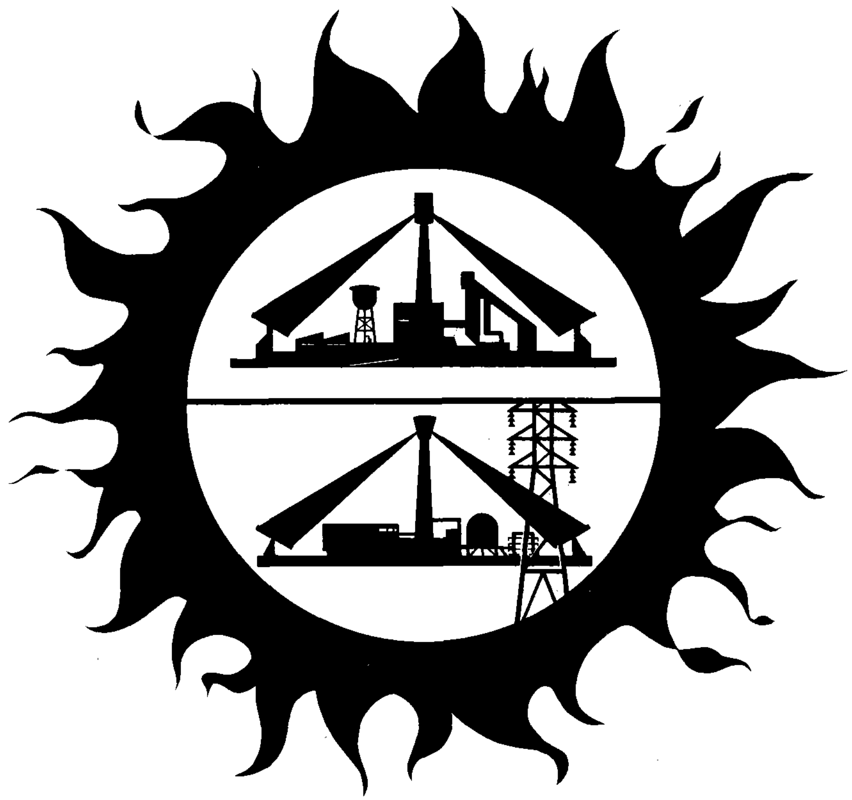
ATR-80(7773-01)-3

# TECHNICAL SUMMARIES OF REPOWERING/RETROFIT CONCEPTS

DOE INDUSTRY CONCEPTUAL DESIGN STUDY CONTRACTS

JANUARY 1980




THE AEROSPACE CORPORATION
El Segundo, California

Aerospace Report No.
ATR-80(7773-01)-3

# TECHNICAL SUMMARIES OF REPOWERING/RETROFIT CONCEPTS

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CONTENTS

## FOREWORD

This report presents summary descriptions of the 12 repowering/retrofit industry conceptual designs. The data presented here are based on the contractor proposed site-specific designs for utility and industrial process heat plants.

The study was conducted by The Aerospace Corporation under contract no. EY-76-03-1101 under the cognizance of Mr. R. Hughey, Director of the Division of Solar Energy, and the general direction of Dr. S.D. Elliott, Program Manager, DOE/SAN.

This report was prepared by M. Masaki, P. Mathur, and P. DeRienzo of the Energy Projects Directorate in the Energy and Resources Division of The Aerospace Corporation. Mr. S.D. Huffman is the General Manager and Mr. H. Bernstein is the Acting Group Director. Dr. P. Mathur is the Principal Investigator on this contract.

## REPOWERING SYSTEMS SUMMARY

The characteristics of the six selected repowering system designs are summarized in the table. These designs, with solar capacity varying between 33-70 $MW_e$, utilize water-steam, sodium and salt technologies (receiver coolant and storage fluid where applicable). All existing plants, with the exception of APS, utilize reheat turbines with nameplate ratings ranging from 80-100 $MW_e$.

The collector field designs in all cases are 360° field and use glass heliostats with an area of 49 $m^2$. All systems utilize external receiver designs with the exception of APS which utilizes a Martin cavity design for a 360° field. The last row presents contractor capital cost estimates for the first plant normalized to a heliostat unit cost of $\$280/m^2$.

## REPOWERING SYSTEMS SUMMARY

| PRIME | BLACK & VEATCH | GE | MDAC | ROCKWELL INT | APS | EL PASO |
|---|---|---|---|---|---|---|
| • Site/Utility | Oolagah, OK PSC | Earth, TX SW-PSC | Yerington, NE SPP | Monahan, TX TEC | Saguaro, TX APS | El Paso, TX El Paso |
| • Solar/Fossil ($MW_e/MW_e$) | 33/150 = 0.22 | 60/100 = 0.60 | 70/110 = 0.637 | 60/120 = 0.50 | 60/115 = 0.52 | 62/82.3 = 0.75 |
| • Technology (W. Fluid) | Water-Steam | Na | Salt | Na | Salt | Water-Steam |
| • Heliostats | 2,616 | 5,176 | 11,045 | 8,160 | 8,985 | 6,200 |
| • Mirror Area, ($10^6 m^2$) | 0.128 | 0.25 | 0.54 | 0.39 | 0.44 | 0.36 |
| • Storage (hr) | 0 | 1/6 | 3 | 3 | 3 | 1/4 - 1/2 |
| • Heliostat Cost ($\$/m^2$) | 65 | 100 | 80 | 125 | 126 | 69 |
| • Capital Cost ($M) | 28 | 82 | 74 | 93 | 89 | 61 |
| • Capital Cost at $\$280/m^2$ ($M) | 56 | 127 | 187 | 153 | 144 | 134 |

# INDUSTRIAL PROCESS HEAT RETROFIT SYSTEMS SUMMARY

The characteristics of six selected industrial process heat solar retrofit systems are summarized in the opposite table. These designs, with solar capacity varying between 5.7-43 $MW_t$, utilize water steam (not superheated steam like in Barstow Pilot Plant), air, oil and gas as the receiver coolant. None of the systems proposed utilizes storage.

All designs, with the exception of Boeing and PFR (use cavity design), utilize external receivers. The tower height for these designs varies betwee 40m and 93m. An exception is the Northrop design, which utilizes the unique towerless north field central receiver collector system with modular design. All designs utilize glass heliostats of $49m^2$ in size, except the Boeing $52.2m^2$) and Northrop ($50.5m^2$). The last row in the table gives the contractor capital costs for a first plant normalized to a heliostat unit cost of $\$280/m^2$.

## INDUSTRIAL PROCESS HEAT RETROFIT

## SYSTEMS SUMMARY

| CONTRACTOR | FOSTER-WHEELER | PFR | BEC | MDAC | MM | NORTHROP |
|---|---|---|---|---|---|---|
| • Application | Oil-Refinery | Ammonia Plt., Valley Ni. | Gypsum Bd. Drying, USG | Ore Process, Gulf R&D | Enhance Oil Recovery, Exxon | Nat. Gas Conversion, ARCO |
| • Plant Site | Mobile, AZ | El Centro, CA | Sweetwater, TX | San Mateo, NM | Bakersfield, CA | Bakersfield, CA |
| • Solar Heat, Output Temperature | Saturated Steam, 497°F/650P | Direct to Nat. Gas, 1475°F | Air, 1068°F | Saturated Steam, 366°F | Saturated Steam, 550°F | Oil 380°F |
| • Process Capacity ($MW_t$) | 105 | 51 | 35.2 | 36.6 | 13.8 | 11.4 |
| • Solar Capacity ($MW_t$) | 43 | 15 AV. | 10.8 | 8.3 | 6.7 | 5.7 |
| • Tower Height, m | 93 | 93 | 50 | 40 | 90 | NA |
| • Heliostats/ Mirror Area, ($10^3 m^2$) | 1274/62 | 1153/56.5 | 392/19.7 | 331/16.2 | 837/41 | 437/22 |
| • Capital Cost $M/Heliostat Cost ($\$/m^2$) | 14.7/176 | 13.9/190 | 6.86/162 | 4.7/185 | 10.4/126 | 3.41/96 |
| • Capital Cost @ $\$280/m^2$ ($M) | 21.2 | 19.0 | 9.19 | 6.24 | 16.76 | 7.5 |

# II. REPOWERING SYSTEM CONCEPTS

## BLACK & VEATCH (REPOWERING)

Nearly all of the diagram represents the existing reheat fossil plant. Only the left block, designated as the solar steam boiler/superheater, in parallel with the fossil boiler/superheater, is added for solar repowering. The additions are the solar steam receiver, the associated steam valves and piping, the heliostat field to collect and direct the solar energy to the receiver, and the control subsystem. Although the steam turbine is of the reheat type, only the steam into the high pressure portion of the turbine is provided in the solar energy mode. Therefore, fossil fuel is always required for the steam reheater which results in the low solar power generation as indicated in the chart.

The solar receiver is a steam boiler evaporator and superheater. This type of receiver is larger than those using a single phase heat transfer working fluid such as sodium. However, a separate boiler and superheater (heat exchanger) is not required as for the single phase fluid system to produce the steam. The evaporator tubes are placed in front of the superheater tubes since the liquid in the evaporator tubes has a high heat transfer capability and can withstand a high heat flux. The superheater tubes, being screened by the evaporator tubes, will have a lower heat flux which is necessary due to the low heat transfer capability of steam passing through the tubes.

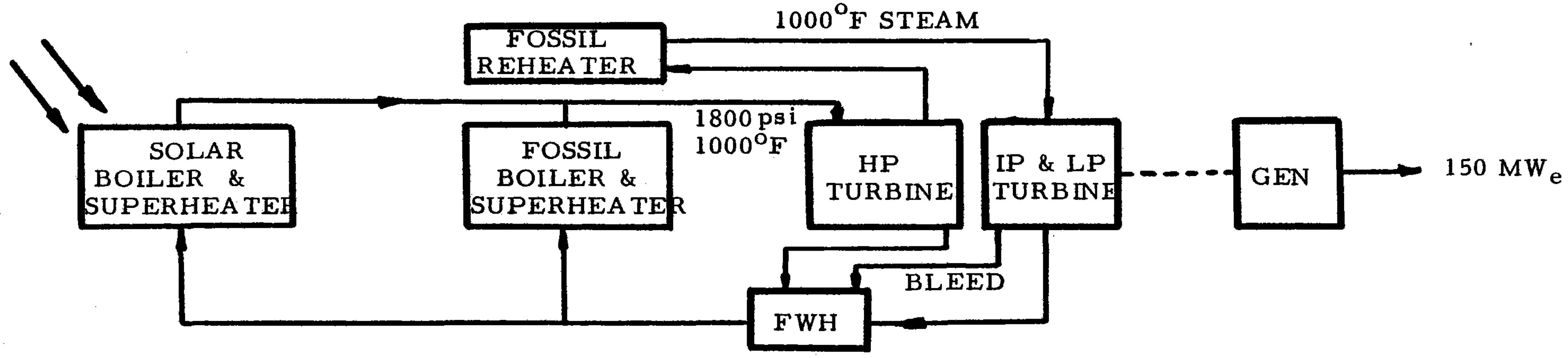
Among the six repowering contractors, Black & Veatch and El Paso Electric are the only ones who use steam and therefore do not include a thermal storage subsystem. Therefore, the water steam receiver concepts being proposed can operate only during times of adequate insolation. This is due to the fact that practical thermal storage for water-steam receivers usually involves the added complexity of a second medium (such as oil) with the associated heat exchangers and degradation in steam conditions.

The project costs shown are the solar repowering capital costs (lowest among the repowering contractors). This is due to the low solar power contribution so that solar equipment is of smaller scale. Other factors for low capital costs are: (1) land and building are presently available at the selected existing plant, (2) unit heliostat costs have been assumed low, and (3) no allowance is made for contingencies. Modifications for these factors will probably bring the solar repowering capitable costs per solar power ($kW_e$) generated in line with those of the other contractors.

# REPOWERING

Contractor: Black & Veatch
Public Service Co. of Oklahoma

Application: Electric generation
Site: Northeastern Station, Unit 1
Oalagah, Oklahoma




- o Plant size: 150 $MW_e$, gas and oil-fired, 1961 startup
- o Solar power generation: 33 $MW_e$
- o Working fluid: water/steam
- o Receiver: external type, no solar reheat, tower ht 108m
- o Collector field: 360°, 2616 DOE type heliostats, \$65/$m^2$, total mirror area .128 x $10^6 m^2$
- o Turbine: 1800psi/1000°F/1000°F reheat
- o Thermal storage: none
- o Project cost: \$28.4M

## GENERAL ELECTRIC (REPOWERING)

The existing fossil plant includes the fossil boiler and reheater shown in the diagram to the right. The solar incorporation is shown by the addition of a sodium receiver/storage loop and the heat exchangers (solar steam generators) to the left. The existing fossil and solar steam generators are in parallel, with associated steam valves, piping, and control subsystem to vary the amount of energy from each of the two sources. A heliostat field collects and directs the solar energy to the receiver. Sodium is used as the working fluid and heat exchangers are used for steam generation. The buffer storage units (tanks) are for producing steam during periods of transient insolation discontinuities. Each of the tanks must be sufficiently large for the total sodium inventory of 10 minutes of storage.

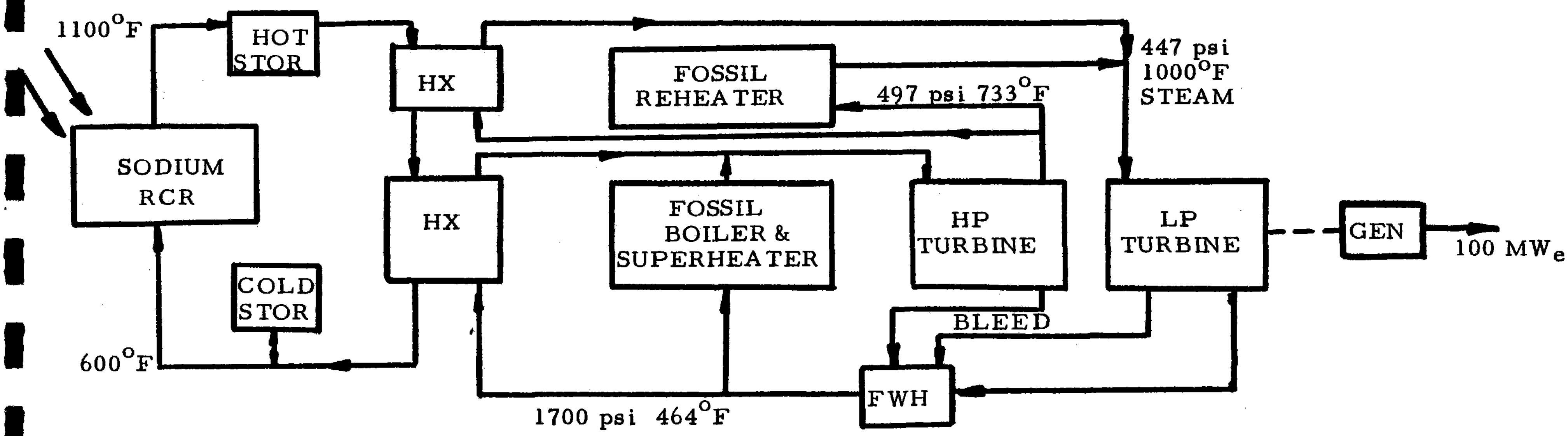
Both reheat and boiler steam generation is provided by solar energy so that a large amount of energy is delivered from the solar energy sources. The use of sodium as the receiver working fluid facilitates the incorporation of buffer storage, but requires the addition of heat exchangers for the steam generation. Electromagnetic pumps are used to control the flow through each of the receiver panels. Although the cost of these pumps is high, flow control should be good. It remains to be demonstrated whether or not there is a need for these pumps as opposed to the option of flow control valves. Only small amounts of solar thermal energy storage capacity is provided in the General Electric concept, primarily to account for insolation transients rather than for prolonged operation during periods of zero insolation (night).

The solar repowering capital costs are based on those of the Phase I Advanced Central Receiver first commercial plant costs. However, the unit heliostat costs ($100/m$^2$) is low for the first solar repowering application. No contingency allowance was considered in the General Electric preliminary capital cost estimate. In the final study capital costs are expected to be higher.

# REPOWERING

Contractor: General Electric Co.
Southwestern Public Service Co.

Application: Electric generation
Site: Plant X, Unit 3
Earth, Texas




- o Plant size: 100 $MW_e$, gas-fired, 1955 startup
- o Solar power generation: 60 $MW_e$ (60% solar fraction)
- o Working fluid: sodium, peak temp 1100°F
- o Receiver: cylindrical external type, tower ht 95m
- o Collector field: 360°, 5176 MDAC 2nd gen. heliostats, $100/$m^2$, total mirror area .25 x $10^6 m^2$
- o Turbine: 1450 psi/1000°F/1000°F reheat
- o Thermal storage: 10 $MW_e$h (~10 min)
- o Project cost: $81.7M

## MDAC (REPOWERING)

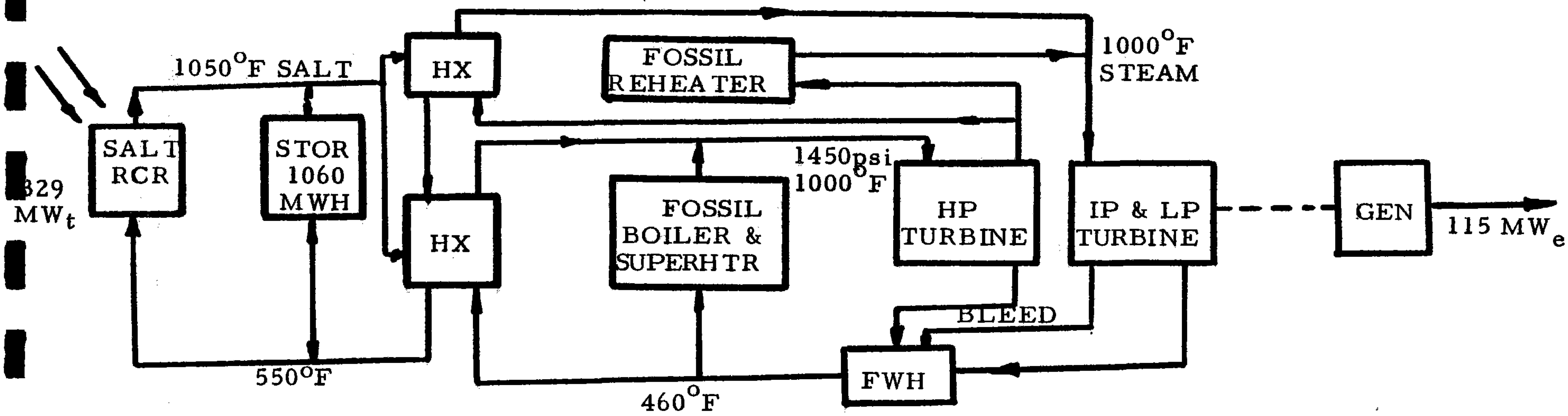
The existing fossil plan and solar energy additions are almost identical to those indicated by General Electric. The main difference is that MDAC uses salt as the working fluid whereas General Electric uses sodium. The MDAC concept includes a solar energy provision in the receiver for reheat as did the General Electric concept.

The use of salt results in two options for the thermal storage. The one shown in the diagram is the thermocline type. Due to the low thermal conductivity of salt, hot salt can be stored at the top of thetank with cold salt in the bottom without the hot salt losing its energy to the cold salt. The second option is similar to that for sodium. That is, separate hot and cold salt tanks are used with each capable of containing the total salt inventory. The choice of storage option will be based on trade studies.

REPOWERING

- Contractor: MDAC
  Foster-Wheeler, Stearns Rogers and Others
  Sierra Pacific Power, U. of Houston,
  Westinghouse, Desert Research Institute

Application: Electric generation
Site: Fort Churchill, Unit 1
Yerington, Nevada




- o Plant size: 115 $MW_e$
- o Working fluid: salt
- o Receiver: external 14.8m (diam) x 18.5m (ht) (cost = $\$26.9 \times 10^6$)
- o Collector field: 360° (495 Ac), 11045 49m² MDAC, 150m tower
- o Turbine: 1450/1000°F/1000°F reheat
- o Thermal storage: 1060 MWh capacity
- o Project cost: $\$138.4 \times 10^6$

## ROCKWELL ENERGY SYSTEMS GROUP (REPOWERING)

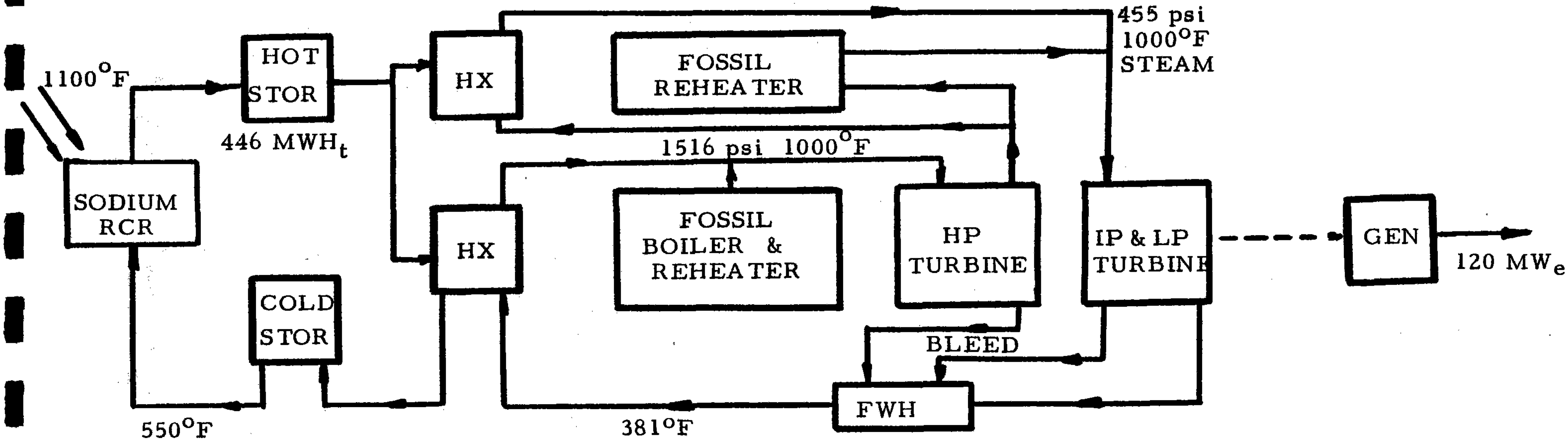
The existing and solar additions concept for Rockwell ESG is identical to that for General Electric with sodium as the receiver working fluid. The system features for both the Rockwell ESG and the General Electric base line configurations are the same.

The differences between the two contractors are in the details. Solar thermal storage capacity for Rockwell ESG is considerably larger which results in a larger heliostat field and a larger receiver size. Thus, the total solar retrofit capital costs are somewhat higher than those for General Electric system.

## REPOWERING

Contractor: Rockwell ESG
Texas Electric Service Co.

Application: Electric generation
Site: Permian Basin Station, Unit 5
Monahans, Texas




- Plant size: 115 $MW_e$, gas-fired, 1958 startup
- Solar power generation: 60 $MW_e$
- Working fluid: sodium, peak temp 1100°F
- Receiver: external, tower ht 128m
- Collector field: 360°, 8160 MDAC 2nd gen heliostats, $125/$m^2$, total mirror area .39 x $10^6 m^2$
- Turbine: 1450 psi/1000°F/1000°F reheat
- Thermal storage: 3 hr at 60 $MW_e$
- Project cost: $93.2M

## EL PASO ELECTRIC CO.(REPOWERING)

The existing reheat fossil plant used for this concept is shown in the diagram with the solar steam system addition represented by the single split block on the left side as the solar boiler and the solar reheater. This concept is similar to that of Black & Veatch with the exception that solar reheat is provided here. The receiver steam output goes directly into the turbine and is in parallel with the fossil steam boiler and reheater.

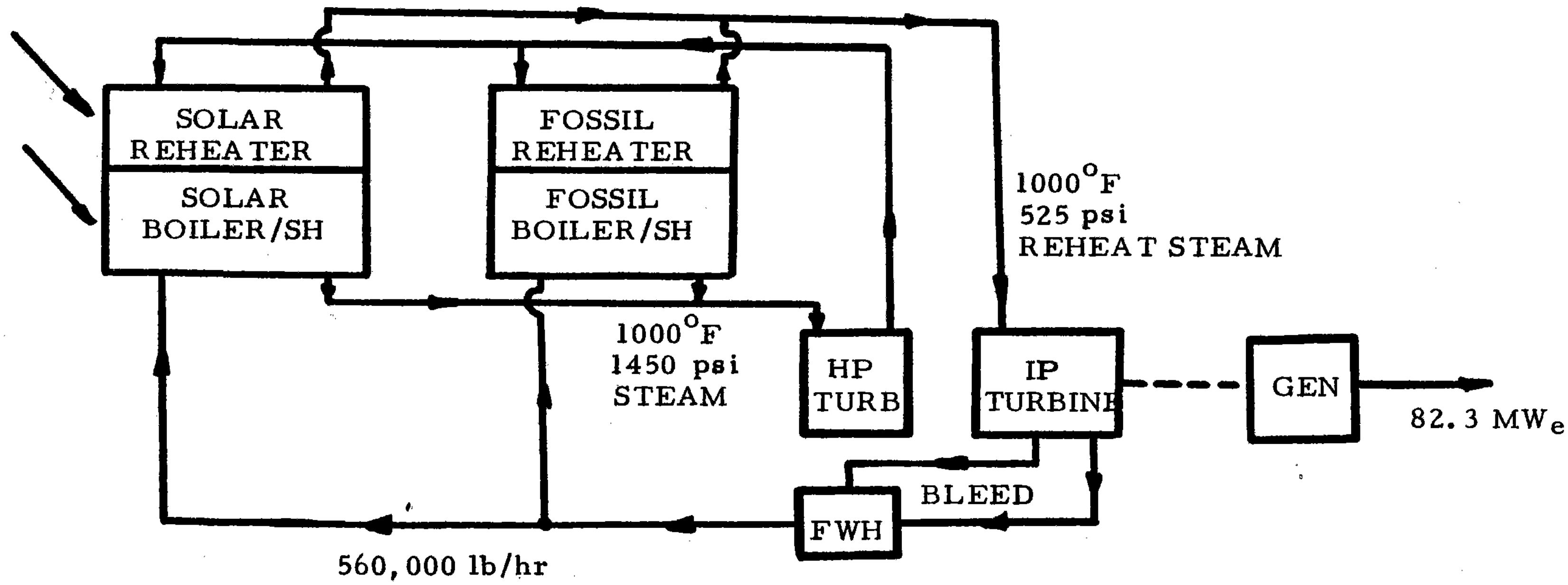
The impact of reheater in the solar receiver is that three pipes to the receiver (one steam generator output, one reheater input, and one reheater output) are required. Furthermore, the receiver is complicated by requiring two loops in it. No solar thermal storage is proposed in the El Paso Electric concept, but trade-off studies will be performed with regard to its inclusion.

The Nth plant estimates of the solar repowering capital costs were used in the preliminary estimates. For 1985 demonstration, the capital cost would be higher than the plant cost indicated on the chart.

REPOWERING

Contractor: El Paso Electric Co.
Stone and Webster, Westinghouse

Application: Electric generation
Site: Newman Power Station, Unit 1
El Paso, Texas




- o Plant size: 83 $MW_e$, gas-fired, 1960 startup
- o Solar power generation: 62 $MW_e$
- o Working fluid: water/steam, Barstow type
- o Receiver: external, with solar reheat, tower ht 210m
- o Collector field: 360°, 6200 Westinghouse heliostats, $67/$m^2$, total mirror area .36 x $10^6 m^2$
- o Turbine: 1450 psi/1000°F/1000°F reheat
- o Thermal storage: 15 to 30 min buffer
- o Project cost: $61.2M

## ARIZONA PUBLIC SERVICE (REPOWERING)

The existing fossil plant shown in the diagram on the right side uses a non-reheat turbine, whereas all other repowering contractors utilized existing fossil plants with reheat turbines. The solar retrofit shown on the left side of the diagram, however, is incorporated in parallel with the fossil boiler the same way as by all other repowering contractors. The solar addition uses salt as the receiver working and storage fluid and with separate hot and cold thermal storage tanks.

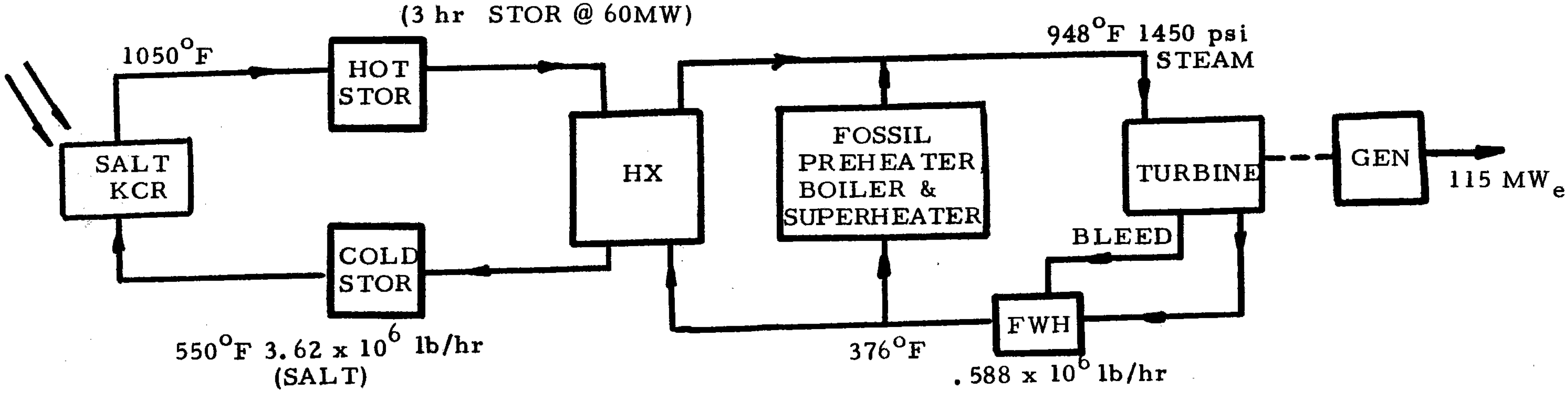
The most significant feature of this concept is that the Martin Marietta cavity receiver design is used, while all other repowering contractors use external cylindrical receivers.

The solar repowering capital costs are consistent with those of the other repowering contractors although the unit heliostat cost is low at about $\$100/m^2$.

REPOWERING

Contractor: Arizona Public Service Co.
MMC

Application: Electric generation
Site: Saguaro Power Plant, Unit 1
Saguaro, Arizona




ALTERNATE STORAGE: THERMOCLINE

- Plant size: 115 $MW_e$, gas-fired with oil standby, 1954 startup
- Solar power generation: 60 $MW_e$
- Working fluid: salt, peak temp 1050°F
- Receiver: MMC 4 cavity, tower ht 140m
- Collector field: 360°, 8985 Barstow type heliostats, \$103/$m^2$, total mirror area .44 x $10^6 m^2$
- Turbine: 1450 psi/1000°F no reheat
- Thermal storage: 3 hr at 60 $MW_e$
- Project Cost: \$88.9M

# III. INDUSTRIAL PROCESS HEAT RETROFIT SYSTEM CONCEPTS

## FOSTER-WHEELER (INDUSTRIAL RETROFIT)

The existing plant design produces superheated steam to be used in the oil refining process by means of a fossil steam generator. The refinery of interest is scheduled to be in operation by 1983 so that this is not a retrofit application.

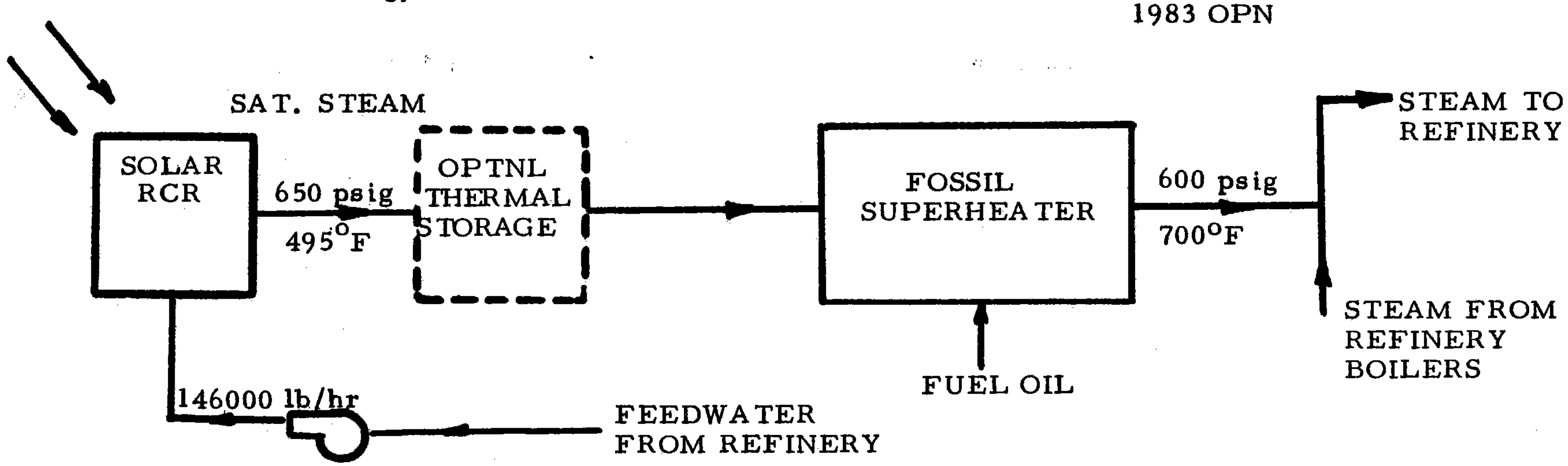
Normally, fuel oil is used to provide superheat steam which is used for the crude oil refining process. In the solar energy mode, a solar boiler (steam receiver) is incorporated in parallel with the normal fuel oil fired boiler which produces saturated steam 495°F. A fossil fuel superheater is in series with the receiver augment energy and to further heat the steam to the 700°F superheated conditions before entering the refinery. Note that in this case the fossil fuel superheater in series is a part of the solar retrofit as shown. The thermal storage is optional and has not been established as a necessity, but its purpose will be to provide for short insolation transients and possibly for periods of low insolation.

First plant capital cost is indicated in the chart and reflects $\$176/m^2$ unit heliostat cost. Nth plant costs are estimated to be approximately 40 percent lower. The collector field is about 75 percent of the total capital cost.

## INDUSTRIAL RETROFIT

Contractor: Foster-Wheeler Development Corp.
McDonnell Douglas
Provident Energy Co.

Application: Oil refining; ATM Distillation and Vacuum Flasher
Mobile, Arizona
1983 OPN




- o Heat req't: produce 700°F 600 psi superheated steam
- o Fossil displ: ~ 20% (of fuel oil)
- o Plant pwr: 117 $MW_t$
- o S.G. pwr (oil): 105 $MW_t$ (80% of steam to ATM, distill, vac. flasher, & FCC unit)
- o Solar SG pwr: 43 $MW_t$ (peak)
- o Heliostats: 1274 49$m^2$ MDAC (\$176/$m^2$)
- o Collector field: north with 93m tower, 6.2 x $10^3 m^2$ mirror area
- o Project cost: \$15 x $10^6$ (1980)

## MDAC (INDUSTRIAL RETROFIT)

The existing uranium mill uses fossil fuel steam (saturated conditions) to maintain the leaching temperature of uranium ore. The solar addition is shown in the upper block of the diagram. The solar steam generator is parallel with the existing fossil steam generator. Either one or both steam generators can be used to feed the mill by proper control of the feedwater flow. The steam is used primarily in the second stage leaching step where uranium contained in the ore solids is dissolved. It is to be noted that more steam is required during winter than in summer.

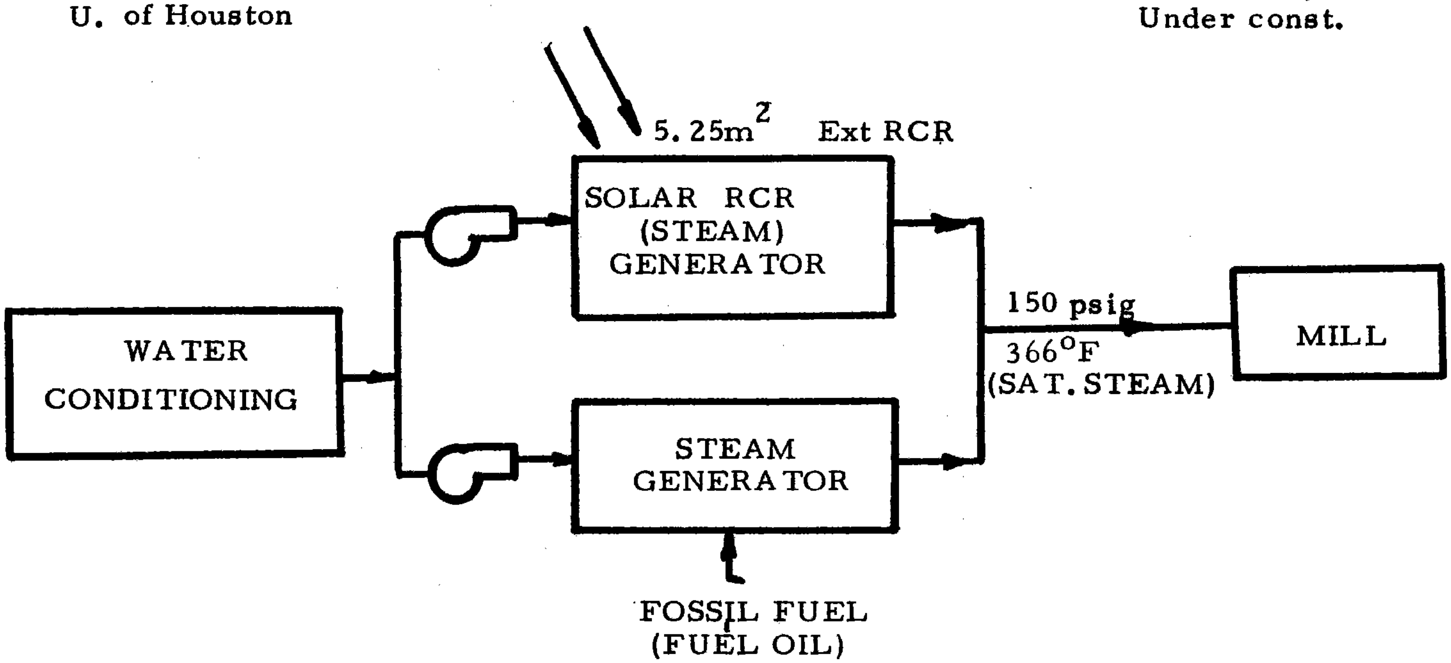
Alternatives which will be examined before the final configuration is chosen are: (1) use of a heat transfer fluid through the receiver with a separate heat exchanger to produce the solar energy steam with a solar thermal energy storage provision, (2) water-steam in the receiver loop with an intermediate heat transfer fluid loop to facilitate thermal storage to a final water-steam loop for use in the mill.

The capital cost indicated on the chart is for the first plant although the unit heliostat cost may be low. Therefore, a slightly higher capital cost might be expected.

INDUSTRIAL RETROFIT

Contractor: McDonnell Douglas Astronautics Co.
Gulf Research and Development Co.
Foster-Wheeler
U. of Houston

Application: Uranium Mill for Ore Leaching Process
San Mateo, New Mexico
Under const.




- o Heat req't: produce saturated steam at 366°F
- o Fossil displ: ~ 23% (of fuel oil)
- o Site pwr: 36.6 MW
- o Solar pwr: 8.3 MW
- o Heliostats: 331 $49m^2$ MDAC 2nd generation ($185/$m^2$)
- o Collector field: north with 40m tower, $16.2 \times 10^3 m^2$ mirror area
- o Project cost: $\$4.7 \times 10^6$ (1980)

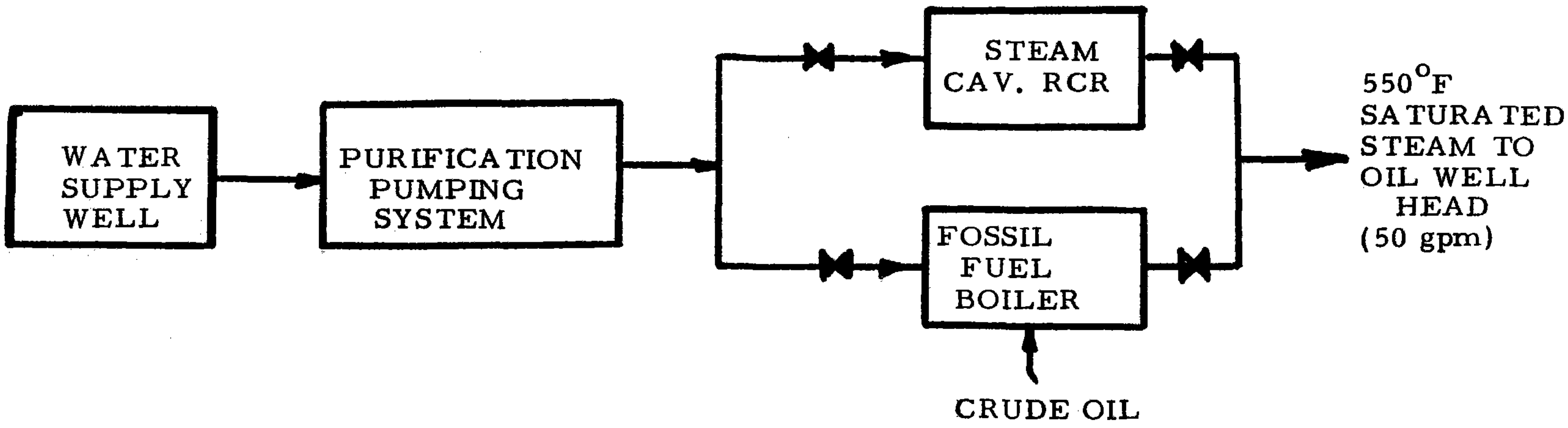
## MARTIN MARIETTA (INDUSTRIAL RETROFIT)

The oil recovery enhancement process involves pumping saturated steam into oil wells. The existing operation uses the crude oil to fire the steam generators. The procedure is to produce steam in a fossil boiler and inject the steam into an oil well for 5 to 7 days. During the soaking period of about 4 days, the steam permeates the oil/rock/sand formation and lowers the viscosity of the oil so that it can be pumped out during the following several weeks. In the solar mode, a solar boiler in parallel with the existing fossil boiler is used to feed steam to various wells in rotation. The solar receiver is a cavity design.

## INDUSTRIAL RETROFIT

Contractor: Martin Marietta
Exxon
Foster-Wheeler
Black & Veatch

Application: Enhanced Oil Recovery
Bakersfield, California




- o Heating req't: produce saturated steam at 550°F
- o Fossil displ: ~50% (of crude oil)
- o Process pwr: 13.8 $MW_t$
- o Solar pwr: 6.7 $MW_t$ (av over 24 hr)
- o Heliostats: 837 $49 m^2$ Barstow type ($\$126/m^2$)
- o Collector field: north with 90m tower, $41 \times 10^3 m^2$ mirror area
- o Project cost: $\$10 \times 10^6$ (1980)

NOTE: Normal operation with two fossil fueled boilers with total of 90 gpm flow rate (for two wellheads)

## NORTHROP (INDUSTRIAL RETROFIT)

The existing natural gas conversion plant is shown in the diagram with the solar addition shown by the left block indicated as the oil cooled flat receiver. The process consists of raw natural gas being bubbled through a hydrocarbon absorbing oil. The absorption oil is heated by the medium oil to drive off the absorbed hydrocarbons which are further processed to obtain ethane, propane, butane, and gasoline. The medium oil is normally heated by fossil fuel. The solar mode proposed is to use the medium oil as the receiver working fluid using surge tank as the source of cold fluid. A fossil heater is added in series and turned on or off as needed. Note that shutoff valves direct the heated oil at 470°F or 570°F to the proper process components.

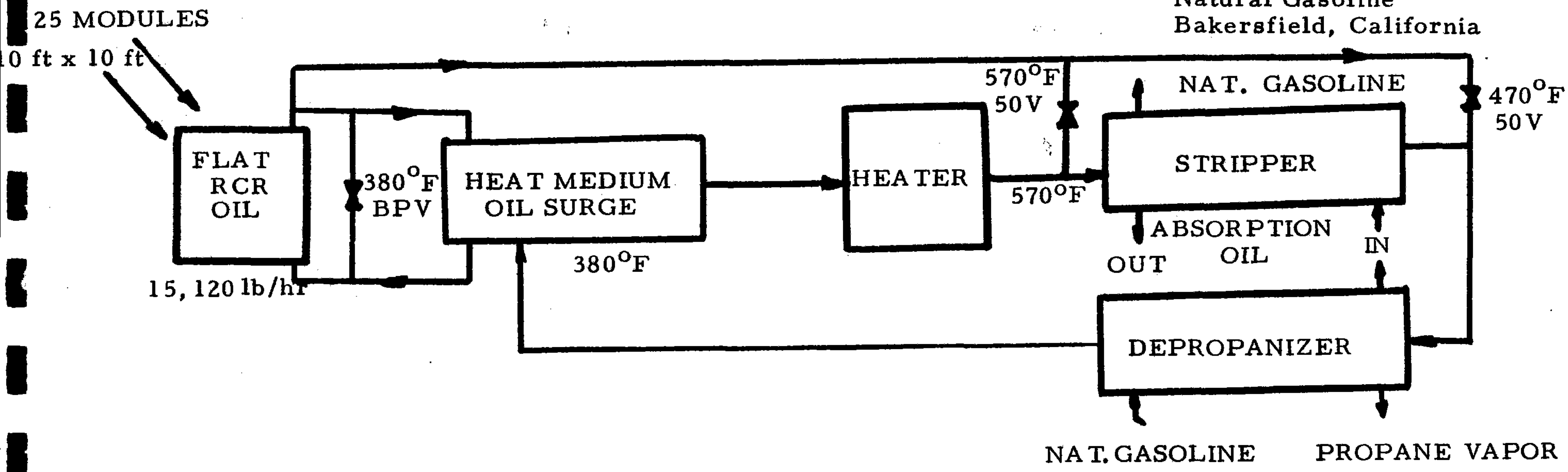
As a special feature small "towerless central receiver" modules are proposed in this concept. Twenty-three modules, each with 19 heliostats and a receiver at ground level, are used in this application. The advantage is that no tower is required with the associated cost savings resulting from easier installation and maintenance.

The significant cost item is the heliostats which were based on a 50,000 production level. Since the heliostats contribute over 60 percent of the total capital cost, the expected first plan capital cost will be higher than shown on the chart.

## INDUSTRIAL RETROFIT

Contractor: Northrop, Inc.
Arco Oil and Gas Co.

Application: Natural Gas Conversion to Gas Components and Natural Gasoline
Bakersfield, California

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- o Heat req't: heat "heat medium oil" to 380-570°F
- o Fossil displ: ~38% (of natural gas)
- o Plant pwr: 14.9 MW
- o Proc pwr (oil htg): 11.4 MW
- o Solar oil htg: 5.7 MW
- o Heliostats: 437 50.5m$^3$ N.I. Type II (\$96/m$^2$)
- o Field: 23 towerless RCR modules, $22 \times 10^3 m^2$ mirror area
- o Project cost: \$3.4 x 10$^6$

## BOEING (INDUSTRIAL RETROFIT)

The natural gas fired furnace and the kiln shown on the right side of the diagram represent the existing fossil plant for drying gypsum boards in the final stage of its manufacture. The left side of the diagram is the solar additions. In the solar energy mode, ambient air is compressed to a little over two atmospheres before entering the solar receiver. The heated air from the receiver then flows to existing furnace for distribution to drying kilns. Some of the receiver heated output air is bypassed to power the turbine which runs the compressor. An electric motor is also clutched into the compressor-turbine shaft to augment the turbine for compressor power requirements.

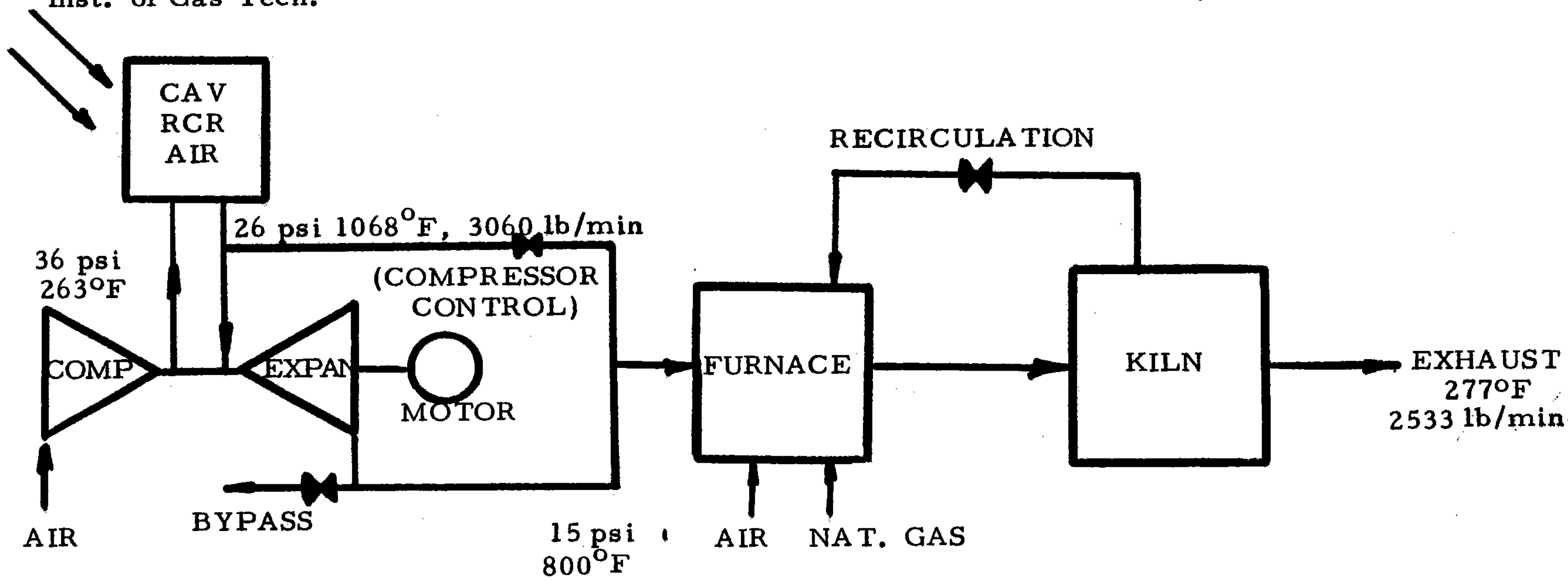
A cavity solar receiver concept is used in this design to obtain higher efficiency which is required to heat the low heat transfer air used as the working fluid. Increasing the air density by compressing the receiver inlet air increases the volumetric heat capacity of the air and reduces the size requirements of the receiver.

The capital cost shown in the chart are for the first plant. However, unit heliostat appears to be that for high production. Therefore, the actual cost is higher. It should be noted that the compressor-turbine system for air delivery to the solar receiver is a significant fraction capital cost item (approximately $\$1 \times 10^6$).

INDUSTRIAL RETROFIT

Contractor: Boeing Engineering Co.
U. S. Gypsum
Inst. of Gas Tech.

Application: Gypsum Board
Drying
Sweetwater, Texas




- Heat req't: heat air from ambient conditions to 600°F
- Fossil displ: ~25% (of natural gas)
- Site pwr: 35.2 MW
- Process pwr.: 10.8 MW (peak)
- Solar pwr: 10.9 MW (peak)
- Heliostats: 392/50.2m$^2$ Boeing pre. prod. (\$162/m$^2$)
- Collector field: north with 50m tower, 19.7 x 10$^3$m$^2$ mirror area
- Project cost: \$6.86 x 10$^6$ (1980)

## PFR ENGINEERING (INDUSTRIAL RETROFIT)

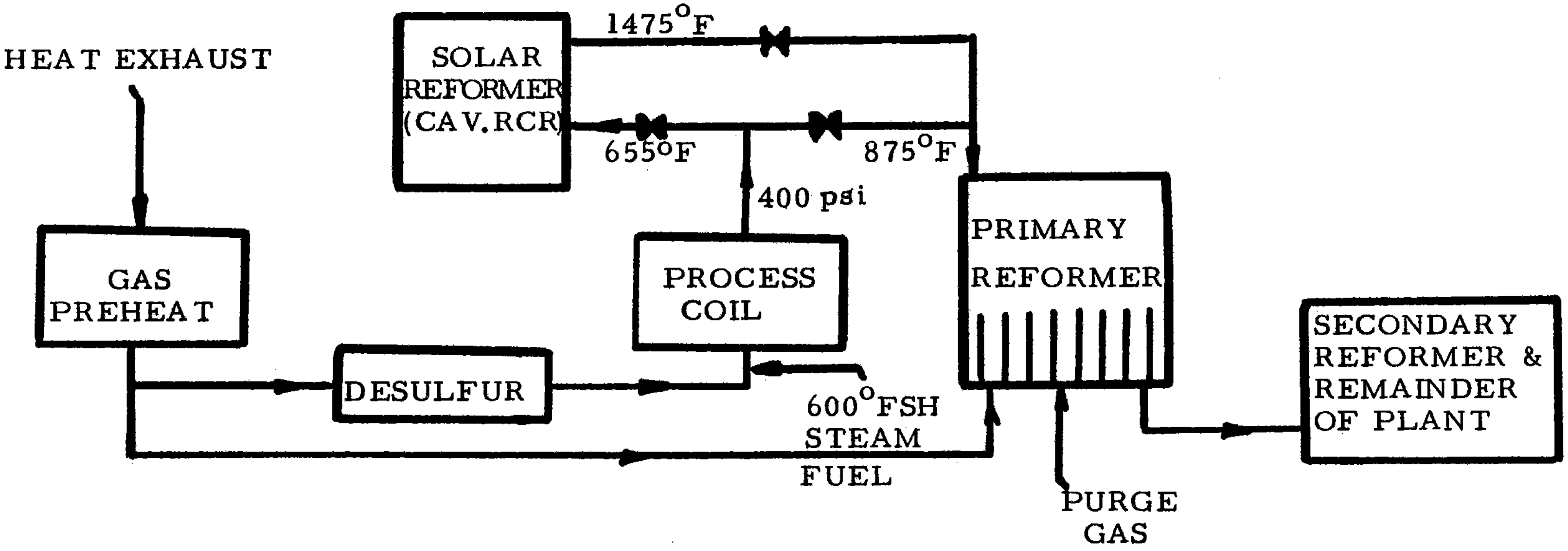
The existing fossil plant is represented by the diagram with the solar addition shown in the upper block indated as the solar reformer. Normally, natural gas fuel is used to heat the primary reformer with additional heat obtained from the purge gas. The processed natural gas passes through the preheat (heat from the exhaust gas of primary reformer), then through the desulfurizer, and finally through the process coil (heat from the primary reformer exhaust gas and 600°F steam addition) before entering the reformer. In the fossil operation mode, the gas from the process coil bypasses the solar reformer and flows directly into the primary reformer and subsequently through the remainder of the ammonia forming process.

In solar operation, the primary reformer is heated only by the purge gas with the natural gas fuel firing shutoff. The primary reformer exhaust temperature is lower than for fossil operation so that the output of the process coil is lower. The process coil output flows into the solar reformer and then through the primary reformer to maintain approximately the same primary reformer output as for the fossil operation so that the remainder of the plant process remains the same.

## INDUSTRIAL RETROFIT

Contractor: PFR Engineering Systems
MDAC
Valley Nitrogen Producers

Application: Ammonia Plant
El Centro, California




- o Heat req't: heat natural gas from 655°F to 1475°F
- o Fossil displ: ~25% (of natural gas fuel)
- o Site pwr: 58.6 $MW_t$
- o Plant pwr: 51.3 $MW_t$
- o Solar pwr: 15.2 $MW_t$ average
- o Heliostats: 1153 $49m^3$ MDAC ($\$190/m^2$)
- o Collector field: north with 93m tower, $56.5 \times 10^3 m^2$ mirror area
- o Project cost: $\$14 \times 10^6$ (1980)