**Appendix F**

Evaluation of O&M Costs – Trough

# F. EVALUATION OF O&M COSTS – TROUGH

## F.1 SUMMARY

Table F-1 shows the SunLab projected O&M costs.

**Table F-1 – CSP Trough Technology O&M Costs — SunLab Projections**

| | Trough 2004 | Trough 2007 | Trough 2010 | Trough 2015 | Trough 2020 |
|---|---|---|---|---|---|
| Annual Net Generation, MWhe | 468,617 | 492,175 | 738,922 | 984,831 | 1,981,490 |
| Field Aperture Area, $m^2$ | 1,120,480 | 1,037,760 | 1,477,680 | 1,955,200 | 3,910,400 |
| Staff | 45 | 44 | 51 | 58 | 90 |
| Average Annual Cost (with burden), $1,000 | 58.8 | 62.0 | 60.8 | 59.9 | 57.7 |
| Staff Cost, $1,000 | 2,643 | 2,705 | 3,081 | 3,490 | 5,164 |
| Annual Material & Services Cost, $1,000 | 3,054 | 2,243 | 2,507 | 2,952 | 5,029 |
| Total O&M Cost, $1,000 | 5,697 | 4,948 | 5,588 | 6,442 | 10,193 |
| Total O&M Cost, $/kWhe | 0.012 | 0.010 | 0.008 | 0.007 | 0.005 |

## F.2 O&M STAFF

The staffing in the SunLab model was reviewed and is a reasonable estimate. The staffing compares with SEGS, power-generating facilities and the recent O&M Cost Reduction Study performed at Kramer Junction (KJCOC 1999). The staffing for trough technology is shown in Table F-2.

**Table F-2 — Staffing for Trough Technology — SunLab Projections**

| | 2004 | 2007 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| Administrative | 7 | 7 | 7 | 7 | 7 |
| Plant Operations | 15.5 | 15.2 | 16.9 | 18.8 | 26.6 |
| Power Plant Maintenance | 8 | 8 | 8 | 8 | 8 |
| Solar Field Maintenance | 14.4 | 13.5 | 18.7 | 24.5 | 47.9 |
| Total | 44.9 | 43.6 | 50.6 | 58.3 | 89.6 |

The power plant staffing, exclusive of solar field maintenance, is comparable to the industry average for a 120-MWe combined-cycle power plant.

The estimated staff increases were determined to be reasonable based on the following evaluation.

The SunLab model estimated a staff of approximately 45 for trough 2004 and 2007 (100-MW plant each).

- The administrative staff would be the same for the increased plant sizes through 2020.
- The increase in plant size from 100 MWe to 400 MWe will not require additional maintenance staff for maintenance of the power plant. The difference between 100 and 400 MWe does not increase the quantity or complexity of the equipment.
- Each additional 50-MW plant size will require two additional mirror wash technicians in the operations staff to account for the increased field aperture area.
- The increase in the solar field maintenance staff is required to support the increase in the solar field. For Kramer Junction, approximately 0.03 maintenance staff is required per 1,000 $m^2$ of solar field aperture area. The larger solar plant is estimated to be approximately directly proportional to increase of the solar field. For example, the solar field maintenance staff for 2020 is estimated to be (3,910,400 $m^2$ / 1,120,480 $m^2$) = 3.49 x14 maintenance staff (in 2004) = 49 maintenance staff (in 2020).

## F.3 O&M MATERIAL AND SERVICE COSTS

### F.3.1 Service Contract

The service contracts include typical contracts and costs expected for this type of facility (control computers, office equipment, waste disposal, road maintenance, vehicle maintenance, etc.).

### F.3.2 Raw Water and Chemicals

The SunLab estimate is based on water usage and chemical costs from SEGS VI/VII as shown below. The costs and estimated usage values are consistent with industry averages.

**Table F-3 — Water Usage and Chemical Costs — SunLab Projections**

| | |
|---|---|
| Raw Water Costs | \$0.32 per $m^3$ |
| Cooling Water Chemical Cost | \$0.043 per $m^3$ cooling tower make-up |
| Demineralizer Chemical Cost | \$0.540 per $m^3$ condensate make-up |
| Cooling Tower Make-up | 2.90 $m^3$/MWhe |

| | |
|---|---|
| Power Cycle Condensate Make-up | 0.17 $m^3$/MWhe |
| Demineralizer Blowdown | 10% |
| Mirror Wash Water Consumption | 0.022 $m^3$ (water)/ $m^2$ (of collector) /year |

| | Raw Water ($m^3$) | Percentage |
|---|---|---|
| Cooling Tower Make-up | 1,031,547 | 93.5% |
| Power Cycle Demin. Make-up | 67,189 | 6.1% |
| Mirror Wash Demin Make-up | 4,596 | 0.4% |
| Total | 1,103,332 | |

### F.3.3 Parts and Material

The SunLab projections are based on the following unit costs and annual replacement rates.

**Table F-4 — Parts and Materials Cost Basis — SunLab Projections**

| | Unit Cost ($) | Replacement Rate |
|---|---|---|
| Mirrors | 80 | 0.005 |
| HCEs | 847 | 0.02 |
| Sun Sensors | 150 | 0.005 |
| LOCs | 200 | 0.005 |
| Ball Joints | 2,100 | 0.005 |
| Hdr. Drive | 3,000 | 0.005 |
| Miscellaneous | 5% of total equipment costs | |
| HTF Pump Seals | 1,200 | 2 |
| HTF Makeup | 9 | 0.01 |

### F.3.4 Miscellaneous

Miscellaneous costs include administration costs (safety, training, travel, supplies, telephones, etc) and vehicle fuel and repair. The cost of $253,000 per year is reasonable for this size of power plant.

### F.3.5 Capital Equipment

Capital equipment covers the equipment required to operate and maintain the facility (dump truck, operator vehicles, mirror-washing equipment, mirror container carrier, lube trailer and tractor). The cost of the equipment is based on the recent O&M Cost Reduction Study performed at Kramer Junction (KJCOC 1999) and Kramer Junction's latest information. The quantity of equipment is increased proportionally to the size of the solar field, which is a reasonable assumption.

## F.4 ESTIMATED O&M COSTS BASIS

The O&M costs for comparison to the SunLab projections are based on the following:

- Solar Field
  - — The initial unit costs are based on the SunLab values
  - — Replacement rate for the mirrors and HCE are based on the average actual replacement rates for SEGS III – VII for the period 1997–2001
  - — The replacement rates for the balance of the solar field are based on the SunLab values
- Power Block and Balance of Plant
  - — Costs are based on S&L data for the respective MW size plant for the steam turbine systems and balance of plant
- Water and Process
  - — Costs are based on are based on the average actual costs for SEGS III – VII for the period 1997–2001
- Staffing, Services Contracts, Miscellaneous, and Capital Equipment
  - — The costs are based on the SunLab values since the SunLab values were determined to be reasonable
- Thermal Storage
  - — The costs are based on 0.4% of the capital cost per annum

## F.5 O&M COST COMPARISON

The SunLab and S&L estimated O&M costs are compared in Table F-5.

**Table F-5 — O&M Cost Comparison**

| | | 2004 | 2007 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| SunLab | $(2002) | 5,697,000 | 4,948,000 | 5,588,000 | 6,442,000 | 10,193,000 |
| Levelized | $/kWhe | 0.012 | 0.010 | 0.008 | 0.007 | 0.005 |
| S&L | $(2002) | $8,114,516 | $6,611,838 | $7,553,692 | $8,286,682 | $13,731,497 |
| Levelized | $/kWhe | $0.0173 | $0.0134 | $0.0102 | $0.0084 | $0.0069 |

Analyzing the two estimates revealed the major component to account for the cost difference is the HCE replacement rate. The SunLab projections indicate the following replacement rates:

- 2004 – 2%
- 2007 – 1%
- 2010 through 2020 – 0.5%

compared to the following S&L values:

- 2004 – 5.5%
- 2007 – 4.0%
- 2010 – 2.5%
- 2015 – 1.0%
- 2020 – 0.5%

The SunLab near-term values are not consistent with the average actual HCE replacement rate of 5.5% reported for SEGS III – VII for the period 1997–2001.

Sargent & Lundy reviewed the actual receiver (HCE) replacement rate reported by KJC Operating Company over the last five years. The S&L evaluation is based on total HCE replacement reported for the SEGS III – VII for the period 1997–2001. S&L's evaluation is based on the current replacement rate at all the SEGS plants, with step reductions in the replacement rate based on the following:

- The average actual HCE replacement rate of 5.5% was reported for SEGS III – VII for the period 1997–2001. The total HCE replacement includes breakage and fluorescence. Fluorescence is due to cermet coating failures. This failure is due to the existence of molybdenum in the original Luz cermet coating. Solel no longer uses molybdenum in the UVAC cermet coating, so this type of failure will presumably no longer occur. Eliminating replacements due to these failures reduces the site failure/replacement rate.

- SunLab has used the SEGS VI plant as the baseline reference plant. The SEGS III – V plants had problems during initial startup and the early years of operation that caused bowing of the HCEs, which increased breakage at those plants. SEGS VII has had higher breakage on the LS-3 half of the field, although the LS-2 failures are similar to SEGS VI. SEGS VI was the last full plant constructed with LS-2 collectors and represents the most mature version of this generation of collector technology. The HCE total replacement rate at SEGS VI during the 5 years is in the 5.5% range. Discounting the fluorescence failures, the replacement rate was 4.2% over the 5-year period.
- The high HCE failure rate at the existing plants is in part due to issues that would not be found at a future plant. A significant portion of the failures has been due to the hydrogen remover (HR) device installed in the HCEs at SEGS VI – X, operational problems that caused bowing, and HCE installation procedures. The HR is no longer part of the HCEs provided by Solel.

Based on these factors, it is possible that future plants will have substantially lower HCE failure rates than currently occur at the SEGS plants; however, the SunLab assumption of a 2% failure rate assumes that current approaches for reducing failures are successful. S&L believes this is an aggressive assumption that cannot be assured for future plants without the field data to verify the failure rate reduction. Using the current replacement rate at all the SEGS plants, with step reductions in the replacement rate, reflects the current conditions and allows for the aforementioned improvements to reduce the replacement rate.

Additional development of the HCE will likely be necessary to achieve the future receiver reliability goals. The current glass-to-metal seal is one of the more expensive elements and the key failure point of the current receiver design. The current design, known as a Housekeeper seal, relies on a sharp metal point being inserted into a glass bead. Failures occur when concentrated light focus on seal and the differential expansion between the glass and metal causes the failure of the seal. New designs are currently under investigation that attempt to improve the match between the coefficient of thermal expansion of the metal and glass. Kramer Junction is currently testing a new design UVAC2 with a revised internal shield.

Another factor that contributes to the higher S&L-estimated O&M costs is the higher component costs, as detailed in Appendix D.

If the HCE reliability can be improved to reduce the replacement rate to that projected by SunLab, the O&M costs converge on the values projected by SunLab.