NOTICE

THIS DOCUMENT HAS BEEN REPRODUCED FROM MICROFICHE.ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE
SOLAR DOMESTIC HOT WATER SYSTEM INSTALLED AT TEXAS CITY, TEXAS - FINAL REPORT

Prepared from documents furnished by

LaQuinta Motor Inns, Inc.
Post Office Box 32064
San Antonio, TX 78216

Under DOE Contract EG-77-G-01-1670

Monitored by

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.   Key Word Abstract</td>
<td>1</td>
</tr>
<tr>
<td>II.  Introduction</td>
<td>1</td>
</tr>
<tr>
<td>III. Design Philosophy</td>
<td>1</td>
</tr>
<tr>
<td>A. Collectors</td>
<td>1</td>
</tr>
<tr>
<td>B. Storage System</td>
<td>2</td>
</tr>
<tr>
<td>C. Heat Exchangers</td>
<td>2</td>
</tr>
<tr>
<td>D. Pump and Controls</td>
<td>2</td>
</tr>
<tr>
<td>IV.  Operation of the System</td>
<td>2</td>
</tr>
<tr>
<td>V.   Problems Encountered and Solutions</td>
<td>2</td>
</tr>
<tr>
<td>VI.  Pictures of Final Installation</td>
<td>3</td>
</tr>
</tbody>
</table>

Appendix A - Roof Plan/Solar                  | A-1  |
Appendix B - Operator's Instructions          | B-1  |
Appendix C - Manufacturer's Literature        | C-1  |
Appendix D - Verification                     | D-1  |
I. KEY WORD ABSTRACT

Application: Domestic Hot Water
Collector Type: Flat Plate, Liquid
Collector Manufacturer: Raypak, Inc.
Collector Area: 2100 sq. ft. (Approximate)
Storage Capacity: 2500 gallons
Hot Water Load: 5.83 x 10^8 BTU/year
BTU's Produced: 3.67 x 10^8 BTU/year
Building Owner: La Quinta Motor Inns, Inc.
Solar System Designer: Travis-Braun & Associates
Contractor (Installer): Solar-Dronics

II. INTRODUCTION

La Quinta Motor Inns, Inc. retained Travis-Braun & Associates to design a solar assisted domestic hot water system for the new 98 unit La Quinta Motor Inn in Texas City, Texas. The system was designed to supply approximately 63% of the total hot water load. The Inn is a low-rise, two story building with flat roof for installation of solar panels.

III. DESIGN PHILOSOPHY

The Texas City, Texas property was chosen for solar installation because of the favorable climatic condition and also because electric hot water heating was specified for this property in response to the Government's request to conserve natural gas during the energy crunch of the 1970's.

The system consists of eleven banks of nine collectors, each mounted on the roof of the property. Originally, the system was designed as a drain down system. But, at the recommendation of the installing contractor, the design was changed to an ethylene glycol system. Balancing valves were installed to regulate the flow to the solar panels. Throughout the system, Pete's Plugs were installed for temperature and pressure measurements.

Two heat exchanger tube bundles were installed in the 2500 gallon storage for transferring the solar heat to the domestic hot water system.

A. Collectors

The collectors chosen for this project were Model SG-18P manufactured by Raypak, Inc. A total of 99 collectors were used. The collectors were supplied with Model PR-18 Solar Panel Rack Kit. (See attached sheets on Raypak collectors.)
B. **Storage System**

A 2500 gallon insulated vertical steel storage tank was located outdoors next to the Inn's cooling tower. A temperature sensor was installed in the storage tank for control function. To improve heat transfer between the heat exchangers and stored water, a 1/12 HP Grundfos recirculating pump was installed.

C. **Heat Exchangers**

Two heat exchanger tube bundles were mounted into the storage tank. The upper heat exchanger which served to extract heat from the storage tank to the domestic hot water system was sized for 100 gpm at 10°F temperature rise. The lower heat exchanger which served to transfer heat from the solar collectors to the storage tank was sized for 51 gpm at 10°F temperature drop.

A solution of ethylene glycol was used as heat transfer fluid between the solar collectors and the lower heat exchanger. With the use of the upper heat exchanger for the domestic hot water system, a double wall separation was achieved between the domestic hot water system and the ethylene glycol.

D. **Pump and Controls**

Two solar loop pumps, each sized for 100% of the solar system requirements were installed. The pumps are controlled by a temperature differential controller with an alternator for equal usage of the pumps.

IV. **OPERATION OF THE SYSTEM**

The system was put into operation in the summer of 1978. Except for a few minor leaks in the piping and control adjustments, the system performed as designed and has been operating satisfactorily since then.

V. **PROBLEMS ENCOUNTERED AND SOLUTIONS**

The winter of 1978 was unusual for the area in that there was an extended period of cloudy sub-freezing temperature. To avoid any possibility of freezing the insulated 3/4" storage tank recirculating line, the control of the 1/12 HP Grundfos recirculating pump was modified so that it is also activated when the ambient temperature drops to 32°F or below.

---

*ORIGINAL PAGE IS OF POOR QUALITY*
VI. PICTURES OF FINAL INSTALLATION

-Solar Control Panel-

-Solar Pumps-
-Solar Panels on Roof-
APPENDIX A

ROOF PLAN/SOLAR

FOR

LA QUINTA MOTOR INNS, INC.

TEXAS CITY, TEXAS
October 29, 1980

National Aeronautics & Space Administration
Commercial Demonstration Office
Solar Energy Applications Projects
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Mr. Douglas W. Westrope, Jr.
Project Manager

Subject: La Quinta Motor Inns, Inc.
Texas City, Texas #533
Solar Installation

Dear Doug:

Attached is the final report on the above subject installation. Original tracings of drawings are included for your use.

Please call me if you have any questions.

Sincerely,

Ronald Wang
Mechanical/Electrical Engineer
Development Division

RW:cs

Attachments

cc: Martin Carson/file
COLLECTOR PIPING & LAYOUT

FOLDOUT FRAME

SCALE: 1/4" = 1'-0"
GENERAL DISCUSSION

This is a closed solar system utilizing two heat exchangers to transfer heat from the solar collectors to the domestic hot water system. Please refer to attached schematic drawing of the solar system.

P-1 and P-2 are solar loop pumps that circulate a solution of 30% ethylene glycol and 70% water between the solar collectors and the heat exchanger, HX-1. Only one solar loop pump is needed for the system operation, the other solar loop pump serves as 100% standby. The solar loop pumps are controlled by a temperature differential controller which starts the pump when the temperature at the solar collectors is 20°F higher than the temperature in the 2500 gallon storage tank. The temperature differential controller will deactivate the solar loop pump when the temperature at the solar collectors is not more than 30°F higher than the temperature in the 2500 gallon storage tank. An alternator alternates the operation of P-1 and P-2 for equal usage.

P-3 is a recirculating pump to improve the heat transfer between the heat exchangers and the stored water in the 2500 gallon storage tank. P-3 is interlocked with P-1 and P-2 so that if either P-1 or P-2 is activated, so will P-3. In addition, P-3 will activate when the ambient temperature is 32°F or lower.

When the temperature in the 2500 gallon storage tank reached a minimum of 15°F higher than the temperature of the water in the 750 gallon water heater, the temperature differential controller will activate pump P-4 to transfer the heat from the 2500 gallon storage tank to the building's hot water system. Pump P-4 will be deactivated when the temperature in the 2500 gallon storage tank is only 5°F higher than the temperature of the 750 gallon water heater.

P-5 is the usual hot water recirculating pump of the building's hot water system.

Mixing valve, V-1 is set to prevent the temperature of the hot water supplied to the building from exceeding 140°F.
MAINTENANCE REQUIREMENTS

1. Once a Week:
   a. Check fluid level in the solar system expansion tank. If low, add a 30-70 mixture of ethylene glycol and water to the system. CAUTION: NEVER ADD PLAIN WATER TO THE SYSTEM.

2. Once a Month:
   a. Wash glass surfaces of the solar collectors using a mild detergent solution and a soft brush. Thoroughly rinse with clean water.
   b. Check temperature differential controllers and alternator for proper operation.
   c. Check for fluid leaks from collectors and piping.

3. Once a Year:
   a. Check pump seals for leakage.
   b. Draw a sample of heat transfer fluid from the solar system for analysis and determination of any action needed to provide maximum corrosion inhibition.
APPENDIX C

MANUFACTURER'S LITERATURE
BULLETIN 340B
340 SERIES
SINGLE STAGE
END SUCTION
PUMPS
CAPACITIES TO 1900 G.P.M.
HEADS TO 360 FEET
TEMPERATURES TO 225°F.

MODEL 342A
MODEL 344A
MODEL 341A

ORIGINAL PAGE IS OF POOR QUALITY
ENGINEERING SPECIFICATIONS AND DIMENSIONS

FLEXIBLE-CLOSE COUPLED PUMPS
The contractor shall furnish (and install as shown on the plans) Aurora Model (341A horizontal close coupled) (342A vertical close coupled) (344A horizontal flexible coupled) back pull out centrifugal pumps size . . . of (bronze fitted) (all iron) construction. Each pump shall have a capacity of . . . GPM at . . . ft. total head, with a temperature of . . . °F., . . . specific gravity and structureborne sound level not to exceed . . . ADB. Each pump is to be furnished with a mechanical seal with all metal parts to be 303 stainless steel with “Buna-N” elastomers, Nipponit seal, and carbon washer. The unit must be equipped with (bronze) (stainless steel) keylocked shaft sleeve that extends the length of the seal box. The pump shaft extension shall be “O” ring sealed from the pumped liquid. Pump shall have case wearing ring (impeller wearing ring). Impellers to be vacuum cast, dynamically balanced, and keylocked to the shaft.

FLEXIBLE COUPLED PUMPS (344A)
Pump and motor are to be mounted on a common (fab. steel drip rim) (steel) baseplate. The shaft is to be steel, installed in a cast iron power frame. Pumps shall have a shaft design for 002° deflection at the seal face with the pump running under max. load condition. (Grease) (oil) lubricated ball bearings, having a 3 year life (AFBMA B) under the max. condition of load protected by separate oil seals and slingers, shall be used. The pump shall be flexible coupled to a standard horizontal NEMA . . . HP . . . phase . . . Hertz . . . volts . . . RPM (drip-proof) (totally enclosed) (explosion-proof) motor. Alignment shall be checked in accordance with the Standards of the Hydraulic Institute after installation and there shall be no strain transmitted to the pumps.

CLOSE COUPLED PUMPS (341A)
CLOSE COUPLED PUMPS (342A)
Each pump is to be close coupled to a standard HI-NEMA-JM . . . HP . . . phase . . . Hertz . . . volt . . . RPM (drip-proof) (totally enclosed) (explosion-proof) motor. Model 341A in motor frame sizes up to 184JM shall be supported by a separate support foot on the pump bracket.

PUMPS WITH THREADED CONNECTIONS

AURORA PUMP
A UNIT OF GENERAL SIGNAL
800 AIRPORT ROAD - NORTH AURORA, ILLINOIS - 60542
SALES OFFICES IN ALL MAJOR CITIES AND COUNTRIES
Refer to Poums in the yellow pages of your phone directory
MANUFACTURING FACILITIES ARE LOCATED IN THE FOLLOWING CITIES: NORTH AURORA, ILLINOIS - CITY OF INDUSTRY (GREATER LOS ANGELES), CALIFORNIA
Export Dept. No. Aurora, Illinois: Cable Address: NYABINT
The Trade mark AURORA is registered in U.S. Patent Office
## Material of Construction

<table>
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<tr>
<th>Pump Part</th>
<th>Bronze Fitted</th>
<th>All Iron</th>
</tr>
</thead>
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<td>Cast Iron ASTM A48</td>
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<td>Bronze ASTM B62</td>
<td>Cast Iron ASTM A48</td>
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<td>Impeller</td>
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<td>Steel AISI C1045</td>
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<td>Cast Iron ASTM A48</td>
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<td>Mechanical Seal</td>
<td>303 Stainless Steel Metal Parts, “Buna N” Elastomer Parts, Ni Resist Seat and Carbon Washer</td>
<td></td>
</tr>
</tbody>
</table>

## Limitations

**Maximum Limitations based on Standard Materials and Pumping Clear Water**

- **Speed (RPM):** 3600
- **Horsepower:***
  - **Close O.D.P.:** 25 HP
  - **Coupled T.E. & EX PR:** 20 HP
  - **Frame Mounted 1750 R.P.M.:** 60 HP
  - **Frame Mounted 1750 R.P.M.:** 75 HP
- **Temperature (°F):**
  - **Close Coupled:** 275°F
  - **Frame Mounted:** 225°F
- **Hydrostatic:**
  - 2” & 5” Bore Pumps up to 1 1/2” Disch. 265 PSI
- **Test Press.:**
  - 9” Bore Pumps 2” Disch. & Larger 265 PSI
  - All 12” Bore Pumps 265 PSI
- **Case Working Pressure (PSI):**
  - 7” & 9” Bore Pumps up to 1 1/2” Disch. 175 PSI
  - 9” Bore Pumps 2” Disch. & Larger 175 PSI
  - All 12” Bore Pumps 175 PSI

Details are available from the factory.
SERIES 60
the extra quiet
in-line pump for general services

BELL & GOSSETT ITT
FLUID HANDLING DIVISION
Discharge Gage Tapping (on side opposite)

Rear Bearing

Coupler Assembly

Shaft

Motor Bracket Assembly

Bearing Bracket Assembly

Front Bearing

Suction Gage Tapping

Seal Assembly

Impeller (Enclosed)

Volute

1AA, 1⅛ AA, ⅞ AA and 2 AA construction details

Discharge Gage Tapping (on side opposite)

Rear Bearing

Coupler Assembly

Shaft

Motor Bracket Assembly

Bearing Bracket Assembly

Front Bearing

Suction Gage Tapping

Seal Assembly

Impeller (Enclosed)

Volute

1¼ A and 2 A construction details
Series 60 Pumps can be furnished in bronze-fitted, all iron, or all bronze construction to suit your application.

Curves based upon shop test using clear cold water at a temperature of not over 85° F.

Horsepower curves do not include motor service factor.
Dimensions FIG. 1 AA SIZES

STANDARD VOLTAGES
¼ HP, 1 PH, 115 Volts. ½ to 1½ HP, 1 PH, 115/230 Volts. ¾ to 4 HP, 3 PH, 200-230/460 Volts. 1 to 2 HP, 208 or 230/460 Volts.
All single phase motors have built-in overload protection.

Companion flanges furnished for suction and discharge

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<tr>
<th>STOCK PUMP MODEL</th>
<th>PUMP SIZE</th>
<th>Dripproof Motor HP</th>
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<th>DIMENSIONS IN INCHES</th>
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<td>15¾ 11 4¾ 6½ 3¾</td>
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<td>1</td>
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<td>1⅝</td>
<td>15¾ 11 5 7½ 3¾</td>
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<td>1½AA</td>
<td>¼</td>
<td>1⅝</td>
<td>16¾ 11 5 7½ 3¾</td>
</tr>
<tr>
<td>-</td>
<td>1½AA</td>
<td>¼</td>
<td>1⅝</td>
<td>17¾ 11 5 7½ 3¾</td>
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<tr>
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<td>¼</td>
<td>1⅝</td>
<td>18 11½ 5 7½ 3½</td>
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<tr>
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<td>1⅝</td>
<td>17½ 11½ 5 8 3¾</td>
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<tr>
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<td>⅔</td>
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<td>21½ 14 5 9½ 3¼</td>
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**Not available in single phase. Dimensions are approximate and not to be used for construction purposes.

Construction Materials FOR PARTS IN CONTACT WITH FLUID PUMPED

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<td>Steel</td>
<td>Steel</td>
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<tr>
<td>Shaft Sleeve</td>
<td>Copper</td>
<td>Stainless Steel</td>
<td>Copper</td>
</tr>
<tr>
<td>Seal Assembly</td>
<td>Carbon Seal Ring, Ceramic Seat, Synthetic Rubber Bellows and Stainless Steel Spring</td>
<td>Carbon Seal Ring, Ceramic Seat, Synthetic Rubber Bellows and Stainless Steel Spring</td>
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</table>
VERIFICATIONS

1. Final Field Inspection:

A team consisting of Jimmy Carter, Ronald Wang (Owner's Representatives), Steve Huck (Inspecting Engineer), and Phil Nutter (Installing Contractor) met for final inspection on November 5, 1979.

The installation was found to be complete and operating as called in the plans. The control system was checked out and confirmed to be performing as designed.

2. Data Obtained During Final Field Inspection:

Please see attached sheets.

3. Acceptance:

The installation is considered complete and accepted.

Ronald K. Wang
Mechanical/Electrical Engineer
Development Division

RW:cs
November 20, 1979

Mr. Ronald Wong
LaQuinta Motor Inns, Inc.
Century Building
P.O. Box 32783
San Antonio, TX 78216

Dear Mr. Wong:

This letter is sent to you along with the enclosed plan and pictures to summarize our firm's site visit and system analysis of the Texas City solar system conducted on November 5.

System temperature and pressure observations were recorded on the hour from 10:00 a.m. to 1:00 p.m. inclusive. The results of those observations, at various system locations, are included on the plan.

Also included is an energy analysis performed on the system for noon conditions. As the results of the calculation indicate, based on the stated assumptions, a reasonably good comparison results between the observed conditions and theoretical solar inputs.

The performed calculation are outlined in detail on the enclosed sheet. More accurate solar energy insolation and pump performance would of course allow for a more accurate determination of the calculated temperature rise. With the available information though a sufficiently good comparison does result between the calculated and observed collector performance.

For this reason, I definitely feel the solar collector array is performing as it should.

Yours very truly,

Steven E. Huck

Enclosure

cc: Lynne Judge
    Marvin Ruben
CALCULATION OF THEORETICAL SOLAR ARRAY PERFORMANCE

1. Solar Insolation available based on assumption that Texas City insolation on November 5 does not deviate significantly for insolation values for 32° North latitude and a 32° collector slope. From ITT’s "Solar Systems Design Manual" insolation values for October 21 and November 21 are 320 BTU/sq. ft.-hr. respectively. Assume November 5 is average of two or 312 BTU/sq. ft.-hr. Also assume a 10% reduction in solar energy available due to Texas City haze, therefore estimated incident solar energy = 280 BTU/sq. ft.-hr.

2. Average collector plate temperature at noon was

\[ \frac{(171-166)}{2} + 166 = 169^\circ F \]

3. Recorded ambient temperature was 75^\circ F

4. Determine collector efficiency from Raypack literature based on 1, 2 & 3 above or \( \frac{(169 - 75)}{280} = 0.34 \) for a collector efficiency of 40%.

5. Total collected energy per collector

\[ 280 \text{ BTU/sq. ft. - hr.} \times 0.4 \times 17.3 \text{ sq. ft.} = 1940 \text{ BTU/hr.} \]

6. Aurora pump curve based on noon pump conditions indicates flow rate at approximately 60 gpm.

\[ \frac{60 \text{ gpm}}{99 \text{ collectors}} = 0.61 \text{ gpm/collector} \]
\[ = 37 \text{ gph/collector} \]
\[ = 305 \text{ lb/hr/collector} \]

7. \[ \frac{1940 \text{ BTU HR LB OF}}{305 \text{ LB HR 1 BTU}} = 6.40 \text{ F} \]

8. Temperature rise recorded at noon was 50 F.

9. Therefore a sufficiently accurate comparison indicates collectors to be performing as required.
<table>
<thead>
<tr>
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<th>10AM</th>
<th>11AM</th>
<th>NOON</th>
<th>1PM</th>
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<td>PUMP SUCTION PRESSURE (PSI)</td>
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<td>PUMP DISCHARGE PRESSURE (PSI)</td>
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<td>COLLECTOR INLET TEMPERATURE (°F)</td>
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<td>COLLECTOR OUTLET TEMPERATURE (°F)</td>
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<td>COLLECTOR INLET PRESSURE (PSI)</td>
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<td>COLLECTOR OUTLET PRESSURE (PSI)</td>
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<tr>
<td>SOLAR HX INLET TEMPERATURE (°F)</td>
<td>148</td>
<td>-</td>
<td>171</td>
<td>175</td>
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<tr>
<td>SOLAR HX OUTLET TEMPERATURE (°F)</td>
<td>140</td>
<td>-</td>
<td>168</td>
<td>171</td>
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</table>

WEATHER: CLEAR, WINDY FROM S.E., TEMP. 75°F @ 0% RH

REVISIONS

<table>
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<th>BY</th>
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PELICAN MOORING TMC

QUALITY
October 29, 1980

National Aeronautics & Space Administration
Commercial Demonstration Office
Solar Energy Applications Projects
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Mr. Douglas W. Westrope, Jr.
Project Manager

Subject: La Quinta Motor Inns, Inc.
Texas City, Texas #533
Solar Installation

Dear Doug:

Attached is the final report on the above subject installation. Original tracings of drawings are included for your use.

Please call me if you have any questions.

Sincerely,

Ronald Wang
Mechanical/Electrical Engineer
Development Division

RW:cs

Attachments

cc: Martin Carson/file