Cycle Analysis Utilizing a High Performance Eductor

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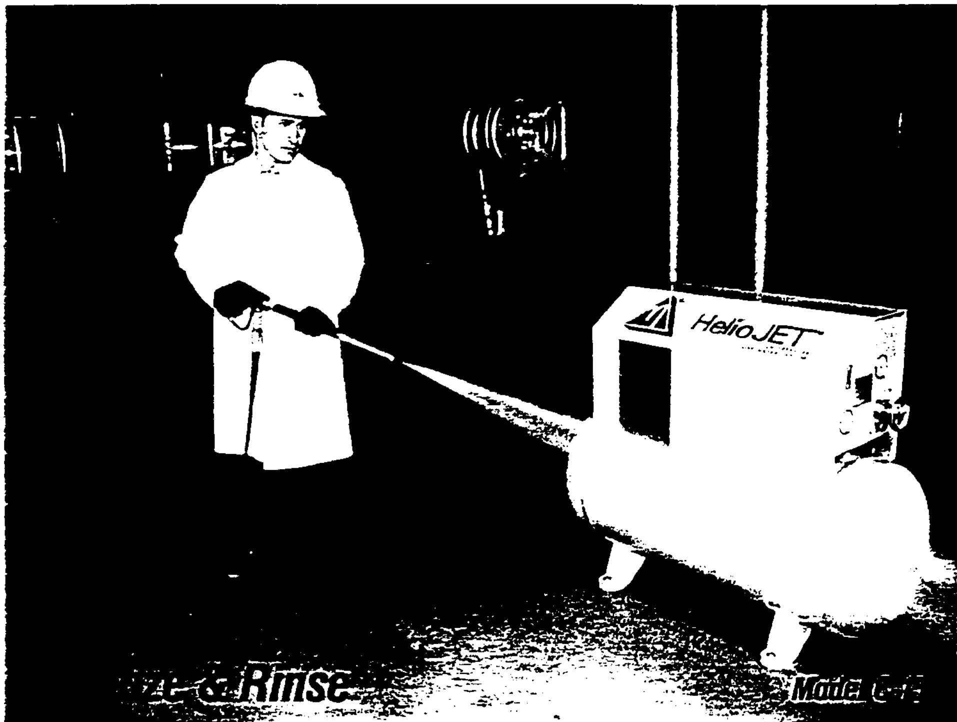
Title: Cycle Analysis Utilizing a High Performance Eductor

Abstract: A high performance eductor is being marketed by the manufacturer for use as a boiler feed device. The eductor utilizes steam to heat and pressurize water, and could possibly be used for feedwater heating in a regenerative Rankine cycle. PEPSE was used to evaluate the turbine cycle performance using this device in place of conventional feedwater heaters and feedpumps.

HelioJET™ CENTRAL CLEANING SYSTEM

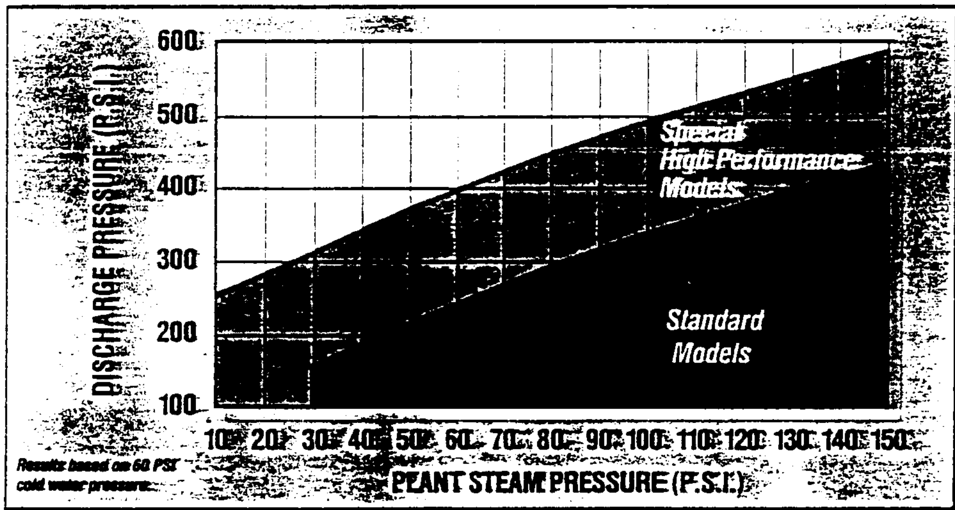


Clean, sanitize, degrease, and disinfect like never before with HelioJET™.

The HelioJET Central Cleaning System supplies pressurized hot water to multiple cleaning stations throughout your plant, simultaneously.

*At the heart of every HelioJET system is the patented pressure amplifier and condenser (HelioPAC™). The HelioPAC combines existing in-plant steam and cold water to give you an unequaled supply of **pressurized hot water** on demand.*

*You will realize rapid payback and cost savings on energy and maintenance because it has **no moving parts.***



The HelioJET delivers pressurized hot water at 150-200° F.

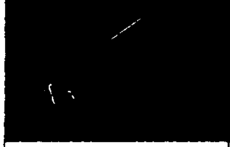
MODEL C-15	MODEL C-30	MODEL C-60	MODEL C-100
OPERATES 3 SIMULTANEOUSLY	OPERATES 8 SIMULTANEOUSLY	OPERATES 14 SIMULTANEOUSLY	OPERATES 20 SIMULTANEOUSLY

Larger capacities & custom systems are available upon request.

Several Models Available

Choose the capacity that's right for you.

S-10 SPRAY GUN



Standard 3-8 GPM 1/2" Hose Standard rinse to 15 ft.

S-50 BIG GUN

High Flow 8-15 GPM 3/4" Hose Big rinse to 25 ft.

DETERGENT INJECTOR

Sanitize with liquid detergent

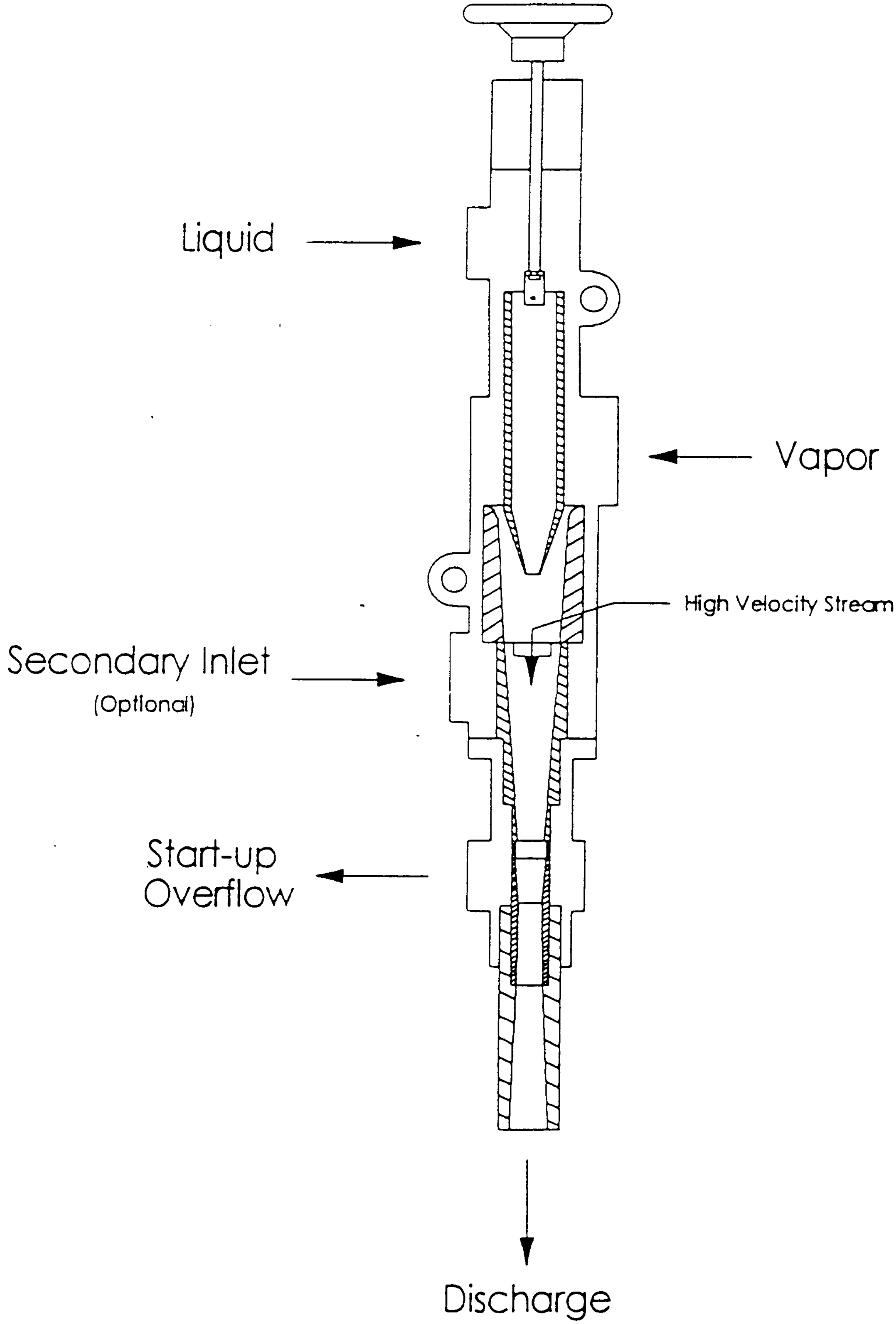
CPS HOT FOAMER

Shoot hot foam up to 35 ft.

A Complete Package

Helios offers a full line of accessories to make your installation and operation easy.

HELIOS RESEARCH CORPORATION 38 Dakin Street, PO Box 307 Mumford, NY 1451?-0307 716 538-6825


Liquid
Vapor
High Velocity Stream
Secondary Inlet
(Optional)
Start-up
Overflow
Discharge

HelioPAC

The Pressure - Amplifier - Condenser

Just What is The PAC & How Does it Work?

By O.T. Bloomer, PhD.

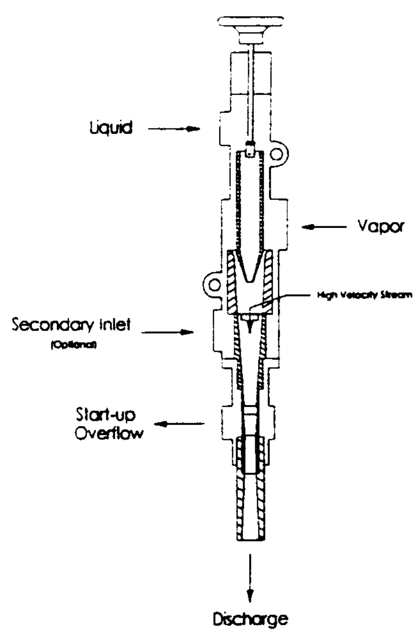
The HelioPAC (pressure - amplifier - condenser) is a greatly improved and highly optimized steam jet pump. Steam jet pumps have the unique capability of using steam to simultaneously heat and pressurize water. The random thermal energy of the steam is partially converted by the PAC to directed kinetic energy which is used to pressurize the water, while the remaining thermal energy of the steam is used to heat the water. Thus the PAC, like all steam jet pumps, is thermodynamically 100 percent efficient. All of the energy of the steam is used to either heat or pressurize the water.

When the steam jet pump was invented by Giffard in 1858, it created quite a sensation. This is because the discharge pressure of the heated water was higher than either the inlet steam or water pressure (often higher than the sum of the inlet water and steam pressure). This presented considerable difficulty to scientists and engineers at the time because the steam jet pump appeared to be a perpetual motion machine, producing more energy than it consumed. However, the emerging science of thermodynamics soon demonstrated that the jet pump was essentially 100 percent efficient, but no more. It was shown that there was no way that the steam jet pump could be used in a closed cycle to generate more energy than it consumed. Thus it was not capable of becoming a perpetual motion machine, much to the relief of patent departments around the world.

Over the next 100 years, over 5 patents were issued for improvements to the steam jet pump. But there was essentially no change in the performance of the pump. How could a device that was 100 percent efficient be improved? Few, if any, of these inventors appreciated that the proportion of the thermal energy of the steam which is converted to discharge water pressure energy could be increased, at the expense of the remaining thermal energy used to heat the water.

The key to understanding the performance of all steam jet pumps is the following simple momentum equation:

Momentum of Discharge Water =
Momentum of Inlet Water +
Momentum of Steam



HelioPAC

Remember from your high school physics that momentum is the product of mass times velocity. If the mass flow rates of steam and water are constant, then we are concerned only with steam and water velocity and the ratio of the steam flow to the water flow. In the conventional steam jet pump, very little of the pressure energy of the inlet water is converted to velocity.

With the PAC, essentially all of the pressure energy of the inlet water is converted to velocity. This is done by a highly optimized water jet with a discharge coefficient as high as 99 percent. This means that the momentum of the water entering the PAC is only one percent less than the maximum possible momentum.

The secret of all steam jet pumps is the expansion of the steam to a very high velocity by the use of a supersonic nozzle. The amount that steam can be expanded depends on the inlet steam pressure and the temperature of the discharge water. Steam boilers in most plants produce steam at 100 psig or higher. At this pressure, expansion of the steam to a velocity approaching MACH 2 (twice the sonic velocity of 1540 ft/second or approximately 3000 feet per second) is possible. With a steam to water ratio of one to ten (which would produce approximately a 100 degree F rise in the water temperature) approximately 3000/10 = 300 feet per second water momentum would be added to the water stream if the transfer of the steam momentum to the water were 100 percent efficient. With the PAC, approximately 75 percent of the steam momentum is transferred to the water as compared to only 50 percent for most previous steam jet pumps.

With an inlet water pressure of 60 psig, the inlet water momentum is about 100 feet per second. Adding 75 percent of 300 feet per second from the steam to the 100 feet per second for the inlet water would result in a discharge water momentum of:

$$(100 + .75 \times 300) / (1 + 1/10) = 295 \text{ feet per second}$$

The PAC, like all steam jet pumps, converts the momentum of the discharge water to pressure using a conventional diffuser. The gradually diverging cross section of the diffuser reduces the water velocity and converts the momentum of the water to pressure. Again, the PAC has been optimized so that the maximum possible efficiency of this conversion is approximately 90 percent under most operating conditions. Converting 295 feet per second of momentum to pressure at 90 percent efficiency results in a discharge pressure of 526 psig. Note that this pressure is over 3 times the sum of the inlet water and steam pressure (100 + 60) as compared to about twice the steam pressure or 200 psig for the best of traditional jet pumps.

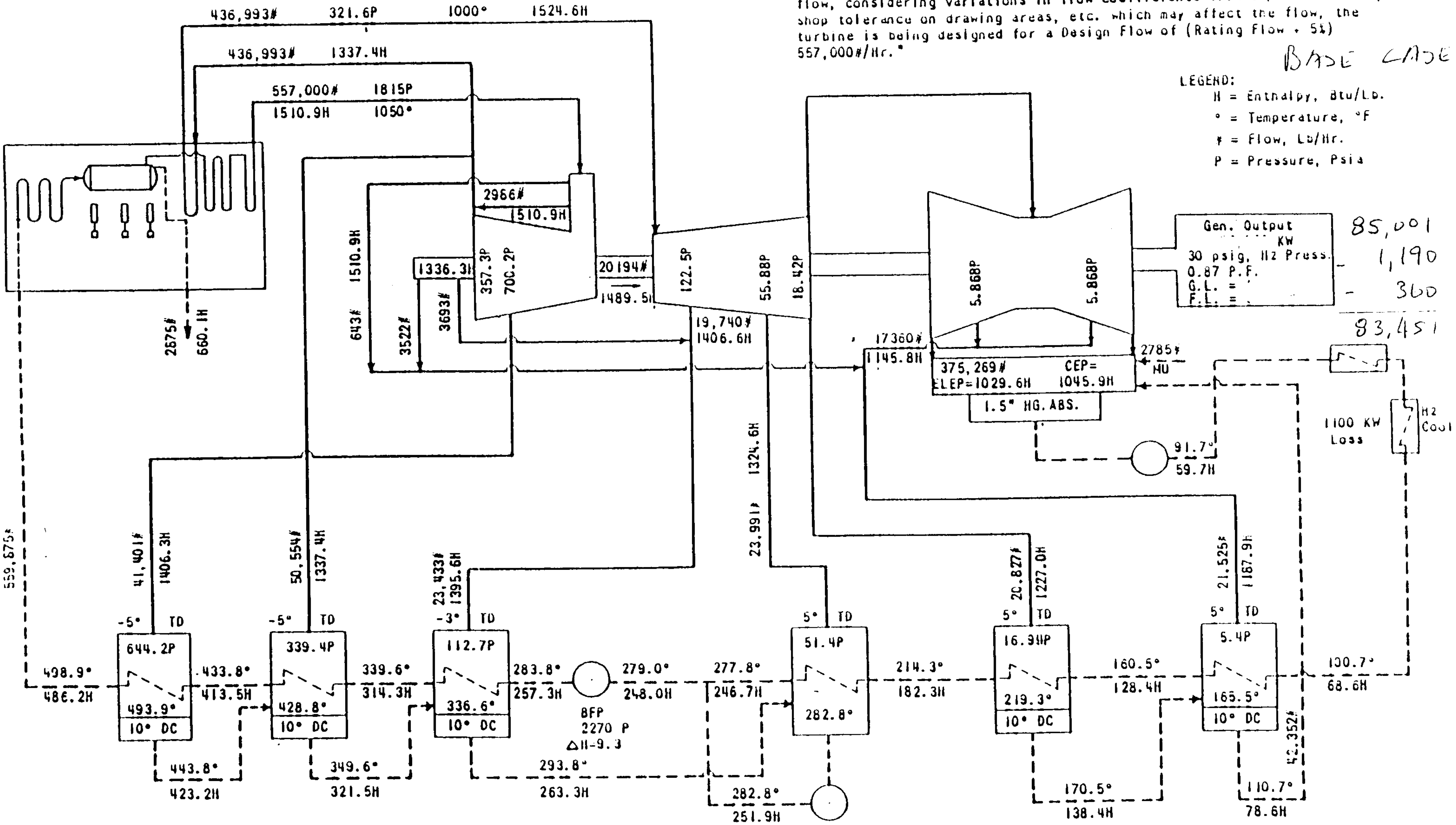
In summary, the PAC is a highly optimized water and steam momentum transfer (water pumping) device in which all three stages of the momentum transfer process: inlet water momentum, steam momentum, and discharge water momentum, have been optimized. As a result, the overall momentum transfer (pumping) efficiency is over twice as great as previous steam jet pumps.

CALCULATED DATA--NOT GUARANTEED

"Rating Flow (Guaranteed) is 530,000#/Hr. at inlet steam conditions of 1800 Psig. 1050° FTT. To assure that the turbine will pass this flow, considering variations in flow coefficients from expected values, shop tolerance on drawing areas, etc. which may affect the flow, the turbine is being designed for a Design Flow of (Rating Flow + 5%) 557,000#/Hr."

BASE CASE

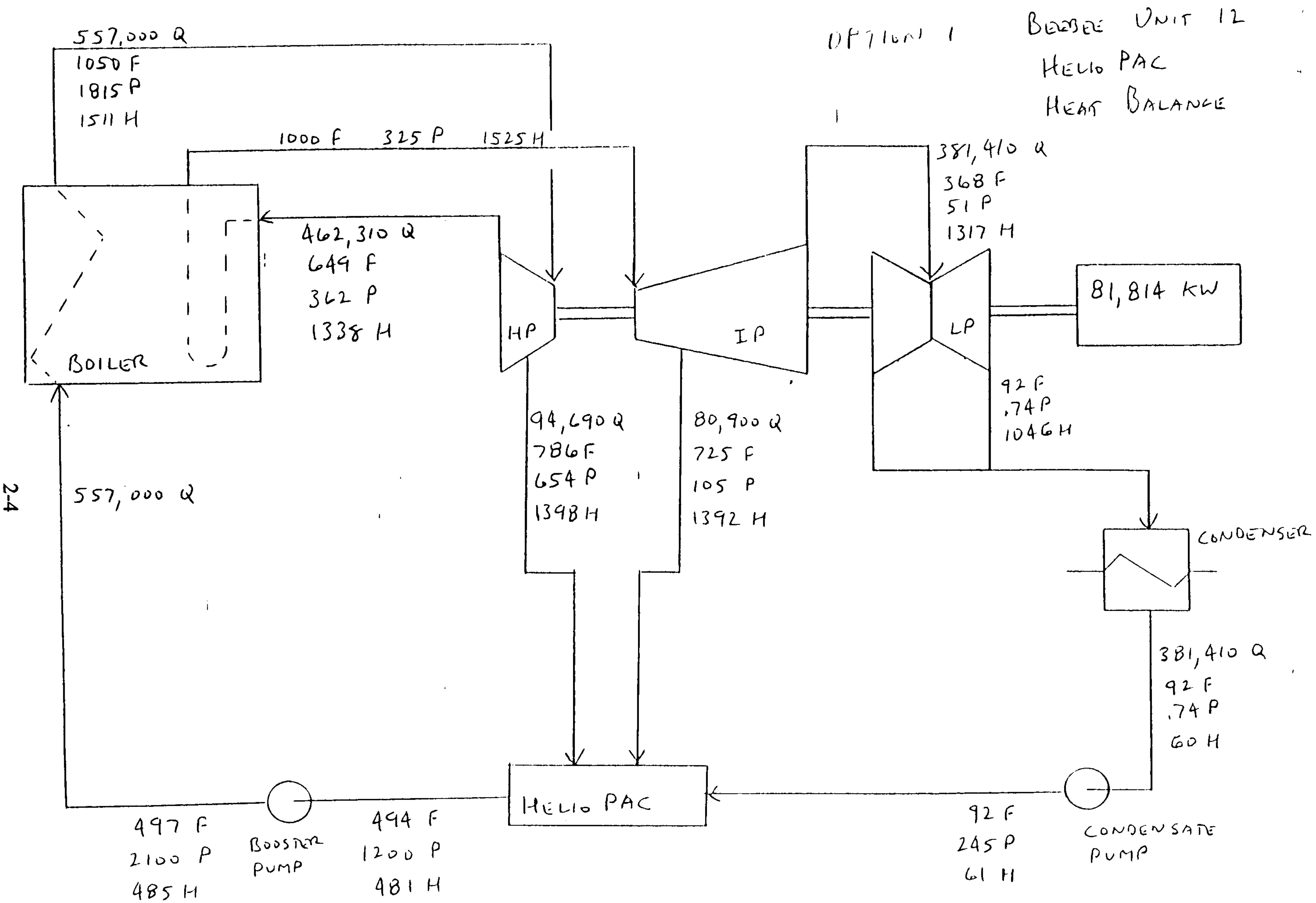
LEGEND:
H = Enthalpy, Btu/Lb.
° = Temperature, °F
# = Flow, Lb/Hr.
P = Pressure, Psia



GROSS HEAT RATE = $\frac{557,000\ (1510.9 - 486.2) + 436,993\ (1524.6 - 1337.4)}{83,270}$ = 7837 BTU/KW-HR.

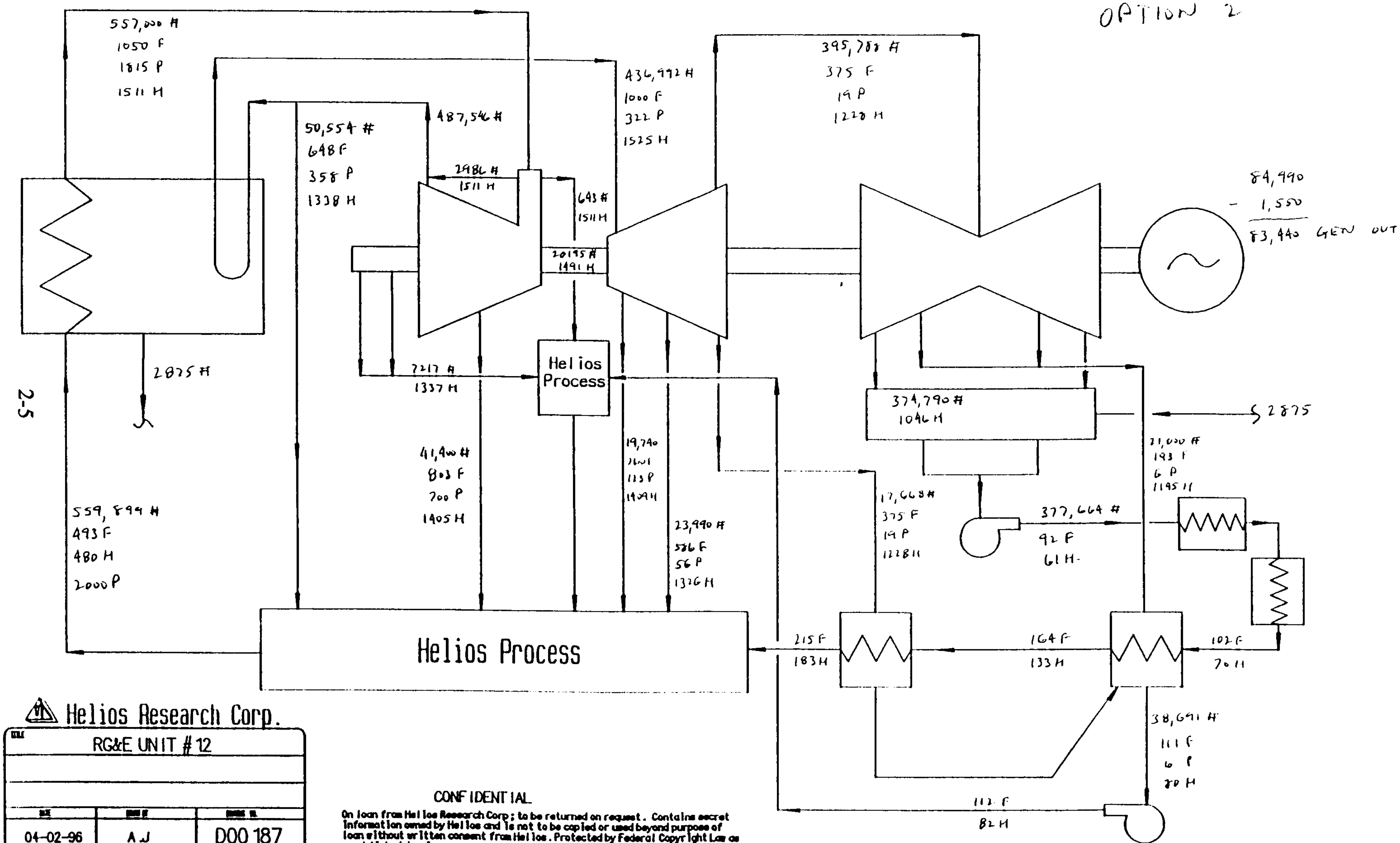
GENERAL ELECTRIC CO., SCHENECTADY, N.Y.

75,000 KW 3600 RPM TC2F-20"
1800 PSIG 1050°/1000°F 1.5" HG. ABS.
GEN: 96 MVA @ 30 PSIG H2 PRESS. & .85 PF
245 HB 192



Q: FLOW LB/HR
F: TEMP
P: PSIA
H: ENTHALPY, BTU/LB

HELIOS
OPTION 2



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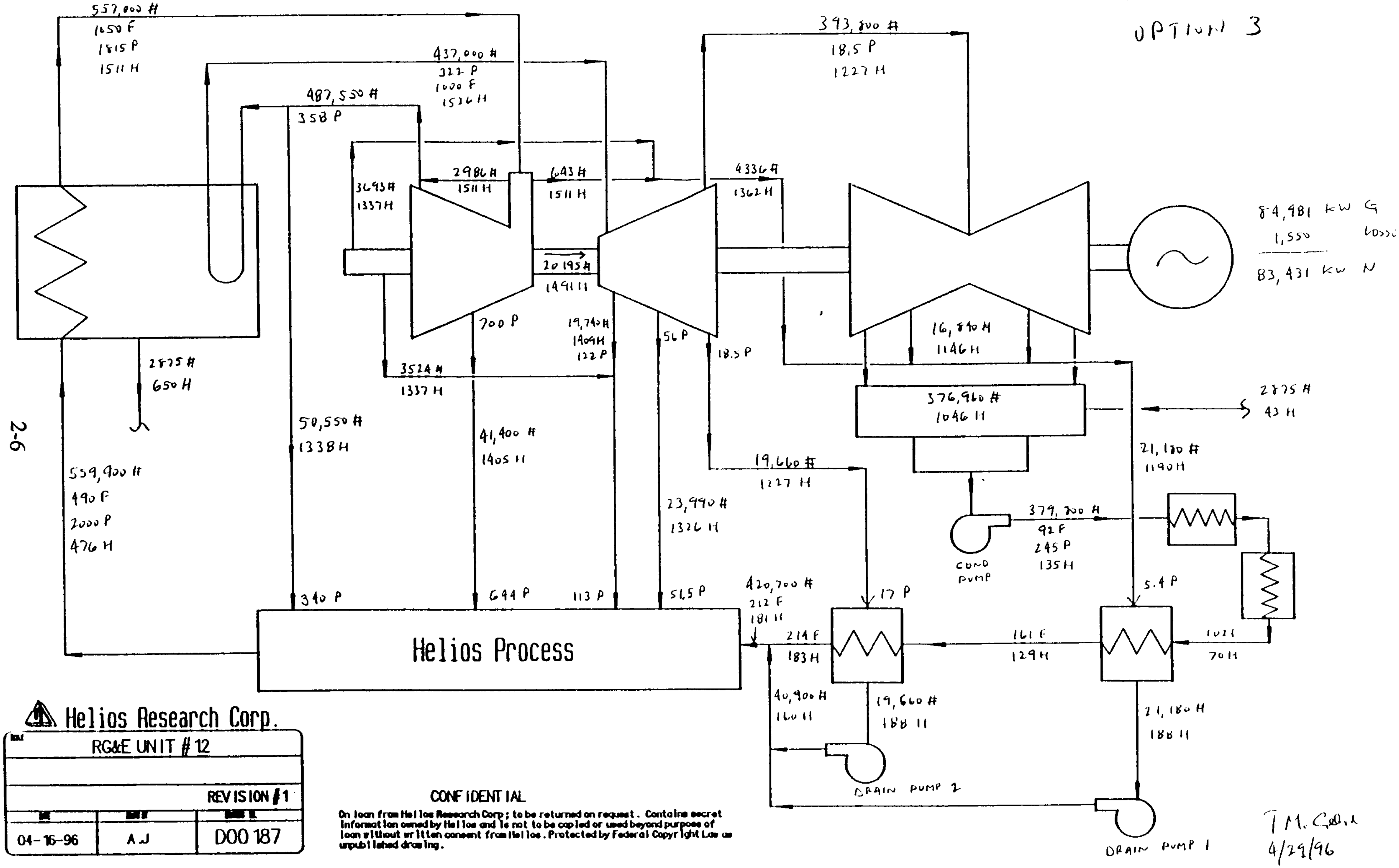
HELIOS OPTION 3



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Heat Rate Calculations

Base Case

Generator Output: 83,451 KW

Condensate Pump	135
Drip Pump	50
Boiler Feed Pump	1,800

Net Generation 81,466

Boiler Heat Input: 6.54E8 BTU/Hour

Net Turbine Cycle Heat Rate: 8028 BTU/KWH

HelioPAC OPTION

Generator Output: 81,814 KW

Condensate Pump	125
Drip Pump	--
Boiler Feed Pump	--
Booster Pump	375

Net Generation 81,314

Boiler Heat Input: 6.58E8 BTU/Hour

Net Turbine Cycle Heat Rate: 8092 BTU/KWH

Revised 3/14/96

Heat Rate Calculations

Base Case

Turbine Shaft Output:	85,001 KW
Generator Losses	1,550
Generator Output:	83,451 KW
Condensate Pump	135
Drip Pump	50
Boiler Feed Pump	1,800
Net Generation	81,466

Boiler Heat Input: 6.54E8 BTU/Hour

Net Turbine Cycle Heat Rate: 8028 BTU/KWH

HelioPAC OPTION 2

Turbine Shaft Output:	84,990 KW
Generator Losses	1,550
Generator Output:	83,440 KW
Condensate Pump	120
Drip Pump	
Boiler Feed Pump	
FWH 1 Drain Pump	30
Net Generation	83,290

Boiler Heat Input: 6.58E8 BTU/Hour

Net Turbine Cycle Heat Rate: 7900 BTU/KWH

Heat Rate Calculations

Base Case

Turbine Shaft Output:	85,001	KW
Generator Losses	1,550	
Generator Output:	83,451	KW
Condensate Pump	135	
Drip Pump	50	
Boiler Feed Pump	1,800	
Net Generation	81,466	

Boiler Heat Input: 6.54E8 BTU/Hour

Net Turbine Cycle Heat Rate: 8028 BTU/KWH

HelioPAC OPTION 3

Turbine Shaft Output:	84,991	KW
Generator Losses	1,550	
Generator Output:	83,431	KW
Condensate Pump	120	
Drip Pump		
Boiler Feed Pump		
FWH 1 Drain Pump	10	
FWH 2 Drain Pump	10	
Net Generation	83,291	

Boiler Heat Input: 6.59E8 BTU/Hour

Net Turbine Cycle Heat Rate: 7912 BTU/KWH