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COMPUTER PROCESSING OF VISUAL RECORDS FROM THE THORNEY ISLAND LARGE SCALE GAS TRIALS

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Summary

Digital image processing of the airborne video record of trials Nos. 007, 008 and 014 of the Thorney Island trials were performed. Comparisons were made with previous processing reported at this Symposium and a good agreement was observed. The processing was extended to the determination of the motion of the cloud edges.

1. Introduction

The present work consists of computer processing of the visual records taken during the experiments organized by the HSE in the Thorney Island large-scale gas trials.

During the tests, concentration sensors were deployed over a large area, and therefore little is known about the first seconds of release. However, for most of the tests, video and still recordings were taken, both from a helicopter and from ground level.

Processing of some of this visual material has already been carried out [1] . The graphical technique described in [1] is straightforward but not suited to the processing of a large number of frames. Since this technique relies on the use of still frames, the interval between processing is governed by a framing rate of one frame every 1—2 seconds.

The digital processing of images from a video tape may produce data at a rate of 25 or 50 frames per second. This is particularly important if one wants to determine the initial accelerating motion of the cloud.

The present work aims at improving the knowledge of this phase of the release. The need for this information is emphasized by the fact that no gas sensor was present in the cloud during the initial moments, and therefore data obtained should not only be a back-up but also a complement to the sensor data.

2. Description of the digital image processing system

2.1 Hardware

The digital image processing System (DIP) used at the von Karman Institute (VKI) is implemented on a PDP 11/34 computer. The general structure of this DIP is shown in Fig.1.

The pictures to be processed may be on slides which will be imaged by a black and white video camera, or may be on video tapes. A frame grabber converts each frame into digital form and stores it as a 256 × 256 matrix. The content of this memory is read by a colour encoder which displays each frame on a colour monitor with 256 different colours encoding an identical number of levels of grey.

The frame grabber, the memories and encoder are connected to the DEC UNIBUS; their operation is controlled by software. It is possible to freeze a certain frame and then dump the image memory on core memory or disk. Once this is achieved, subsequent processing may be started. A processed image will be dumped from core memory to image memory and hence dis-

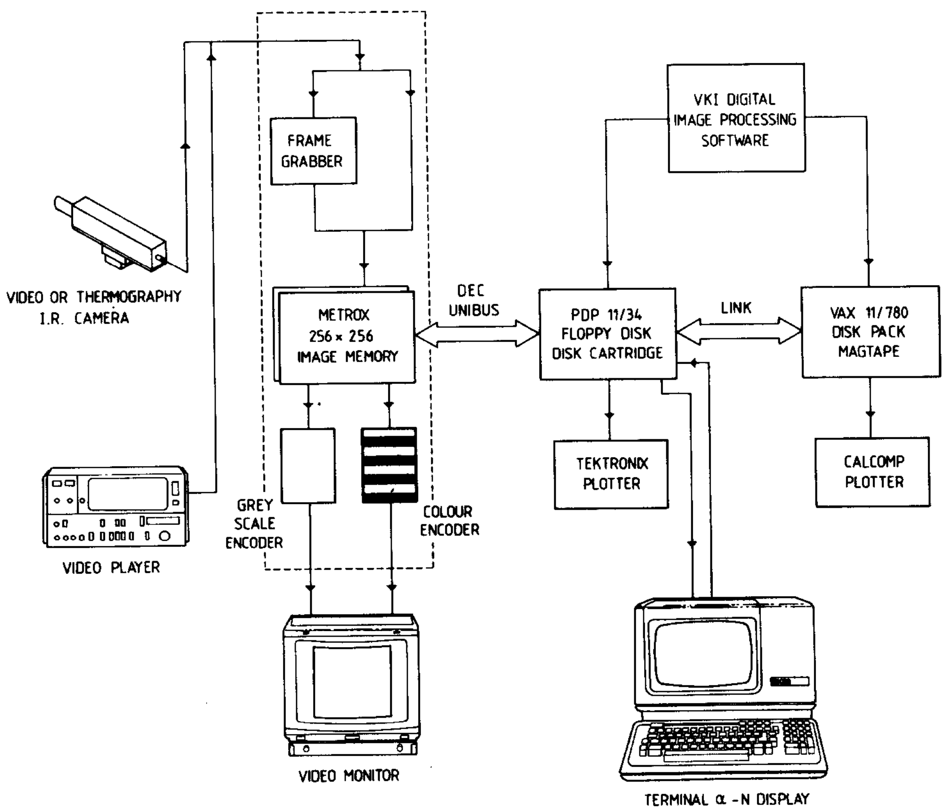

Fig.1. Digital image processing system.

played on the monitor. It is also possible to use the plotter of the computer to obtain a graphical output.

Image processing most often involves the processing of a large matrix and therefore may become a lengthy process. This is why the PDP 11/34 is linked to a VAX 11/780 which is far more powerful and able to handle extensive processing.

The operation of the whole system involves control over two computers and many peripherals. Specialized software has been written in order to fulfil all the necessary tasks.

2.2 Software

The existing software allows the user to perform the following operations:

- single frame grab;
- multiple frame grab;
- display frame with given number of arbitrary colours or levels (8, 16, 32 or 256); also allows to select a range of colours or levels (and hence suppress a range);
- filter — spatially filters an image;
- display graphs of levels; a plot of the distributions of levels along a vertical or horizontal cursor is made;
- zoom — a part of the image is selected and enlarged to full screen size;
- normalization — an image is normalized with another reference image;
- determination of the histogram of densities;
- determination of contours;
- subtraction of images;
- evaluation of areas (on well contrasted pictures).

This software package has been created following the requirements in multiple fields of interest and although it is capable of powerful functions, not all the functions required for the present objective existed. It was therefore necessary to develop specialized software to complement the existing package.

2.3 Specialized software

Specialized functions have been added to the existing software in order to fulfil the present task. These are:

- Creation of a "window" in the image: in most cases, the cloud to be analyzed covers only part of the screen. The "window" is the minimum polygon which includes the cloud. This allows a reduction in the number of data to be processed. Alternatively, the window can be given a circular shape.
- Data compaction: the analysis of the contour of the cloud only requires binary data — cloud or no cloud. The image is transformed into binary form, thus reducing the number of data to be handled by a factor of up to 16.
- Determination of cloud contours.

- Fill overall area covered by the cloud with a single colour.
- Creation of a reference grid.
- Scaling on a reference length (runway most often).
- Scaling of the image.
- Determination of:
  location of center of cloud;
  cloud contour coordinates;
  area of cloud.
- Storage of results.

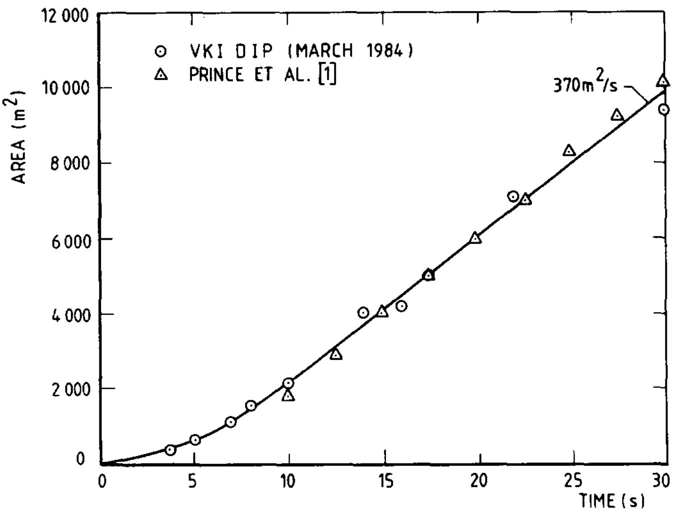

Fig.2. Cloud area vs. time; Trial 007; windspeed 3—4 m/s.

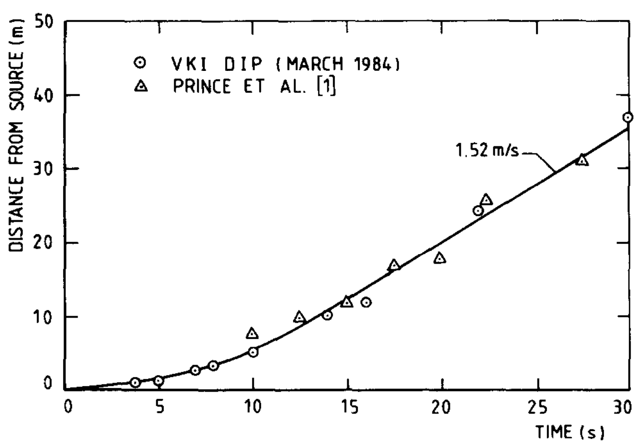

Fig.3. Distance of centroid from source vs. time; Trial 007.

3. Results of the processing

3.1 Validation of the method

Trials Nos. 007 and 008 have been the first ones to be processed in order to be able to verify the method. A good reference existed since manual processing of the pictures taken during these tests had been performed in

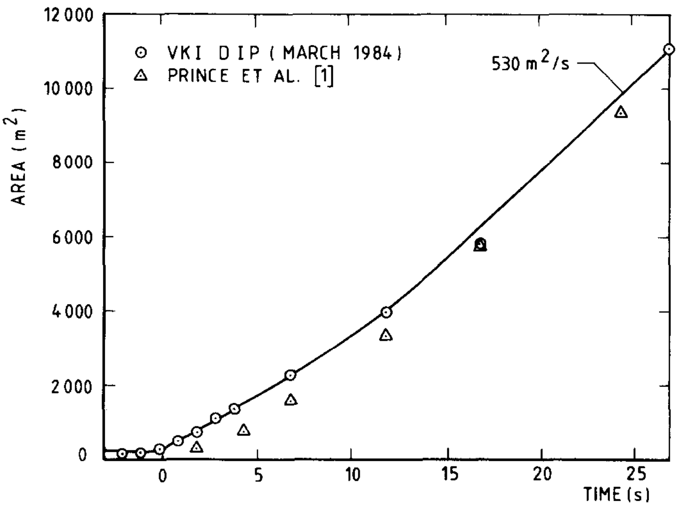

Fig.4. Cloud area vs. time; Trial 008; windspeed 2—3 m/s.

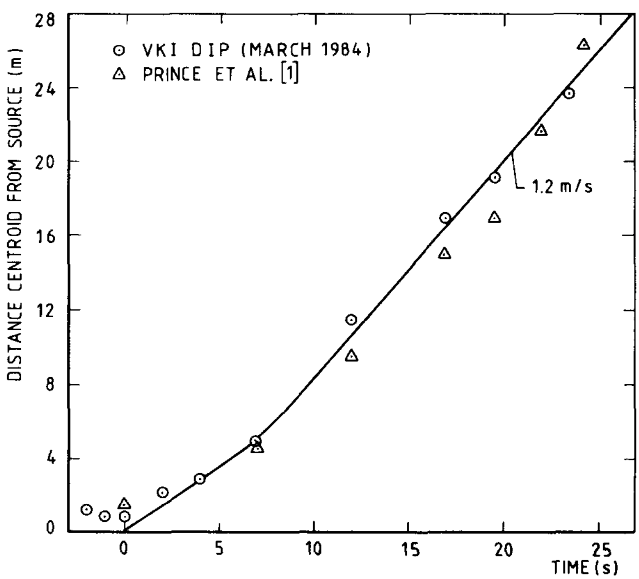

Fig.5. Distance of cloud centroid from source vs. time; Trial 008.

[1]. In this reference, cloud area and centroid location were plotted against time.

After processing with the DIP system, a comparison was made with the results of [1] and good agreement was obtained, as shown in Figs.2 and 3 for Trial 007 and in Figs.4 and 5 for Trial 008.

Because of the variable time delay between the release of the lid and the release of the bag, it was necessary to shift the results of [1] along the time axis. This was achieved by evaluating the time delay from the ground-based video records.

For Trial 007, this correction was unnecessary but it was needed for Trial 008 in which a shift of 3 s was introduced and for Trial 014 in which a shift of 4 s was used.

There still remain some doubts about exact bag release time since it seems that the clock used with the airborne camera was not always reset together with the ground based one. This became obvious from the latest video tapes. In all cases, initial time was chosen as the time the bag started to fall.

Advantage has been taken of the processing of Trial 014 to further validate the present method, and it is evident from Figures 6 and 7 that good agreement was obtained.

Smooth curves were drawn through the data without an automatic curve-fitting procedure.

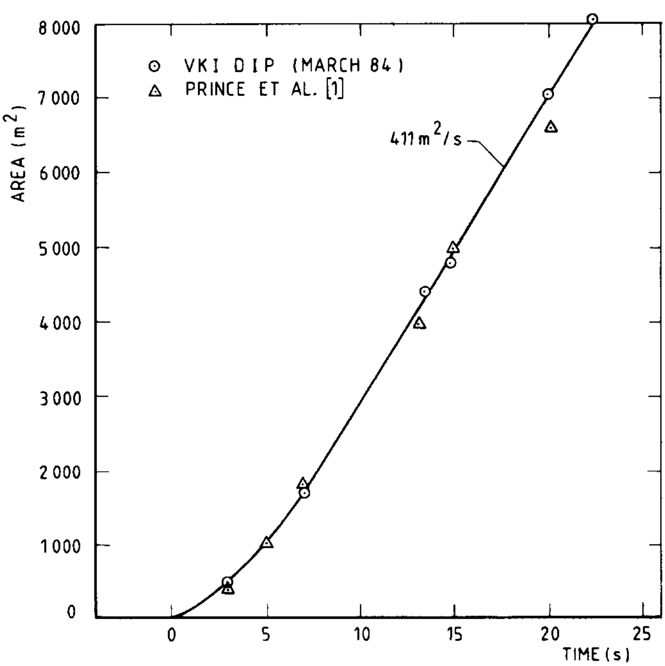

Fig.6. Cloud area vs. time; Trial 014; windspeed 5—6 m/s.

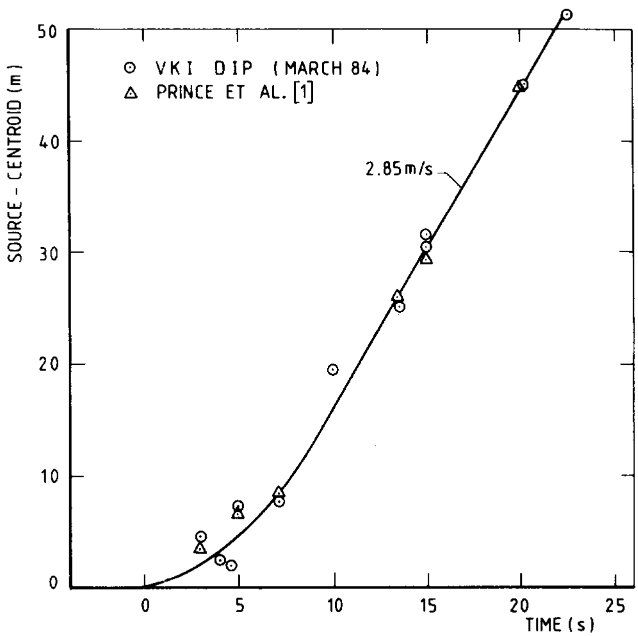

Fig.7. Distance of cloud centroid from source vs. time; Trial 014.

3.2 Results

Besides the duplication of the manual processing of SRD [1] , further information has been obtained. Figure 8 shows the distance of upwind and downwind front from the source versus time. This distance is always counted from the source and is therefore positive for both.

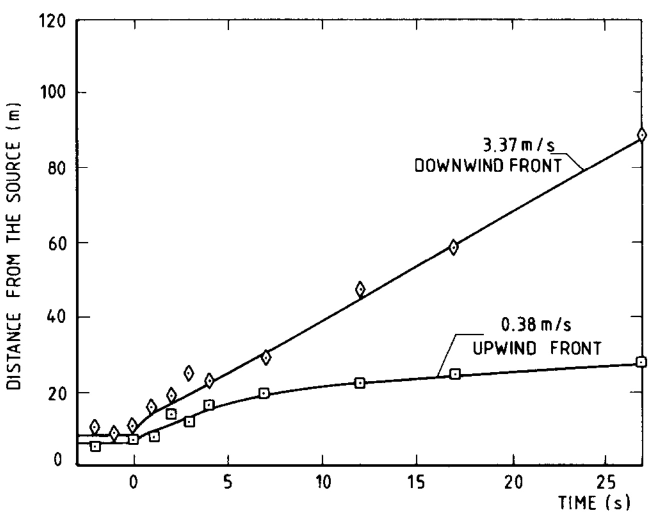

Fig.8. Distance of fronts from source vs. time; Trial 008, VKI DIP.

In Fig.9, the distance of these fronts from the centroid of the cloud is plotted against time. The side fronts (transverse to the wind) have not been represented in this figure but they fall on the same common curve.

A similar exercise has been carried out for Trial 014. Figure 10 shows the distance of fronts from the source, while distances from fronts to centroid are plotted in Fig.11. In the latter, side fronts have been represented.

In Fig.12, the path of the centroid of the cloud has been plotted for Trial 014. On the cloud path, time markers are indicated in seconds.

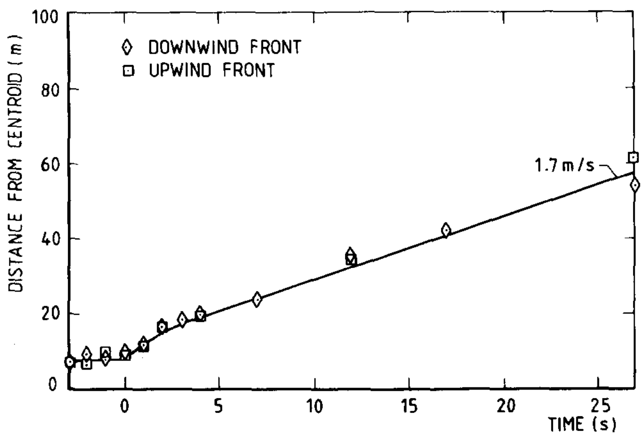

Fig.9. Distance of fronts from centroid vs. time; Trial 008, VKI DIP.

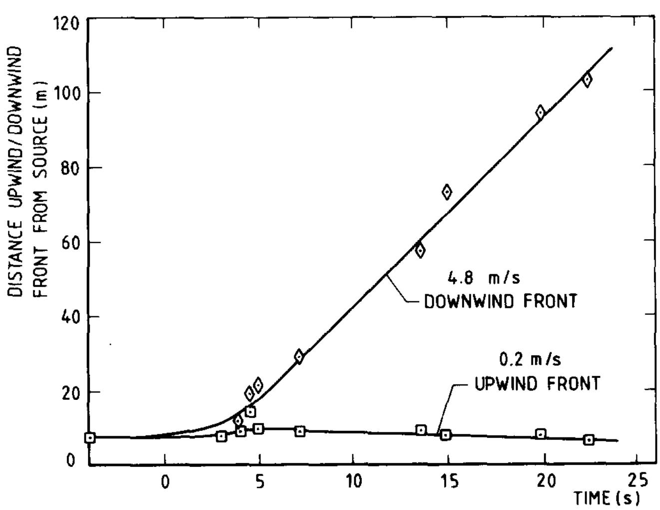

Fig.10. Distance of fronts from source vs. time; Trial 014, VKI DIP (March 84).

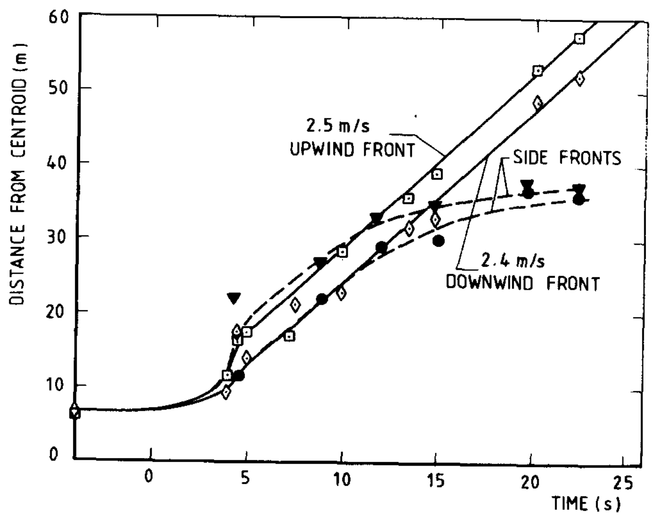

Fig.11. Distance of fronts from centroid vs. time; Trial 014, VKI DIP.

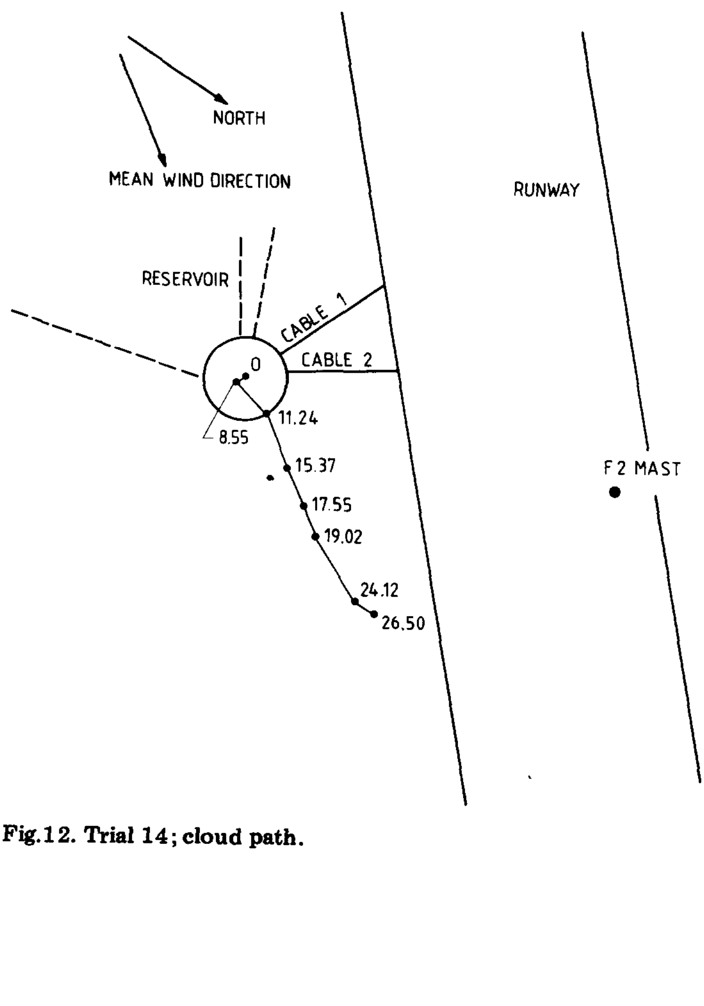

Fig.12. Trial 14; cloud path.

4. Discussion of the results

4.1 Assessment of the technique

It is apparent that valid results may be obtained even though the quality of the video tapes is not perfect.

In some instances, such as in Fig.7, a relatively large scatter was obtained. This was due to the difficulty encountered in locating the source when the cloud was still hiding it. This problem has since been overcome by defining a set of auxiliary references by choosing prominent objects easily visible during this phase. The locations of these auxiliary references were determined using an image on which the source could be located.

4.2 Detailed results

The outcome of the processing of Trial 008 is that, as seen in Fig.7, the cloud was not affected by the wind during the first 25 s. The fronts moved radially at equal velocity from the cloud centroid. This appears to indicate that during this period most of the process was dominated by gravity effects. This is to be expected since Trial 008 corresponds to a relatively low wind speed.

On the other hand, Trial 014 has been performed with wind velocities of the order of 5 to 6 m/s. Figure 11 shows upwind, downwind and side fronts displacement. For the first 10 s, the cloud was seen to be expanding radially in a uniform way. After 10 s, the side fronts very rapidly stopped expanding while the upwind and downwind ones moved at almost constant velocity. This appears to indicate that, in this particular trial, gravity was the dominant factor during the first 10 s of the release and atmospheric turbulence took over thereafter.

Finally, it is interesting to note that the cloud path of Trial 014 shown in Fig.12 was very well aligned with the average wind direction. This is not too surprising and confirms the coherence of the data.

5. Conclusions

At the present time, processing of the video tapes is still underway and a much more detailed analysis is needed to extract all useful information from these results. It is intended to use them to validate laboratory tests and numerical models.

Although incomplete, the present work has demonstrated the high power of digital image processing in such an exercise and it is hoped that further useful information will be extracted in the near future.

Reference

1 A.J. Prince, D.M. Webber and P.W.M. Brighton, Thorney Island Heavy Gas Dispersion Trials — determination of paths and area of cloud from photographs, Report SRD R318, Safety and Reliability Directorate, UKAEA, Culcheth, UK, 1985.