DESIGNING THE L-1011 TO MINIMIZE ROTOR FAILURE EFFECTS

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Despite the considerable emphasis on containment, and the effort spent in analysis, research, and design development testing in attempting to achieve same, the experience of the aircraft industry is that an uncontained fragment of significant size and energy is to be anticipated at some time in the life of an aircraft type. In recognition of this fact, the Federal Aviation Regulation Special Propulsion Condition P-I states, in part: "The airplane must incorporate design features to minimize hazardous damage to the airplane in the event of an engine rotor failure ..." The L-1011 incorporates numerous design features that provide a high level of protection against rotor fragments. Some of these features are reviewed herein.

Protection against rotor fragments may be provided in one or more of the following ways: (1) By incorporating design features into the rotor that tend to promote small fragments if failure occurs, (2) By containing the fragments within the engine shell or greatly reducing the energy content of those fragments that are eventually uncontained, (3) By shielding vulnerable elements or systems with heavy structural members that tend to stop or deflect high velocity fragments, and (4) By incorporating redundant and/or "backup" systems into the basic design and separating these systems so as to minimize the probability that more than one system will be damaged by an uncontained rotor fragment. The L-1011 utilizes all of these design philosophies.

Some of the design features that have been incorporated into the Rolls-Royce RB211 engine are discussed briefly and two in-service experiences are considered in order to illustrate the practical operation of these features. The penalties

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that would be imposed by trying to design for 100% containment are assessed. Designing for 100% containment is found to be: (1) less effective than a rational integration of all techniques and (2) prodigally wasteful of our energy resources.

The aircraft systems such as flight controls, engine controls, fuel, hydraulic, and electrical control systems are considered and shown to be located and multiplicated so as to maximize the protection and availability of these vital systems. Special attention is given to the location of fuel lines, fuel shut-off valves, and the fuel valve control systems to minimize fire hazard.

Secondary equipment possessing high speed rotating elements are reviewed to illustrate the design philosphies followed, the design features utilized, and the in-service results attained.

The L-1011 has, to date accumulated close to a million flight hours with an excellent safety record showing the viability of the design philosophy utilized in designing the L-1011 to minimize rotor failure effects.

DISCUSSION

G. Gunstone, CAA-UK

I would like to ask Mr. Wignot if he could give some indication of the cost he feels has been allocated in the 1011 design against meeting the fragment protection requirement. In other words, trying to estimate the cost effectiveness of various solutions, what penalty is he paying now for having had to design the airplane the way it is, or would the aircraft have been just the same without a containment requirement?

J.E. Wignot, Lockheed-California

I think that's a very fair question. I think the answer is that, to date, the airplane proper has had very little weight added to it for containment. The additional weight that is associated with containment lies primarily in the engine.

J.C. Wallin, BAC

I couldn't help noticing that in your statement you said that there were certain systems, I think, that were protected by the structure. Now, that would presume based on your philosophy that you were not going to have more than a certain size disk piece coming out. I think that in an overall assessment (even with the best will involved and the best that Denis and his boys can do to the engine) one is unrealistic if one doesn't allow for the fact that one day there could be a failure of a disk piece and I don't believe that any structure, however heavy, will stop a disk piece. Having said all that, I will say that in our assessment, the L-1011 was one aircraft that would meet the current CAA requirements without any changes.

J.E. Wignot, Lockheed-Cal.

I want to thank Mr. Wallin for his comments and to acknowledge the pertinence of his question. Yes, we do have to face up to the possibility that a large fragment of a disk may be released. But after all, it's a matter of probability, isn't it? And here we're talking about the probability that we will have a bit of a disk come out, escape with the proper energy in the correct direction and do more than the damage that we have anticipated.

I would like to add that although philosophically we have to accept a rotor fragment size of one-third of the disk, it has been demonstrated many times that when a contributing problem is recognized, such as excitation of the lower disk modes by partial local blockage, it is possible to alter the design to promote smaller fragment production in the event of a failure. It would be hoped that through the efforts of this group, that the technology base and the theoretical base that is developed will tend to make the probability of the release of a third of a disk negligible. If we design so as to keep the rotor burst fragments small it makes all the other design problems that much easier.