FUEL AND OXIDIZER TURBINE LOSS ANALYSIS

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An assessment of the turbine losses for the fuel and oxidizer turbines at the FPL condition was conducted using a quasi-3D loss analysis method. This recently developed loss analysis method uses two flow codes - MERIDL and TSONIC - to calculate the flow velocities along the blade surfaces and endwalls. These velocities are then used as input to the boundary layer code - BLAYER - to calculate the friction losses due to incidence, secondary flow, and tip clearance.

The results of the loss analysis for the fuel turbine indicated an overall two-stage efficiency of about 90 percent. The largest loss was due to rotor tip clearance. The loss analysis for the oxidizer turbine is nearly completed. Results for the first stage of the two-stage design indicated an efficiency of about 80 percent, with high losses due to rotor incidence and blade and endwall friction.

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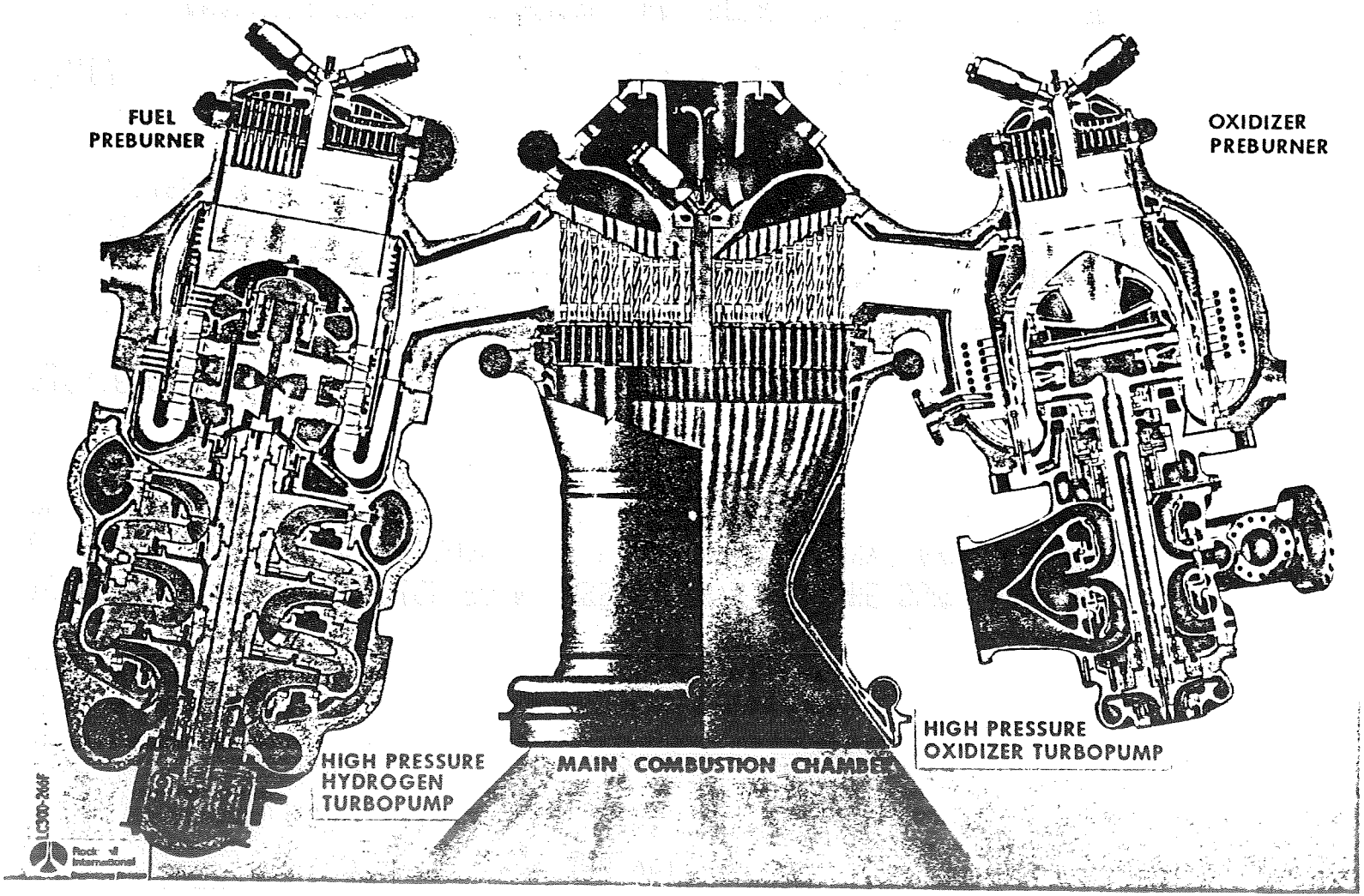
SSME POWERHEAD COMPONENT ARRANGEMENT



TURBINE LOSS ANALYSIS

- OBJECTIVE

  TO CONDUCT TURBINE DESIGN POINT ASSESSMENTS FOR THE SSME FUEL AND OXIDIZER TURBINES USING QUASI-3-D FLOW AND BOUNDARY LAYER ANALYSIS METHODS.

- SIGNIFICANCE

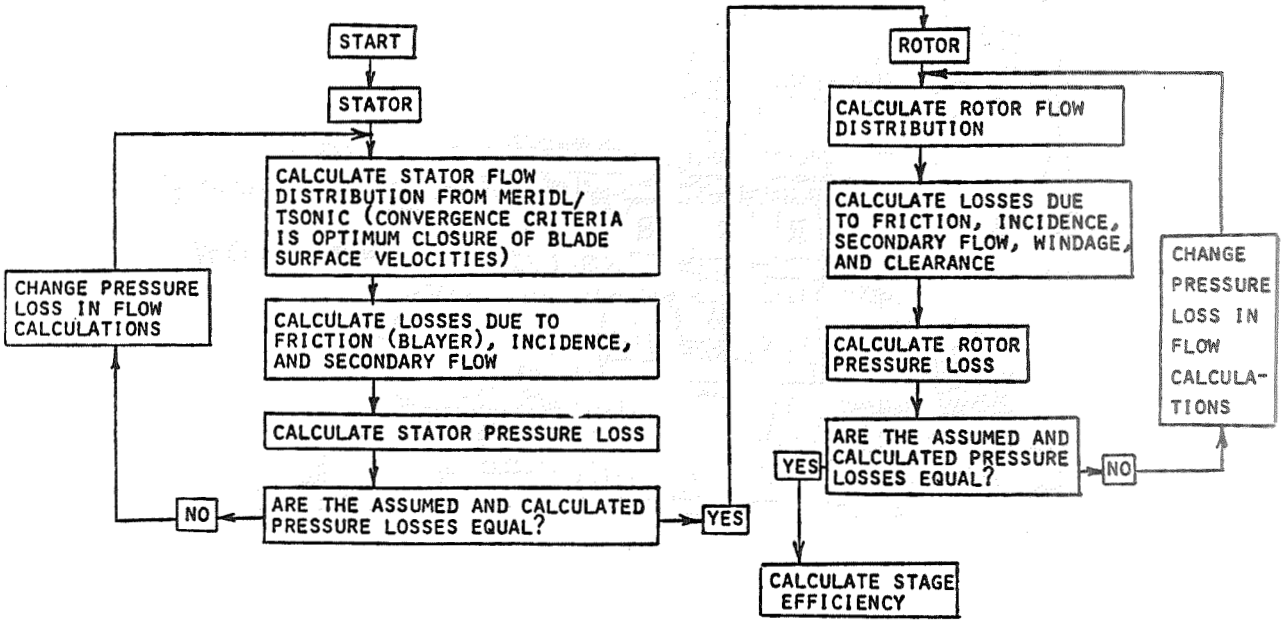
  TO VERIFY THE DESIGN POINT EFFICIENCY GOALS FOR BOTH TURBINES, IDENTIFY POTENTIAL AREAS FOR EFFICIENCY IMPROVEMENT, AND FURTHER ASSESS THE ADEQUACY OF THE ANALYSIS PROCEDURE FOR FUTURE SSME DESIGN ACTIVITIES.

- STATUS

  THE LOSS ANALYSIS FOR BOTH TURBINES HAS BEEN COMPLETED AT THE FPL CONDITION.

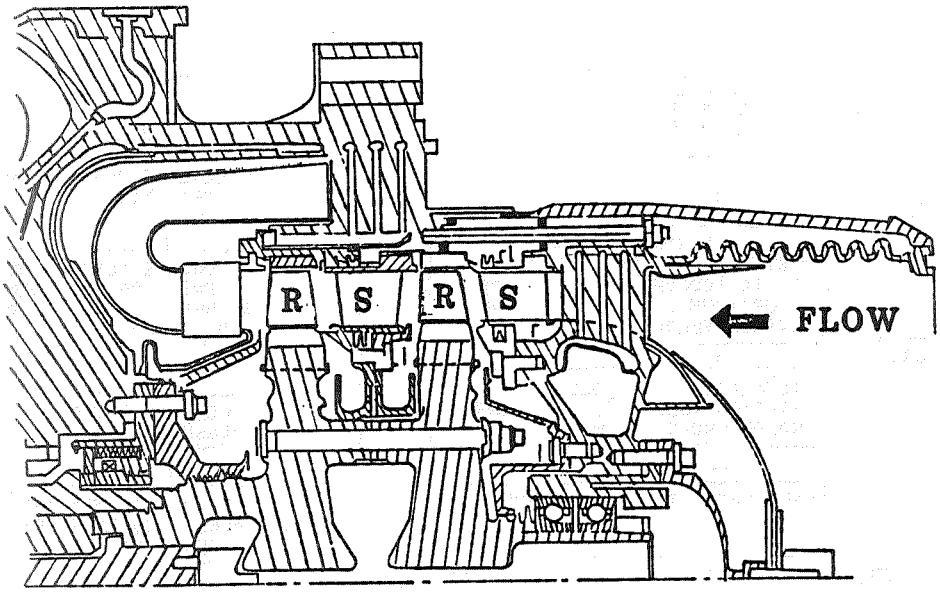
THE TURBINE LOSSES ARE COMPUTED ON A BLADE ROW BASIS. FOR EACH BLADE ROW TWO ITERATIVE LOOPS ARE EMPLOYED. THE INNER LOOP CONVERGES ON CLOSURE OF THE BLADE SURFACE VELOCITIES. THE OUTER LOOP CONVERGES ON THE TOTAL PRESSURE LOSS. COUPLING THE STATOR AND ROTOR LOSSES GIVES A STAGE EFFICIENCY. FOR THE SSME TURBINES, WHICH ARE TWO-STAGE DESIGNS, THE PROCEDURE SHOWN BY THE FLOW CHART IN THIS FIGURE MUST BE REPEATED TO CALCULATE AN OVERALL TWO-STAGE EFFICIENCY.

LOSS ANALYSIS FLOW CHART

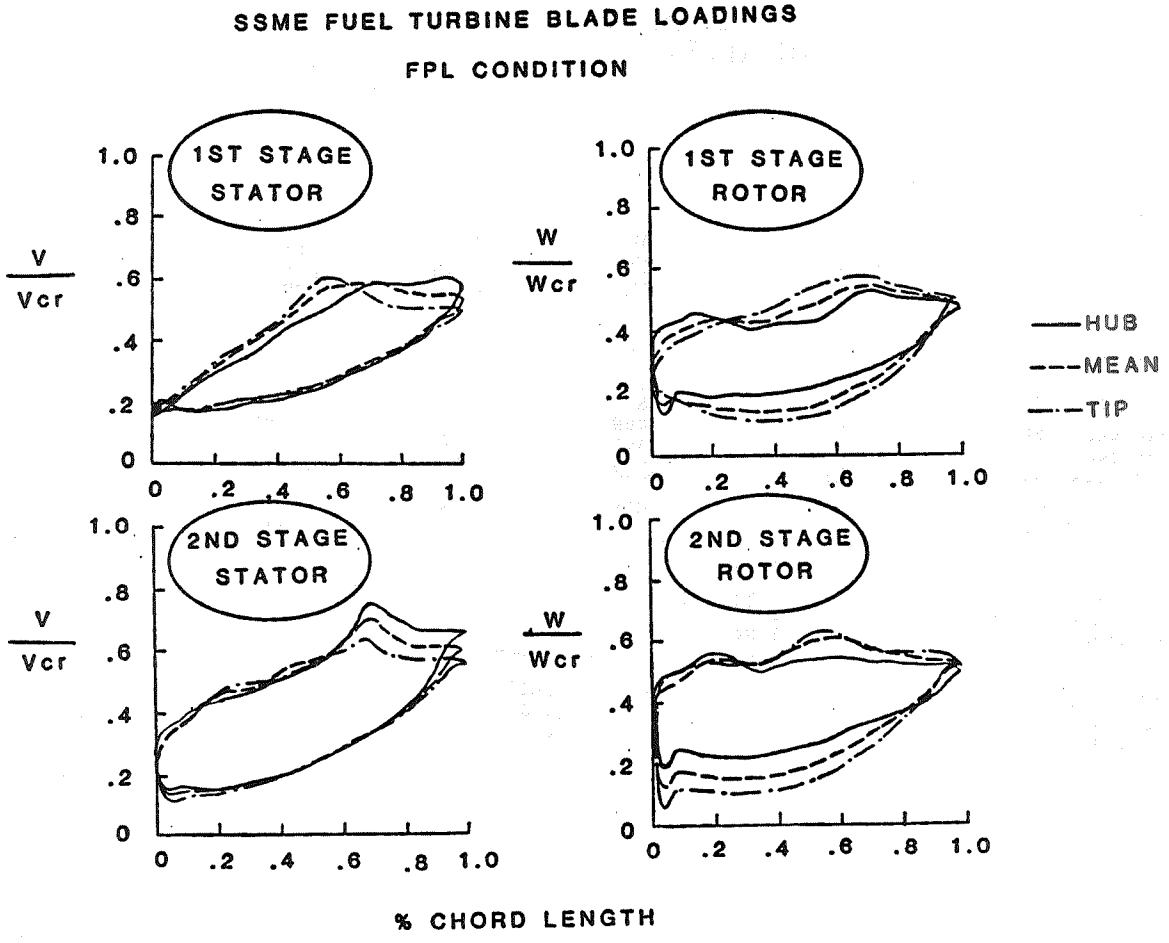


THE SSME FUEL TURBINE IS A TWO-STAGE DESIGN WITH A ROTOR MEAN DIAMETER OF 10 INCHES. THE BLADE HEIGHTS VARY FROM ABOUT 0.9 INCH FOR THE FIRST STAGE TO ABOUT 1.0 INCH FOR THE SECOND STAGE. THE HUB AND TIP ENDWALLS ARE CYLINDRICAL. THE ROTOR TIP CLEARANCES VARY FROM ABOUT 1.5 TO 2.0 PERCENT OF THE BLADE HEIGHT. THERE ARE ABOUT 40 BLADES IN EACH STATOR BLADE ROW AND ABOUT 60 BLADES IN EACH ROTOR BLADE ROW.

SSME HIGH-PRESSURE FUEL TURBINE



THE BLADE SURFACE VELOCITIES FOR THE FUEL TURBINE AT THE FPL CONDITION ARE SHOWN IN THE NEXT FIGURE. THE FLOW IN ALL FOUR BLADE ROWS IS GENERALLY ACCELERATING, WITH SOME SMALL DIFFUSION INDICATED ON THE SUCTION SURFACES.



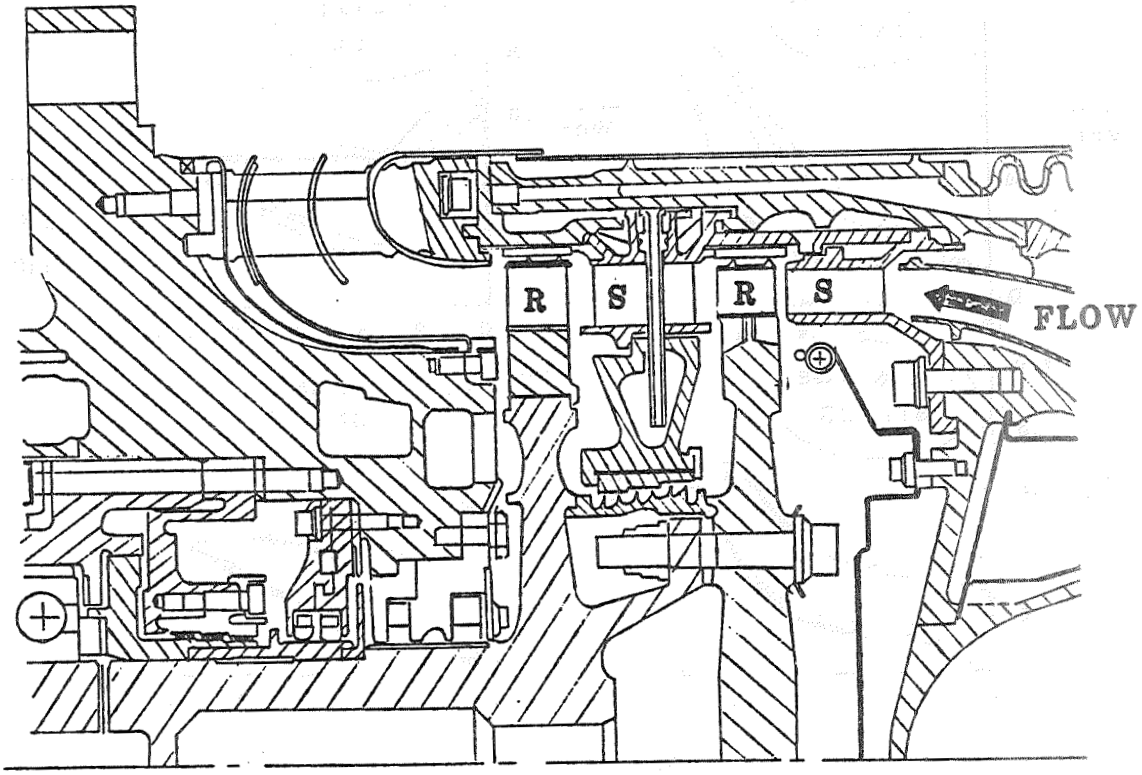
THE CALCULATED LOSSES FOR THE FUEL TURBINE AT THE FPL CONDITION ARE TABULATED IN THE NEXT FIGURE. AN OVERALL EFFICIENCY OF ABOUT 91 PERCENT WAS CALCULATED, WITH THE LARGEST LOSS (ABOUT 4 POINTS) DUE TO ROTOR TIP CLEARANCE.

SSME FUEL TURBINE LOSS ANALYSIS
FPL CONDITION

	FIRST STAGE STATOR	FIRST STAGE ROTOR	SECOND STAGE STATOR	SECOND STAGE ROTOR
LOSSES ($\Delta\eta'$):				
Profile + Mixing	.014	.016	.013	.017
Endwall Friction	.007	.002	.007	.002
Secondary Flow	.005	.009	.004	.009
Incidence	.001	.007	.001	.013
Tip Clearance	.000	.046	.000	.034
$\Delta\eta'$ Blade Row	.027	.080	.025	.075
P_r Blade Row	1.19	1.17	1.24	1.19
η' Stage		.893		.900
P_r' Stage		1.292		1.327
WF Stage		1.98		2.08
η' Overall			.906	
P_r' Overall			1.715	
WF Overall			4.06	

THE SSME OXIDIZER TURBINE IS A TWO-STAGE DESIGN WITH A ROTOR MEAN DIAMETER OF 10 INCHES. THE BLADE HEIGHTS VARY FROM ABOUT 0.5 INCH FOR THE FIRST STAGE TO ABOUT 0.7 INCH FOR THE SECOND STAGE. THERE ARE ABOUT 45 BLADES IN EACH STATOR ROW AND ABOUT 75 BLADES IN EACH ROTOR ROW. THE HUB AND TIP ENDWALLS ARE CYLINDRICAL AND THE ROTORS ARE SHROUDED.

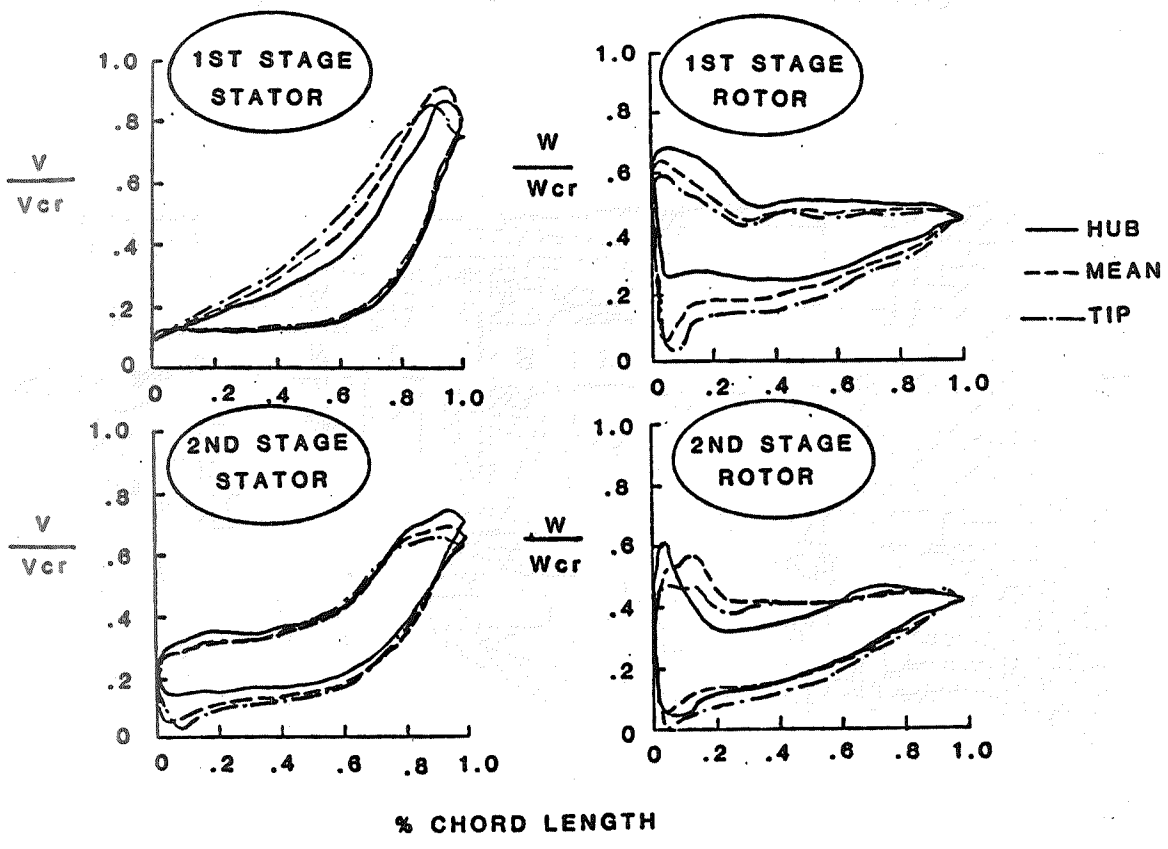
SSME HIGH-PRESSURE OXIDIZER TURBINE



THE BLADE SURFACE VELOCITIES FOR THE OXIDIZER TURBINE AT THE FPL CONDITION ARE SHOWN IN THE NEXT FIGURE. THE FLOW IS WELL ACCELERATED IN BOTH STATORS. HOWEVER, THE SUCTION SURFACE VELOCITIES FOR BOTH ROTORS, ESPECIALLY THE FIRST ROTOR, SHOW LARGE DIFFUSION, WHICH RESULTS IN HIGH FRICTION LOSSES.

SSME OXIDIZER TURBINE BLADE LOADINGS

FPL CONDITION



THE CALCULATED LOSSES FOR THE OXIDIZER TURBINE AT THE FPL CONDITION ARE TABULATED IN THE NEXT FIGURE. AN OVERALL EFFICIENCY OF 80 PERCENT WAS CALCULATED. FOR THIS TURBINE THE LARGEST LOSS WAS DUE TO ROTOR INCIDENCE IN BOTH ROTOR BLADE ROWS, WITH LARGE FRICTION LOSS ALSO CALCULATED FOR THE FIRST ROTOR.

SSME OXIDIZER TURBINE LOSS ANALYSIS
FPL CONDITION

	FIRST STAGE STATOR	FIRST STAGE ROTOR	SECOND STAGE STATOR	SECOND STAGE ROTOR
LOSSES ($\Delta\eta'$):				
Profile + Mixing	.024	.049	.029	.024
Endwall Friction	.019	.011	.016	.004
Secondary Flow	.013	.028	.016	.016
Incidence	.000	.077	.000	.083
Tip Clearance	-----	------	-----	-----
$\Delta\eta'$ Blade Row	.056	.165	.061	.127
P_r Blade Row	1.48	1.20	1.32	1.15
η' Stage		.779		.812
P_r' Stage		1.446		1.346
WF Stage		3.61		2.84
η' Overall			.801	
P_r' Overall			1.946	
WF Overall			6.45	

CONCLUSIONS

- THE QUASI-3D ANALYSIS METHOD PROVED TO BE A USEFUL TOOL FOR ASSESSING THE LOSSES OF THE SSME TURBINES
- FOR THE FUEL TURBINE AN OVERALL EFFICIENCY OF 90.6% WAS PREDICTED WITH THE LARGEST LOSS DUE TO ROTOR TIP CLEARANCE
- FOR THE OXIDIZER TURBINE AN OVERALL EFFICIENCY OF 80.1% WAS PREDICTED WITH THE LARGEST LOSS DUE TO ROTOR INCIDENCE