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ENGINEERED MATERIALS ARRESTING SYSTEM (EMAS)

EXECUTIVE SUMMARY

An Engineered Materials Arresting System uses a specially installed surface which quickly stops any aircraft that moves on it and is installed at the end of runways to reduce the extent, and associated risks, of any overrun off the end of a runway compared to the equivalent soft ground distance. This emerging technique is being used widely in the USA and in Australia, the UK, Canada, France and Spain. In the absence of ICAO SARPs for EMAS the use of EMAS is being monitored closely and attention of the member states are drawn to this emerging technique to offset the consequences of a landing overrun, or one following a rejected take off initiated from high speed.

1. **Background:** It was an overrun by an SAS DC10-30 following a late touchdown on runway 04R at New York JFK in February 1984 which was the catalyst for the development of EMAS. The extent of the overrun led to both passenger injuries and substantial aircraft damage. The FAA and the United States Air Force (USAF) agreed to determine the feasibility of, and develop criteria for, the design of soft-ground arresting systems on 21 December 1984 and, in 1989, the FAA initiated an experimental program with the U.S. Naval Air Engineering Center to conduct experiments on soft-ground materials.

2. The purpose of these experiments was to verify the theoretical calculations of stopping distances. Tests were conducted on phenolic foam and cellular cement with an FAA Boeing 727 in the summer of 1990. The FAA Technical Center then conducted two successful full-scale 'arrestments' using the same instrumented Boeing 727 in the summer of 1993 using a phenolic foam bed 207 metres long, 15 metres wide and 18 inches deep. The most significant early overall review of the subject was the 1993 FAA Report "Soft Ground Arresting Systems for Airports."

Between 1994 and1996, the FAA and the Operator of New York JFK developed and installed a prototype arrestor bed built with pre-cast cellular cement blocks for runway 04R at KJFK. As early as 1998, the FAA issued the first generic specification for EMAS design, installation and maintenance. Since then it has encouraged the only current (US) manufacturer of a viable EMAS system, Zodiac Aerospace, in the development of its "EMASMAX" ® product for more widespread civil use.

3. An EMAS installed in accordance with the FAA specification is stated to provide a level of safety that is equivalent to an FAA 305m Runway Safety Area (RSA) - which corresponds to the ICAO Recommended Practice for RESA plus the required Runway Strip detailed in Annex 14. The total extent of the overrun 'system' which incorporates an EMAS bed can then be reduced subject to FAA approval to 180m - exactly the same distance as the ICAO RESA Standard provides for - but to considerably more effect.

The current FAA Circular on the subject is AC 150/5220-22A "Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns" which was issued in September 2005 and includes requirements for:

- design using a verified system performance model
- use of fire resistant and non toxic materials
- system suitability for all ambient temperatures and other weather variables
- resistance to jet blast hazard
- no adverse effects in the event of a landing undershoot in the direction opposite to intended use
- no impediment to transit by RFFS vehicles
- any bed elevated above the surrounding surface must have access to or egress from it by vehicles or persons facilitated by provision of ramped or stepped edges
- an approved maintenance programme.

The requirements in respect of both jet blast and undershoot are largely met by the requirement for a "setback" zone between the runway end and the EMAS bed. The limiting factor is usually the jet blast risk, but continued development of pavement surfaces which are resistant to jet blast has allowed the EMAS set back distances to be reduced, in some cases to as little as 7.5m.

EMAS outside the USA.

A number of NAAs have recently introduced, or are actively preparing, generic guidance for the approval of EMAS based on the currently applicable FAA standards. These NAAs include those in Australia, the UK, Canada, France and Spain. The definition of the term 'Engineered Materials' adopted by the FAA - 'high energy absorbing materials of selected strength which will reliably and predictably crush under the weight of an aircraft'- has been widely accepted outside the USA.

EMAS Installations.

The core application of EMAS has been seen as locations where the ground profile at the end of a runway is such that the consequences of a landing overrun, or one following a rejected take off initiated from high speed, are serious damage to, or the complete destruction, of an aircraft. More recently, it has been promoted as an option to avoid an overrun trajectory conflicting with the extended centreline of another runway. It has also been argued that it is not only an alternative to a longer RESA, where the criteria for the profile of the latter cannot be met, but is also an alternative which will ensure that high speed overruns will be stopped even where the full recommended RESA length may not be sufficient for an aircraft to stop within it.

Since the first EMAS were installed on runways 04R and 22L at New York JFK in 1996, there has been a steady increase in installations so that by June 2011, systems had been installed at 52 runway ends at 36 airports in the USA including Boston 15R and 04L, Chicago O'Hare 04R/22L and all four runways at Chicago Midway. The first installations outside the US were carried out on 33L and 33R at Madrid Barajas (Spain), on both ends of 02/20 at Juizhai-Huanglong (China) and on 10 at Taipei Songshan (Taiwan).

EMAS Installation on Runway 04L at KBOS (Source: Zodiac Aerospace)

The presence of an EMAS should be included in the AIP entry for the Airport concerned and the main commercial chart providers have now developed a standard depiction for an EMAS installation.

EMAS Design.

The design of the Zodiac Aerospace EMAS product is predicated on being able to cope with the overrun speeds that have occurred in the past and the aircraft sizes which may use particular runways. Each installation is adapted to the prevailing environmental circumstances and a maximum EMAS entry speed by aircraft type. It meets all the requirements of the applicable FAA guidance.

The Zodiac EMAS is a bed of cellular cement blocks encased in a protective cover positioned after a 'setback distance' which begins immediately after the end of the paved runway surface. The blocks crush reliably and predictably under the weight of an aircraft and thus facilitate a rapid but nevertheless gentle and consistent deceleration. Each lightweight block is secured to the EMAS base with hot asphalt and the seams between blocks are then taped at their upper surface to prevent water penetration. The depth of the EMAS bed gradually increases with increasing distance from the runway, typically from around 25cm up to 75cm.

An FAA-approved computer model of the wheel / compacted cellular cement interface is used to determine the required arrestor bed configuration according to aircraft weight and EMAS entry speed. The heaviest aircraft will usually be the 'critical aircraft' but, since landing gear configuration and tyre pressures are also relevant, this does not hold universally.

Each system is also designed to take account of runway length / width, elevation, and the length and slope of the available installation area. Performance usually takes account of aircraft types which have more than 500 movements per year and assumes that these aircraft will be operating at 100% of runway MTOM or 80% of runway MLW. Most installations to date have used a maximum 70 knots bed-entry speed.

Additional assumptions for all designs are that:

A number of overruns in the USA have had less serious consequences than might have been the case due to the presence of an EMAS. Runway 04R at JFK has seen three EMAS-mitigated overruns in which the aircraft have been undamaged and the occupants uninjured including:

- A very late and fast flapless day landing at New York JFK by a Saab 340B in 1999.
- A deep landing at night at New York JFK by a Boeing MD-11F in 2003

Other successful EMAS-mitigated overruns in the US have included:

- A high speed Rejected Take Off (RTO) at Charleston WV by a Bombardier CRJ in 2010
- A deep landing at Teterboro NJ by a Gulfstream IV in 2010.

4. Dealing with the Problem: There is no set of ready out-of-the-box rules to be followed universally. As with any unusual or emergency situation, controllers should exercise their best judgment and expertise when dealing with the apparent consequences of brake related problems and the possible outcomes. A generic checklist for handling unusual situations is readily available from EUROCONTROL but it is not intended to be exhaustive and is best used in conjunction with local ATC procedures.

4.1 One such system provides easily recognizable light indication about the status of the landing gear. The principle is simple - green light when the landing gear is down and locked and red light when there is a discrepancy between the gear lever and landing gear positions. The unsafe indication might be the first sign for a problem, related to the proper preparation of the landing gear for landing. Depending on the aircraft type retraction system the exact nature of the problem may vary significantly.

4.2 Due to big variety of modern aircraft gear design, it could be quite hard for non-professional to distinguish between normal and abnormal gear operation. In case of a partial extension the visual inspection should be done only by qualified professional.

5. Effects :

Landing with main/nose gear that might not be locked/fully extended could result in:

- Gear-up landing;
- Landing with partially extended undercarriage;
- Gear malfunction with subsequent airframe damage.
- All of the above could be followed by runway excursion and post-landing fire inflicting different extent of damage.
- Anticipated Impact on Crew
- In case of a gear problem, the crew bears significant stress. It might need time to fully assess the nature of the problem. Further steps could include crew visual inspection (if viewers are set by aircraft design), manual emergency extension or special maneuvers for forced drop. All of these steps require significant preparation opposed to the time shortage in any unusual situation.
- Several low pass approaches might be necessary to be performed in order to inspect visually the landing gear status and position by qualified technical personnel. The landing with confirmed unlocked gear could result in emergency evacuation of the aircraft. Depending on the situation

the crew might have to brief cabin attendants with any important details to ensure adequate response when on ground.

6. Suggested Controller's Actions:

6.1 Best practice embedded in the **ASSIST** principle could be followed:

A - Acknowledge;

S - Separate,

S- Silence;

I - Inform,

S Support,

T- Time

A - acknowledge the gear problem, ask for the crews' intentions when the situation permits, and establish whether the crew is able to extend the gear into locked position;

S - separate the aircraft from other traffic, prioritize it for landing (allow long final if requested), keep the active runway clear of departures, arrivals and vehicles;

S- silence the non-urgent calls (as required) and use separate frequency where possible;

I- inform the airport emergency services and all concerned parties according to local procedures;

S- support the flight experiencing gear problems with any information requested and deemed necessary (e.g. type of approach, runway length and aerodrome details, etc.);

T- provide time for the crew to assess the situation, don't press with non urgent matters.

6.2 What to Expect.

If a crew has declared gear problems, the controller may anticipate:

- Need of time to resolve the exact nature of the problem;
- Holding pattern request for preparation and execution of manual extension;
- The necessity of time and place to perform specific maneuvers with the purpose of full extension;
- One or multiple low passes for visual inspection;
- Low speed approach;
- Late engagement of ground emergency units;
- Runway blockage after landing.

What to Provide.

Apart from the above mentioned, a controller should consider the following:

- Transfer affected aircraft to another frequency, if applicable;
- Maintain close coordination with ground emergency units - an early call could facilitate the effective deployment of manpower;
- Have direct contact with aircraft operator's technical representative (if possible) - any result of a visual inspection should be passed to the crew without delay.
- Provide a wider range of information to the crew - in case of a maneuver for gravitational drop, the crew will surely need minimum safety altitude.
- NOT certify the down and locked position of the landing gear - the visual inspection during low pass should be done by qualified personnel. If not possible, the tower controller should provide information about landing gear not extended or only partly extended to the aircraft concerned without delay.

Use the proper phraseology as recommended by ICAO for such events, i.e. "The landing gear appears down" and "Landing gear appears up".

If the low pass is made for the purpose of observing the undercarriage, one of the following replies could be used to describe its condition but these examples are not exhaustive:

a) landing gear appears down;
b) right (or left, or nose) wheel appears up (or down);
c) wheels appear up;
d) right (or left, or nose) wheel does not appear up (or down).

Defences

- Provide timely response to crew;
- Allow time and space for the affected aircraft;
- Provide sufficient personnel in order to transfer affected aircraft to own frequency.