TRIP REPORT:
Visit to Nook Industries

(Prepared by Jeff Guzzett on Jan. 2, 2002)

Visit to Nook in Cleveland, Ohio
December 20, 2001
To Discuss MD-80 Jackscrew Design

NTSB Attendees:

- Richard Rodriquez (ASA 261 IIC)
- Jeff Guzzetti (ASA 261 Systems Group Chairman)
- Joe Epperson (ASA 261 Materials Group Chairman),
- Joe Kolly (ASA 261 Grease Group Chairman)

The NTSB met with several engineers for about 5 hours at Nook Industries in Cleveland, Ohio, on December 20, 2001. The purpose of this informal meeting was to obtain a fresh, outside perspective on the design of the DC-9 / MD-80 Horizontal Stabilizer Jackscrew Assembly, and to receive input for possible recommendations related to the investigation of Alaska Airlines Flight 261.

Nook Industries is the largest manufacturer of precision acme screws in the world. However, none of their products are used in aircraft flight controls. Nook employs about 150 people. They have been in business for nearly 30 years, and manufactured acme screws for about 23 of those years. They design and produce a large selection of acme screws, ball screws, ball splines, linear ball bearings, work gear screw jacks, and electric cylinders.

The following persons were present from Nook:

- Chief Engineer
- President
- Applications Engineer

Also present from Nook for the first 2 hours of the meeting were:

- Chairman and CEO
- Vice President, Manufacturing Operations

During the first 45 minutes of the meeting, we presented a verbal briefing of the facts, conditions, and circumstances of the Alaska Airlines accident. We also showed drawings and photographs of the MD-80 jackscrew from the docket.

The following is a summary of the discussion points:

- The length of the MD-80 acme nut seemed greater than Nook is used to seeing. Because of "lead error" (variation from pitch to pitch), Nook's normal application philosophy calls for a 2-1/2-inch long nut for a 1-3/4-inch diameter screw, assuming at 15,000 lb load. (The MD-80 acme screw uses a 8-inch nut for the same diameter, and roughly the same load).

- Nook observed that it would be difficult to apply grease to all of the nut thread surfaces if the nut was lubed UNDER LOAD, as is the case when airline mechanics lube the acme nut. Lubing the nut with no load applied (such as during the endplay check) would probably provide a more thorough and effective application of lubricant.

- If the nut threads wear down and begin to deform, the endplay reading can be erroneous due to the deformed threads, and thus provide a measurement that may mask the excessive wear.

- A Nook rule of thumb for jackscrew/nut replacement is to replace the nut when the "lash", or endplay, equals one-quarter of the pitch. In the case of the MD-80 jackscrew, the 0.040-inch endplay equals about one-third of the pitch; therefore, the MD-80 limit is less conservative than the Nook rule.

- Nook believes that the wear rate of aluminum bronze on steel is very unpredictable and probably not linear.

- According to Nook, the number one reason for excessive acme nut wear is LACK OF LUBRICATION. They stated that there are usually two reasons for this: (1) The operator never bothers to lube the jackscrew after they purchase it new from Nook (it has lube on it at that time), or (2) the operator will lube it once, then think that it never needs to be lubed again. (Nook also stated that operators incorrectly assume that the jackscrew does not need a new application of grease because they can always see a glob of grease on the end of the nut.) According to the Nook Operator's Manual: "Lubrication Inspection is recommended at regular intervals. Usually, one month intervals are satisfactory unless experience indicates that regreasing should occur at shorter or longer intervals."

- Nook also stated that lack of lubrication would also be significantly aggravated by ONE-WAY LOADING, which is the case in the MD-80 jackscrew.

- Nook discovered that imbedding a "reservoir" into the acme nut causes improved lubrication. The reservoir can simply be a cut-out of two or three thread spirals inside the nut casting, so that grease can be captured in this area.

- According to Nook, the number two reason for excessive acme nut wear is MISALIGNMENT. They have seen this occur in applications involving the acme nut rotating along a long stretch of jackscrew. However, they have NEVER seen this cause for a rotating screw (as is the case for the MD-80). Additionally, this failure mode causes binding of the acme nut, as opposed to continual operation until the threads wear down to failure.

- In "critical" applications, when lives could be at stake for a Nook jackscrew, Nook has a "safety nut" attached to the screw, near the primary nut. This secondary nut rides along with the primary nut, but does not carry load. Should the primary nut threads fail to carry the load, the load is transferred onto the secondary nut, which is shorter but has fresh threads. When the load is transferred onto the secondary nut, a gap between the primary nut and secondary nut closes up; it is easy to visually observe that the gap is no longer present, so the inspector can see that they are riding on the secondary nut. Nook also

stated that the endplay could be more easily measured by measuring the endplay between the primary nut and the safety nut.

- In "critical" applications, OSHA regulations require that the jackscrew may be moved into position with no persons on board, and then must be stopped, and the jackscrew "pinned", before persons can be boarded.

- Nook stated that it has "been their experience that measuring back lash is difficult" therefore, they put on a "safety nut". They typically do not provide instructions for operators to perform backlash checks…rather they do it themselves for critical applications.

- Nook stated that BALLSCREW life is much easier to predict when compared with aluminum-bronze acme screws and nuts, because predicting the fatigue of the balls is much more direct and proven.

- Nook representatives could remember only one case involving abnormal nut wear due to grease type. This involved a Vandenburg rocket part and "out gassing". After discussing this with Nook, it was determined that this case would not be analogous to the MD-80 jackscrew failure seen on the accident.

- Nook stated that they DO NOT use finite element modeling or sophisticated design techniques to design acme screws and nuts. Rather they perform the following: (1) Design to a certain psi (for bronze nuts); (2) examine tooth geometry and overlap; and (3) begin to hone the design at the theoretical maximum contact area.

- Nook stated that purging old grease out of the jackscrew, and then refreshing the jackscrew with new grease, increases the life of the acme nut. They believe that aluminum-bronze grit begins to infiltrate the working grease, and will actually act as a "lapping compound" on the acme nut.

- Rarely has Nook manufactured a HOLLOW acme screw. But they have done it. The reasons to manufacturer this type of screw would be for weight reduction or a slightly higher column strength. One application called for a telescoping pole to be held inside the acme screw. Another acme screw was hollow to allow coolant to flow through it. When asked if a hollow screw could cause different acme nut wear rates, they stated that it would not have an effect. They do not recall ever having a problem with these unique screw designs, nor would they expect to have a problem. After discussing and reviewing the MD-80 jackscrew, they felt that the characteristics of the torque tube design would not effect acme nut wear.

- Nook representatives stated that the "wobbling" jackscrew effect would have an "insignificant" effect on acme nut wear rate. They stated that the side-load force produced by the wobble is insignificant in comparison to the 5,000 lb thrust load to the center of the screw axis.