

GAS TURBINE MODELING WITH PEPSE[®]

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Abstract

Gas turbines have become an attractive alternative for small base loaded electric generation units. Simple cycle, advanced design gas turbines have efficiencies approaching that of conventional regenerative steam cycles, and combined cycle (gas turbine with heat recovery steam generator and steam turbine) have efficiencies exceeding those of steam cycles. PEPSE can be used to model simple cycle, simple cycle with regenerator, steam injection cycle and combined cycle gas turbine plants.

PEPSE sub models were developed to analyze the various configurations of gas turbine cycles. The sub models were then combined with larger models to analyze full combined cycle plants. Electric generation, heat rates and thermal efficiency were calculated from the PEPSE model output.

Introduction

Rochester Gas and Electric serves the Upstate New York area, with corporate headquarters in Rochester, New York. Electric generation consists of a 500MW nuclear plant, five (5) coal units with a total output of 350MW, hydro-electric stations along the Genesee River with a total output of 50MW, and two (2) 15MW gas turbines. RG&E is also a partner with neighbor utilities for 200MW of oil fired generation and 150MW of nuclear. RG&E is a member of the New York Power Pool and will supply the pool or draw from the pool, depending upon the generating units available. Currently the nuclear plants are base loaded, the hydro plants will produce based upon the river flow, and the coal units will load swing on economic reserve.

RG&E currently has studies underway in several areas where gas turbines are being considered. The first is in the evaluation of new generating units, where gas turbines are being considered for the next increment of electric generation. Also under study is the repowering of one of the existing pulverized coal units with a gas turbine and heat recovery steam generator, making a combined cycle plant. Cogeneration using gas turbines is also being studied, with a third party providing steam and electricity to current RG&E customers. PEPSE is being used to help evaluate all of these gas turbine applications.

PEPSE Gas Turbine Models

A number of PEPSE gas turbine sub models were developed to cover a wide range of gas turbine cycles, as follows:

- Simple cycle
- Regenerative cycle
- Simple cycle with Heat Recovery Steam Generator
- Simple cycle with Steam Injection
- Combined cycle

* Simple Cycle

The simple cycle gas turbine heat balance for a typical 30MW machine is shown in Attachment 1A. Air at atmospheric conditions is compressed by the shaft driven air compressor. Natural gas fuel is compressed and then fired in the combustor. The high temperature and pressure exhaust is then expanded through the turbine and exhausted at atmospheric pressure. The pressure in the combustor varies upon application, from 100 PSIG to 450 PSIG. The combustion temperature varies from 1400°F to 2300°F. The higher temperatures and pressure result in a cycle with higher efficiency. The air to fuel ratio will determine the combustion temperature. On a mass basis, 55 to 1 air to fuel will result in a combustion temperature of approximately 1800°F. The exhaust temperature is typically 900-1000°F, and represents most of the thermal losses from the cycle. Simple cycle heat rates are typically 12,500 BTU/KWH with a cycle thermal efficiency of 27%.

The PEPSE schematic for this cycle is shown in Attachment 1B. The gas turbine is a component type 9, with the exhaust pressure and temperature specified to allow

PEPSE to calculate turbine efficiency. The combustor is a component type 70. The fuel compressor is a type 43 (motor driven) and the air compressor a type 44 (shaft driven). A type 61 fixed flow splitter is included to adjust the air to fuel ratio. A control is included to adjust the splitter "B" port flow to obtain the desired combustion temperature. Operations are included to calculate a heat rate and cycle efficiency.

* Regenerative Cycle

The next sub model includes a regenerator to recover some of the exhaust heat, as shown in the heat balance on Attachment 2A. In this cycle the air leaving the compressor is pre-heated by the exhaust gases prior to entering the combustor, thereby reducing the fuel required to obtain the desired combustion temperature. The exhaust gases typically are reduced in temperature by 300°F, which improves the heat rate to 9300 BTU/KWH and raises efficiency to 36%. A measure of performance of the regenerator is the effectiveness, which is the ratio of the actual temperature rise of the air divided by the maximum available temperature rise. This value is typically 85%.

The PEPSE schematic for this cycle is shown in Attachment 2B. The regenerator is a type 20 heat exchanger, with the exhaust gases on the tube side, the air from the compressor entering the "S" port and the heated air leaving at the "D" port. This allows the air temperature leaving

the regenerator to be specified. To help the model converge, a double ended source is included between the regenerator outlet and the combustor inlet. This source provides the expected air temperature for the first few PEPSE iterations, then passes through the calculated temperature. The air flow rate is fixed at a value calculated from the simple cycle run, and fuel flow varied to obtain the desired combustion temperature. An operation is included to calculate the regenerator effectiveness.

* Simple Cycle with Heat Recovery Steam Generator

A heat recovery steam generator is next added to the simple cycle, as shown on the heat balance in Attachment 3A. The exhaust products are used to produce steam, thereby utilizing the heat and lowering the cycle exit temperature to 300°F. This improves overall cycle efficiency to 77%.

The PEPSE schematic is shown in Attachment 3B. The HRSG is a type 20 heat exchanger, with the exhaust gases on the tube side, the feedwater entering at the "S" port and the steam exiting at the "D" port. The heat exchanger is in the performance mode, which allows the steam conditions leaving the heat exchanger to be specified. A control is added to adjust the flow leaving the source component to produce the desired exhaust gas exit temperature.

* Simple Cycle with Steam Injection

The output of the gas turbine can be improved by increasing the mass flow through the turbine. This can be

done by injecting steam into the turbine inlet to augment the exhaust flow from the combustor, as shown in the heat balance on Attachment 4A. This is done in applications where excess steam is available. The addition of approximately 6% steam (by mass) to the flow going to the turbine improves the heat rate to 11,200 BTU/KWH.

The PEPSE schematic is shown is Attachment 4B. A type 50 mixer is used to mix the injection steam and the gases, with the combustor exhaust going to the "IA" port and the steam to the "IB" part. The addition of steam reduces the temperature of the stream going to the turbine, so additional fuel is fired to provide a higher temperature leaving the combustor. A control on fuel flow is added to produce the desired 1800°F temperature at the mixer outlet versus the combustor outlet.

* Simple Cycle with HRSG in Design Mode

The HRSG can be separated into a three (3) zone heat exchanger, with separate economizer, evaporator and superheater sections. To simplify the analysis, the feedwater leaving the economizer is a saturated liquid, the steam leaving the evaporator is a saturated vapor and all of the superheat is added in the superheater. The heat balance is shown on Attachment 5A.

The PEPSE schematic, shown in Attachment 5B, uses type 28 heat exchangers to model each of the 3 zones. The physical dimensions and characteristics of each of the zones

is input. Each zone has extended surface tubes, so the heat transfer area can be varied with the same outside unit dimensions. Additional double ended sources are added to help the model converge.

* Combined Cycle

The last cycle considered is a combined cycle, as shown in the heat balance in Attachment 6A. The steam produced in the HRSG is expanded through a steam turbine to generate additional electricity. This cycle maximizes the electrical production. With a condensing steam turbine, the cycle heat rate is 8800 BTU/KWH with a cycle efficiency of 38%.

The PEPSE schematic is shown in Attachment 6B. A splitter is included to direct steam to the turbine or to a process consumer. The steam turbine is modeled as a type 8 turbine, and a surface condenser is included. Operations are included to calculate heat rate and cycle efficiency.

Applications

These models were applied to two studies currently underway at RG&E. This first is a re-powering study of Unit 1 at RG&E Russell Station. Unit 1 is a 46MW, non-reheat, pulverized coal boiler which went on line in 1948. The study considers replacing the boiler with a gas turbine and HRSG, thereby supplying steam at the present conditions to the steam turbine (375,000 lb/hour, 1260 PSIA, 950F). The heat balance is shown in Attachment 7A, and the PEPSE schematic in Attachment 7B. This requires a gas turbine of 103MW, resulting in total unit output of 149MW. The

heat rate of the combined cycle is 7500 BTU/KWH, versus 8800 for the steam cycle only. One interesting feature is that both heat rate and output are improved by removing feedwater heaters from service. The colder feedwater to the HRSG allows the exhaust gases to be cooled to a lower temperature, and the steam turbine output increases with the reduced extraction flow. The heat rate improves to 7200 BTU/KWH with generation of 153 MW when bypassing heaters 2 through 5.

A cogeneration combined cycle was also analyzed using PEPSE. Attachment 8A shows the heat balance proposed by a vendor who wants to sell electricity to RG&E and steam/hot water to a local process consumer. The schematic shown in Attachment 8B was developed to help analyze the cycle and determine the potential electric/steam/hot water production.

Conclusions

The PEPSE output for various cycles was compared with data from gas turbine vendors. In general, PEPSE predicts approximately 10% less exhaust flow than that in the published vendor data. Often the cycle is not fully characterized by the vendor, so the comparison of stream conditions is difficult. Further study of the vendor data may be required to reconcile the differences in predicted cycle performance.

A summary of the various cycles is as follows:

<u>Cycle Description</u>	<u>Gross Heat Rate BTU/KWH</u>	<u>Thermal Efficiency, %</u>	<u>Exhaust Temp, °F</u>	<u>Output MW</u>
Simple	12,500	27	1,000	29.9
Regenerator	9,300	36	670	28.9
Simple w/HRSG	12,500	77 (1)	300	29.9
Steam Injection	11,200	63 (1,2)	300	35.0
Combined	8,800	38 (3)	300	42.6

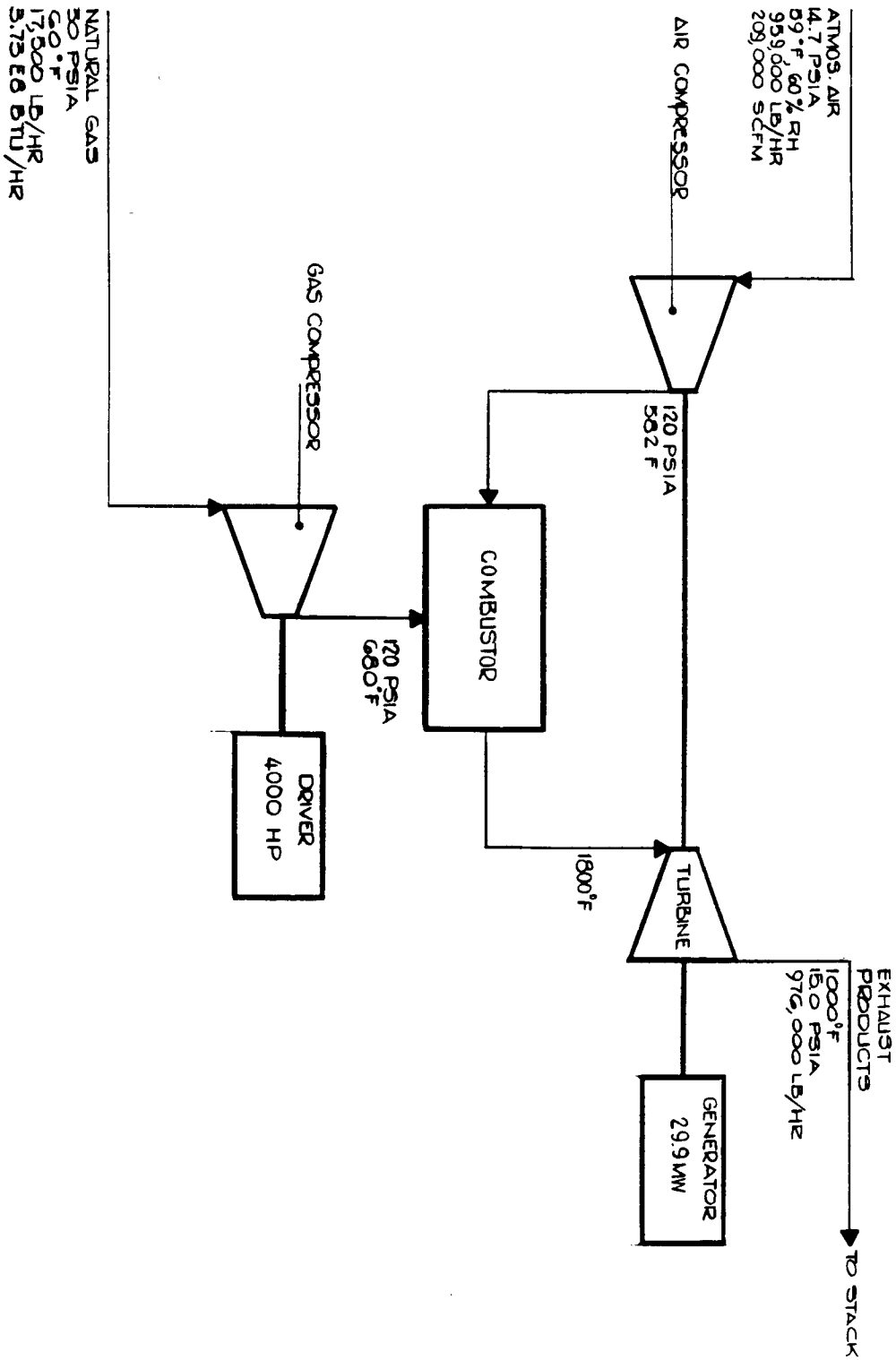
Notes:

- 1) Assumes all steam produced is utilized.
- 2) Assumes 6% steam injection.
- 3) Assumes all steam is expanded through condensing turbine.

List of Attachments

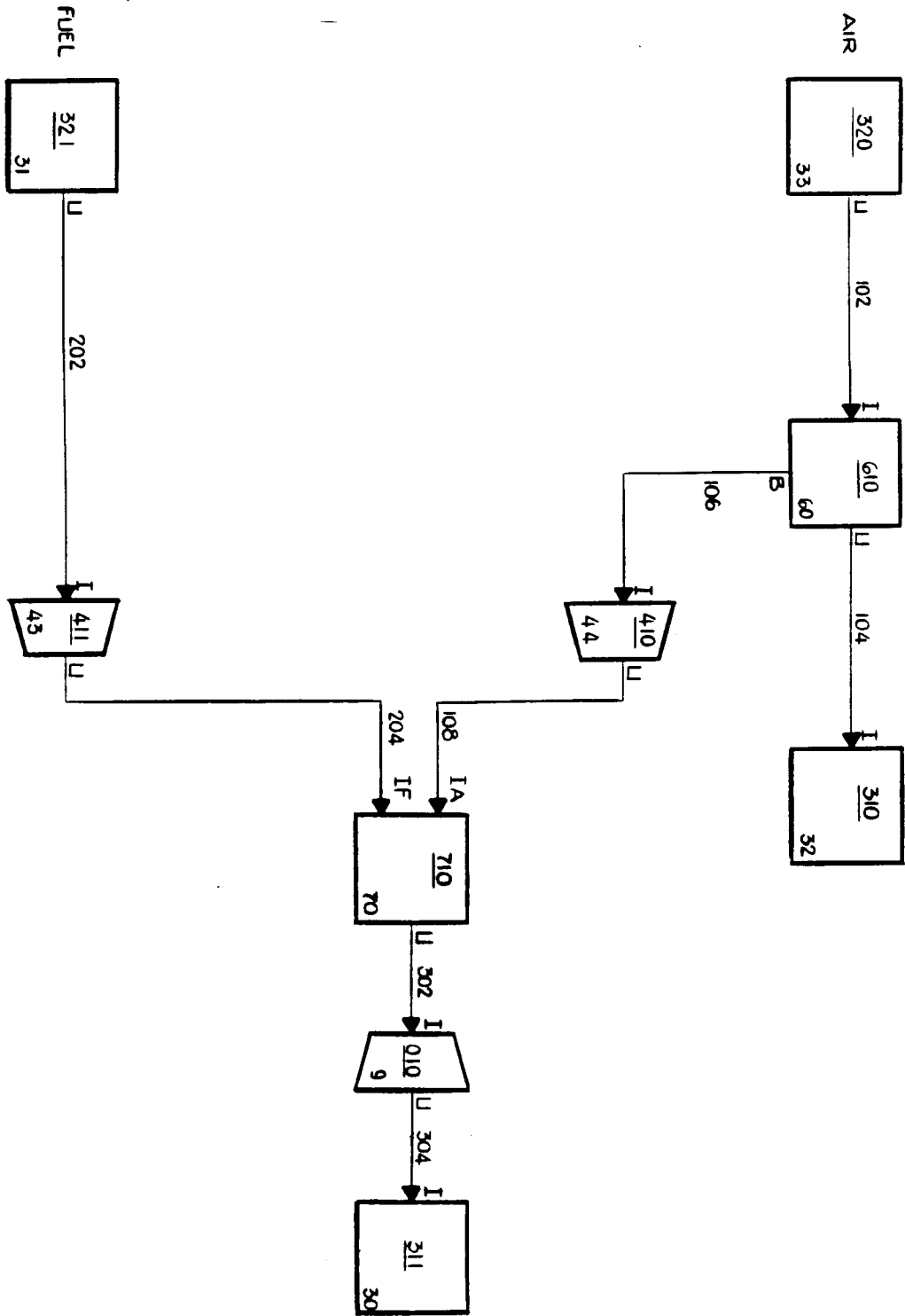
<u>Number</u>	<u>Description</u>	
1A	Simple Cycle	- Heat Balance
1B		- PEPSE Schematic
1C		- PEPSE Input File
2A	Regenerative Cycle	- Heat Balance
2B		- PEPSE Schematic
2C		- PEPSE Input File
3A	Heat Recovery Cycle	- Heat Balance
3B		- PEPSE Schematic
3C		- PEPSE Input File
4A	Steam Injection Cycle	- Heat Balance
4B		- PEPSE Schematic
4C		- PEPSE Input File
5A	Design Mode HRSG	- Heat Balance
5B		- PEPSE Schematic
5C		- PEPSE Input File
6A	Combined Cycle	- Heat Balance
6B		- PEPSE Schematic
6C		- PEPSE Input File
7A	Repowering Study	- Heat Balance
7B		- PEPSE Schematic
7C		- PEPSE Input File
8A	Cogeneration Study	- Heat Balance
8B		- PEPSE Schematic
8C		- PEPSE Input File

[TWM\024]



HEAT BALANCE
GAS TURBINE CYCLE

CONTACT SUPPLY ←



PEPSE SCHEMATIC
GAS TURBINE CYCLE

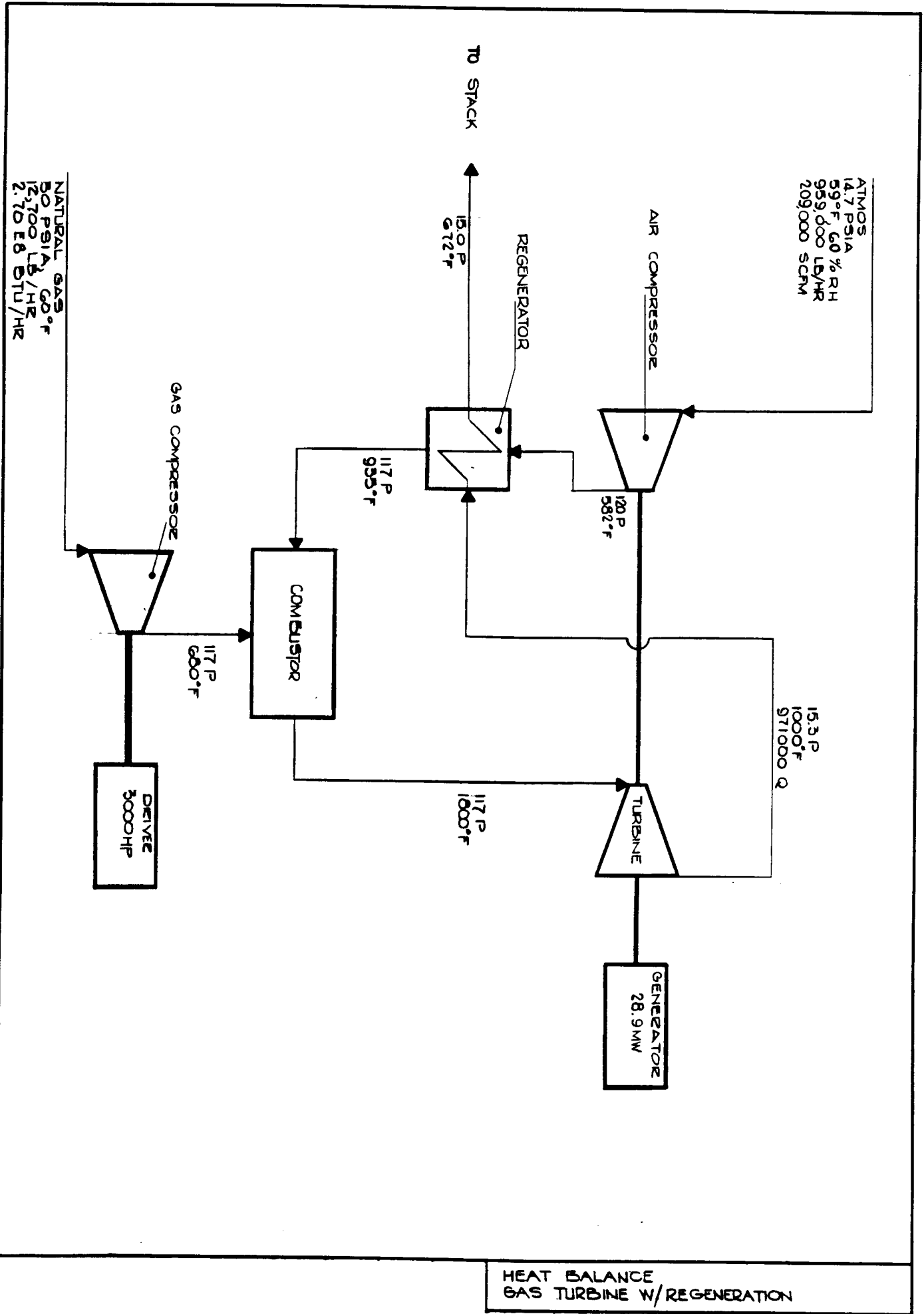
LISTING OF INPUT DATA FOR CASE 1

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2   * CONTROL ON AIR FLOW TO PROVIDE 1800F TURBINE INLET TEMP
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4   010200 3,0,1,0,0
5   011010 1,2,5,0,3600,32000...85,45.,45.
6   011011 200, 350.
7   * TABLE SUPPRESSION
8   020001 NOPRNT
9   020002 NOPRNT
10  020004 NOPRNT
11  020005 NOPRNT
12  020012 NOPRNT
13  020013 NOPRNT
14  020016 NOPRNT
15  020020 NOPRNT
16  020021 NOPRNT
17  020022 NOPRNT
18  020023 NOPRNT
19  020025 NOPRNT
20  020026 NOPRNT
21  020028 NOPRNT
22  020034 NOPRNT
23  020037 NOPRNT
24  020042 NOPRNT
25  * GEOMETRY INPUT
26  501020 320, U, 610, I
27  501040 610, U, 310, I
28  501060 610, B, 410, I
29  501080 410, U, 710, IA
30  502020 321, U, 411, I
31  502040 411, U, 710, IF
32  503020 710, U, 10, I
33  503040 10, U, 311, I
34  * TURBINE DATA
35  700100 9 1 2 1 6
36  700106 15, 1000.
37  * SOURCE AND SINK DATA
38  703100 32
39  703110 30
40  703200 33 59, 14.7 2.E6
41  703203 AIR .6
42  703210 31 60, 30, 17500.
43  703213 FUEL 21300, SSVL 44.5 C .754 H2 .234 N2 .012
44  * COMPRESSOR DATA
45  704100 44 1 120, 1, .8
46  704110 43 120, 1, 1, .8
47  * SPLITTER DATA
48  706100 61 0, 1.E6
49  * COMBUSTOR DATA
50  707100 70 0 2 0 0.
51  * CONTROL ON EXCESS AIR TO PRODUCE DESIRED GAS TEMP
52  840100 WNFIXB 610 1800, 0, 1, TT 302
53  * OPERATIONAL VARIABLES
54  870010 21300.
55  870020 1000.
56  870030 3412.
57  * CALCULATE GROSS CYCLE HEAT RATE
58  880010 MW 202 MUL OPVB 1 OPVB 4
59  880020 BKGR0 1 MUL OPVB 2 OPVB 5
60  880030 OPVB 4 DIV OPVB 5 OPVB 6
61  * CALCULATE OVERALL CYCLE EFFICIENCY
62  880040 OPVB 5 MUL OPVB 3 OPVB 7
63  880050 OPVB 7 DIV OPVB 4 OPVB 8
64  * PRINT OUTPUT VARIABLES
65  890100 'GENERATOR ELECTRICAL OUTPUT, MW'
66  890101 BKGR0 1
67  890200 'GROSS CYCLE HEAT RATE, BTU/KWH'
68  890201 OPVB 6
69  890300 'CYCLE THERMAL EFFICIENCY'
70  890301 OPVB 8
71  *
72  .

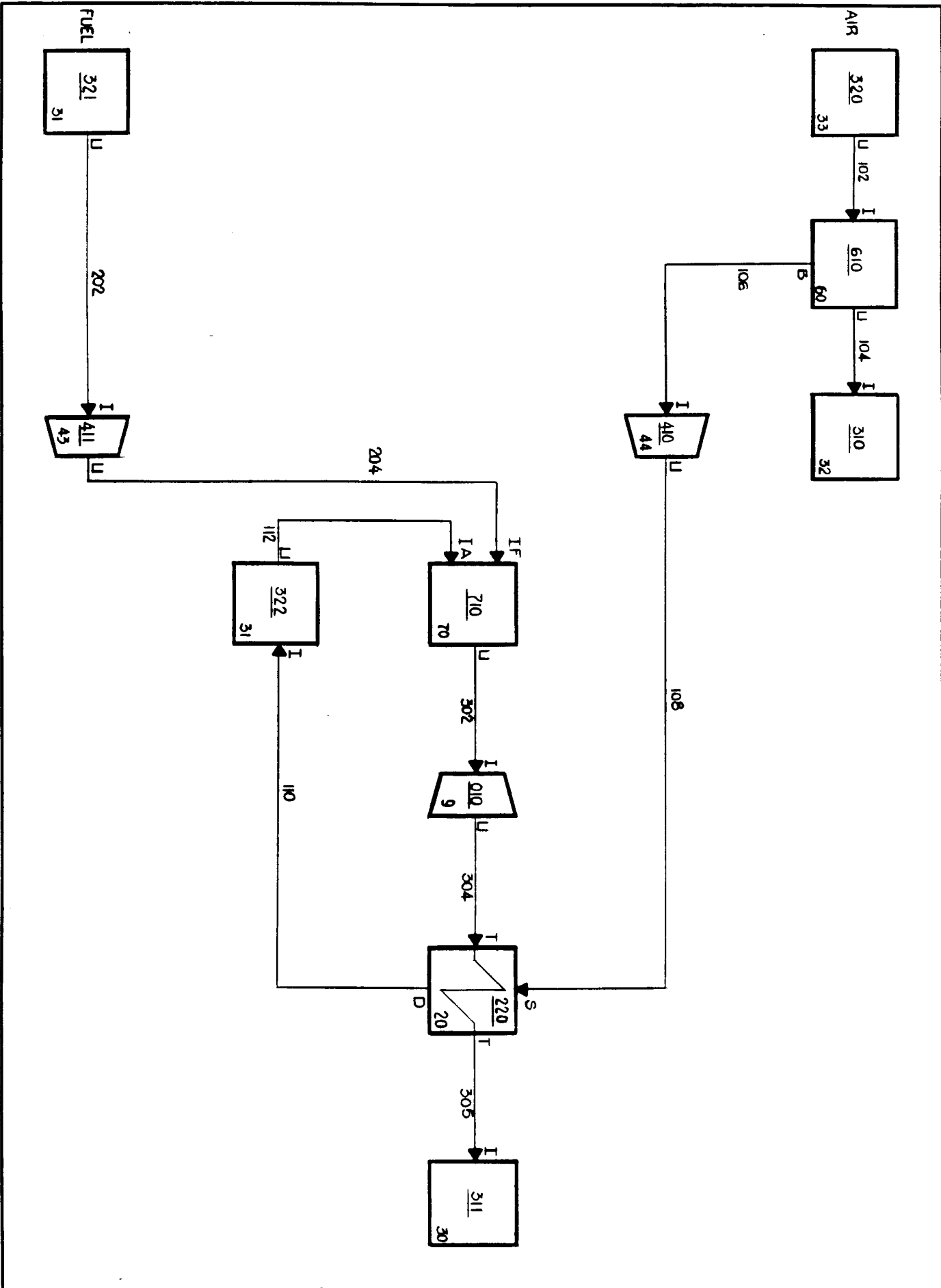
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CONTACT SUPPLY ←



HEAT BALANCE
 GAS TURBINE W/ REGENERATION

CONTACT SUPPLY ↑



PEPSE SCHEMATIC
GAS TURBINE CYCLE W/REGENERATOR

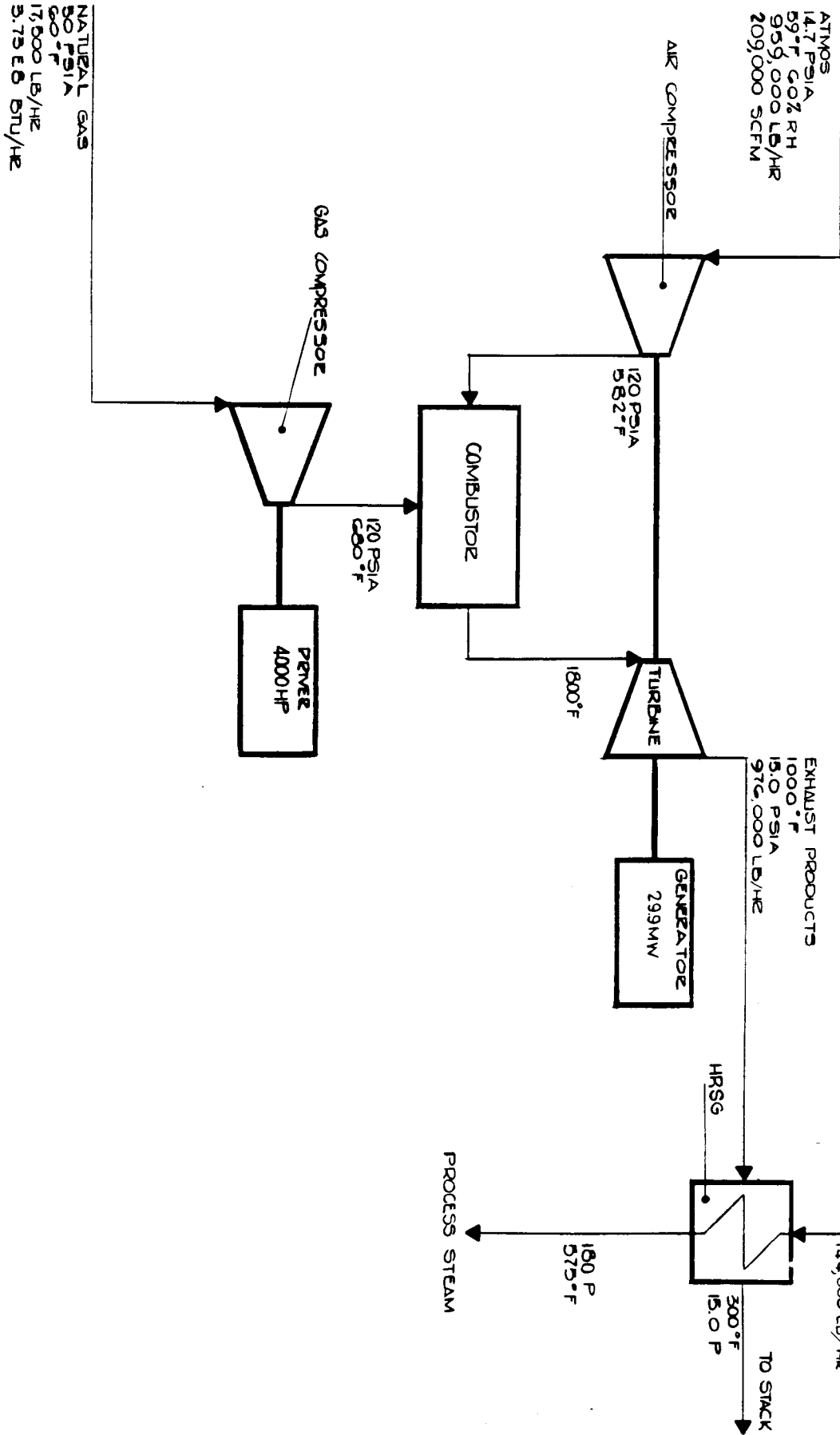
LISTING OF INPUT DATA FOR CASE 1

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3  * CONTROL ON FUEL FLOW TO PROVIDE 1800F TURBINE INLET TEMP
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6  011010 1,2,5,0,3600,32000.,.85,45.,45.
7  011011 200, 350.
8  * TABLE SUPPRESSION
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10 020002 NOPRNT
11 020004 NOPRNT
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20 020026 NOPRNT
21 020028 NOPRNT
22 020034 NOPRNT
23 020037 NOPRNT
24 020042 NOPRNT
25 * GEOMETRY INPUT
26 501020 320, U, 610, I
27 501040 610, U, 310, I
28 501060 610, B, 410, I
29 501080 410, U, 220, S
30 501100 220, D, 322, I
31 501120 322, U, 710, IA
32 502020 321, U, 411, I
33 502040 411, U, 710, IF
34 503020 710, U, 10, I
35 503040 10, U, 220, T
36 503050 220, T, 311, I
37 * TURBINE DATA
38 700100 9 1 2 1 6
39 700106 15.3 1000.
40 * REGENERATOR DATA
41 702200 20 935. .02 .02 .02
42 * SOURCE AND SINK DATA
43 703100 32
44 703110 30
45 703200 33 59. 14.7 2.E6
46 703203 AIR .6
47 703210 31 60. 30. 13200.
48 703213 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
49 703220 31 900. 115. 9.58562E5
50 703223 AIR
51 703222 5
52 * COMPRESSOR DATA
53 704100 44 1 120. 1. .8
54 704110 43 120. 1. 1. .8
55 * SPLITTER DATA
56 706100 61 0. 9.58562E5
57 * COMBUSTOR DATA
58 707100 70 0 2 0 0.
59 * CONTROL ON FUEL FLOW TO PRODUCE DESIRED GAS TEMP
60 840100 MWVSC 321 1800. 0. 1. TT 302
61 * OPERATIONAL VARIABLES
62 870010 21300.
63 870020 1000.
64 870030 3412.
65 * CALCULATE CYCLE HEAT RATE
66 880010 MW 202 MUL OPVB 1 OPVB 4
67 880020 BKGR0 1 MUL OPVB 2 OPVB 5
68 880030 OPVB 4 DIV OPVB 5 OPVB 6
69 * CALCULATE OVERALL CYCLE EFFICIENCY
70 880040 OPVB 5 MUL OPVB 3 OPVB 7
71 880050 OPVB 7 DIV OPVB 4 OPVB 8
72 * CALCULATE REGENERATOR EFFECTIVENESS
73 880060 TT 110 SUB TT 108 OPVB 9
74 880070 TT 304 SUB TT 108 OPVB 10
75 880080 OPVB 9 DIV OPVB 10 OPVB 11
76 * PRINT OUTPUT VARIABLES

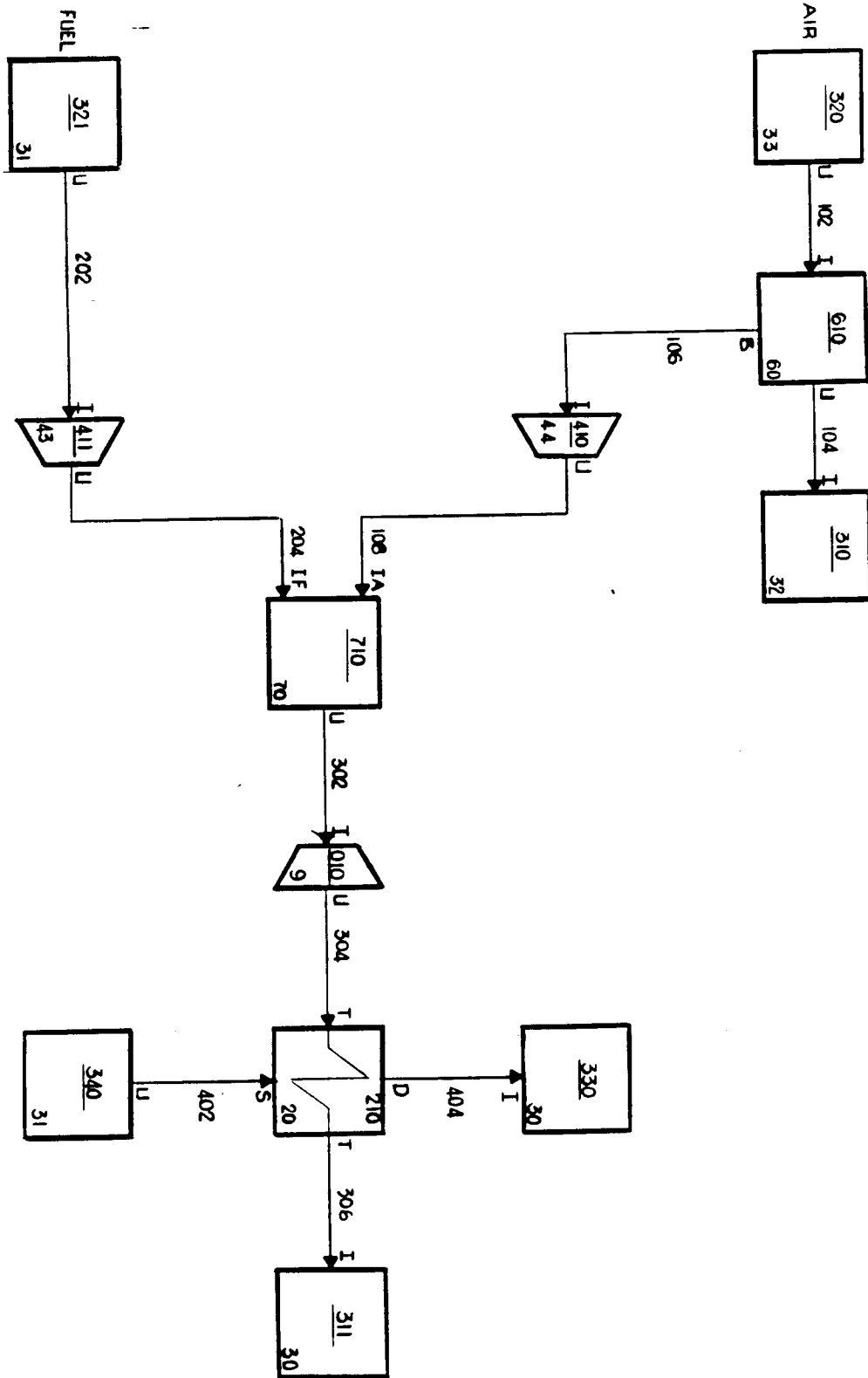
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79 890200 'REGENERATOR EFFECTIVENESS'
80 890201 OPVB 11
81 890300 'GROSS CYCLE HEAT RATE, BTU/KWH'
82 890301 OPVB 6
83 890400 'CYCLE THERMAL EFFICIENCY'
84 890401 OPVB 8
85 *
86 .



HEAT BALANCE
GAS TURBINE CYCLE W/HRSG

CONTACT SUPPLY ←



PEPSE SCHEMATIC
GAS TURBINE W/HRSG

LISTING OF INPUT DATA FOR CASE 1

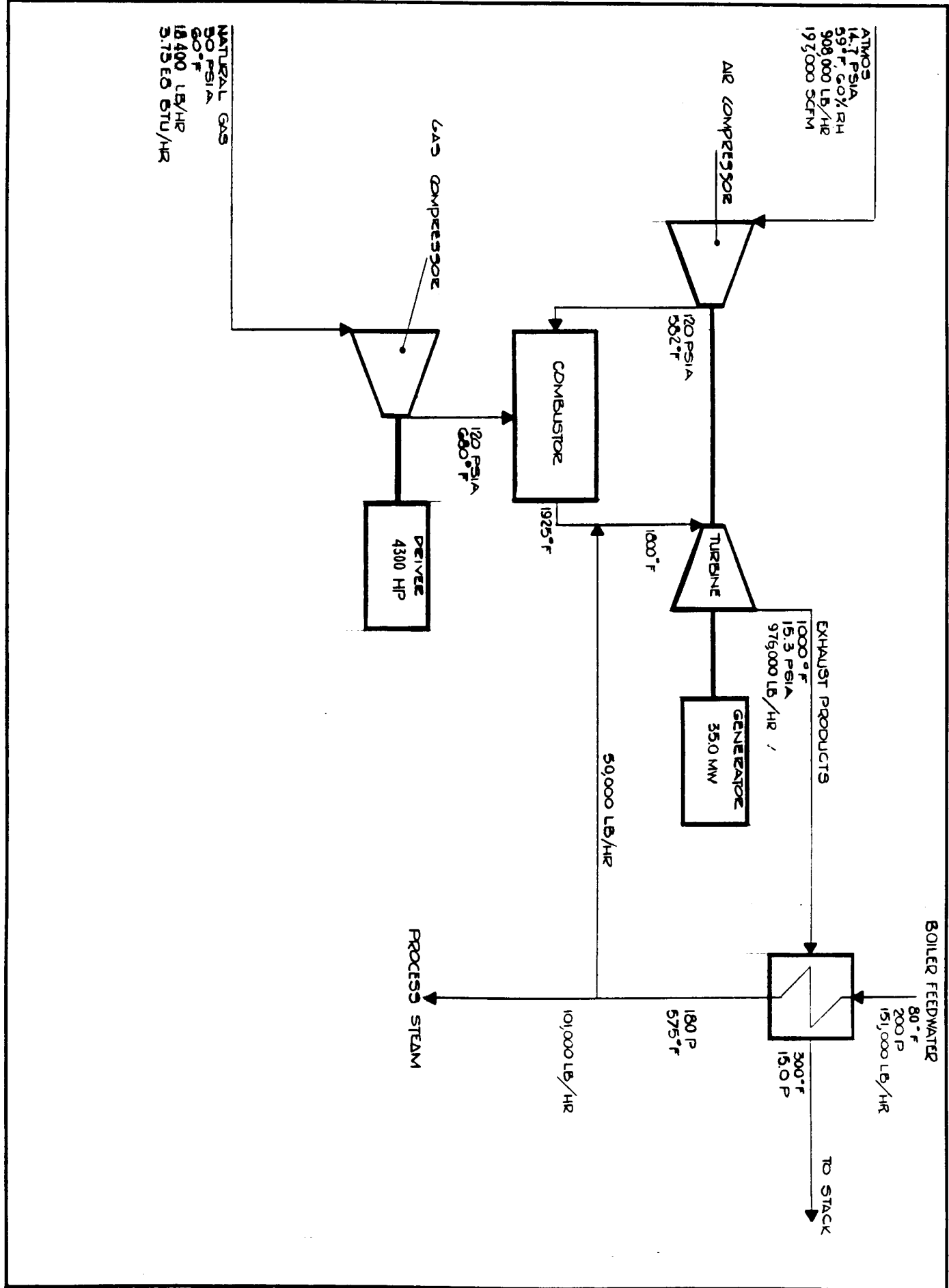
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1   SIMPLE CYCLE GAS TURBINE WITH HRSG (EXAMPLE NUMBER 3)
2   * HRSG IN PERFORMANCE MODE
3   * CONTROL ON EXCESS AIR TO PROVIDE 1800F TURBINE INLET TEMP
4   * CONTROL ON BFW FLOW TO PRODUCE 300F HRSG GAS EXIT TEMP
5   012000 25
6   010200 3,0,1,0,0
7   011010 1,2,5,0,3600,32000,..85,45,..45.
8   011011 200. 350.
9   * TABLE SUPPRESSION
10  020001 NOPRINT
11  020002 NOPRINT
12  020004 NOPRINT
13  020005 NOPRINT
14  020013 NOPRINT
15  020016 NOPRINT
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19  020023 NOPRINT
20  020025 NOPRINT
21  020026 NOPRINT
22  020028 NOPRINT
23  020034 NOPRINT
24  020037 NOPRINT
25  020042 NOPRINT
26  * GEOMETRY INPUT
27  501020 320, U, 610, I
28  501040 610, U, 310, I
29  501060 610, B, 410, I
30  501080 410, U, 710, IA
31  502020 321, U, 411, I
32  502040 411, U, 710, IF
33  503020 710, U, 10, I
34  503040 10, U, 210, T
35  503060 210, T, 311, I
36  504020 340, U, 210, S
37  504040 210, D, 330, I
38  * TURBINE DATA
39  700100 9 1 2 1 6
40  700106 15.3 1000.
41  * HRSG DATA
42  702100 20 575. 0. .1 .02
43  * SOURCE AND SINK DATA
44  703100 32
45  703110 30
46  703200 33 59. 14.7 2.E6
47  703203 AIR .6
48  703210 31 60. 30. 17500.
49  703213 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
50  703300 30
51  703400 31 80. 200. 150000.
52  * COMPRESSOR DATA
53  704100 44 1 120. 1. .8
54  704110 43 120. 1. 1. .8
55  * SPLITTER DATA
56  706100 61 0. 1.E6
57  * COMBUSTOR DATA
58  707100 70 0 2 0 0.
59  * CONTROL ON EXCESS AIR TO PRODUCE DESIRED GAS TEMP
60  840100 WNFIXB 610 1800. 0. 1. TT 302
61  840109 8.E5 1.3E6
62  * CONTROL ON BFW FLOW TO PRODUCE HRSG OUTLET TEMP
63  840200 WNWSC 340 300. 0. 1. TT 306
64  840209 1.E5 2.E5
65  * OPERATIONAL VARIABLES
66  870010 21300.
67  870020 1000.
68  870030 3412.
69  * CALCULATE CYCLE HEAT RATE
70  880010 MW 202 MUL OPVB 1 OPVB 4
71  880020 BKGRD 1 MUL OPVB 2 OPVB 5
72  880030 OPVB 4 DIV OPVB 5 OPVB 6
73  * CALCULATE OVERALL CYCLE EFFICIENCY
74  880040 BBSTRM 402 ADD OPVB 4 OPVB 7
75  880050 OPVB 5 MUL OPVB 3 OPVB 8
76  880060 BBSTRM 404 ADD OPVB 8 OPVB 9

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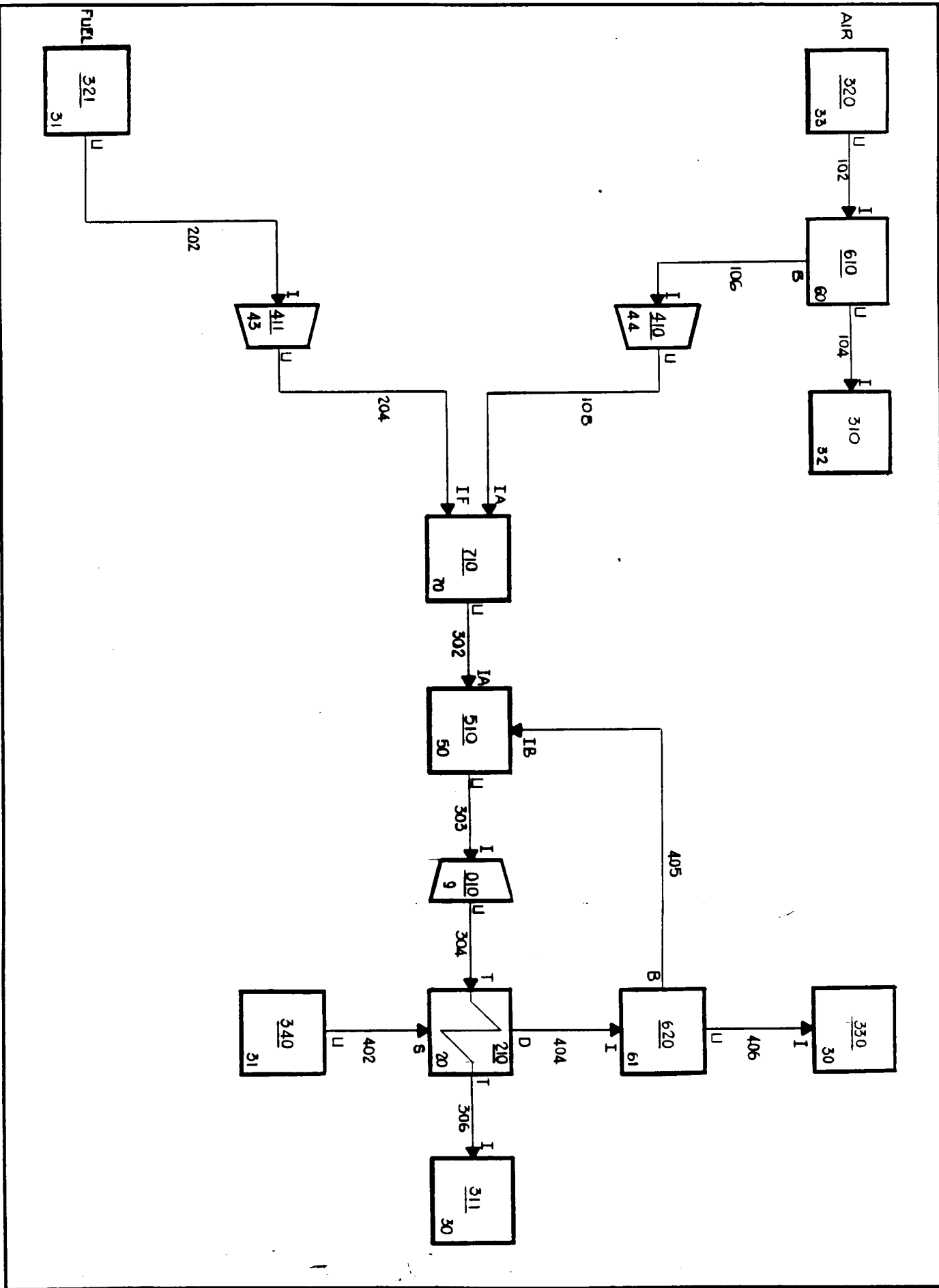
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81 890200 'GROSS CYCLE HEAT RATE, BTU/KWH'
82 890201 OPVB 6
83 890300 'CYCLE THERMAL EFFICIENCY'
84 890301 OPVB 10
85 *
86 .
```

ATMOS
 14.7 PSIA
 59°F, 60% RH
 908,000 LB/HR
 197,000 SCFM



HEAT BALANCE
 GAS TURBINE CYCLE W/HRSG & STEAM
 INJECTION

CONTACT SUPPLY ←



PEPSE SCHEMATIC
GAS TURBINE CYCLE - STEAM INJECTION

LISTING OF INPUT DATA FOR CASE 1

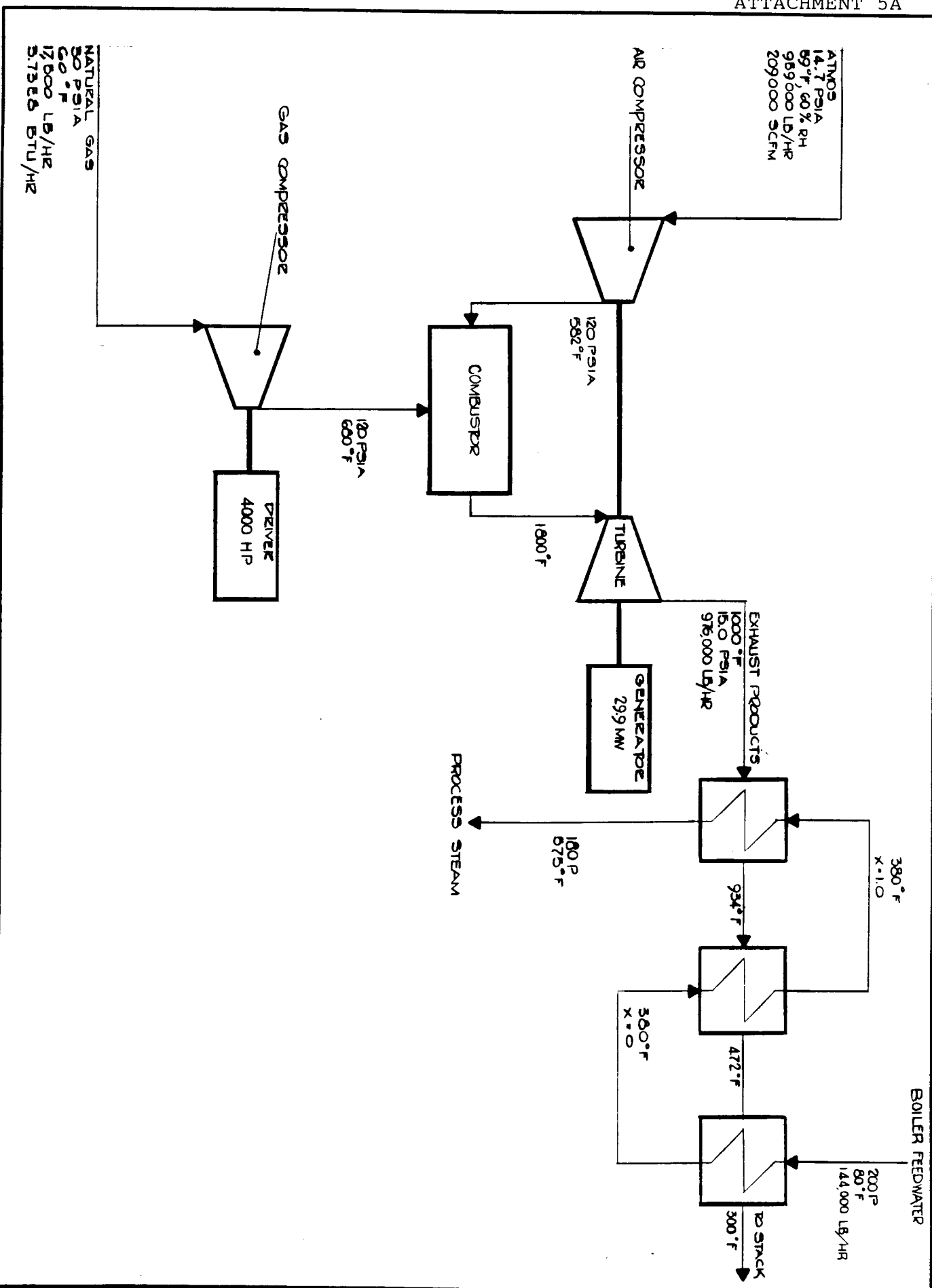
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1   SIMPLE CYCLE GAS TURBINE WITH HRSG AND STEAM INJECTION
2   * (EXAMPLE NUMBER 4)
3   * TOTAL MASS FLOW RATE THROUGH TURBINE EQUAL TO SIMPLE CYCLE
4   * CONTROL ON FUEL TO PROVIDE 1800F TURBINE INLET TEMP
5   * CONTROL ON BFW FLOW TO PRODUCE 300F HRSG GAS EXIT TEMP
6   012000 25
7   010200 3,0,1,0,0
8   011010 1,2,5,0,3600,32000,..85,45,.45.
9   011011 200. 350.
10  * TABLE SUPPRESSION
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12  020002 NOPRINT
13  020004 NOPRINT
14  020005 NOPRINT
15  020013 NOPRINT
16  020016 NOPRINT
17  020020 NOPRINT
18  020021 NOPRINT
19  020022 NOPRINT
20  020023 NOPRINT
21  020025 NOPRINT
22  020026 NOPRINT
23  020028 NOPRINT
24  020034 NOPRINT
25  020037 NOPRINT
26  020042 NOPRINT
27  * GEOMETRY INPUT
28  501020 320, U, 610, I
29  501040 610, U, 310, I
30  501060 610, B, 410, I
31  501080 410, U, 710, IA
32  502020 321, U, 411, I
33  502040 411, U, 710, IF
34  503020 710, U, 510, IA
35  503030 510, U, 10, I
36  503040 10, U, 210, T
37  503060 210, T, 311, I
38  504020 340, U, 210, S
39  504040 210, D, 620, I
40  504050 620, B, 510, IB
41  504060 620, U, 330, I
42  * TURBINE DATA
43  700100 9 1 2 1 6
44  700106 15.3 1000.
45  * HRSG DATA
46  702100 20 575. 0. .1 .02
47  * SOURCE AND SINK DATA
48  703100 32
49  703110 30
50  703200 33 59. 14.7 2.E6
51  703203 AIR .6
52  703210 31 60. 30. 17500.
53  703213 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
54  703300 30
55  703400 31 80. 200. 150000.
56  * COMPRESSOR DATA
57  704100 44 1 120. 1. .8
58  704110 43 120. 1. 1. .8
59  * MIXER DATA
60  705100 50 1
61  * SPLITTER DATA
62  706100 61 0. .9077E6
63  706200 61 0. 5.E4
64  * COMBUSTOR DATA
65  707100 70 0 2 0 0.
66  * CONTROL ON FUEL TO PRODUCE DESIRED GAS TEMP
67  840100 WWVSC 321 1800. 0. 1. TT 303
68  * CONTROL ON BFW FLOW TO PRODUCE HRSG OUTLET TEMP
69  840200 WWVSC 340 300. 0. 1. TT 306
70  840209 1.E5 3.E5
71  * OPERATIONAL VARIABLES
72  870010 21300.
73  870020 1000.
74  870030 3412.
75  * CALCULATE CYCLE HEAT RATE
76  880010 WW 202 MUL OPVB 1 OPVB 4

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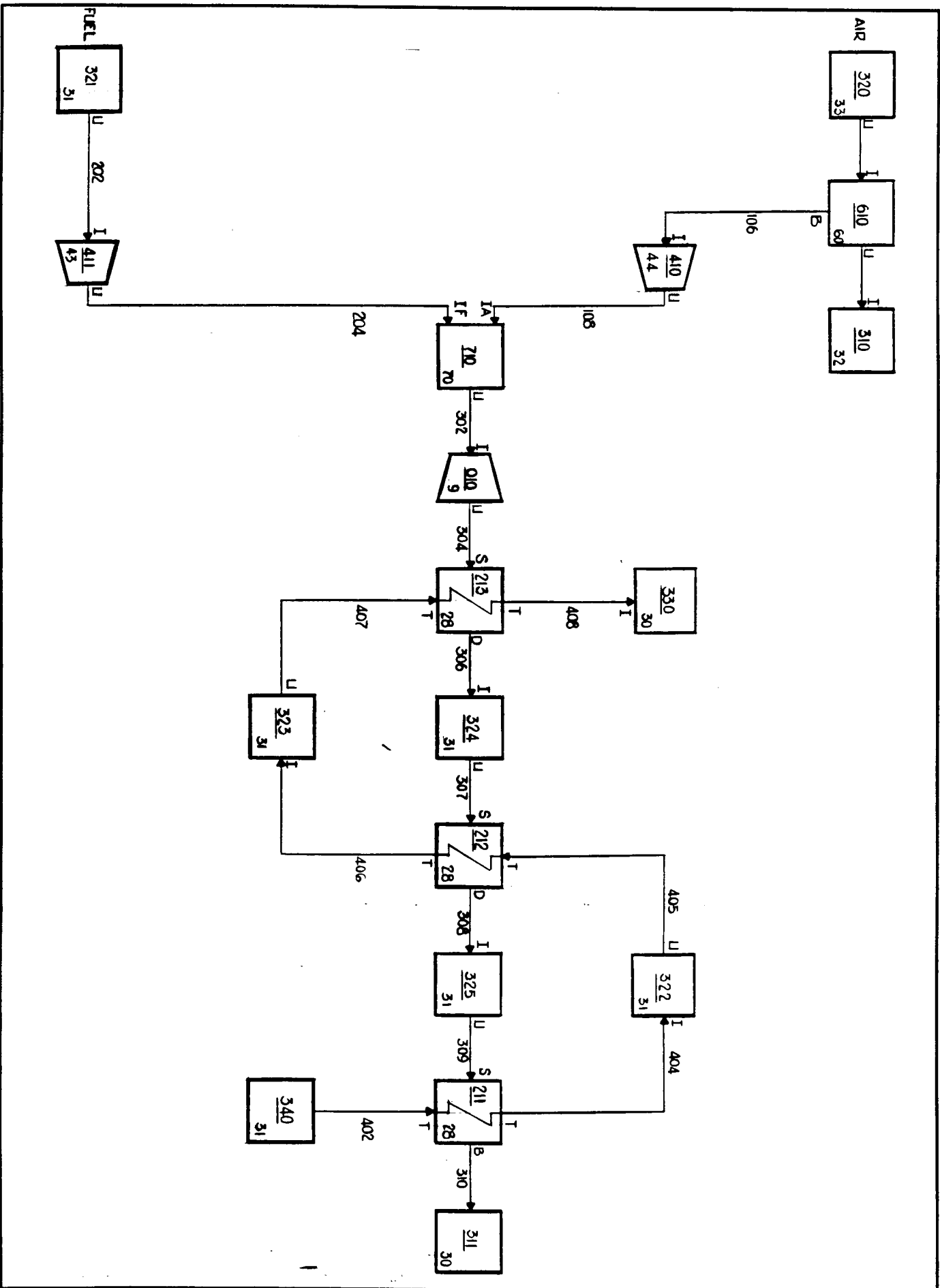
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77 880020 BKGRD 1 MUL OPVB 2 OPVB 5
78 880030 OPVB 4 DIV OPVB 5 OPVB 6
79 * CALCULATE OVERALL CYCLE EFFICIENCY
80 880040 BBSTRM 402 ADD OPVB 4 OPVB 7
81 880050 OPVB 5 MUL OPVB 3 OPVB 8
82 880060 OPVB 8 ADD BBSTRM 406 OPVB 9
83 880070 OPVB 9 DIV OPVB 7 OPVB 10
84 * PRINT OUTPUT VARIABLES
85 890100 'GENERATOR ELECTRICAL OUTPUT, MW'
86 890101 BKGRD 1
87 890200 'GROSS CYCLE HEAT RATE, BTU/KWH'
88 890201 OPVB 6
89 890300 'CYCLE THERMAL EFFICIENCY'
90 890301 OPVB 10
91 *
92 .
```

CONTACT SUPPLY ←



HEAT BALANCE
 GAS TURBINE CYCLE W/HRSG IN DESIGN
 MODE

CONTACT SUPPLY



PEPSE SCHEMATIC
GAS TURBINE W/ HRSG
DESIGN MODE

LISTING OF INPUT DATA FOR CASE 1

```

1  SIMPLE CYCLE GAS TURBINE WITH HRSG (EXAMPLE NUMBER 5)
2  * CONTROL ON EXCESS AIR TO PROVIDE 1800F TURBINE INLET TEMP
3  * HRSG IN DESIGN MODE (3 ZONE)
4  * ADDITIONAL DOUBLE ENDED SOURCES ADDED TO HELP CONVERGENCE
5  * CONTROLS ON HRSG SURFACE AREAS TO PRODUCE DESIRED GAS TEMPS
6  012000 25
7  010200 3,0,1,0,0
8  011010 1,2,5,0,3600,32000,..85,45,..45.
9  011011 200, 350.
10 * TABLE SUPPRESSION
11 020001 NOPRNT
12 020002 NOPRNT
13 020004 NOPRNT
14 020005 NOPRNT
15 020013 NOPRNT
16 020016 NOPRNT
17 020020 NOPRNT
18 020021 NOPRNT
19 020022 NOPRNT
20 020023 NOPRNT
21 020025 NOPRNT
22 020026 NOPRNT
23 020028 NOPRNT
24 020034 NOPRNT
25 020037 NOPRNT
26 020042 NOPRNT
27 * GEOMETRY INPUT
28 501020 320, U, 610, I
29 501040 610, U, 310, I
30 501060 610, B, 410, I
31 501080 410, U, 710, IA
32 502020 321, U, 411, I
33 502040 411, U, 710, IF
34 503020 710, U, 10, I
35 503040 10, U, 213, S
36 503060 213, D, 324, I
37 503070 324, U, 212, S
38 503080 212, D, 325, I
39 503090 325, U, 211, S
40 503100 211, D, 311, I
41 504020 340, U, 211, T
42 504040 211, T, 322, I
43 504050 322, U, 212, T
44 504060 212, T, 323, I
45 504070 323, U, 213, T
46 504080 213, T, 330, I
47 * TURBINE DATA
48 700100 9 1 2 1 6
49 700106 15, 1000.
50 * HRSG DATA
51 * ECONOMIZER
52 702110 28 1 150000. 200. 230.
53 702114 2 0 3 15. 6. 12. 4. 25. 4. 1.9
54 702115 2. 12. 2.5 0. 0. .9 25. 0. 0. 0.
55 702116 0. 30000.
56 * EVAPORATOR
57 702120 28 1 150000. 190. 350.
58 702124 2 0 3 15. 6. 12. 10. 25. 1. 1.9
59 702125 2. 12. 2.5 0. 0. .9 25. 0. 0. 0.
60 702126 0. 12000.
61 * SUPERHEATER
62 702130 28 1 150000. 180. 375.
63 702134 2 1 3 15. 6. 12. 4. 25. 4. 1.9
64 702135 2. 12. 2.5 0. 0. .9 25. 0. 0. 0.
65 702136 0. 1100.
66 * SOURCE AND SINK DATA
67 703100 32
68 703110 30
69 703200 33 59. 14.7 2.E6
70 703203 AIR .6
71 703210 31 60. 30. 17500.
72 703213 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
73 703220 31 0. 199. 144265.
74 703222 5
75 703230 31 1. 198. 144265.
76 703232 5

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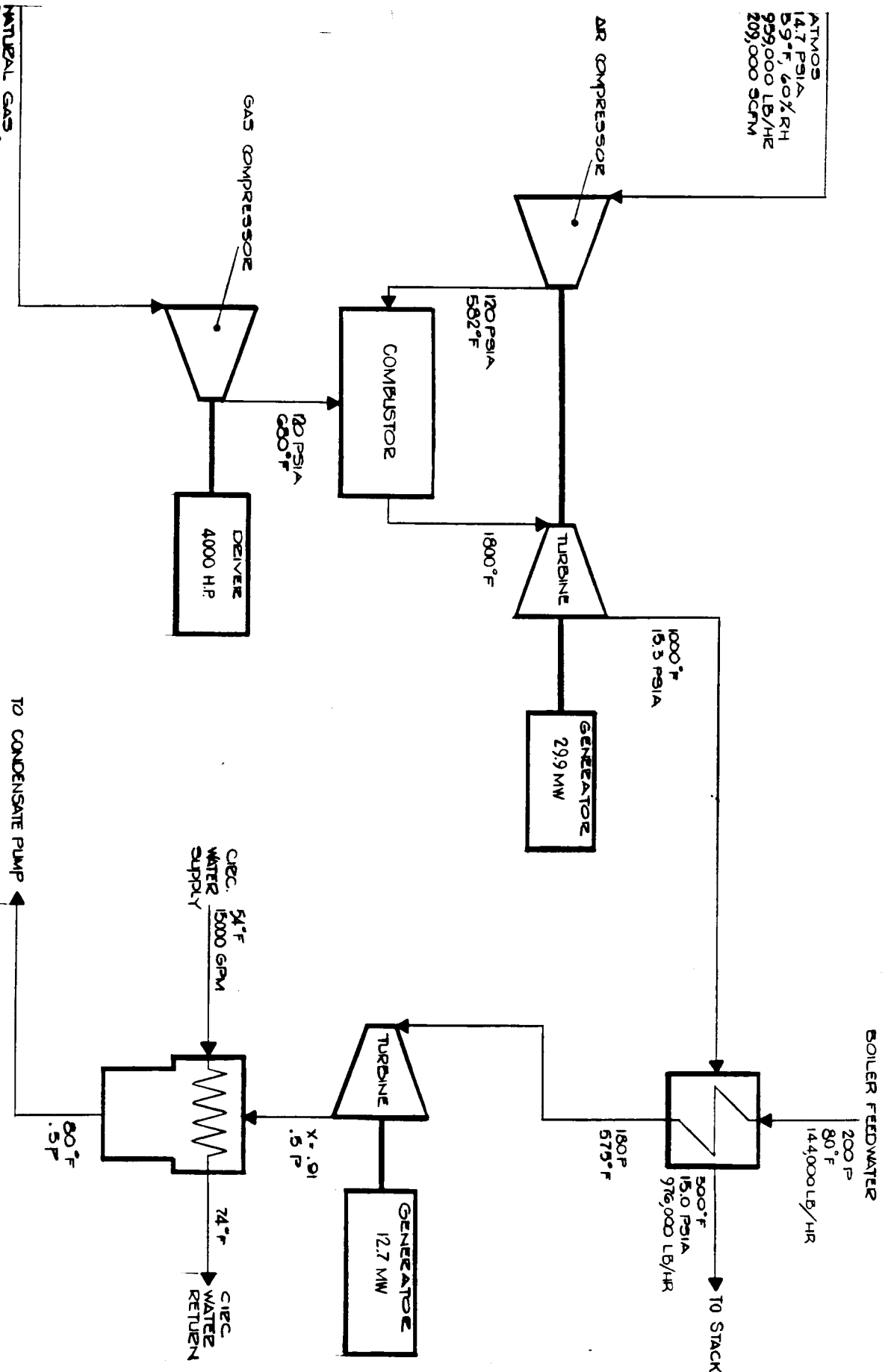
77 703240 31 934. 15. 976062.
78 703242 5
79 703243 CO2 .04953 H2O .04371 O2 .15660 N2 .75016
80 703250 31 472. 15. 976062.
81 703252 5
82 703253 CO2 .04953 H2O .04371 O2 .15660 N2 .75016
83 703300 30
84 703400 31 80. 200. 144265.
85 * COMPRESSOR DATA
86 704100 44 1 120. 1. .8
87 704110 43 120. 1. 1. .8
88 * SPLITTER DATA
89 706100 61 0. 1.E6
90 * COMBUSTOR DATA
91 707100 70 0 2 0 0.
92 * CONTROL ON EXCESS AIR TO PRODUCE DESIRED GAS TEMP
93 840100 MMFIXB 610 1800. 0. 1. TT 302
94 * CONTROL ON SUPERHEATER AREA
95 840200 AATIRH 213 934. .005 1. TT 306
96 840209 500. 1500.
97 * CONTROL ON EVAPORATOR AREA
98 840300 AATIRH 212 472. .01 1. TT 308
99 840309 12000. 13000.
100 * CONTROL ON ECONOMIZER AREA
101 840400 AATIRH 211 300. .01 1. TT 310
102 840409 28000. 32000.
103 * OPERATIONAL VARIABLES
104 870010 21300.
105 870020 1000.
106 870030 3412.
107 * CALCULATE CYCLE HEAT RATE
108 880010 MW 202 MUL OPVB 1 OPVB 4
109 880020 BKGRD 1 MUL OPVB 2 OPVB 5
110 880030 OPVB 4 DIV OPVB 5 OPVB 6
111 * CALCULATE OVERALL CYCLE EFFICIENCY
112 880040 BBSTRM 408 SUB BBSTRM 402 OPVB 7
113 880050 OPVB 5 MUL OPVB 3 OPVB 8
114 880060 OPVB 7 ADD OPVB 8 OPVB 9
115 880070 OPVB 9 DIV OPVB 4 OPVB 10
116 * CALCULATE HRSG LMTD VALUES
117 880100 HTTURH 211 MUL AATIRH 211 OPVB 11
118 880110 BBHXFL 211 DIV OPVB 11 OPVB 12
119 880120 HTTURH 212 MUL AATIRH 212 OPVB 13
120 880130 BBHXFL 212 DIV OPVB 13 OPVB 14
121 880140 HTTURH 213 MUL AATIRH 213 OPVB 15
122 880150 BBHXFL 213 DIV OPVB 15 OPVB 16
123 * PRINT OUTPUT VARIABLES
124 890100 'GENERATOR ELECTRICAL OUTPUT, MW'
125 890101 BKGRD 1
126 890200 'GROSS CYCLE HEAT RATE, BTU/KWH'
127 890201 OPVB 6
128 890300 'CYCLE THERMAL EFFICIENCY'
129 890301 OPVB 10
130 890400 'ECONOMIZER LMTD, F'
131 890401 OPVB 12
132 890500 'EVAPORATOR LMTD, F'
133 890501 OPVB 14
134 890600 'SUPERHEATER LMTD, F'
135 890601 OPVB 16
136 *
137 .

```

CONTACT SUPPLY

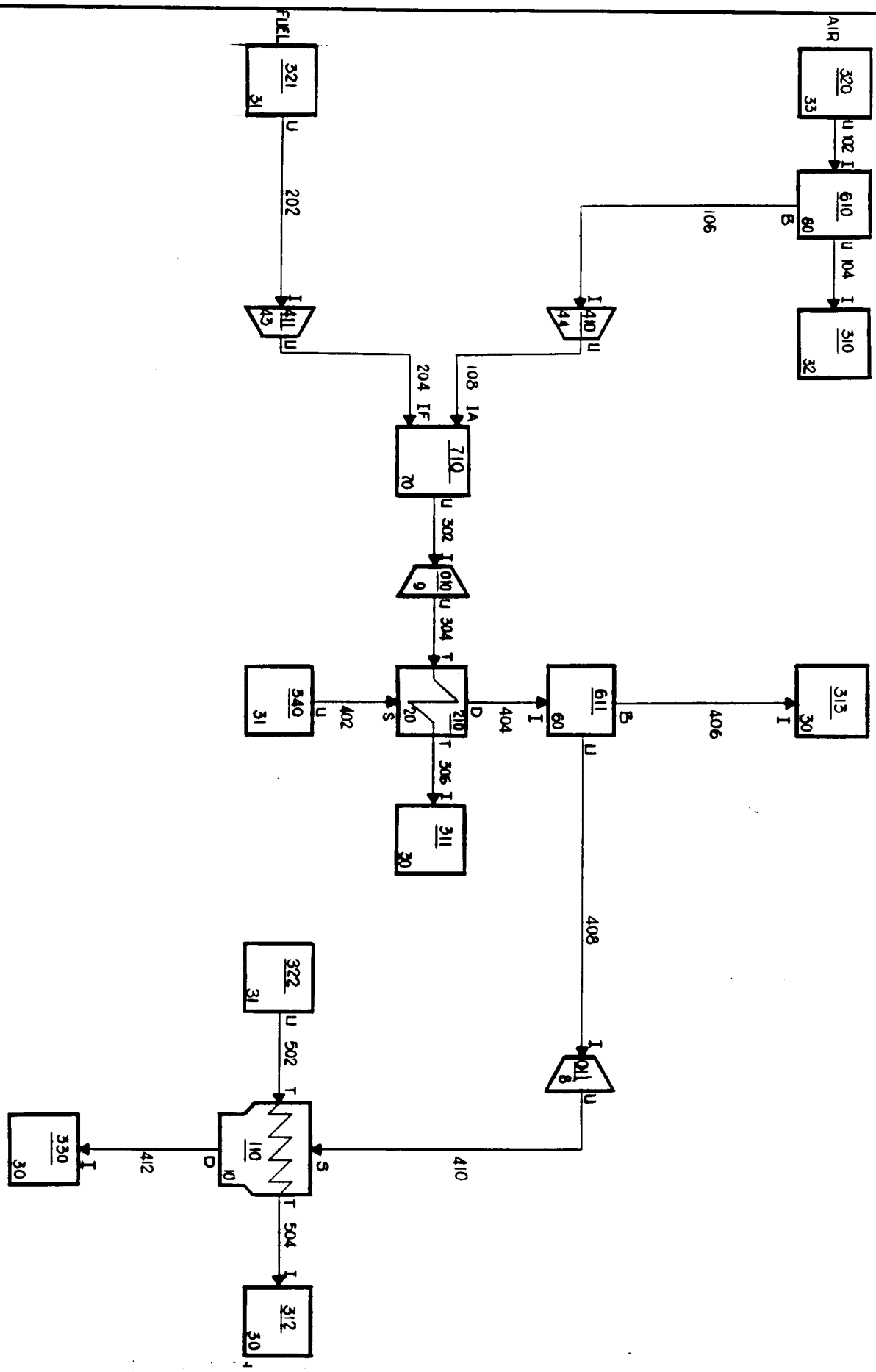
ATMOS
 14.7 PSIA
 59°F, 60% RH
 959,000 LB/HR
 209,000 SCFM

NATURAL GAS
 60 PSIA, 60°F
 17,500 LB/HR
 3.75 EB BTU/HR



HEAT BALANCE
 GAS TURBINE - COMBINED CYCLE

CONTACT SUPPLY ←



PEPSE SCHEMATIC
COMBINED CYCLE

LISTING OF INPUT DATA FOR CASE 1

```

1   COMBINED CYCLE (GAS TURBINE WITH HRSG AND STEAM TURBINE)
2   * (EXAMPLE NUMBER 6)
3   * GAS TURBINE IS SIMPLE CYCLE (NO REGENERATOR)
4   * CONTROL ON EXCESS AIR TO PROVIDE 1800F TURBINE INLET TEMP
5   * CONTROL ON BFW FLOW TO PRODUCE 300F HRSG GAS EXIT TEMP
6   012000 25
7   010200 2,3,2,1,0
8   011010 1,2,5,0,3600,32000,..85,45,..45.
9   011011 200. 350.
10  011020 2,2,5,0,3600,25000,..85,45,..45.
11  011021 100. 200.
12  * TABLE SUPPRESSION
13  020001 NOPRNT
14  020002 NOPRNT
15  020004 NOPRNT
16  020005 NOPRNT
17  020013 NOPRNT
18  020016 NOPRNT
19  020020 NOPRNT
20  020021 NOPRNT
21  020022 NOPRNT
22  020023 NOPRNT
23  020025 NOPRNT
24  020026 NOPRNT
25  020028 NOPRNT
26  020034 NOPRNT
27  020037 NOPRNT
28  020042 NOPRNT
29  * GEOMETRY INPUT
30  501020 320, U, 610, I
31  501040 610, U, 310, I
32  501060 610, B, 410, I
33  501080 410, U, 510, IA
34  502020 321, U, 411, I
35  502040 411, U, 510, IF
36  503020 510, U, 10, I
37  503040 10, U, 210, T
38  503060 210, T, 311, I
39  504020 340, U, 210, S
40  504040 210, D, 611, I
41  504060 611, B, 313, I
42  504080 611, U, 11, I
43  504100 11, U, 110, S
44  504120 110, D, 330, I
45  505020 322, U, 110, T
46  505040 110, T, 312, I
47  * GAS TURBINE DATA
48  700100 9 1 2 1 6
49  700106 15.3 1000.
50  * STEAM TURBINE DATA
51  700110 8 2 2 0 5 0 1 1 0.
52  700111 .75 .5
53  * CONDENSER DATA
54  701100 10 0 2 0. .5
55  * HRSG DATA
56  702100 20 575. 0. .1 .02
57  * SOURCE AND SINK DATA
58  703100 32
59  703110 30
60  703120 30
61  703130 30
62  703200 33 59. 14.7 2.E6
63  703203 AIR .6
64  703210 31 60. 30. 17500.
65  703213 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
66  703220 31 54. 30. 7.5E6
67  703300 30
68  703400 31 80. 200. 150000.
69  * COMPRESSOR DATA
70  704100 44 1 120. 1. .8
71  704110 43 120. 1. 1. .8
72  * COMBUSTOR DATA
73  705100 70 0 2 0 0.
74  * SPLITTER DATA
75  706100 61 0. 1.E6
76  706110 61 0. 0.

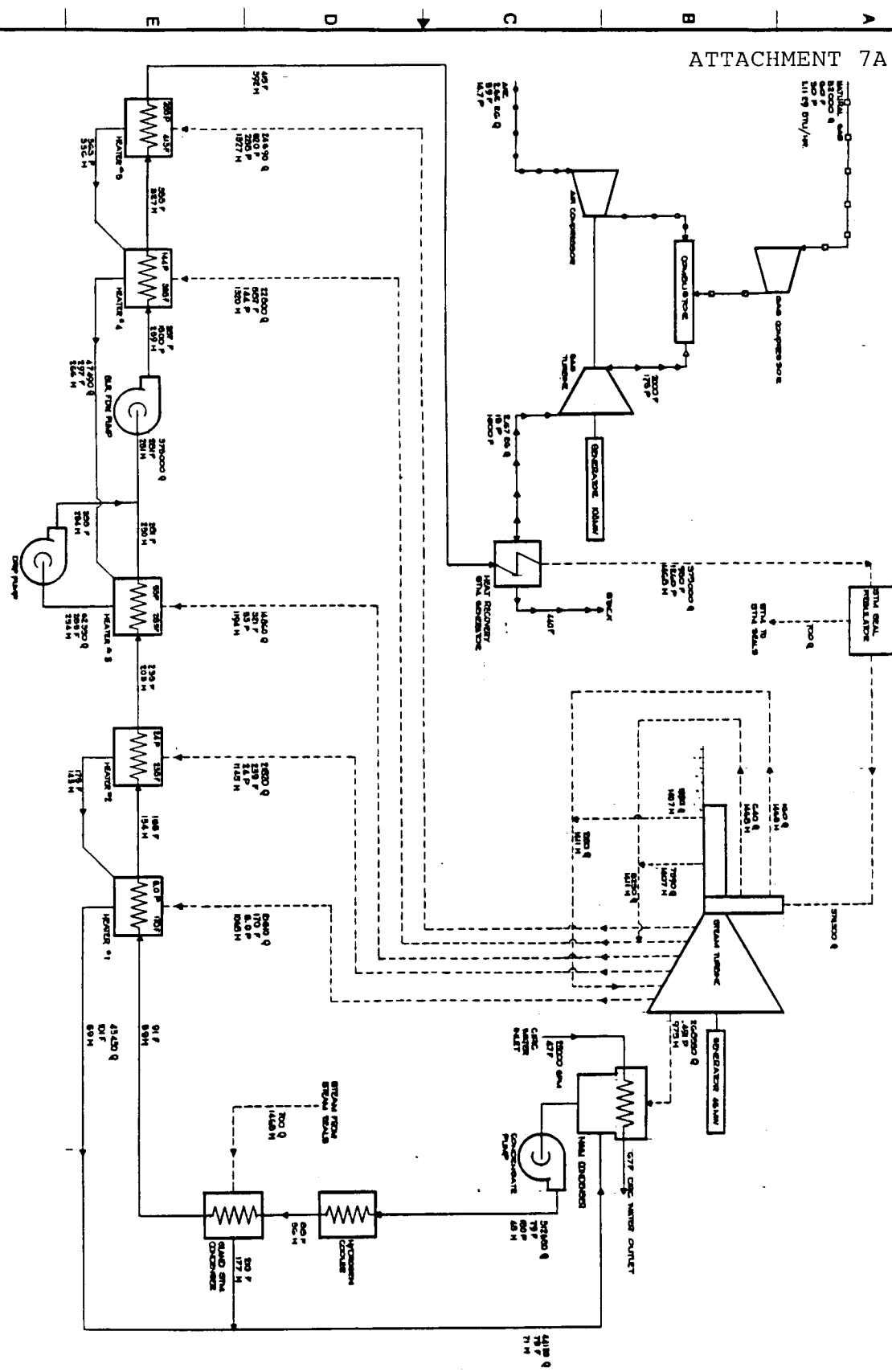
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77 * CONTROL ON EXCESS AIR TO PRODUCE DESIRED GAS TEMP
78 840100 MWFIXB 610 1800. 0. 1. TT 302
79 * CONTROL ON BFW FLOW TO PRODUCE HRSG OUTLET TEMP
80 840200 MWVSC 340 300. 0. 1. TT 306
81 840209 5.E4 2.E5
82 * OPERATIONAL VARIABLES
83 870010 21300.
84 870020 1000.
85 870030 3412.
86 * CALCULATE CYCLE HEAT RATE
87 880010 MW 202 MUL OPVB 1 OPVB 4
88 880020 BKGRD 1 ADD BKGRD 2 OPVB 5
89 880030 OPVB 5 MUL OPVB 2 OPVB 6
90 880040 OPVB 4 DIV OPVB 6 OPVB 7
91 * CALCULATE CYCLE EFFICIENCY
92 880050 BBSTRM 402 ADD OPVB 4 OPVB 8
93 880060 OPVB 6 MUL OPVB 3 OPVB 9
94 880070 BBSTRM 406 ADD OPVB 9 OPVB 10
95 880080 OPVB 10 DIV OPVB 8 OPVB 11
96 * PRINT OUTPUT VARIABLES
97 890100 'GAS TURBINE GENERATOR OUTPUT, MW'
98 890101 BKGRD 1
99 890200 'STEAM TURBINE GENERATOR OUTPUT, MW'
100 890201 BKGRD 2
101 890300 'TOTAL ELECTRICAL OUTPUT, MW'
102 890301 OPVB 5
103 890400 'GROSS CYCLE HEAT RATE, BTU/KWH'
104 890401 OPVB 7
105 890500 'CYCLE THERMAL EFFICIENCY'
106 890501 OPVB 11
107 *
108 .

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ATTACHMENT 7A



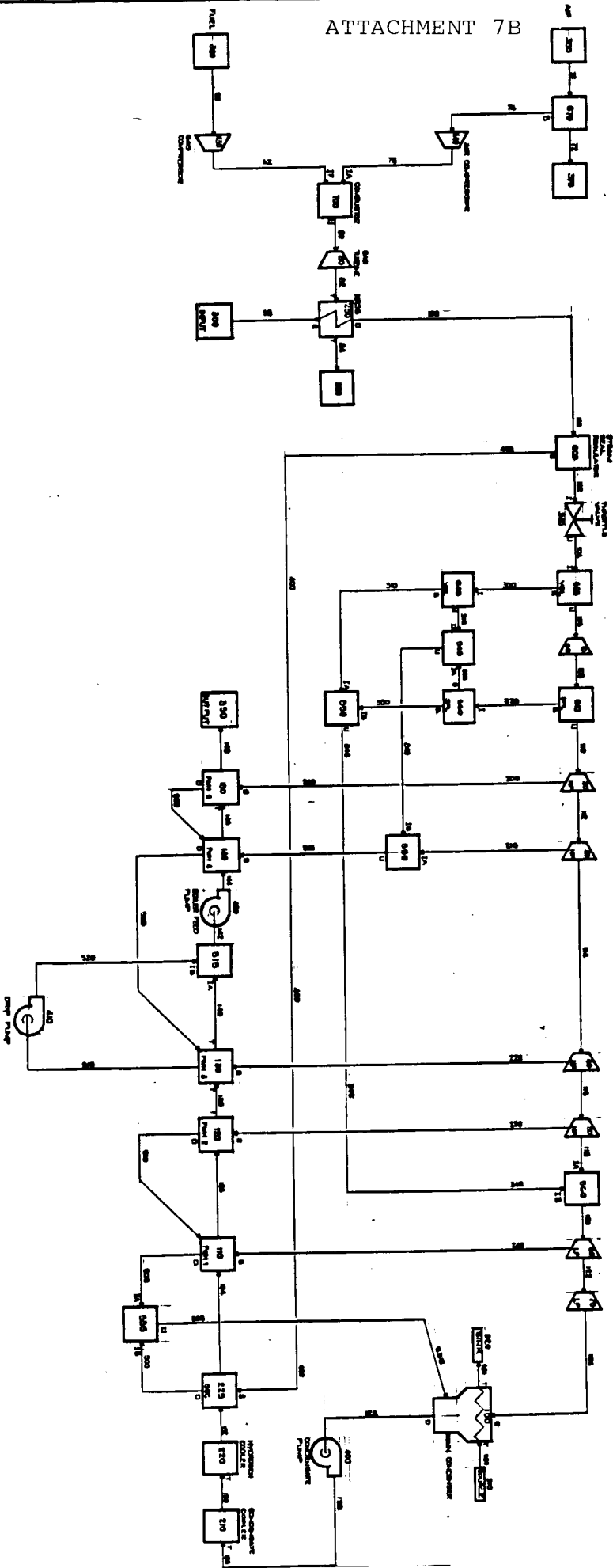
REVIS DATE HEAT BALANCE - 10/30/01

- LEGEND:
- Flow Rate, Lbs/hr
 - Temperature, °F
 - Pressure, PSIA
 - Flow, direction
 - Water
 - Gas
 - Exhaust
 - Caustic
 - Products

DATE	SYMBOL	REVISION	DESCRIPTION
10/30/01	1	1	INITIAL DESIGN
10/30/01	2	2	REVISIONS
10/30/01	3	3	REVISIONS
10/30/01	4	4	REVISIONS
10/30/01	5	5	REVISIONS
10/30/01	6	6	REVISIONS
10/30/01	7	7	REVISIONS
10/30/01	8	8	REVISIONS
10/30/01	9	9	REVISIONS
10/30/01	10	10	REVISIONS

CONVENED CYCLE - HEAT BALANCE

ATTACHMENT 7B



NO.	DESCRIPTION	DATE	BY	REVISION
1	CONDENSATE SYSTEM	10/15/78	J. H. [unclear]	1
2	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
3	WATER TREATMENT	10/15/78	J. H. [unclear]	1
4	CONDENSATE COOLER	10/15/78	J. H. [unclear]	1
5	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
6	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
7	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
8	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
9	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
10	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
11	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
12	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
13	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
14	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
15	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
16	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
17	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
18	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
19	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
20	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
21	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
22	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
23	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
24	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
25	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
26	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
27	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
28	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
29	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
30	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
31	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
32	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
33	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
34	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
35	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
36	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
37	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
38	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
39	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
40	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
41	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
42	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
43	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
44	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
45	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
46	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
47	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
48	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
49	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
50	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
51	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
52	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
53	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
54	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
55	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
56	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
57	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
58	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
59	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
60	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
61	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
62	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
63	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
64	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
65	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
66	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
67	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
68	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
69	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
70	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
71	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
72	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
73	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
74	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
75	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
76	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
77	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
78	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
79	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
80	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
81	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
82	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
83	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
84	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
85	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
86	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
87	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
88	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
89	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
90	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
91	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
92	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
93	STEAM GENERATOR	10/15/78	J. H. [unclear]	1
94	WATER TREATMENT TANK	10/15/78	J. H. [unclear]	1
95	WATER TREATMENT PUMP	10/15/78	J. H. [unclear]	1
96	CONDENSATE HEAT EXCHANGER	10/15/78	J. H. [unclear]	1
97	CONDENSATE TANK	10/15/78	J. H. [unclear]	1
98	CONDENSATE PUMP	10/15/78	J. H. [unclear]	1
99	STEAM GENERATOR PUMP	10/15/78	J. H. [unclear]	1
100	STEAM GENERATOR	10/15/78	J. H. [unclear]	1

LISTING OF INPUT DATA FOR CASE 1

```

1   RG&E RUSSELL STATION UNIT 1 COMBINED CYCLE PLANT
2   * MODEL INCLUDES THE FOLLOWING:
3   * GAS TURBINE WITH HRSG REPLACES BOILER
4   * SCHEDULE FOR HEAT INPUT FROM H2 COOLER
5   * SCHEDULE FOR GENERATOR LOSSES
6   * SCHEDULE FOR TURBINE EXHAUST LOSS USING ANNULUS VELOCITY AND GE-2007C
7   * SPECIFIED COEFFICIENT 'A' FOR EXTRACTION LINE PRESSURE DROP
8   * SPECIFIED LEAKAGE COEFFICIENTS SPLITTER FLOWS
9   * SPECIFIED TURBINE EFFICIENCY FACTORS
10  * CALCULATION FOR CYCLE HEAT RATE
11  * Convergence Criteria
12  012000 25 50. 50. 0. 0. 0. 0 1.E5
13  * Table Suppression
14  020001 NOPRNT
15  020002 NOPRNT
16  020004 NOPRNT
17  020005 NOPRNT
18  020006 NOPRNT
19  020007 NOPRNT
20  020009 NOPRNT
21  020010 NOPRNT
22  020011 NOPRNT
23  020012 NOPRNT
24  020013 NOPRNT
25  020014 NOPRNT
26  020015 NOPRNT
27  020016 NOPRNT
28  020017 NOPRNT
29  020018 NOPRNT
30  020020 NOPRNT
31  020021 NOPRNT
32  020022 NOPRNT
33  020023 NOPRNT
34  020024 NOPRNT
35  020025 NOPRNT
36  020026 NOPRNT
37  020028 NOPRNT
38  020031 NOPRNT
39  020032 NOPRNT
40  020033 NOPRNT
41  020034 NOPRNT
42  020035 NOPRNT
43  020036 NOPRNT
44  020037 NOPRNT
45  020038 NOPRNT
46  020040 NOPRNT
47  020042 NOPRNT
48  010200 2 3 2 1 0
49  010201 3
50  011010 1 2 5 0 3600 100000. .85 45. 45.
51  011011 600. 1100.
52  011020 2 2 1 0 3600 47058. .85 45. 45.
53  011021 300. 563.
54  * GEOMETRY
55  * GAS TURBINE STREAMS
56  500600 360, U, 430, I
57  500620 430, U, 700, IF
58  500700 350, U, 670, I
59  500720 670, U, 370, I
60  500740 670, B, 440, I
61  500760 440, U, 700, IA
62  500800 700, U, 80, I
63  500820 80, U, 250, T
64  500840 250, T, 380, I
65  * MAIN STEAM AND FEEDWATER STREAMS
66  500980 300, U, 250, S
67  501000 250, D, 600, I
68  501020 600, U, 340, I
69  501040 340, U, 605, I
70  501060 605, U, 10, I
71  501080 10, U, 610, I
72  501100 610, U, 20, I
73  501120 20, U, 30, I
74  501140 30, U, 40, I
75  501160 40, U, 50, I
76  501180 50, U, 560, IA

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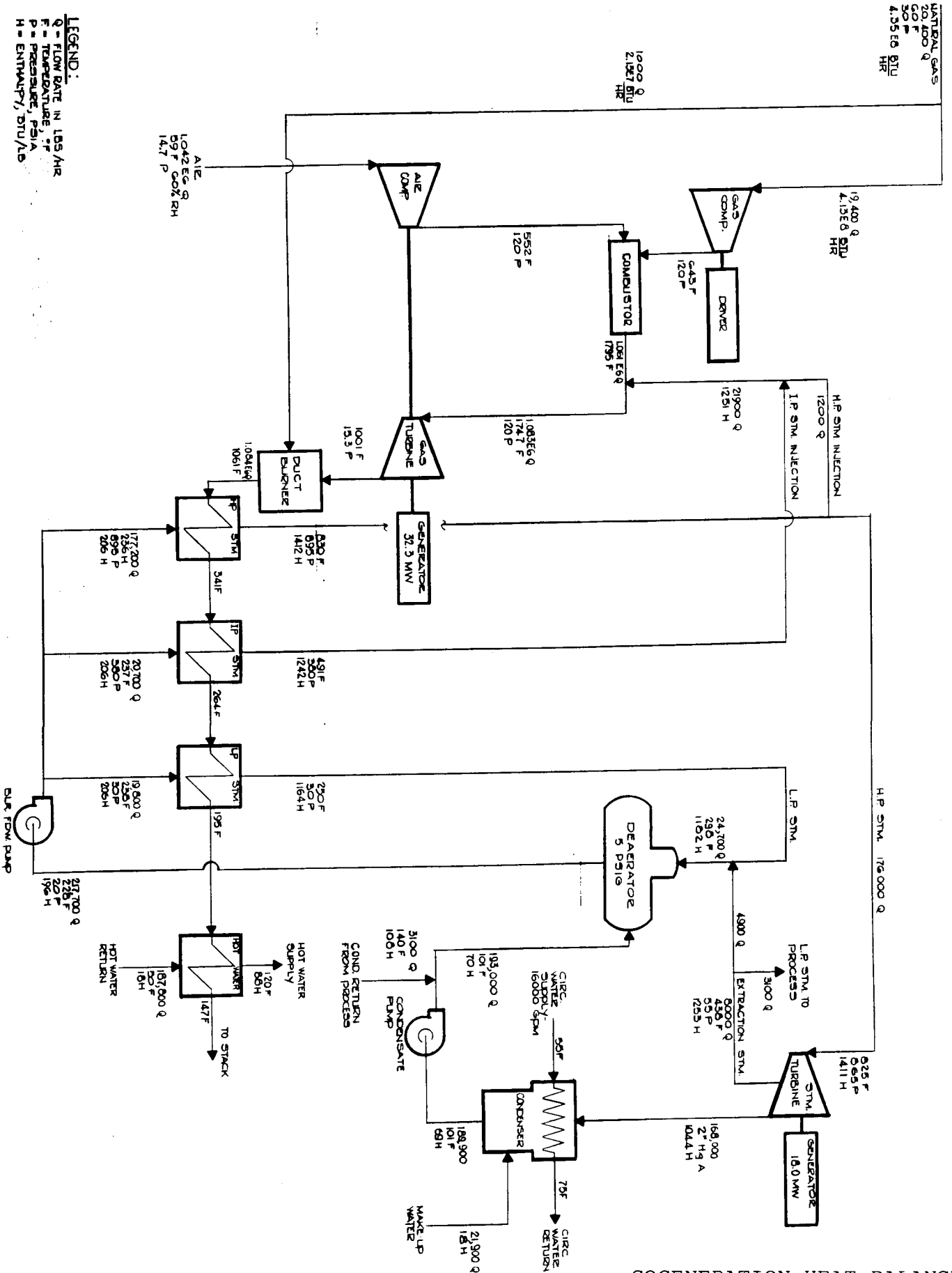
77 501200 560, U, 60, I
78 501220 60, U, 70, I
79 501240 70, U, 100, S
80 501260 100, D, 400, I
81 501280 400, U, 210, T
82 501300 210, T, 220, T
83 501320 220, T, 225, T
84 501340 225, T, 110, T
85 501360 110, T, 120, T
86 501380 120, T, 130, T
87 501400 130, T, 515, IA
88 501420 515, U, 420, I
89 501440 420, U, 140, T
90 501460 140, T, 150, T
91 501480 150, T, 330, I
92 * EXTRACTION STREAMS
93 502000 20, E, 150, S
94 502100 30, E, 555, IA
95 502150 555, U, 140, S
96 502200 40, E, 130, S
97 502300 50, E, 120, S
98 502400 60, E, 110, S
99 * PACKING LEAKOFF LINES
100 503000 605, B, 645, I
101 503050 645, U, 545, IB
102 503100 645, B, 550, IA
103 503200 610, B, 660, I
104 503250 660, U, 545, IA
105 503300 660, B, 550, IB
106 503400 545, U, 555, IB
107 503450 550, U, 560, IB
108 * OTHER SPLITTER LEAKOFFS
109 504000 600, B, 225, S
110 * DRAIN LINES
111 505000 225, D, 535, IB
112 505050 110, D, 535, IA
113 505100 120, D, 110, D
114 505150 130, D, 410, I
115 505200 410, U, 515, IB
116 505250 140, D, 130, D
117 505300 150, D, 140, D
118 505350 535, U, 100, D
119 * MISCELLANEOUS LINES
120 506200 310, U, 100, T
121 506300 100, T, 320, I
122 * GAS TURBINE DATA
123 700800 9 1 2 1 6
124 700806 15. 1000.
125 * STEAM TURBINE DATA
126 700100 4 2 2 1 2 0 0 0 38.01
127 700108 .982014
128 700200 7 2 0 1 1 1 0. 1000. 1431. 364600. 307. 24180.
129 700300 7 2 1 1 1 1 0. 307. 1336.5 340420. 154. 14520.
130 700400 7 2 1 1 1 1 0. 154. 1275. 325900. 56.5 15380.
131 700500 7 2 1 1 1 1 0. 56.5 1198.6 306020. 26.1 17430.
132 700600 7 2 1 1 1 2 0. 26.1 1150.1 290750. 6.45 22210.
133 700700 7 2 3 0 1 2 0. 6.45 1068. 268540. -1. 0. 20.67 0. 0. 0. 0. 0. 3 21.9
134 * FW HEATER DATA
135 701000 10 1 2 0. -1.
136 701100 16 1 60 2 0. 5. 10.
137 701200 16 0 50 2 0. 5. 10.
138 701300 17 1 40 2 0. 5.
139 701400 18 1 30 2 0. 2. 10.
140 701500 18 0 20 2 0. -1.5 10.
141 * HEAT EXCHANGER DATA
142 702100 27 0.
143 702200 27 3.04E6
144 702250 20 0. 0. 0. 0. 0. 0. 14.
145 702500 20 950. 0. .1
146 * COMPRESSOR AND PUMP DATA
147 704000 41 150. 1. 1. 1. 0. 0.
148 704100 41 150. 1. 1. 1. 0. 0.
149 704200 41 1500. 1. 1. 1. 0. 8.
150 704300 43 175. 1. 1. .8
151 704400 44 1 175. 1. .8
152 * SOURCE, SINK AND VALVE DATA
153 703000 33 175. 1400. 375000.
154 703100 31 47. 33. 1.25E7
155 703200 30
156 703300 32
157 703400 35 -2. -2. -2. .3 1265. 1468.12 376000.

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158 703500 31 59. 14.7 2.E7
159 703503 AIR
160 703600 31 60. 100. 52000.
161 703603 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
162 703700 30
163 703800 30
164 * MIXER DATA
165 705150 50 1
166 705350 51 1
167 705450 50 1
168 705500 50 1
169 705550 50 1
170 705600 51 1
171 * SPLITTER DATA
172 706000 61 0. 700.
173 706050 68 0. 17.6978
174 706100 64 362.351
175 706450 68 0. 31.0595
176 706600 64 369.474
177 706700 61 0. 2.62E6
178 * COMBUSTOR DATA
179 707000 70 0 2 0 0.
180 * STREAM DATA
181 602000 2 .0599
182 602100 2 .0597
183 602200 2 .0602
184 602300 2 .0613
185 602400 2 .0698
186 *602006 CLOSE
187 *602156 CLOSE
188 *602206 CLOSE
189 *602306 CLOSE
190 *602406 CLOSE
191 * CONTROL ON EXCESS AIR FOR GAS TURBINE INLET TEMP
192 *840100 MWFIXB 670 2000. 0. 1. TT 80
193 * CONTROL ON FUEL RATE FOR STEAM TEMPERATURE
194 *840200 MWVSC 360 950. 0. 1. TT 100
195 * DEFINE TURBINE EXHAUST LOSS
196 870310 0.
197 870320 150300.
198 870330 .87
199 870340 1.
200 870350 .65
201 880100 OPVB 31 PHG PP 124 OPVB 10
202 880110 PP 124 PHV OPVB 10 OPVB 11
203 880120 PP 124 PHX HHACP 70 OPVB 12
204 880130 MW 124 MUL OPVB 11 OPVB 13
205 880140 OPVB 13 MUL OPVB 12 OPVB 14
206 880150 OPVB 14 DIV OPVB 32 OPVB 15
207 800100 'EXHAUST LOSS VS. ANNULUS VEL'
208 810101 128. 150. 175. 200. 250. 300. 350. 400. 450. 500.
209 810111 0. 25.6 20.6 16.1 12.8 8.83 5.53 4.09 3.73 3.95 4.90
210 810102 550. 600. 650. 700. 800. 900. 1000. 1100. 1200. 1300.
211 810112 6.57 8.65 10.9 13.6 19.4 25.6 32.0 38.4 44.4 49.9
212 830100 1 OPVB 16 OPVB 15
213 880160 OPVB 34 SUB OPVB 12 OPVB 17
214 880170 OPVB 17 MUL OPVB 35 OPVB 18
215 880180 OPVB 34 SUB OPVB 18 OPVB 19
216 880190 OPVB 16 MUL OPVB 33 OPVB 20
217 880200 OPVB 20 MUL OPVB 12 OPVB 21
218 880210 OPVB 21 MUL OPVB 19 EXUSLS 70
219 * DEFINE GENERATOR LOSSES
220 800200 'GENERATOR LOSSES'
221 810201 10. 15. 20. 25. 30. 35. 40. 50.
222 810210 0. 323. 344. 374. 412. 457. 507. 564. 564.
223 830200 2 BKELEI 2 BKTURB 2
224 * DEFINE HYDROGEN COOLER HEAT INPUT
225 800300 'HYDROGEN COOLER HEAT'
226 810301 9.9 20.9 31.1 40.6 45.6
227 810310 0. 2.16E6 2.38E6 2.77E6 3.12E6 3.46E6
228 830300 3 BBHXGR 220 BKGRD 2
229 * CALCULATE GROSS CYCLE HEAT RATE
230 870010 21300.
231 870020 1000.
232 870030 3412.
233 880010 MW 60 MUL OPVB 1 OPVB 4
234 880020 BKGRD 1 ADD BKGRD 2 OPVB 5
235 880030 OPVB 5 MUL OPVB 2 OPVB 6
236 880040 OPVB 4 DIV OPVB 6 OPVB 7
237 890010 'GROSS CYCLE HEAT RATE, BTU/KWH'
238 890011 OPVB 7

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239 890020 'GROSS GENERATION, MW'
240 890021 OPVB 5
241 *
242 .



LEGEND:
 Q - FLOW RATE IN LBS AHR
 T - TEMPERATURE, °F
 P - PRESSURE, PSIA
 H - ENTHALPY, BTU/LB

COGENERATION HEAT BALANCE

LISTING OF INPUT DATA FOR CASE 1

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1 COGENERATION HEAT BALANCE
2 * COMBINED CYCLE MODEL
3 * AIR AND FUEL RATES EQUAL HEAT BALANCE RATES FROM VENDOR
4 * COMBUSTOR INCLUDED IN MODEL FOR DUCT BURNER
5 * SPECIFIED EXTRACTION RATE TO DEAERATOR
6 012000 25
7 010200 2,3,2,1,0
8 011010 1,2,5,0,3600,40000.,.85,45.,45.
9 011011 200. 600.
10 011020 2,2,5,0,3600,20000.,.85,45.,45.
11 011021 100. 300.
12 * TABLE SUPPRESSION
13 020001 NOPRINT
14 020002 NOPRINT
15 020004 NOPRINT
16 020005 NOPRINT
17 020013 NOPRINT
18 020015 NOPRINT
19 020016 NOPRINT
20 020020 NOPRINT
21 020021 NOPRINT
22 020022 NOPRINT
23 020023 NOPRINT
24 020025 NOPRINT
25 020026 NOPRINT
26 020028 NOPRINT
27 020034 NOPRINT
28 020037 NOPRINT
29 020042 NOPRINT
30 * GEOMETRY INPUT
31 501000 311, U, 430, I
32 501020 430, U, 710, IF
33 502000 312, U, 440, I
34 502020 440, U, 710, IA
35 503000 710, U, 510, IA
36 503050 510, U, 10, I
37 503100 10, U, 720, IA
38 503110 316, U, 720, IF
39 503120 720, U, 210, T
40 503150 210, T, 220, T
41 503200 220, T, 230, T
42 503250 230, T, 240, T
43 503300 240, T, 310, I
44 504000 120, D, 410, I
45 504020 410, U, 540, IA
46 504040 540, U, 110, FW
47 504060 110, D, 420, I
48 504080 420, U, 620, I
49 504100 620, B, 230, S
50 504120 620, U, 630, I
51 504140 630, B, 220, S
52 504160 630, U, 210, S
53 504180 210, D, 610, I
54 504200 220, D, 520, IA
55 504220 230, D, 530, IA
56 504240 520, U, 510, IB
57 504260 610, B, 520, IB
58 504300 610, U, 303, I
59 504310 315, U, 20, I
60 504320 20, E, 530, IB
61 504330 20, U, 640, I
62 504340 640, U, 21, I
63 504350 21, U, 120, S
64 504380 640, B, 250, T
65 504400 250, T, 540, IB
66 504420 530, U, 110, S
67 505020 313, U, 120, T
68 505040 120, T, 302, I
69 506020 331, U, 240, S
70 506040 240, D, 321, I
71 507000 314, U, 120, D
72 * GAS TURBINE DATA
73 700100 9 1 2 1 6
74 700106 15.3 1001.
75 * STEAM TURBINE DATA
76 700200 8 2 0 1 5 0 1 5 0. 4900.

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77 700205 55. 1253.
78 700210 8 2 3 0 5 0 1 1 0.
79 700211 .75 .982
80 * DEAERATOR DATA
81 701100 15 0 20 0. 0. 20. 0.
82 * CONDENSER DATA
83 701200 10 1 2 0. .982
84 * HRS6 DATA
85 * HP SECTION
86 702100 20 830.
87 * IP SECTION
88 702200 20 491.
89 * LP SECTION
90 702300 20 1.
91 * HOT WATER SECTION
92 702400 20 120.
93 * PROCESS STEAM CONSUMER
94 702500 27 -3.55E6
95 * SOURCE AND SINK DATA
96 703100 30
97 703020 30
98 703030 30
99 703120 31 59. 14.7 1.0417E6
100 703123 AIR .6
101 703110 31 60. 30. 19400.
102 703113 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
103 703130 31 55. 30. 8.E6
104 703140 31 50. 50. 21900.
105 703150 31 830. 895. 176000.
106 703160 31 60. 30. 1014.
107 703163 FUEL 21300. SSVL 44.5 C .754 H2 .234 N2 .012
108 703210 32
109 703310 33 50. 80. 187800.
110 * PUMP DATA
111 704100 41 65.
112 704200 41 1000. 0. 0. 0. 0. 10.
113 * COMPRESSOR DATA
114 704300 43 120. 1. 1. .85
115 704400 44 1 120. 1. .85
116 * COMBUSTOR DATA
117 707100 70 0 2 0 0.
118 707200 70 0 2 0 0.
119 * MIXER DATA
120 705100 50 1
121 705200 50 1
122 705300 50 2
123 705400 50 1
124 * SPLITTER DATA
125 706100 61 0. 1200.
126 706200 61 0. 19800.
127 706300 61 0. 20700.
128 706400 61 0. 3100.
129 * ACTIVE STREAMS
130 604100 5 30.
131 604140 5 380.
132 604160 5 895.
133 604310 5 865. 825.
134 * OPERATIONAL VARIABLES
135 870010 21300.
136 870020 1000.
137 870030 3412.
138 * CALCULATE CYCLE HEAT RATE
139 880010 MW 100 MUL OPVB 1 OPVB 4
140 880020 MW 311 MUL OPVB 1 OPVB 5
141 880030 OPVB 4 ADD OPVB 5 OPVB 6
142 880040 BKGRD 1 ADD BKGRD 2 OPVB 7
143 880050 OPVB 7 MUL OPVB 2 OPVB 8
144 880060 OPVB 6 DIV OPVB 8 OPVB 9
145 * CALCULATE CYCLE EFFICIENCY
146 880070 BBSTRM 604 SUB BBSTRM 602 OPVB 10
147 880080 BBSTRM 438 SUB BBSTRM 440 OPVB 11
148 880090 OPVB 10 ADD OPVB 11 OPVB 12
149 880100 OPVB 8 MUL OPVB 3 OPVB 13
150 880110 OPVB 12 ADD OPVB 13 OPVB 14
151 880120 OPVB 14 DIV OPVB 6 OPVB 15
152 * PRINT OUTPUT VARIABLES
153 890100 'GAS TURBINE GENERATOR OUTPUT, MW'
154 890101 BKGRD 1
155 890200 'STEAM TURBINE GENERATOR OUTPUT, MW'
156 890201 BKGRD 2
157 890300 'TOTAL ELECTRICAL OUTPUT, MW'

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158 890301 OPVB 7
159 890400 'GROSS CYCLE HEAT RATE, BTU/KWH'
160 890401 OPVB 9
161 890500 'CYCLE THERMAL EFFICIENCY'
162 890501 OPVB 15
163 *
164 .