SPECIALISED IMAGING

RESEARCH ARTICLE

Instrumenting Cylinder Expansion Test. EMTAP Test No44

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Instrumenting Cylinder Expansion Test. EMTAP Test No44

Purpose: To determine the work done or force generated from a confined detonating explosive charge. Data obtained is used in an "equation of state" process in material modelling programs

Objective: To instrument the test in accordance with Method Statement. The test is instrumented using a streak camera imaging technique. A streak camera is used to give a continuous record of the event, producing a homogenous time/distance chronology of the expanding cylinder walls. The provision of a framing camera used in tandem with the streak camera, whilst giving a time partitioned image sequence, will provide high resolution discreet images of the event that will relate directly with streak record obtained.

Camera Imaging System

The Specialised Imaging Combined Framing and Streak Camera System. A combined optical system, incorporating two types of camera, and sharing a common optical path in order to image the explosive events.

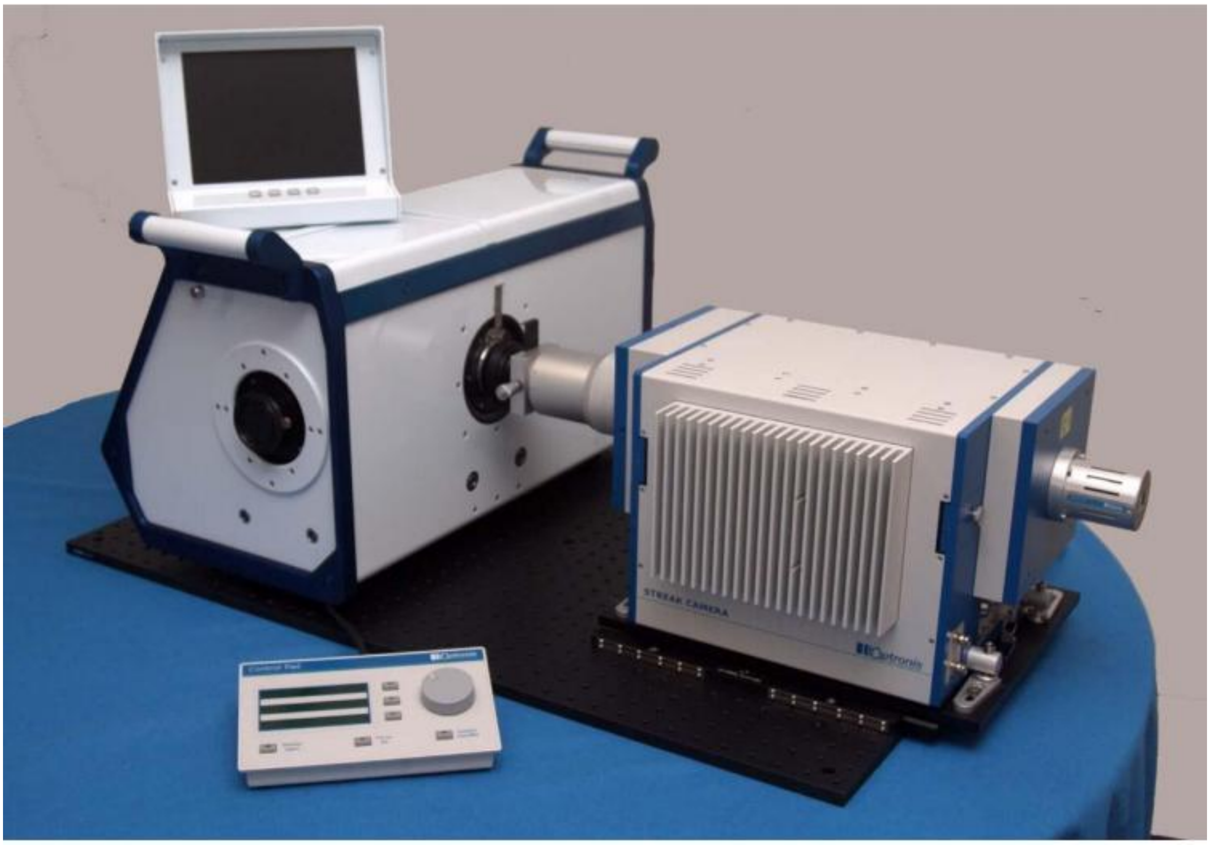

Fig 1. The Specialised Imaging Combined Framing and Streak Camera System incorporating a Specialised Imaging SIM 16 Channel Framing Camera coupled with an Optronis SC10 Streak Camera.

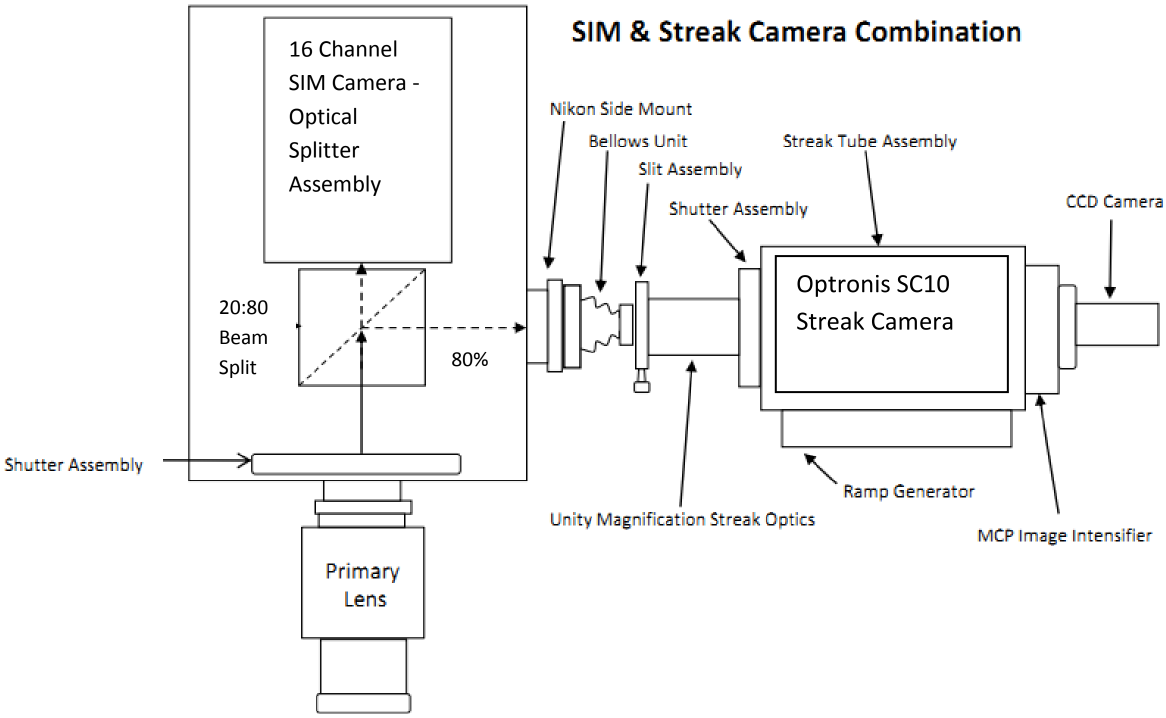

Fig 2. Schematic of Camera linkage and Optical path

Optronis SC10Streak Camera Features and Specification.

- Modular Design
- Exchangeable sweep units
- Local Control via control pad
- Easy to use software Package
- 100 Mhz Ethernet interface
- TCP/IP Protocol

Broad range of scientific applications

Temporal resolution down to 2ps

Synchroscan up to 250 MHz

Dual sweep possible

High Dynamics

SI SIM 16 Channel Framing Camera Features and Specification

- 16 individual channels
- Auxiliary optical interface
- Single input beam splitting optics
- Lenses: Nikon F Mount
- Image Sensor ICX285AL
- Active CCD Pixel 1360(H) x 1024(V)
- Dynamic range: 12 Bit

Dynamic resolution 36lp/mm

Exposure Times 3ns – 10ms

Inter-frame Times 1ns – 1ms

Dynamic Resolution 50lp/mm

Framing Rate up to 1 Billion fps

Delay to first exposure 50ns -10ms

Focus Monitor 8.4” TFT + keypad control

Process: A copper cylinder 301mm long with an internal diameter of 25.4mm and a wall thickness of 2.5mm is filled with the test explosive. The filled cylinder is placed in a vertical orientation and an initiating system is attached to its top end. The initiation system should be of the high voltage type in order to facilitate reliable synchronisation for the streak camera instrumentation system. The performance characteristics Velocity of Detonation in mm/µsec) of both the initiating system and the charge under test need to be established prior to conducting this test.

Streak Camera Set-up:

The test charge should be imaged through the streak camera "slit" such that the slit bisects the vertical image of the cylinder 200mm down from its initiation point. The camera field of view should be 7 times the outside diameter (o/d) of the test cylinder with the centre line of the cylinder bisecting the slit at its mid point. The streak camera writing speed / recording rate should be matched to the anticipated duration of the event. The time-frame required must encompass the total movement of the cylinder walls, from initial movement, out to a point of at least 2 diameters either side of the cylinder outer edge. Ideally the duration of the recording period should be of sufficient length to incorporate the cylinder wall failure. The typical initial wall movement velocity will be in the order of 0.5 -2mm/ µsec, possibly accelerating to 4mm/µsec as the cylinder wall fails. Therefore, a recording period of 50µsec will be sufficient to capture all cylinder wall movement. An imaging point, 200mm down the cylinder length, is used in order to sample a point in the test charge where the effects of the initiator system are no longer present and the test charge is performing on its own. The event is illuminated using back lighting through a translucent diffuser screen. The expanding cylinder walls will produce a dark silhouette against a bright white back ground. This produces a high definition (contrast) image that best facilitates later analysis. Given the highly destructive nature of this type of firing, if the camera system is to look directly at the event it should be fully protected. Housing the camera system in an armoured cabinet with at least 3 sheets of double ply anti-bandit glass in front of the lens. The safest option is to look indirectly at the event by way of a turning mirror. The mirror will have to be of high optical quality. The use of a mirror will enable the number of armoured glass sheets to be cut down to one.

Framing camera Set-up

The field of view of the framing camera will be the same width as that of the streak camera however the frame height will be considerably greater. This will facilitate the capture of high resolution images at individually pre-programmed points in time. The images obtained will produce a direct "translation" of the streak images therefore providing full visualisation of the event captured. The back-illumination system used for the streak recording will be suitable for the framing camera which will then utilise the light emitted from the detonating explosive within the deforming copper cylinder.

Illumination Light Source.

Given that the type of event being recorded is extremely destructive (blast and fragmentation, a disposable light source is an essential requirement.

There are three types available.

- **Argon Flash Bomb**. This is an explosively driven device which produces an intense short duration burst of light as a result of a volume of Argon gas incandescing as a result of being shocked by an explosive charge. The light emitted has a duration of some 60µsecs and burns at 7000°K. They have a build up time in the order of 20µsecs. These devices can compromise the event being recorded and add significantly to the explosive quantity used in the firing.

- **Photographic Flash Bulb**. These devices produce an intensely bright light from a conventionally shaped lamp bulb. The peak light duration is approximately 30 milliseconds and their peak intensity is reached after 15 milliseconds. Their relatively long duration simplifies synchronisation with the event being fired. They can be placed very close to the experiment without compromising it as is the case with Argon Flash Bombs.

- **Overdriven LED Lamps**. LED lamps can be used when subjected to very high voltage inputs > 5Kv. Typical light duration is 100µsecs with only approximately 10µsecs ramp up time. As with Flash Bulbs they can be placed near the event without compromising it.

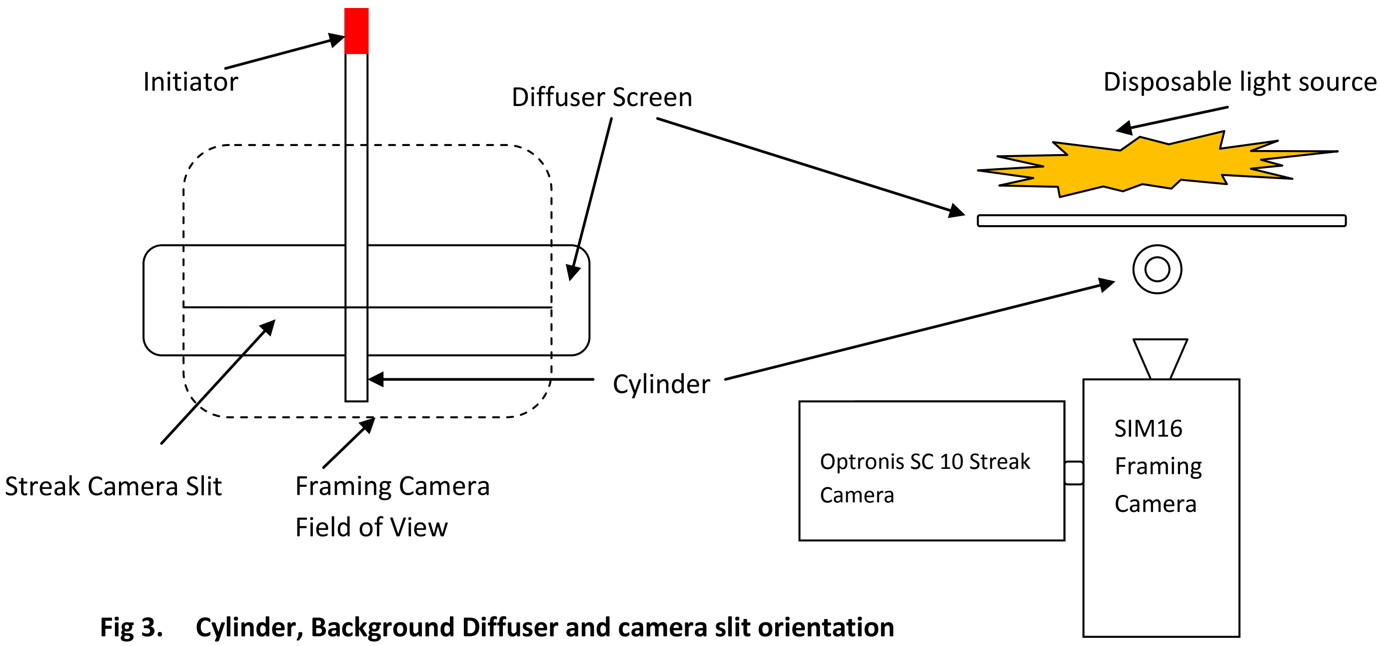

Fig 3. Cylinder, Background Diffuser and camera slit orientation

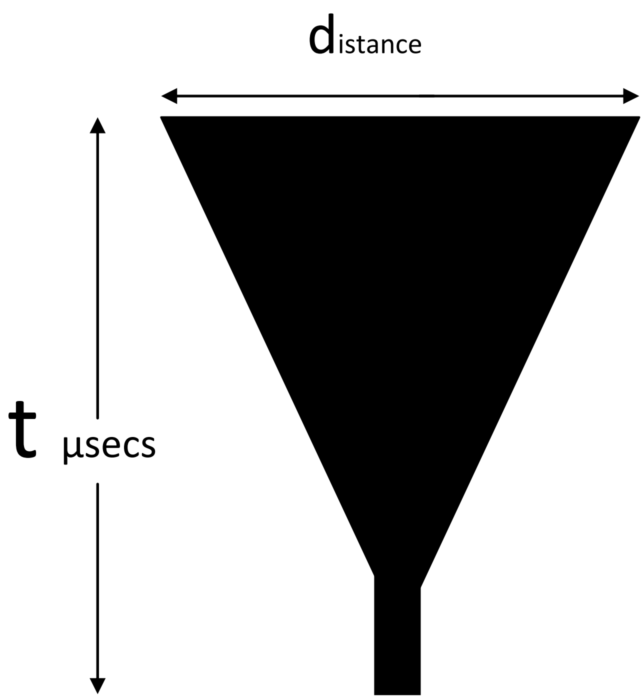

Fig 4. Simulated Streak Image of the event:

From the resulting streak image it is a relatively straight forward operation to plot the distance of cylinder wall travel (d) against the time (t) taken to reach the cylinder wall failure point. Cylinder wall failure point is observed when the continuous line formed by the silhouette of the expanding cylinder wall starts to fragment.

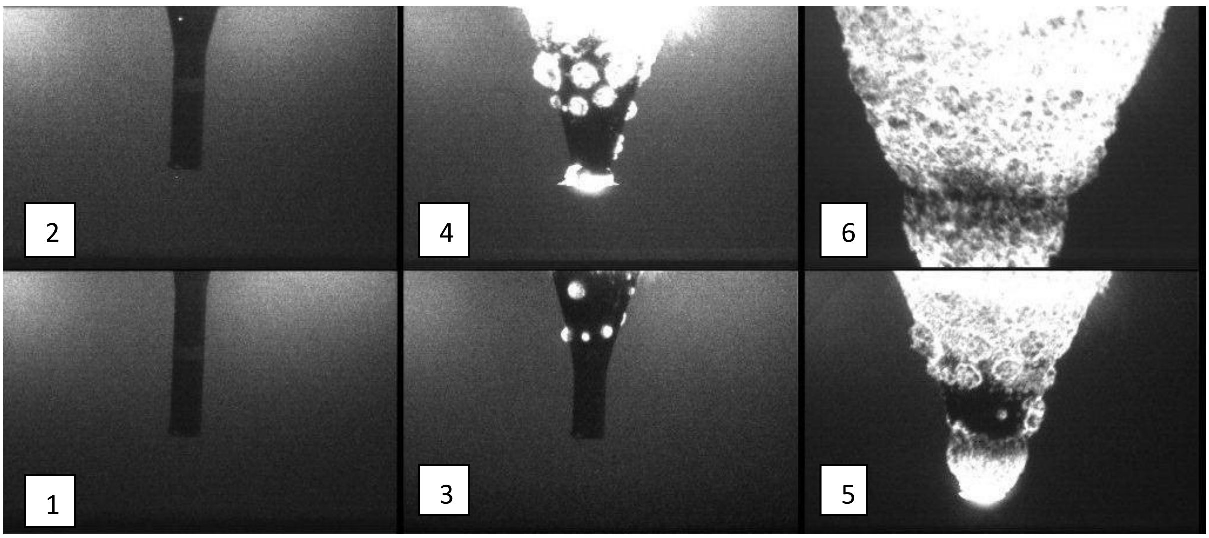

Fig 5. Framing Image (inverted) of a Cylinder Expansion test.

In order to capture the expanding cylinder event there are potentially complex synchronisation issues that need to be addressed. It is therefore essential that the whole process (firing as well as instrumentation activities) is accurately time managed with microsecond accuracy. This can easily be achieved using a multichannel delay generator (SI 4DU), incorporated into the fire control system.

Synchronisation factors: Camera operating Delay Streak recording at 2.5 µsec/mm providing a recording window 50µsec duration, delay from trigger = 85 µsec

	Framing camera delay from trigger = 70ns
Illumination System	Argon Flash Bomb = 20 µsec to peak output
	Over-driven LEDs 10-30 µsec to peak output
	Photographic Flash Bulbs – 20 milliseconds to peak output
Explosive booster	EBW detonator = 1.5 µsec +Booster Pellet = 25mm deep = 3 µsec
Test Cylinder Composition	Estimated Velocity of Detonation (V of D) = 8mm/ µsec over a distance of 200mm to the imaging point = 25 µsec

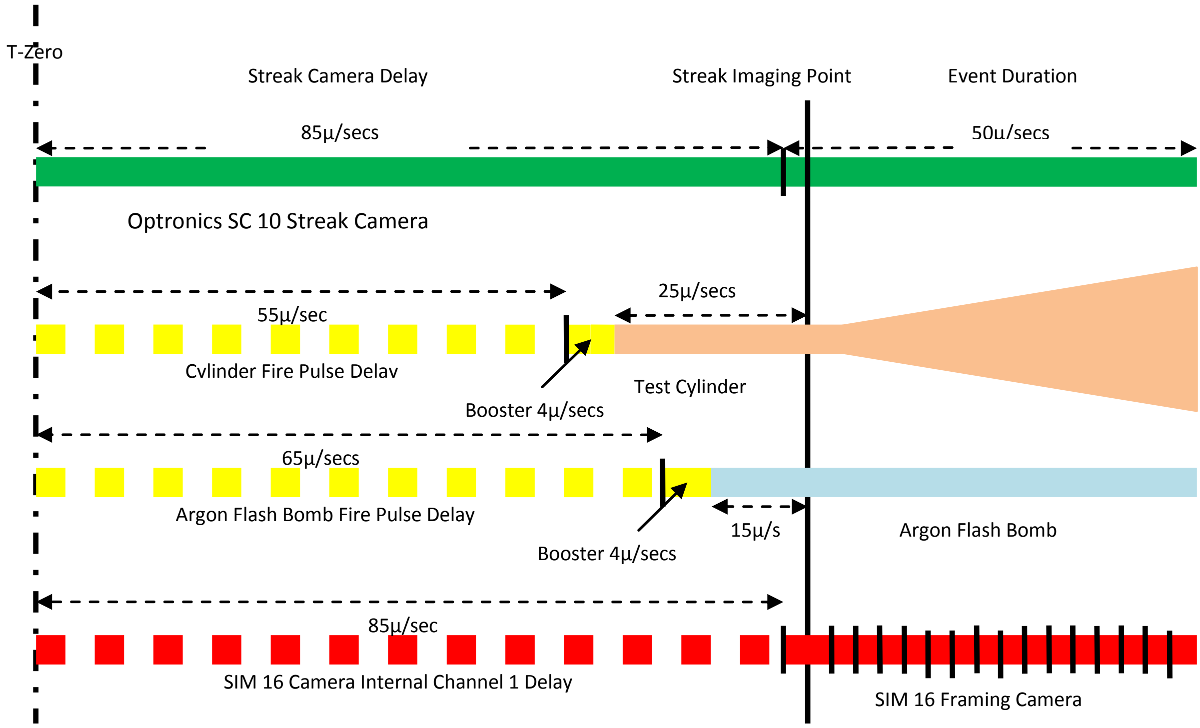

Fig 6. Streak & Framing Camera Synchronisation Schematic