GA-A16094
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UC-77

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by
A. T. McMAIN, JR., and J. D. STANLEY

Prepared under
Contract DE-AT03-76SF70046
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GENERAL ATOMIC COMPANY

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INTRODUCTION

Basic chemical, petrochemical, and petroleum refining processes are all very energy intensive. For this and other reasons, a large number of plants were built years ago on the U.S. Gulf Coast to use the area's inexpensive, plentiful natural gas to fuel process operations.

The recent dramatic changes in natural gas cost and availability and in government policy have caused process industries on the Gulf Coast and elsewhere to plan to ultimately convert to alternative process energy fuels, such as coal and uranium.

This report summarizes a study to apply an 1170-MW(t) high-temperature gas-cooled reactor - process steam/cogeneration (HTGR-PS/C) to an industrial complex at Geismar, Louisiana. This study compares the HTGR with coal and oil as process plant fuels. This study uses a previous broad energy alternative study by the Stone and Webster Corporation on refinery and chemical plant needs in the Gulf States Utilities service area (Ref. 1).

The HTGR-PS/C was developed by General Atomic (GA) specifically for industries which require both steam and electric energy. The GA 1170-MW(t) HTGR-PS/C design is particularly well suited to industrial applications and is expected to have excellent cost benefits over other energy sources. Because the HTGR produces high-temperature, high-pressure steam at conditions identical to those from fossil-fired boilers, a fairly direct substitution can be made for existing large oil or gas-fired industrial boilers. This gives maximum flexibility in establishing cogeneration heat cycles to produce steam at process conditions.

APPLICATION REQUIREMENTS

Steam Requirements

Table 1 gives the total projected steam requirements for consumers in the Geismar region.

Electrical Requirements

The present (1978) electrical requirements (in megawatts) for the consumers in the Geismar region are

User No. 1	User No. 2	User No. 3	User No. 4	Total
150	24	96	78	348

Projections indicate more than a 50% increase in electrical power consumption by 1985.

PLANT DESIGN

The study selected steam distribution conditions from the cogeneration plants to the several industrial users at each site. Where possible, these conditions conform to extraction or exhaust conditions from the plant turbine generators. Further steam conditioning by throttling and/or desuperheating to meet required process conditions was assumed to be performed as necessary at each user plant. Steam flow rates were established to meet projected user process steam demands.

Electric power was assumed to be purchased from or sold to Gulf States Utilities as necessary. The electric power cogenerated by the heat cycle used in the Stone and Webster study was insufficient to meet user plant requirements. However, this study developed a modified cycle with condensing turbine generators using three 1170-MW(t) HTGR-PS/C plants at full

TABLE 1
STEAM REQUIREMENTS FOR GEISMAR AREA APPLICATION

	Steam Requirements [kg/s (10^6 lb/hr)]					
	User No. 1	User No. 2	User No. 3	User No. 3	User No. 4	Total
Pressure [MPa (psig)]	4.41 (640)	4.48 (650)	4.41 (640)	6.55 (950)	1.72 (250)	
Temperature [°C (°F)]	393 (740)	393 (740)	393 (740)	393 (850)	NA	
1981	222 (1.76)	95 (0.75)	113 (0.90)	47 (0.37)[a]	45 (0.36)	522 (4.14)
1982	256 (2.035)	97 (0.77)	120 (0.95)	47 (0.37)	47 (0.37)	566 (4.495)
1983	280 (2.22)	98 (0.775)	132 (1.05)	47 (0.37)	54 (0.43)	611 (4.85)
1984	280 (2.22)	126 (1.0)	145 (1.15)	47 (0.37)	55 (0.44)	653 (5.18)
1985	292 (2.32)	189 (1.5)	151 (1.2)	47 (0.37)	57 (0.45)	736 (5.84)
1986	292 (2.32)	202 (1.6)	157 (1.25)	47 (0.37)	58 (0.46)	756 (6.0)
1987	296 (2.35)	214 (1.7)	164 (1.3)	47 (0.37)	59 (0.47)	780 (6.19)
1988	300 (2.38)	227 (1.8)	170 (1.35)	47 (0.37)	60 (0.48)	804 (6.38)
1989	307 (2.44)	239 (1.9)	183 (1.45)	47 (0.37)	62 (0.49)	838 (6.65)
1990	315 (2.5)	252 (2.0)	195 (1.55)	47 (0.37)	63 (0.5)	872 (6.92)

[a] Projected steam usage not available; initial demand held constant.

capacity to cover user needs and to produce surplus electric power for sale to the utility. Figure 1 shows the heat cycle.

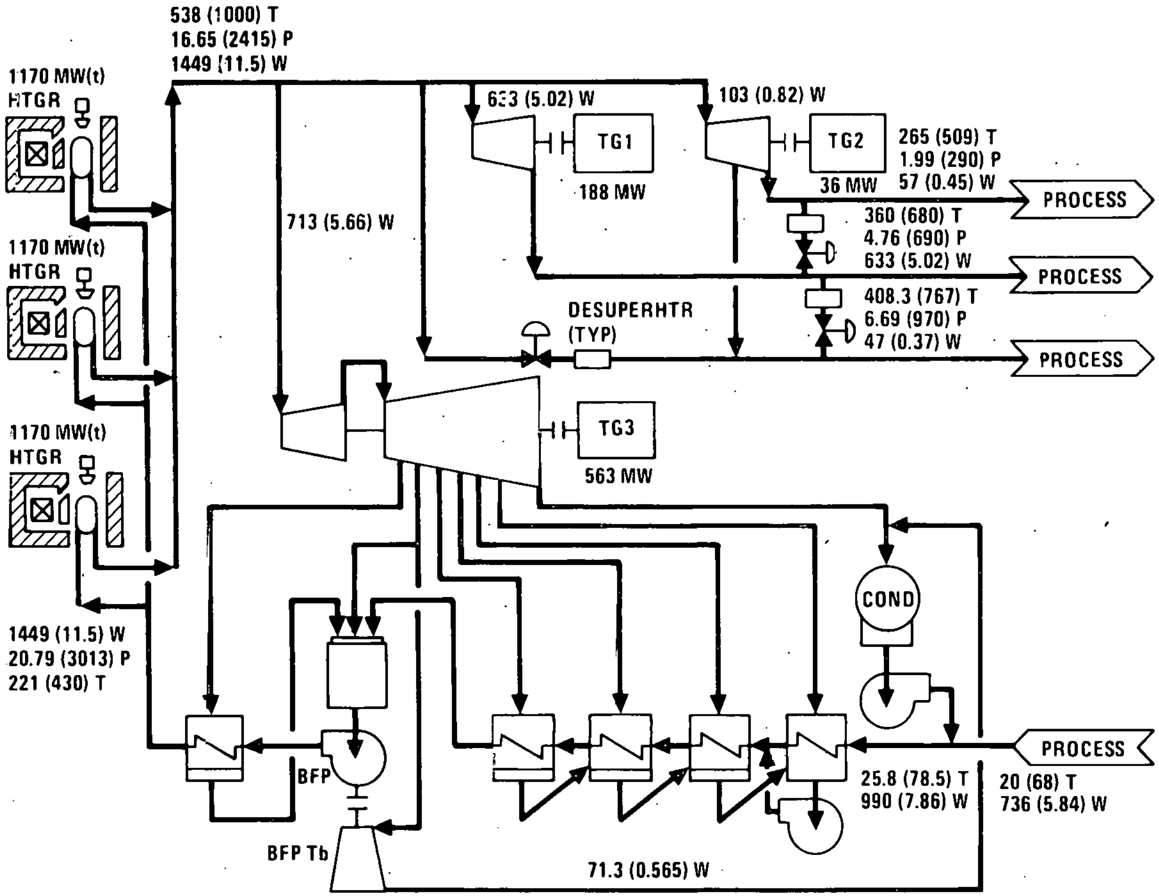
Steam is distributed to the user plants at 6.69 MPa/408°C (970 psia/767°F), 4.55 MPa/366°C (660 psia/690°F), and 2.0 MPa/265°C (290 psia/509°F). The plant produces 2214 MW (7757 x 10^6 Btu/hr) of steam power and 702 MW(e). Current consumption by the user plants is 348 MW(e), leaving 354 MW(e) of surplus for sale to the utility or for future increases in the user plant consumption.

ECONOMIC ANALYSIS

The revenue requirement method was selected to evaluate alternative projects. This technique is appropriate for evaluating long-lived coal and nuclear cogeneration power plant projects. It determines the revenue needed by the firm as compensation for all fixed and variable expenditures. Hence, the revenue requirements of the firm equal the consumer cost for the process steam cogenerated.

Table 2 compares estimated energy costs for the 1170-MW(t) HTGR-PS/C versus the comparable coal-fired PS/C plant and existing oil-fired plant for a refinery/chemical complex. It shows a clear advantage of the HTGR over both the coal-fired and oil-fired plants.

This analysis is based on economic assumptions used to evaluate utility cogeneration projects in progress for the Department of Energy (DOE) by GA in coordination with Gas Cooled Reactor Associates (GCRA). Table 3 gives the principal assumptions of the economic analysis, a key one being the 18% fixed charge rate for capital use/recovery. Such a rate may be higher if industrial ownership ground rules are applied. Therefore, the economics should be determined using the economic ground rules appropriate for the specific application. Industrial user input is being developed regarding possible alternative economic ground rules.



ALLOCATION OF REACTOR POWER OUTPUT	MW	%
PROCESS USES		
ELECTRIC POWER	348.0	9.9
STEAM POWER TO PROCESS	2214.2	63.1
SUBTOTAL	2562.2	73.0
OTHER USES		
ELECTRIC POWER	375.3	10.7
LOSSES		
CONDENSER	532.5	15.2
OTHER	40.0	1.1
TOTAL REACTOR POWER OUTPUT	3510	100

LEGEND

W = FLOW KG/S (10^6 LB/HR)

P = PRESSURE MPa (PSIA)

T = TEMPERATURE ^oC (^oF)

C102-E007

Fig. 1. Cycle diagram for an 1170-MW(t) HTGR-PS/C plant for Geismar, Louisiana, petrochemical complex application (with condensing cycle)

TABLE 2
ECONOMIC ANALYSIS OF HTGR-PS/C AND
ALTERNATIVE PLANTS FOR GEISMAR AREA APPLICATION

	HTGR-PS/C	Coal Without Condensing	Existing No. 2 Oil
Heat input to cycle (MW)	3510.0	2631.0	2214.6
Heat output in process steam (MW)	2214.2	2214.6	2214.6
Net electrical power output (MW)	723.3	352.2	--
Capital Costs ($ x 10^6)			
Base capital cost (1/80 $)	1654	825	--
Escalation through construction	1650	932	--
Interest during construction	1037	349	--
Total capital cost (1/95 $)	4341	2106	--
Annual Costs ($ x 10^6/year)[a]			
Fixed charges	781	379	--
Fuel costs	242	640	2771
O&M costs	189	148	38
Credit for electric power	(751)	(366)	--
Total annual costs	461	801	2809
Process Steam Cost [mills/kW(t)-hr ($/MMBtu)]	34.0 (9.96)	59.0 (17.30)	206.7 (60.61)
Ratio of Energy Cost to Cost with HTGR-PS/C		1.7	6.1

[a] 1/95 $ levelized over a 30-year period.

TABLE 3
ECONOMIC ANALYSIS ASSUMPTIONS

Commercial operation of all plants:	1/95
Capacity factor:	70%
Levelizing period:	30 years
Electric power credit:	22 mills/kW-hr (80 $)
Discount rate:	10%/year
Fixed charge rate:	18%/year
Interest during construction:	10%/year (simple interest)
Coal cost escalation:	8%/year
Fuel oil escalation:	9%/year
All other escalation:	6%/year
Construction period:	6 years for all plants (2 years for No. 6 oil-fired plants)
U_3O_8 (yellowcake) cost:	$121/kg ($55/lb) in 1990, rising to $264/kg ($120/lb) in 2030
Separative work unit (SWU) cost:	$100/kg-SWU (80 $)
Tails assay:	0.2%
Coal cost:	4.64 mills/kW-hr ($1.36/MMBtu) (80 $)
No. 2 oil cost:	18.2 mills/kW-hr ($5.33/MMBtu) (80 $)
No. 6 oil cost:	13.5 mills/kW-hr ($3.95/MMBtu) (80 $)
HTGR-PS/C fuel cycle cost (includes recycle):	11.23 mills/kW-hr ($3.29/MMBtu) (1/95 $ levelized over 30 years)

Ultimately, the economic analysis method will be determined by the nuclear cogeneration plant ownership:

1. Industrial ownership with connection to the utility grid for backup electric power and sale of excess power (per recent Federal Energy Regulatory Commission rulings regarding a more favorable arrangement for industry).

2. Utility ownership with both steam and cogenerated electric power sold to nearby industry.

3. Consortia ownership and sale of energy to industry and local utilities.

The analysis compares the cost of process steam produced by the HTGR-PS/C with that produced by a coal-fired cogenerating plant and with the cost of burning No. 2 oil in existing equipment. It includes a credit for the electric power produced by the HTGR and coal-fired cogenerating plants. The analysis indicates a clear advantage for the HTGR over the coal and oil alternatives.

REFERENCE

1. "Cogeneration Feasibility Study in the Gulf States Utilities Service Area," Stone and Webster Corporation Report No. 12977, July 1979.

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