unit was fabricated according to manufacturing procedures with redesigned End Connectors. The Qual unit was installed in the Test Facility on August 31st. Air flow tests across the collector showed that the new End Connector design allowed a pressure drop across the collector of less .1 inch of water.

Certification Test Support

A statement of work was given to an architectural engineer to review the installation drawings and the IOM Manual. As a result of this review, the SC4x8106 drawings were redrawn. The Installation Operation & Maintenance Manual was also rewritten.

Manufacturing

A welding jig was constructed and used on the Qual Unit. The jig was designed to assure that all subsequent collectors have nearly identical dimensions. Our welder recently demonstrated his capability to weld the H-bar corners of the Tedlar frame which will greatly improve its strength.

Preliminary use of the Gelva 1753 on the Mockup Unit to glue the Tedlar was found to be unsatisfactory. Mr. Stucky of MSFC suggested waiting 15 minutes for the Gelva to set prior to installing the Tedlar. This procedure was used on the Qual Unit and further testing of the Qual Unit became necessary to evaluate the Gelva/Tedlar retention.

Certification Test Preparation

A Certification Test Report was prepared to contain the test data and provide sign off sections as tests were completed.

Acceptance Test

An Acceptance Test was prepared in two parts: 1, for the first 3 Prototype Collectors and 2, for the remaining 7 collectors that were to be shipped without glass.

4.4.2 September

The Qualification Unit was installed in the Test Facility on August 31st. Performance testing was run on September 3rd and 14th. The Performance Test on September 3rd was monitored by the Certification Agent who also monitored the structural testing of the Qualification Unit on September 30th.

Deliverable Prototype Collectors

The first three prototype collectors were completed by mid September. The 'built-in' end connector developed on the Qual Unit was incorporated into the design of all collectors. It was designed to attach to the end connector and pass through the ends of the shipping container/test assembly. Mr. Stucky's recommendation to wait 15 minutes for the Gelva 1753 to set has improved the Tedlar/Gelva retention problem. The Tedlar is solar heated to 150°F surface temperature and allowed to cool rapidly in order to shrink the Tedlar. Testing to date indicates that the corners of the Tedlar should be installed in the Tedlar H-bar frame after the Tedlar has been shrunk. This relieves some of the stress on the corners. A thin bead of Dow Corning 732 on the inside corners of the H-bar and Tedlar further strengthens these corners. The Tedlar-Gelva interface at the corners will be monitored and may require further testing.

Test Facility

During September, data was taken on the Qual Unit and the first three deliverable prototype collectors. During testing of LSE4x8-00-002, the Dwyer Micro Tector Hook gage air flow readings were not in agreement with the Thomas Meter readings of air flow. A hot wire anemometer and a Davis Rotating Vane were used to show that the Thomas Meter was found to be functioning properly at low inlet air temperatures and testing of the prototype collector continued. This delayed the First Article Configuration Inspection one week and the structural testing of the Certification Test two weeks.

Test Data

The Certification Test's Performance Tests were run at the Test Facility on the Qual Unit with input temperatures of 78°F and 140°F. The weather was so hot that input temperatures of 70°F were unobtainable. The output temperatures of the collector were above specifications. The pressure drop across the collector was just under .1 inches of water. On account of the air flow problem mentioned above, the Qual unit was retested on September 14th with good results.

Stagnation testing of the Qual Unit reported temperatures in excess of 300°F. The deliverable prototype collectors # -001, -002, -003 were performance tested with a 70°F inlet temperature and all three collectors had outlet air temperatures above specifications.

Certification Test

In addition to the Certification Test Plan, a Certification Test Report was prepared to include further information and sectional sign off sheets. The structural testing included a Drop Test, Rack Test, Tedlar Air Leak Test Tedlar Water Loading, Collector Maximum Load Test, Plenum Pressurization, Thermal Shock, and Flutter Test. The Certification Test was completed on September 30th.

Design Brochure

The preliminary Design Brochure review was completed by the Architectural Engineer and brochure improvements were made at his direction.

Verification Status Summary

The Verification Status Summary to the Verification Plan was completed. It summarized testing status through the end of August.

Manufacturing

Manufacturing of the last seven collectors began during the last week of

September. Most of the materials were cut for welding, painting, and final assembly. A set of manufacturing process plans were prepared to provide a step by step procedure for making collectors.

Problems

The only problem was the Gelva 1753 retention of the Tedlar. Mr. Stucky's recommendation to air dry the Gelva before inserting the Tedlar did show improvement in retention.

4.4.3. October

Certification Test Report.

A Certification Test Statement containing the data and analysis of the Certification Test was prepared for the Certification Test Report. The Certification Test Report was reviewed and signed by the Certification Agent and LSE test engineers on October 1st.

First Article Configuration Inspection (FACI) and Acceptance Test I

The First Article Configuration Inspection for LSE4x8-00-001 collector and Acceptance Test inspection of -002 and -003 collectors were held on October 6th. The three Solar II Collectors were inspected. In addition, the Installation, Operation and Maintenance Manual, the Warranty, and Special Handling procedures were reviewed. Four Review Item Discrepancies were answered. The Certification Test Report of the Qual Unit was reviewed as part of FACI and signed off by the Technical Monitor. Test data and analysis of the first three Solar II Prototype Collectors were reviewed. A list of items was developed for LSE to complete including: hardware and documentation, revised set of reproducible drawings and an up dated list of specifications.

Acceptance Test II

Acceptance Test for the last seven prototype collectors was delayed while the problems at the test facility were remedied. The seven prototype Solar II Collectors, serial numbers LSE 4x8-00-004 through -010 were inspected along with the shipping containers. The NASA Quality Control Inspector directed LSE to add additional strength to the sides of the shipping containers in the form of 4'x8'x1/4'' plywood. Minutes were prepared and included in the shipping containers with the collectors. The DD250 was signed by Mr. Howard B G Kittredge of NASA Quality Control.

Test Data

As described in section 4.3, the air flow was above 120 CFM during the high temperature testing giving misleading data. LSE repeated the high temperature data for the correct air flow. The problems encountered with the Test Facility caused a three week delay in obtaining reliable data. The new data was included in the Certification Test Report.

Manufacturing

Manufacturing of the last seven prototype collectors was completed in the middle of October. Four shipping containers were made for the seven collectors and shipment was made on November 7th.