HIGH TIME SERVICE EVALUATION OF THERMAL BARRIER COATINGS ON THE ROLLS-ROYCE RB211 ENGINE

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One of the main concerns of airline operators for the use of thermal barrier coatings (TBC) in the turbine is that the coating will spall and cause a pre-mature engine removal. Even though much cyclic data is available on TBC's, high time data is much harder and expensive to come by. The typical 150 hour type test used to qualify new hardware, or modifications, falls far short of the 5-10,000 hour experience desired.

One way to obtain data demonstrating the longevity of TBC's is through a service evaluation program on a commercial engine. For a meaningful evaluation of the TBC system it must be applied to a component which operates in a typical hot end environment. In addition the component performance should not suffer if the coating is lost. For these reasons Rolls-Royce chose to coat the IP turbine nozzle guide vanes, and run these in an RB211 engine.

Two ceramic top coats and several different bond coats were tested in a rainbow fashion on several engines. Three layer Magnesium Zirconate was used as a base line. Various Yttria stabilized Zirconia ceramics were used a top MCrAlY bond coats which were applied by various techniques. Some of the coated vanes have now accumulated over 5000 hours. This report presents the results from the first 2 sets with 2500 and 4200 hours of service respectively.

1. Compare various TBC systems in the turbine environment (compare to Mag Zirc).

2. Determine effects of long time exposure (and of cycles).

3. Correlate Carousel rig testing vs. engine data.

4. Identify new coating systems worth testing.

Figure 1. - Thermal barrier coating (TBC's) service evaluation goals.

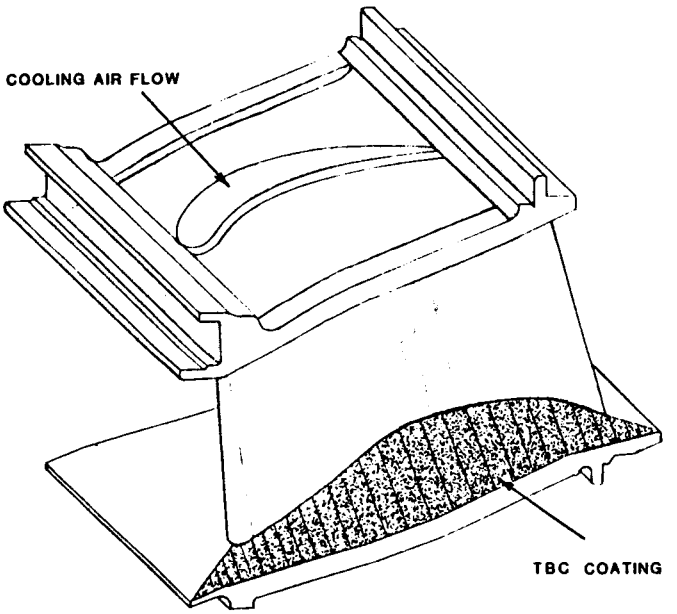


Figure 2. - RB-211 intermediate-pressure (IP) turbine nozzle guide vane (NGV) with thermal barrier coating for service evaluation.

IDENT	BOND	CERAMIC	BOND COAT METHOD	ON ENGINES	TOTAL VANES
A	443+441	210 MZ	Plasma	1234	22
B	443	210 MZ	Plasma	12	12
C	443	YSZ	Plasma	1234	22
D	NiCoCrAlY	YSZ	LPPS	1a234	20
E	NiCoCrAlY	YSZ	Ar Shrouded	1234	21
G	NiCoCrAlY	YSZ	Air Sprayed	34	10
Uncoated Vanes					5
TOTALS					114

Figure 3. - RB-211 service evaluation of intermediate-pressure turbine nozzle guide vanes with thermal barrier coatings.

ENGINE BUILD	ENGINE No.	FLIGHT HOURS	INSPECTED at-hours
1	10676	5068	4160
2	10575	5250	2539
3	10650	3818	3818
4	10398	4272	--

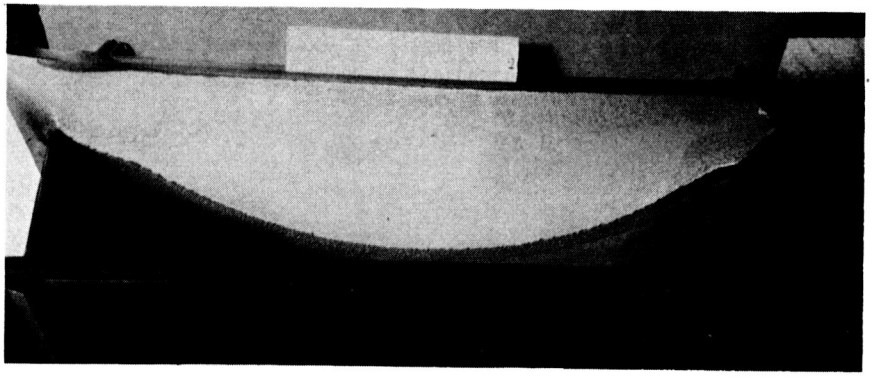
Figure 4. - Thermal barrier coating intermediate-pressure turbine nozzle guide vane service evaluation as of March 1985.

BUILD 1			BUILD 2		
	Coating	Position		Coating	Position
A	M443+441+210MZ	6:00	A	M443+441+210MZ	3:30
B	M443 + 210MZ	3:00	B	M443 + 210MZ	1:30
C	M443 + YSZ	12:00	C	M443 + YSZ	11:00
E	NiCoCrAlY[1] + YSZ	9:00	D	NiCoCrAlY[2] + YSZ	9:00
			E	NiCoCrAlY[1] + YSZ	6:00

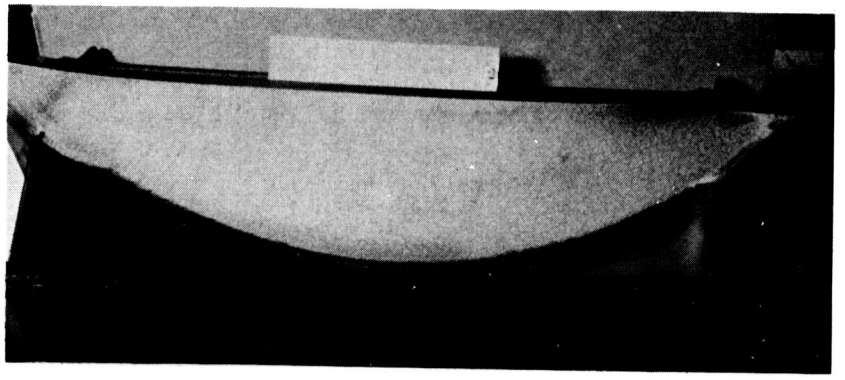
M=Metco, MZ=Mag Zirc
YSZ=Yttria stabilized Zirconia

1=Ar Shrouded, 2=LPPS

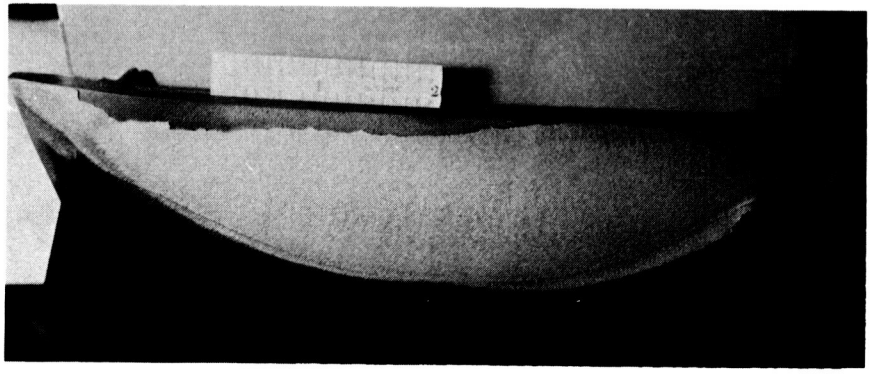
Figure 5. - RB-211 service evaluation of intermediate-pressure turbine nozzle guide vanes with thermal barrier coatings.



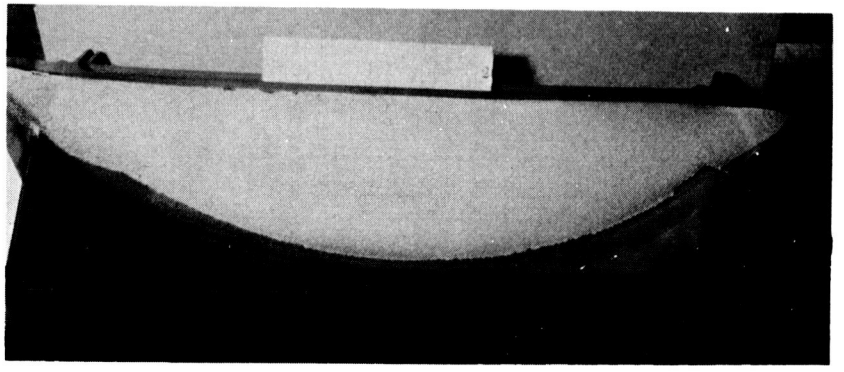
3 Layer Mag. Zirc (Typical)



2 Layer Mag. Zirc (Typical)

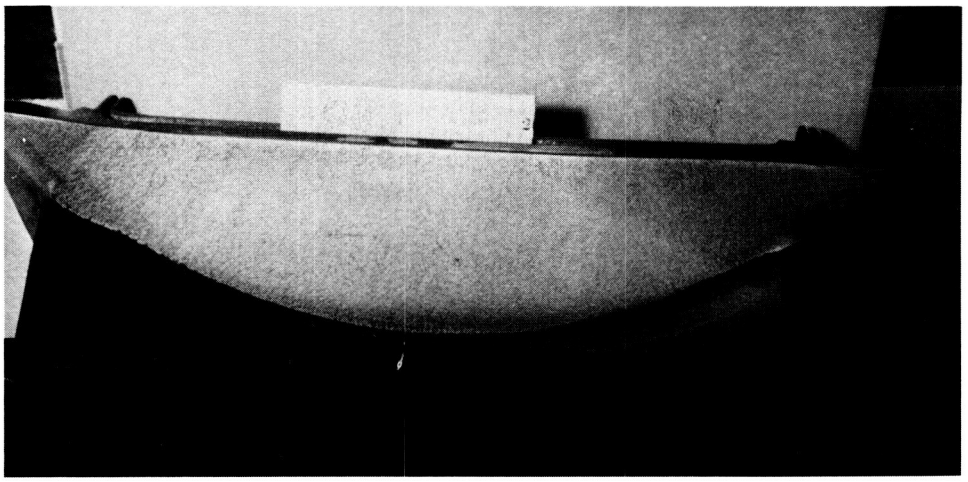


3 Layer Mag. Zirc (Worst)

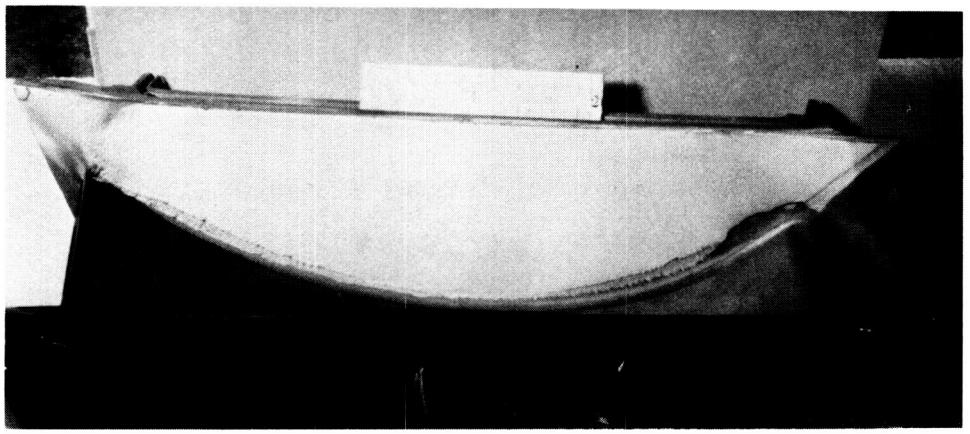


2 Layer Mag. Zirc (Worst)

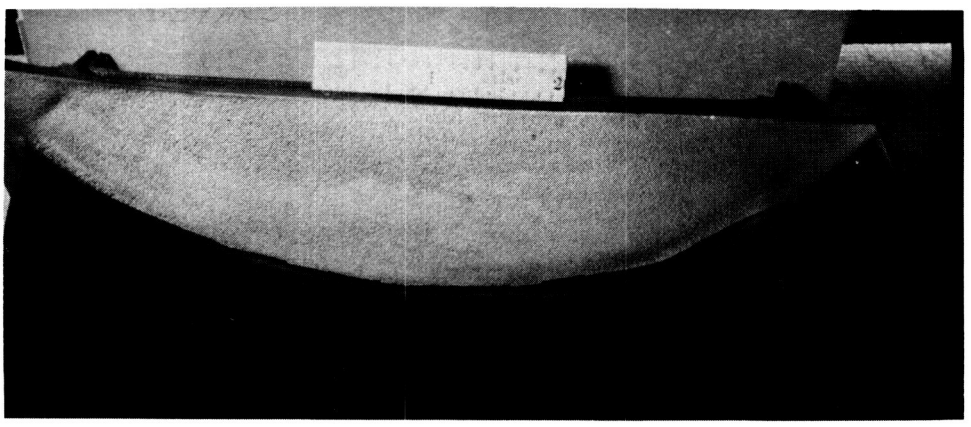
Figure 6. - RB-211 service evaluation of engine build no. 2 with 2539 hr/1353 cycles.



METCO 443 + YSZ (Typical)



LPPS MCrAlY + YSZ (Typical)



Argon Shrouded MCrAlY + YSZ (Typical)

Figure 6. - Concluded.

BUILD 1			BUILD 2		
	Coating	Position		Coating	Position
A	M443+441+210MZ	6:00	A	M443+441+210MZ	3:30
B	M443 + 210MZ	3:00	B	M443 + 210MZ	1:30
C	M443 + YSZ	12:00	C	M443 + YSZ	11:00
E	NiCoCrAlY[1] + YSZ	9:00	D	NiCoCrAlY[2] + YSZ	9:00
			E	NiCoCrAlY[1] + YSZ	6:00

M=Metco, MZ=Mag Zirc
YSZ=Yttria stabilized Zirconia

1=Ar Shrouded, 2=LPPS

Figure 7. - RB-211 service evaluation of intermediate-pressure turbine nozzle guide vanes with thermal barrier coatings.

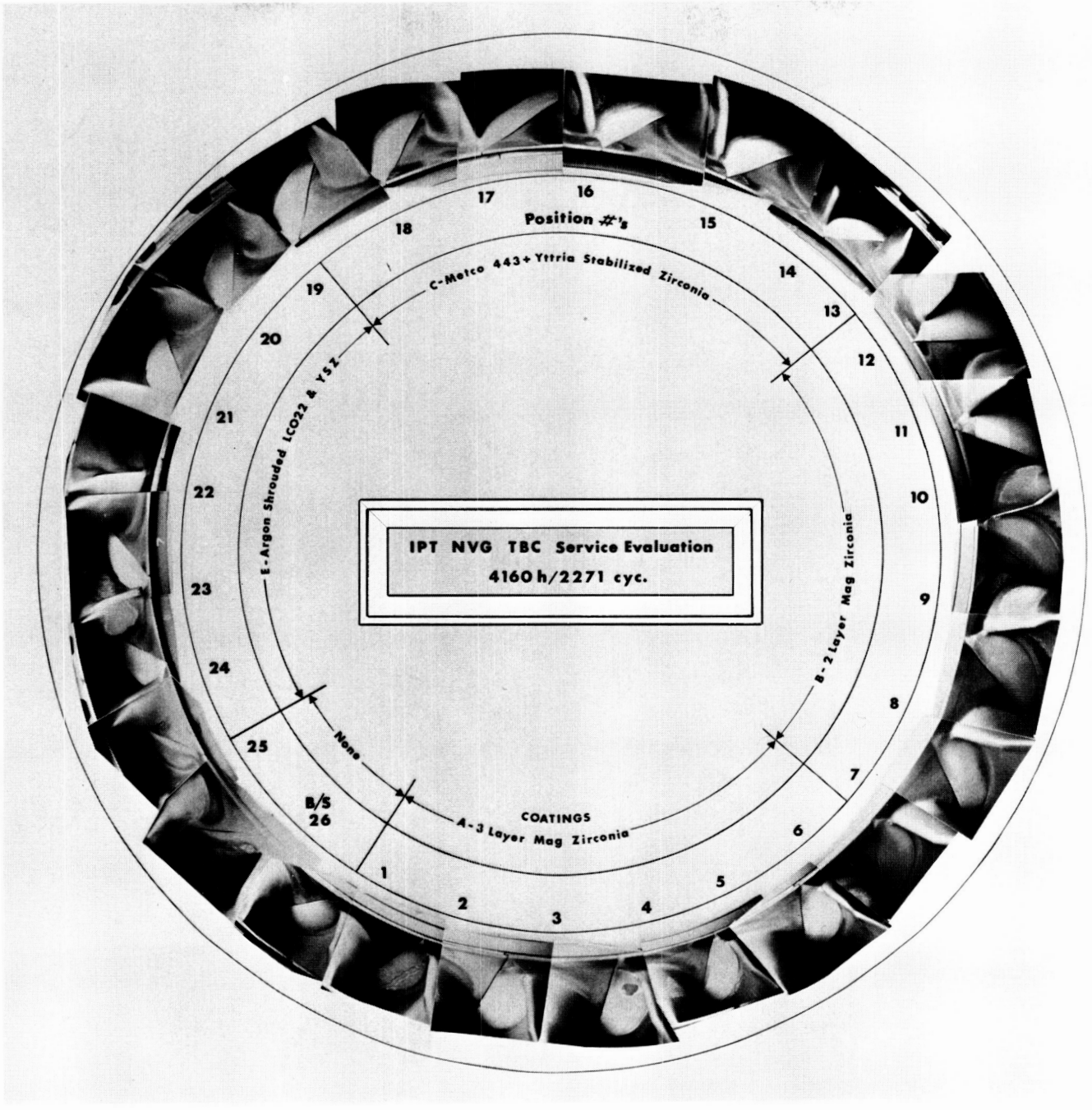
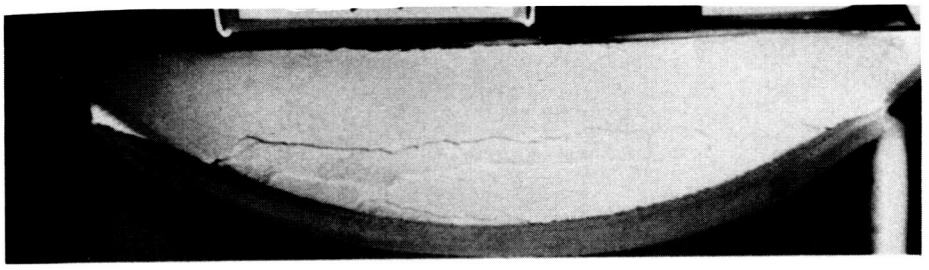
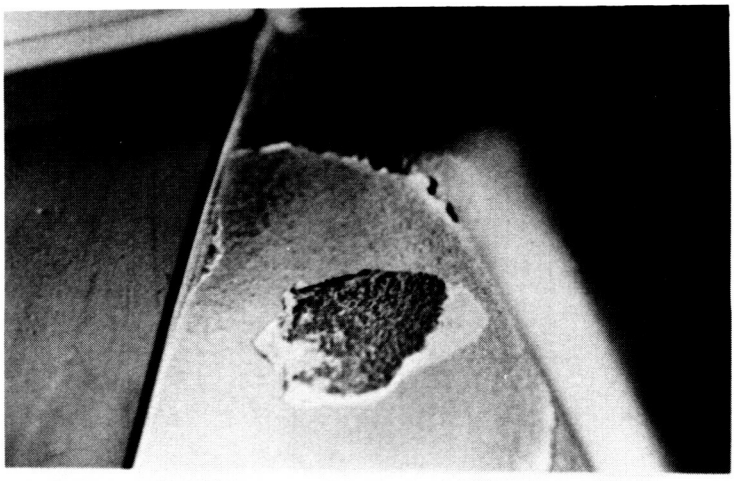


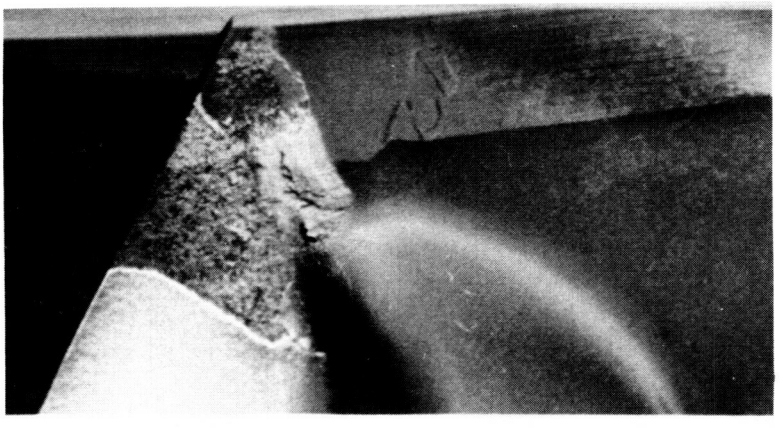
Figure 8. - RB-211 service evaluation.



3 Layer Mag. Zirc

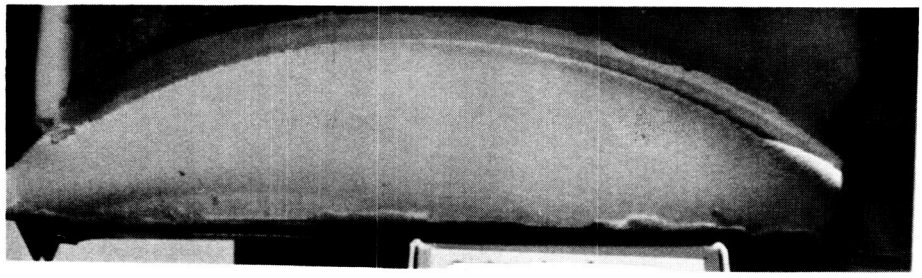


3 Layer Mag. Zirc

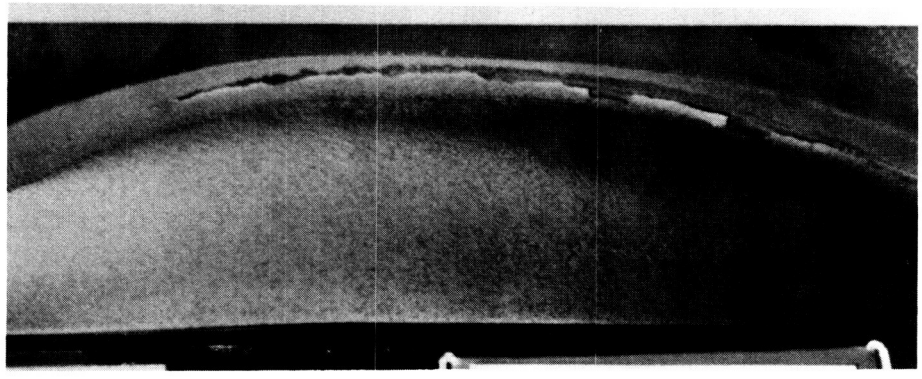


2 Layer Mag. Zirc (Worst)

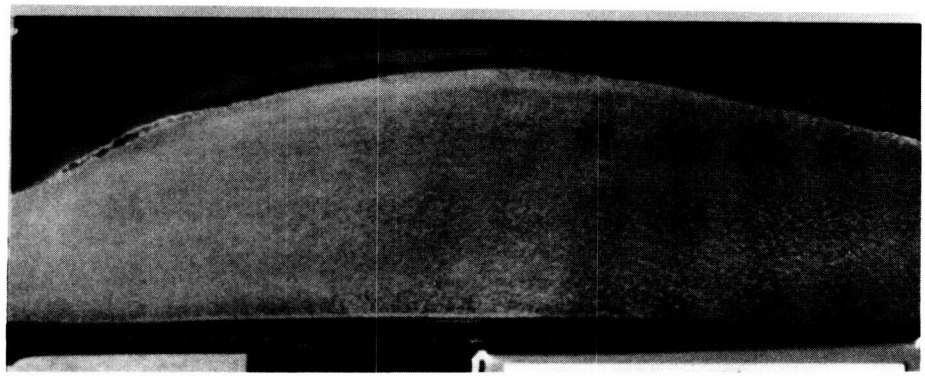
Figure 9. - RB-211 service evaluation of engine build no. 1 with 4106 hr/2271 cycles



2 Layer Mag. Zirc (Typical)



METCO 443 (Worst) + YSZ (Typical)



Argon Shrouded MCrAlY + YSZ (Worst)

Figure 9. - Concluded.

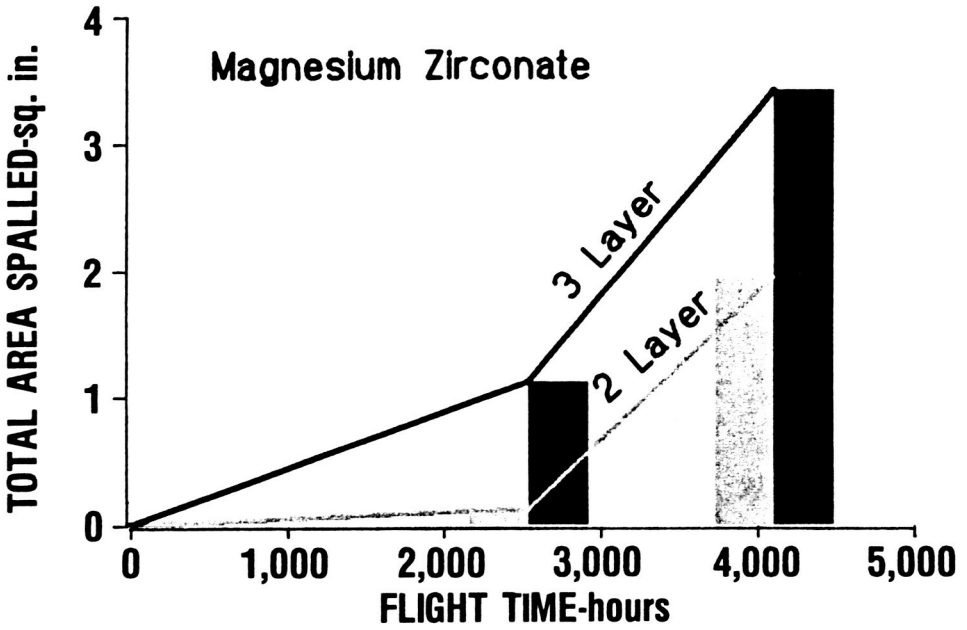


Figure 10. - Service evaluation of thermal barrier coatings on intermediate-pressure turbine nozzle guide vanes.

1. Mag Zirc is not adequate in the turbine.

2. Two layer Mag Zirc will out last 3 layer MZ.

3. Yttria stabilized Zirconia should do the job.

4. To date the Argon Shrouded bond coat looks best.

Figure 11. - Thermal barrier coating service evaluation conclusions.