Re - opening IP 8th & 9th stages

ION ON
CIENCY

AXIAL WIDTH INCHES

APPENDIX A

RULES OF THUMB - FOSSIL

1% η_{HP} = 0.16% H.R. 0.3% KW

1% η_{IP} = 0.12% H.R. 0.12% KW

1% η_{LP} = 0.5% H.R. 0.5% KW

1% Flow increase = 0.94% increase in KWs

1° FF temp. increase = 0.08% decrease in KWs and 0.024% better H.R. (VWO)

1 BTU TEL increase = 0.1% poorer H.R.

10°F decrease in T_T increases η_{HP} 0.11%

5% increase in stage pressure flow relationship cause for alarm

1% ΔP increase in steam path = 0.1% poorer H.R.

1% change in P_{1st} due to a change downstream indicates a 1.5% change in flow for a 1.25 pressure ratio control stage

1% change in P_{st} due to a change upstream of the 2nd stage indicates a 1% change in flow

Bench Mark η HP 2% better than heat rate balance

η IP 2% better than Fig. 13, Paper #1, adjusted for pressure drops (ΔP)

A 10% nozzle area increase due to SPE results in a 6½% loss in stage efficiency for the control stage and 3 to 4% for the other stages

A 10% control stage nozzle area increase increases flow passing capacity 2%

A 10% decrease in control stage nozzle area decreases flow passing capacity 3%

% ΔP SV & CV 4% (VWO)

% ΔP IV 2%

% ΔP x-over 3%

A 1% increase in HP and IP turbine stage pressures due to a restriction downstream of the stage results in a 0.6% increase in pressure upstream of an impulse type stage and 0.7% for a 50% reaction stage

IP7006797

8th Stage

Loss factor

should be .74

$$\frac{\left(1-(.05)(.76)\right)1+6}{7} = \frac{6.962}{7} = .995$$

10% Area inc

-5% stg η

- 0.5% IP Load reduction

$$\sim \frac{\cancel{\omega}\,\Delta H_a}{\cancel{\omega}\,\Delta H_{ken}} \quad \frac{ue}{Ae}$$

- 0.5% IP η reduction

what throat chg to get 10% area

x	y	z	Rit	
.375	.324	.273	5.09	1.649

IP7006798

(2)

Avg throat dia

$$\frac{.375 + 2(.324) + .273}{4} = .324$$

$$1.649(1.10) = 1.814$$

$$1.814 / 5.09 = .356 \text{ new opening}$$

require = 32 mils increase for 10% area

IP7006799

9th Stage

+ 10% Area increase
+ 2% flow ? – control stg – cotton pg 469
– 5% η_{stg}

$\Delta P = 535.6 - 129.0 = 406.6$ p

$\Delta P / 7 = 58$ psi/stg

$$P_{ex.} / P_{Loss} = \frac{129.0}{535.6 - 2(58)} = \frac{129}{419.6} = .307$$

Loss factor – cotton p 75

→ 0.75

$$\frac{1 - (.05)(0.75)(1) + 6}{7} = .995$$

– 0.5% Load Reduction (IP turb)
– 0.5% η_{IP}

Is this additive to 8th stg effect?

If so, then total effect of

8th & 9th Stg area increases (10% ea)

x	y	z		
.492	.422	.352	5.37	Avg .422

2.266 (1.10) = 2.493

$$\frac{2.493}{5.37} = .464$$

Δ = .042 mils throat dia

for 10% area increase

In General for IP turbine 7 stgs

<u>8th stg</u>

10 % Area increase ~ 2% flow

- 5% stg η - cotton p

$$\frac{.95\left(\frac{1}{7}\right) + \frac{6}{7}}{7} =$$

~~Loss factor~~ P ratio $\frac{129}{455} = .28$

Loss factor Cotton pg 75

for Demo use 7 MW, MW/stg $= .76$

% Power Loss $\frac{(.95)(.76)\left(\frac{1}{7}\right) + 6}{7} = \underline{.96}$

$$\frac{(.95)(.76)(1) + 6}{7} = \frac{6.72}{7} = .96$$

IP7006802

1/27/01 — U1 1/22/01 Test data

①

IP inlet P 535.6 psia

Exh. 129.0 psia

ΔP/stg 406.6/7 stgs = 58 psi/stg

8th stg exh = 477.6 psia

Assume 90% stg η

— Based on power out — (using cotton's approach)

* Total P_{IP} wheel power *		MW	η
#5	8th	35.78	90.06 %
#6	9-11		
#7	12-14		

8th stg wheel power

$$5.358692\,e^6 \times (1519.7 - 1497.0) = 121.6\,e^6 \ \frac{Btu}{h}$$

22.7

$$\times\ 2.928104\,e^{-4} = 35.62$$

IP7006803

$\$1.51/10^6$ Btu

— Aux power

$$NTCHR \times \frac{1}{\eta_B} \times \left(\frac{\text{gross mw}}{\text{net mw}}\right)$$

2% 9500 Btu/Kwh

$$(.02)\left(6.3\ \text{mm Btu}/h\right)\left(916\ B/lb\right)\left(\frac{1}{.88}\right)$$

2% what — chg in h rate?

— throttle flow

— BD wtg

$$* \ BD = \dot{m}_{Throttle}(\Delta H_{Th}) + \dot{m}_{reheat}(\Delta H_{Ret}) + \dot{m}_{Blowdown}(\Delta H_{in-sat})$$

$$NTHR = \frac{BD}{gen}$$

35500

1/26/01

- EP 8th 9th 5th cut backs

  Dishing

  η_{EP} — Bunching back for

- Ext. → moving up

  → effect Boiler duty

  where (what sections of boiler effected)

1/27/01 — Find ~~EP η vs~~ effect of cutbacks

increase dishch area on EP η

cotton page 469 Rules of thumb Fossil

10% nozz area increase

3-4% stage eff loss

2% increaces flow passing capacity

Flow function $w/\sqrt{P_1/v_1}$

$w = K A_t \sqrt{2 g_c \rho (\Delta p)}$

Retrat Factor

cotton p 75

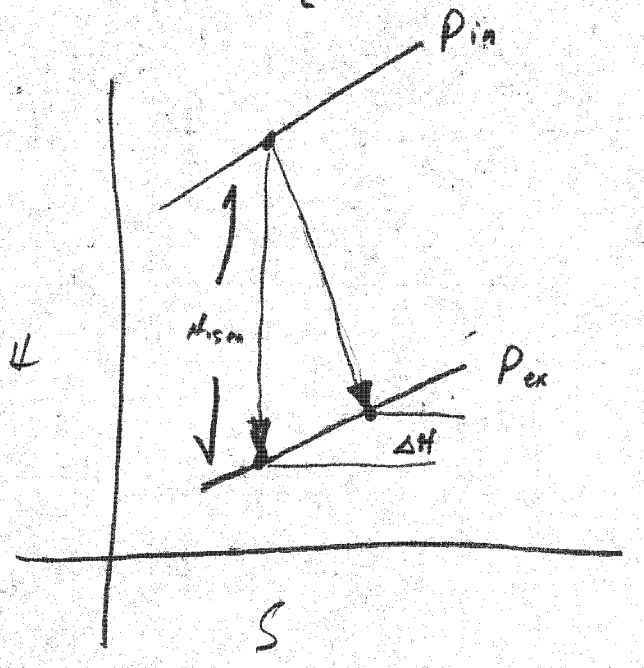
$AE_{io} < \sum_{io} AE$

Loss factor —

TOPS 35500

IP7006805

1/27/01 – Assume η_{IP} 90%



η_{stages} 90%

η_1 drops 5% to 85%

vol flow – $vw = \frac{RT}{P} w$

IP

535.6 Pi
129.0 Po

406.6 ÷ 7 stgs = 58 psi/stg

8th stg exh = 4706

IP7006806

IP Section total wheel Power

8th	35.757	
9-11	121.489	40.496/stg
12-14	120.397	40.132/stg
	277.643	

For a 5% 8th stg eff Loss

$.05(35.757) = 1.788$ Loss

Loss factor — cotton p 75

@ $P_{exh} = 129$

$P_{Loss} = 454.7$

ratio = .28

Loss factor = .76

Actual loss = $.76 \times 1.788$ MW = 1.359 MW

(% total power IP **-0.5 %**)

8th 10 %

IP7006807

8th stp 35.57 mw Power

~~Ap~~ P_{exh} – 129.0

P_{inlet} – 535.6 454.68

P_{in}/P_{ex} – 0.24 ahead of stg

0.28

Loss factor .76

(For 5% stg eff loss

Loss is 1.78 MW x .76 = 1.35 MW)

35.

IP7006808

1/27/01 IP cutbacks

(2)

8th stg eff

$$\frac{1519.7 - 1497.0}{1519.7 - 1494.4}$$

22.70

25.30

P_{in} 535.62

S_{in} 1.72932

P_{out} 454.68

$\eta_{out} = 1494.4$

$\eta_{8th} = 89.7$

~~New~~

$\frac{X}{25.30} = .8524$

21.57

5% stage η drop

$89.7(1-.05) = 85.24$

Power = 35,620 kw

33,845

1498.13

1,774.9 Loss

Total IP wheel power

IP7006809