Industry Technical Advisory Committee
for oil spill response

Technical Paper:
ADDS Pack Application Rates

- **Benchmarking**
- **Best Practice**
- **Technical Support**
- **Advice**

This technical paper provides details of the adjustments that have been made to the Aerial Dispersant Delivery System (ADDS) pack owned by OSRL/EARL. The adjustments were made to address the problem of dispersant overdosing. The information provided may be of value to all response organisations who own or use an ADDS pack system and are interested in varying the dispersant application rate in order to accommodate a range of spill conditions.

Introduction

The ADDS pack was designed and built by Biegert Aviation Inc. Arizona. The intention was to create a roll-on/roll-off aerial dispersant spray system for use in the Hercules transport aircraft that would require no permanent modifications to the aircraft. The ADDS pack has proven over the years to provide a reliable and effective means of aerially applying dispersant. Figure 1 shows the installed ADDS pack on deployment within a C-130.

Fig. 1

Dispersant overdosing can be a costly activity, both financially and environmentally. Response organisations therefore need to be able to regulate the deposition characteristics of their ADDS packs to accommodate varying oil and dispersant properties. Trials were carried out at OSRL/EARL to find a reduced application rate that still maintains a successful spray pattern, droplet size and areal distribution. These trials were conducted in response to previous activations of the ADDS pack that, whilst providing a suitable response, could have been more efficient in the dosing of dispersant.

Previous Testing

Previous testing of the system was carried out at Memorial Airport Arizona during the initial development of the system. This testing included a series of 22 spray runs that were performed at varying pumping rates and altitudes. Each run was analysed using a series of absorbent cards which were then processed to analyse droplet concentrations across the swath. The cards also permitted analysis of droplet size, by assuming that the diameter of the stain appearing on the card correlated to the diameter of the droplet itself. This method allowed the analysis of the dispersant concentration variation across the swath width. During the first run the system was operated at 8.14 GPM/nozzle, the second was carried out at 6 GPM/nozzle. The method provided limited results as the cards directly under the flight path of the plane became saturated due to the high spray rates. The results may also have been affected by droplet coalescence within the dispersant cloud.

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Deployment Experience

Experience in the use of dispersants is vital to the progressive development of techniques within the field. OSRL/EARL has been involved on a number of occasions in the deployment of the ADDS pack and has a detailed knowledge of its capabilities. The experience gained has resulted in alterations being made to the ADDS packs in order to increase the efficiency of spray sorties. Several missions provided particular stimulus for the improvements to the system.

An incident in Equatorial Guinea resulted in the loss of 200 tons of oil. In response to this the ADDS pack was mobilised from Southampton. 30 tons of dispersant were applied to the spill resulting in a dispersant:oil dosing ratio of 1:7. Further to this an incident in the South China Sea, which was responded to from Singapore, resulted in the reported loss of 60 bbls/ 9.2 tons of oil. This oil was treated with 46 tonnes of dispersant resulting in a dispersant:oil dosing ratio of 5:1.

Given that the ideal ratio would be 1:20 these two incidents clearly indicate an opportunity to improve the system's efficiency, by varying the application rate according to the condition of the spill. In each of the incidents described above, the spill behaviour made spraying extremely difficult. The nature of the oil and the prevailing weather and sea conditions caused the oil to fragment and disperse over a wide area. It was therefore necessary to increase the length and number of spray runs required to target the entire slick. Inevitably at high pumping rates this leads to a significant and potentially harmful overdose of dispersant entering the environment.

The Influence of Spill Conditions

Fig. 2

Fig. 3

Figs. 2 and 3 show two very different spill situations. In Fig. 2 the currents and sea conditions have driven the oil in many directions, creating the potential for an inefficient response. In Fig.3 the oil is leaking from a central point and has formed long thin spurs that may be easily targeted with and aerial dispersant system. These two examples demonstrate that oil spill operators need to consider the specific spill conditions. With increasing knowledge and technological advances in this field, it is no longer acceptable to operate a 'hit and hope' philosophy. It is therefore necessary for organisations to be more responsible and precise in their use of dispersants on oil spills.

Dispersant Application

In order for dispersant application to be effective, the droplet size needs to be controlled. If droplets are too small the dispersant can be blown off target. Smaller droplets (30-100µm) also lack the momentum of large droplets that promotes penetration into the oil. Conversely, if the droplet diameter is too large they will be too heavy and will pass straight through the oil layer. It has been suggested in previous studies that the optimum diameter would be in the order of 300-500µm.

The two main factors controlling droplet size and behaviour are:

- Nozzle shear rate (*Sr*) – Shear rate expresses change in shear deformation over time. It is the rate of change per unit distance in the direction of the shear. This relates to the velocity at which the dispersant is forced through the nozzles. Increasing the expulsion velocity generates a wider and finer dispersion of the droplets. This can be controlled by varying the overall pumping rate or varying the number of nozzles so controlling the pumping rate per nozzle.

- Differential exit velocity (*Vd*) – This is the speed at which a fluid leaves a nozzle relative to the airspeed of the aircraft. In theory if the velocity of the discharging fluid matches the airspeed of the aircraft then the fluid will fall as if in dead air. However if the fluid is released at a velocity significantly less than that of the aircraft speed the emerging fluid is subjected to a severe blast. This has the potential to further reduce droplet size and also increase the areal dispersion of the fluid.

Previous work carried out to define these factors suggested that the ideal setup would be to operate at a Nozzle shear rate of less than 10,000 and a differential exit velocity of less than 124knots. In order to operate within these parameters the recommended flow rate per nozzle is 7.0 GPM/nozzle. This assumes an aircraft speed of 140 knots and the standard nozzle aperture diameter of 0.314" or 7.97mm. Fig.4 shows the spray nozzles used on the ADDS pack.

Fig. 4

This work was carried out as part of a technical paper written to advise ADDS pack operators on the specific use of the system. This paper goes on to recommend an initial average treatment rate of around 4 – 5 GPA, after which the system should be modified according to the results observed. It was according to this data that OSRL/EARL previously operated their systems.

Nozzle Calculations

The following calculations assess the spray characteristics of a particular set up of the ADDS pack. As previously discussed the two main factors affecting the properties of the dispersant pattern from the system are the Nozzle Shear Rate and the Differential Exit Velocity measured in knots.

$$Sr = \frac{39.21 \times GPM / Nozzle}{d^3}$$

$$Vd = Va - \left(\frac{0.242 \times GPM / Nozzle}{d^2} \right)$$

Where:
Sr = Nozzle shear rate
GPM = Gallons per Minute
Vd = Differential exit velocity
Va = Aircraft velocity
d = Diameter of spray nozzle aperture

(equations from previous literature: contact ITAC for details)

These formulae give the following results when the aircraft flight speed is 140 knots and the nozzle aperture diameter is 0.314":

- Fig.5 (overleaf) shows a plot of Vd, Sr and GPM/Nozzle. The red margins plotted on the chart represent the optimum margins dictated by the performance data previously calculated. The performance data for nozzles used on the ADDS Pack recommends a Nozzle shear rate of <10,000 sec^{-1} and a differential exit velocity of less than 124 knots. This gives a range of values (from 6.5 to 8.2GPM/nozzle). These values have been calculated from extensive testing of the nozzle by the manufacturer.

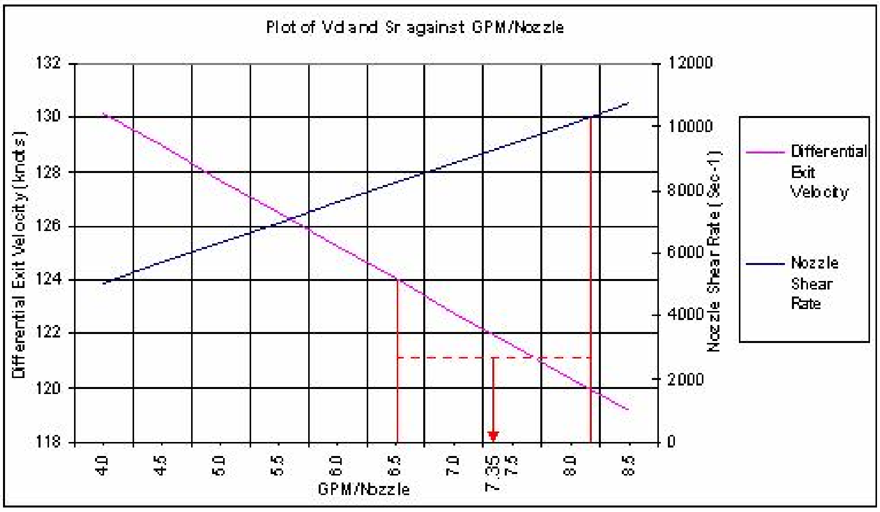

Fig. 5

- Fig.6 shows a plot of nozzle number against pump rate (GPM) for a dosing rate of 7 GPM/nozzle. This plot is of significant importance when spraying with the ADDS pack as it allows quick identification of the required pumping rate for desired number of nozzles. It would therefore be useful to incorporate a copy of this chart into the flight literature to permit alteration of the dosing rate in accordance with the spill conditions encountered.

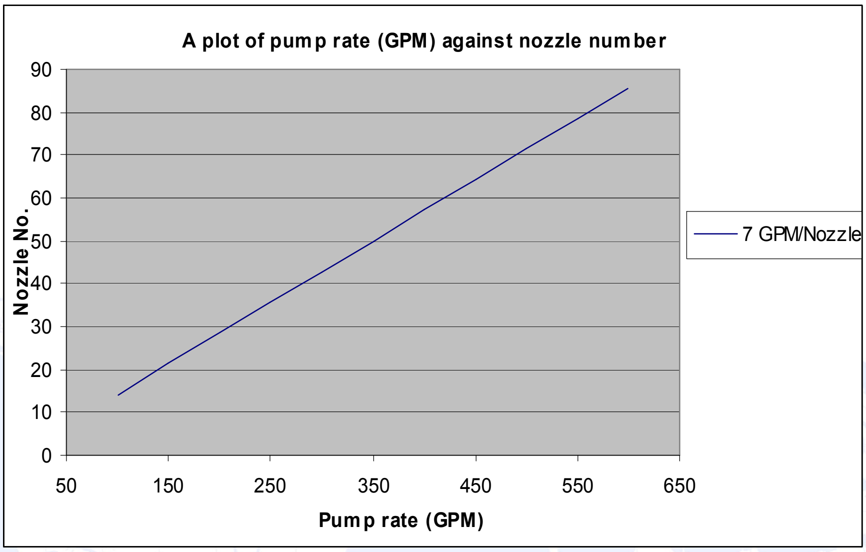

Fig. 6

Work Rate Calculations

In order to calculate the work rate of the aircraft the following equation can be used:

$$WorkRate\,(acres/\min) = \frac{Swath\,(ft) \times AircraftSpeed\,(knots)}{430}$$

The speed of the aircraft is set at a standard of 140 knots. This speed provides the correct nozzle shear rate and differential exit velocity, and is also safely above the stall speed of the aircraft. The swath width generated during previous test flights is confirmed at 150ft, or 45.72 m.

As the ideal properties required for the calculation are constant, the value for work rate is around 48.84acres/min. Any alterations in the velocity or swath width need to be accounted for within subsequent calculations.

The dispersant dosage from the system may then be calculated using the following formula:

$$DispersantDosage_{G/Acre} = \frac{PumpRate_{GPM}}{WorkRate_{Acre/Min}}$$

The pump rate is dictated by the set up of the system according to the number of nozzles used. The dispersant dosage value may therefore be used to tailor the system to obtain the most appropriate spray rate for the treatment of a spill. In order to do this it will be necessary to assess the properties of the oil and the environmental factors affecting it.

OSRL/EARL Adjustments

The research previously described was carried out in order to fully understand the feasibility of adjusting the ADDS pack to suit varying oil spill characteristics.

OSRL/EARL has previously maintained their ADDS packs to be deployed with 50 nozzles and operated at a pump rate of 350 GPM. However, the experiences described earlier led to the conclusion that this is a particularly high application rate.

Following the guidelines set out in this document, the system output was reduced to prevent overdosing on spills where oil is widely fragmented. The system was 'stepped down' to only 34 nozzles and a pump rate of 238GPM. These values maintain the recommended 7 GPM/nozzle. These alterations also reduced the dispersant dosage from 7.17G/Acre to 4.88G/Acre.

The physical adjustments that were made to each boom arm of the ADDS pack are shown in Fig.7.

Fluorometry and other monitoring methods can be used to observe the action of the dispersant in the slick below and report this information back to the plane. The boom arms can then be retracted into the aircraft during the flight and alterations made to the number of active nozzles if necessary. Altering a nozzle to become active or inactive is a relatively simple task; the temporary blanking caps can be quickly removed from the Teejet nozzles and replaced with the active apertures.

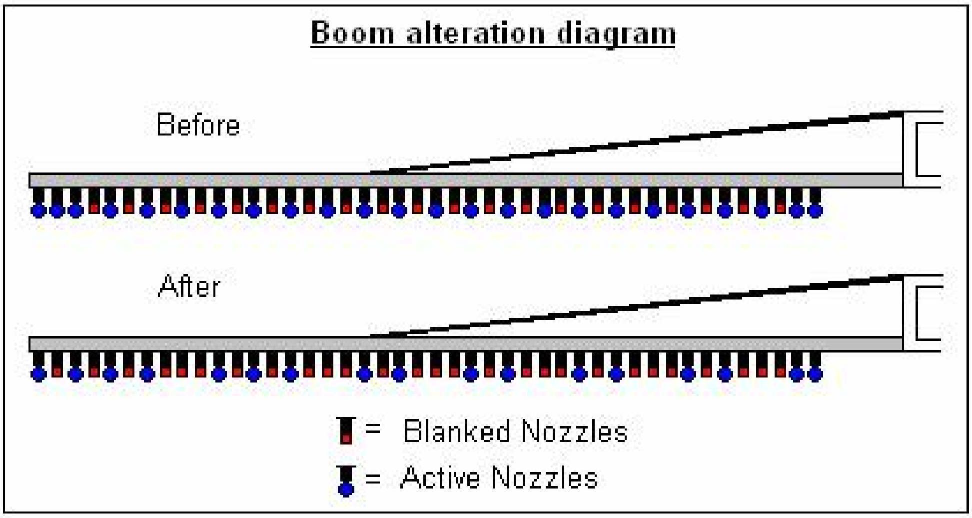

Fig. 7

Fig.8 shows an active nozzle with the narrow aperture to its rear. Fig.9 shows a nozzle that has been blanked with a temporary blanking cap. In the foreground of Fig.9 there is a more permanent blanking plug screwed directly into the boom. These are changed by simply twisting off the cap and replacing it with the alternative.

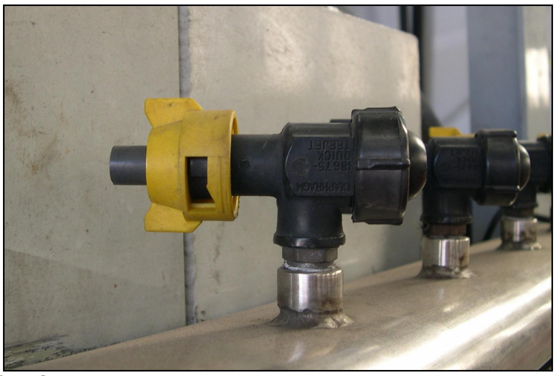

Fig. 8

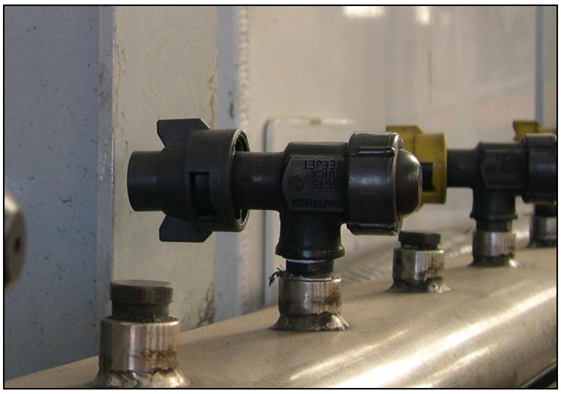

Fig. 9

The alterations made to the ADDS pack by OSRL/EARL are represented graphically in Fig.10. This plot shows the nozzle requirements for the previous spray rate of 350GPM and the new spray rate of 230GPM.

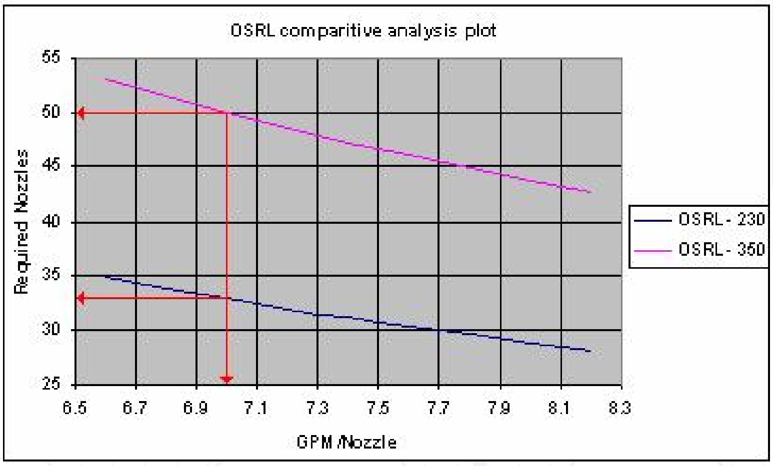

Fig. 10

Summary

Alterations to the spray arms were made according to the following rationale:

- Fragmentation and surface distribution of an oil slick increases the length of spray runs required and the possibility of poor targeting of oil, which increases dispersant use. The increase in surface area of the slick will naturally reduce the oil thickness, thereby reducing the need for heavy dispersant dosing.
- The environmental impacts of using dispersants on an oil spill is often heavily debated. Defining the required dosage more accurately reduces the risk of overdosing and environmental harm.
- The logistical implications of overdosing are severe; with limited stockpiles the availability of dispersant may mean that a more sparing approach is beneficial.
- There are significant financial implications of wasting dispersant, as too high an application rate will use dispersant unnecessarily. This not only increases the cost of dispersant, but also the logistical costs associated with transporting the material.

Conclusions

This ITAC Paper recommends changes to the steady-state settings of the ADDS Pack, in order to achieve more efficient dispersant application.

Configuring the ADDS Pack to reduce the dispersant application rate is expected to be beneficial, as in the majority of spills attended oil spreads to cover a large area with a low oil thickness.

Nonetheless, every situation is different, and the nozzle configurations may therefore need to be re-adjusted subsequently. These adjustments would increase or decrease the application rate according to the type, distribution and thickness of oil.

The new configuration of the ADDS pack enables adjustments to be carried out either prior to the flight or in relation to in-flight observations and communications.