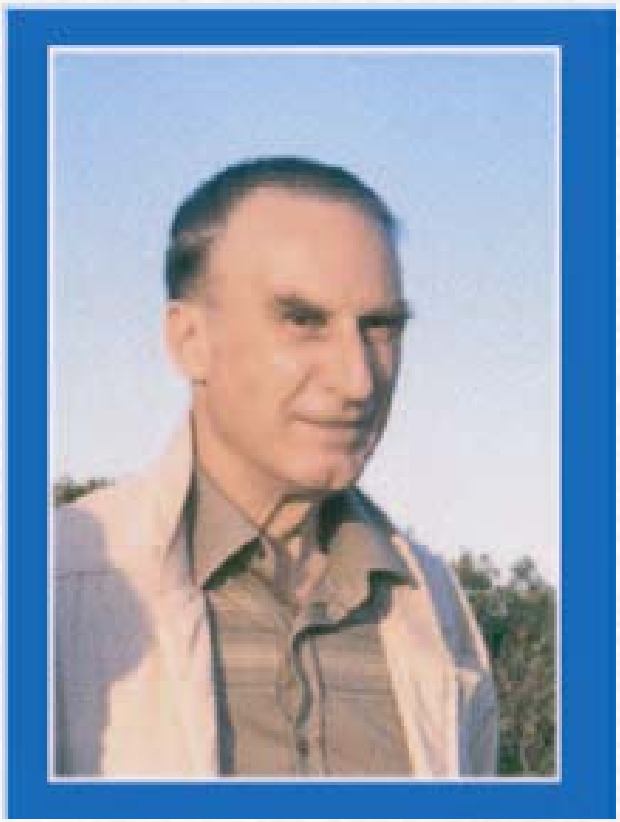


Prof. D.H. Edwards: A career in detonation and explosion Science reviewed

Compiled
by
Geraint Thomas
Presented
by
Gwyn Oakley

Career Overview

- Huw Edwards graduated from the University of Wales, gaining a First Class Honours in Physics in 1946
- He successfully completed a PhD "*The determination of the pressure in detonation waves in various explosive mixtures*"in 1949
- he received a second PhD following a period as a research assistant in Cambridge, working on the permeability of soils and potential flows in porous media
- He returned to Aberystwyth in 1954 to continue work on gaseous detonation, as an ICI Research Fellow

Initial interests on his return

- The first paper on detonation published after his return to Aberystwyth, in Nature , was a study of the influence of tube diameter on detonation velocity deficits and the associated pressure profiles.
  - This had been preceded by technical notes on a mercury vapour light source for use with a streak schlieren camera and on the static calibration of quartz pressure sensor elements

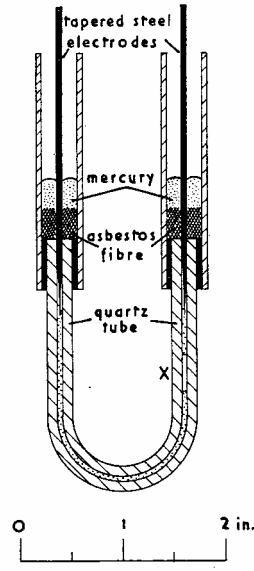


Fig. 1. Section of mercury discharge lamp

Miniature pressure bar gauge

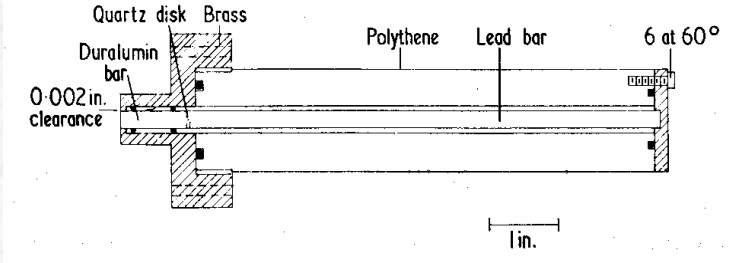
- An important part of his subsequent studies was his involvement in the development of the miniature pressure bar gauge, a development and miniaturisation of the Hopkinson pressure bar which had been studied in detail by the head of the physics department at Aberystwyth, Professor R.M.Davies

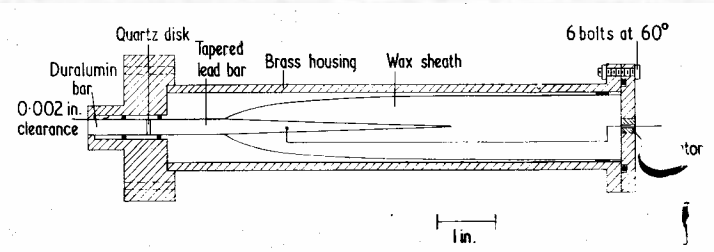
Miniature pressure bar gauge

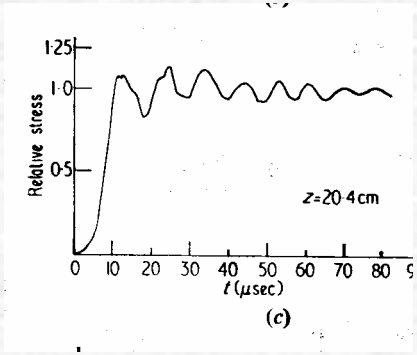
The basic gauge design comprised a quartz crystal sandwiched between an earthed front bar made of duralumin and a lead backing bar, connected to the recording equipment

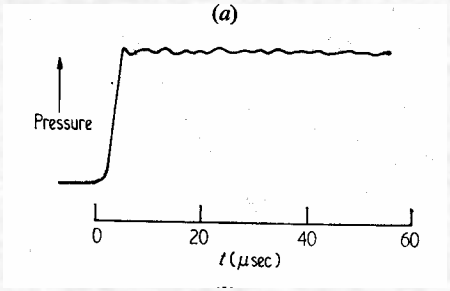
To reduce unwanted reflections further, in the final design, the lead bar was tapered and encased in an acoustically matched wax sheath.

In this way prominent longitudinal wave reflections obtained with the original long bar were almost completely eliminated



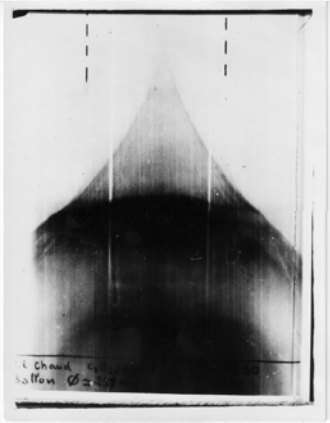




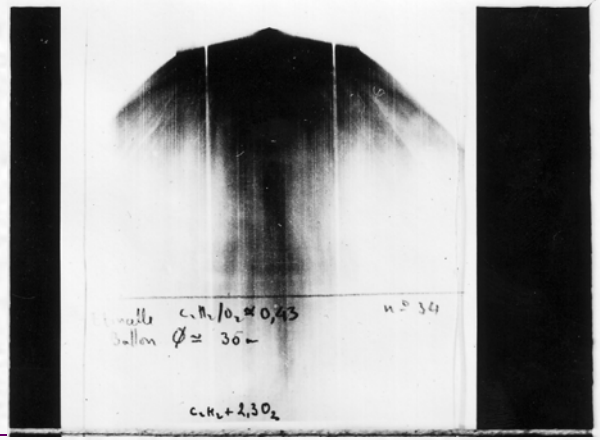


Further historical note

It is highly likely that the the Hopkinson pressure bar gauge was the catalyst that gave rise to the study of detonation waves at Aberystwyth.
This probably arose following the interest expressed by Prof, G I Taylor at Cambridge in using a Hopkinson bar configuration to investigate unconfined spherical detonation.



Taylor's hope, outlined in a letter to Davies, was to prove by experiment that his theoretical work on spherical detonations was correct and that the assertions by French researchers that spherical detonations could not exist were incorrect. In fact the first evidence they could was sent to G.I. by Numa Manson in Poitiers.
Images that he forwarded immediately
to RM in Aberystwyth



First detonation experiments at Aberystwyth

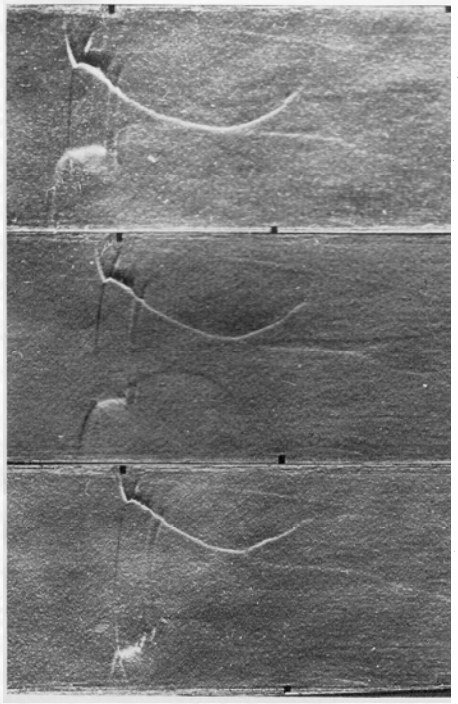
From anecdotal evidence recounted by Huw we know that some experiments were attempted at Aberystwyth one Sunday morning indoors in RM's basement laboratory at the physics department.

These involved balloons filled with c_2h_2-O_2 or H_2-O_2 ignited by sparks or the detonator from a Christmas cracker, with the unfortunate consequence that several of the stained-glass panels in the windows that form the present-day administrative headquarters of the University were blown out. Fortunately nobody was injured within the building or on the seafront promenade outside.

The extent of Huw's involvement in the indoor experiment at Aberystwyth is not known but it must have played a significant part in stimulating his research into understanding gaseous detonation by means of detailed and methodical pressure measurement.

Huw's next detonation studies

Following on from the Nature paper Huw published several papers of pressure and velocity measurements on detonation waves in the hydrogen-oxygen mixtures. These were followed by an increasing interest in the vibration and transverse wave phenomena in detonation waves where in most instances pressure measurements were used to complement schlieren photography



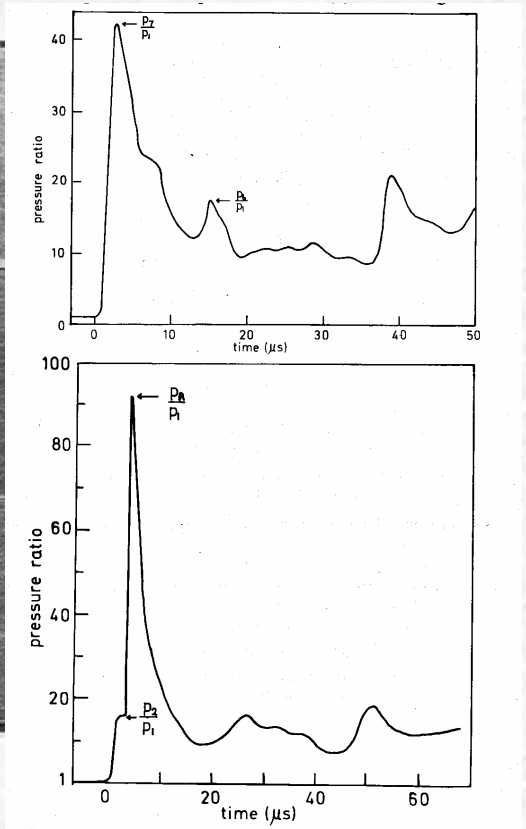
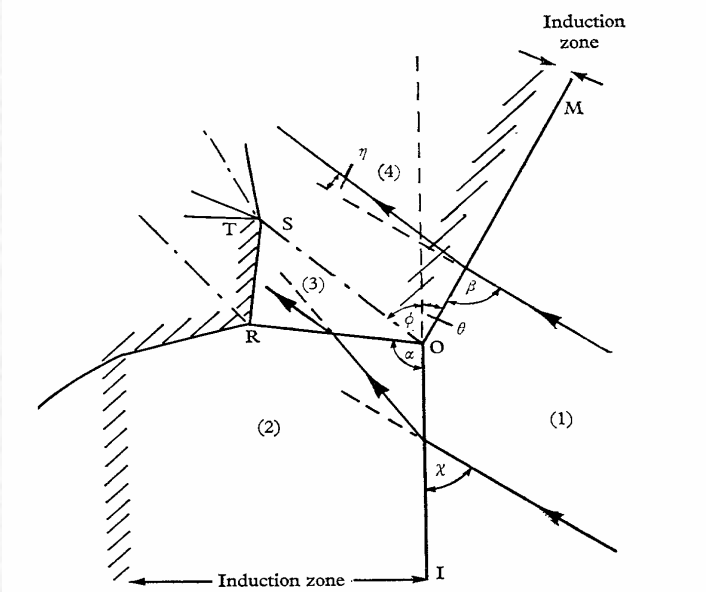


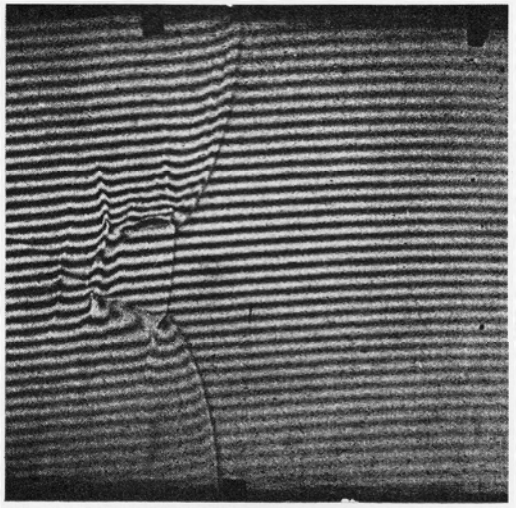
FIG. 4. Pressure records for detonation wave in $2H_2 + O_2$ at initial pressure of 30 torr, showing in (a) the pressure across the transverse wave, p_7/p_1 and in (b) the incident shock pressure p_2/p_1 and the reflection pressure behind the transverse wave at the tube wall.

Understanding detonation structure

His observations contributed to a more detailed understanding of the transverse wave structure proposed by Voitsekhovskii, Mitrifanov and Topchian in Novosobirsk, complementing work by Strehlow in the US



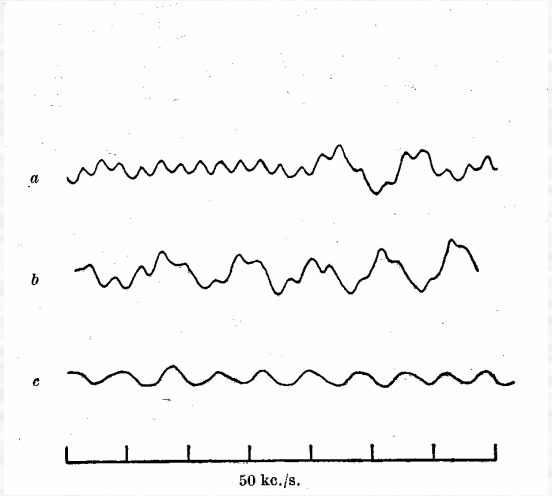
A typical sketch to explain the key elements of transverse wave structure



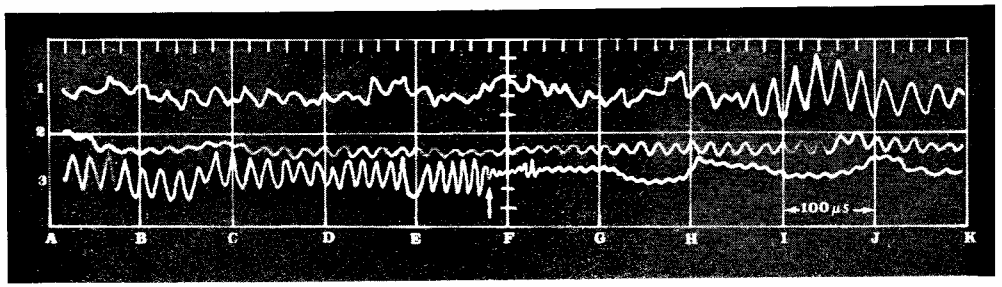
Finite fringe interferogram of two transverse waves about to collide at the end of a detonation "cell" obtained using a Mach-Zehnder interferometer developed at Aberystwyth.

Instrumentation and diagnostic techniques

Later as one who was always ready to explore any new avenue that could lead to increased understanding Huw was one of the first researchers to use a microwave interferometer technique to continuously monitor detonation propagation over long distances



Microwave observations of unstable detonations



- The technique was subsequently used to investigate unstable near limit detonations, often called galloping detonations: Changes in freq = changes in wavefront velocity

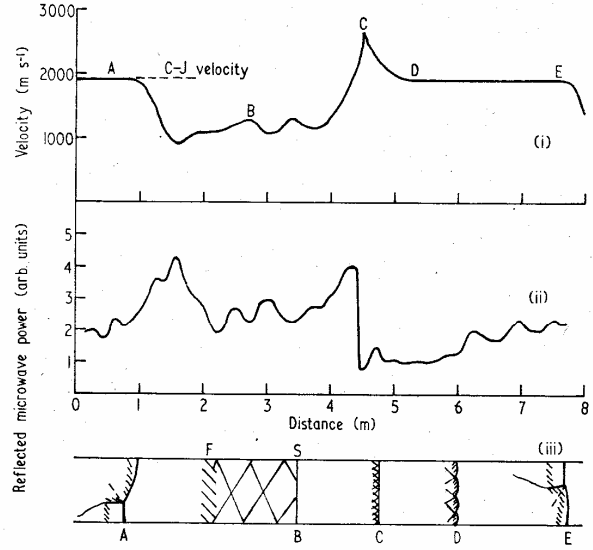


Figure 3. (i) Velocity variation of combustion zone during one cycle derived from interferogram of figure 2. (ii) Amplitude of microwave signal, in arbitrary units, corresponding to graph 3(i). (iii) Sketches of wavefront configuration at various points of the cycle. At position B, S denotes the shock front and F the combustion front.

unconfined detonations

Several years later the original technique conducted in detonation tubes constructed from modified microwave waveguides was extended to facilitate a free field study of the direct initiation of spherical detonation,
He first used small conventional HE charges(2.5 gm) under field conditions and then, later in the laboratory small masses(45 mg) of primary explosive.

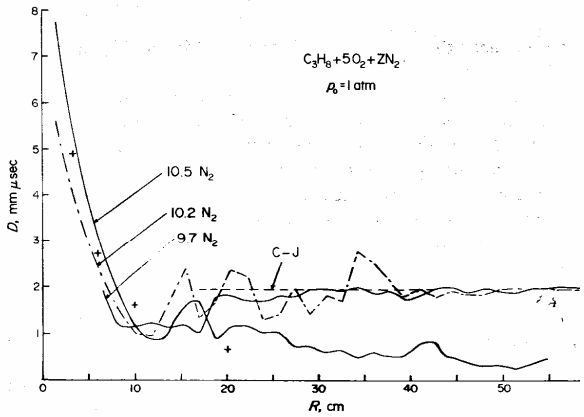


Fig. 5. Observed variation of velocity with radial distance. Initiating source, 2.5 g
+, velocities derived from measured blast wave pressures in air.

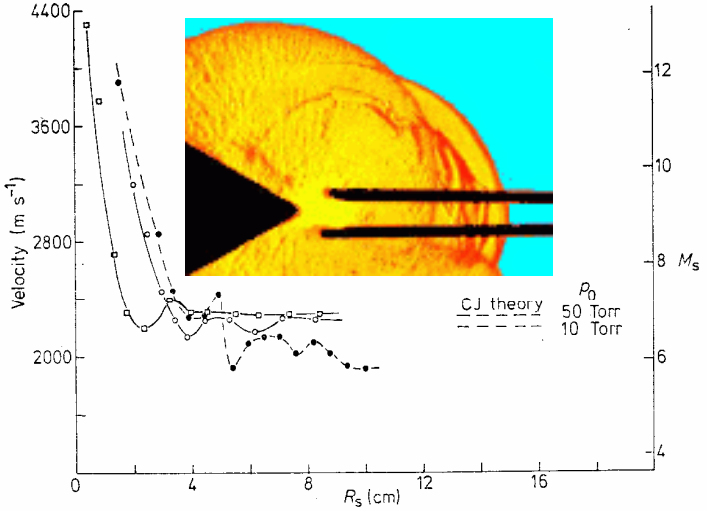
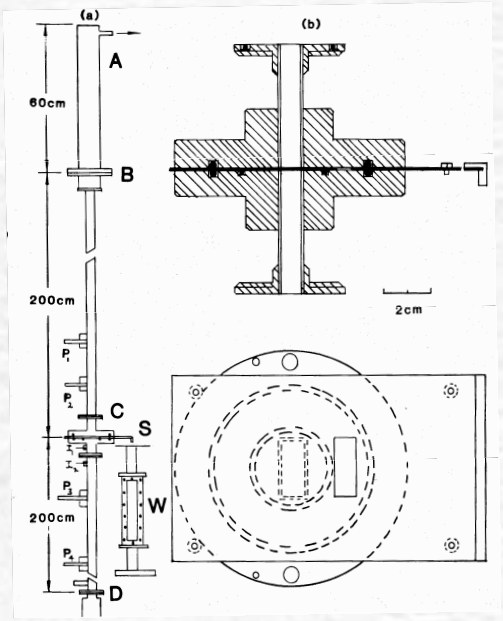
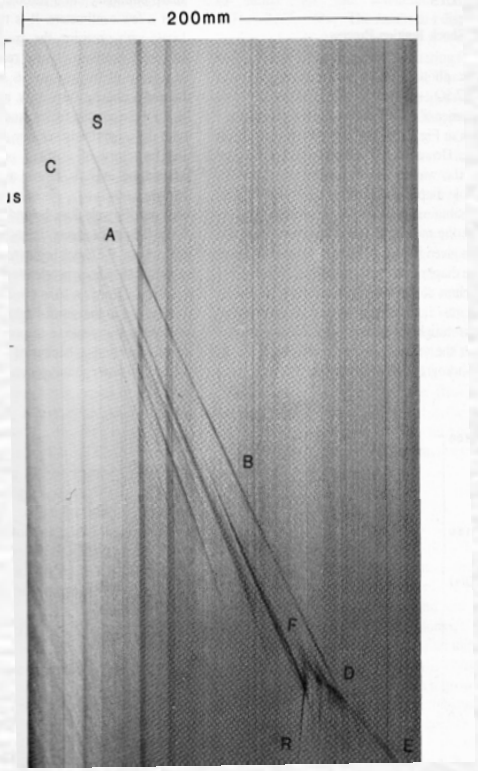


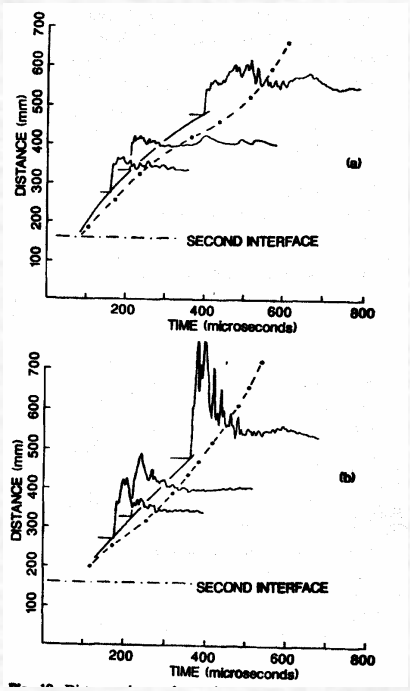
Figure 5. Velocity profile for $2C_2H_2+5O_2$ measured by microwave interferometer. Source: 45 mg lead azide. p_0=(□), 50 Torr; (○) 30 Torr; (●) 15 Torr.

Understanding initiation of detonation

To increase understanding of detonation Huw encouraged the development of a vertical shock tube for direct initiation by strong shock waves.



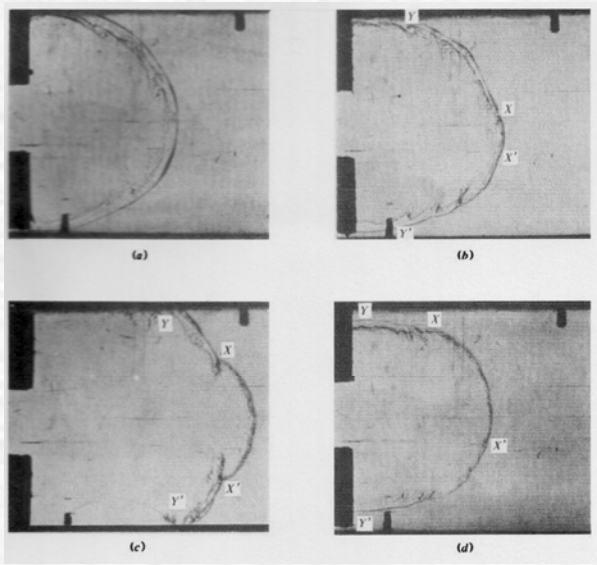


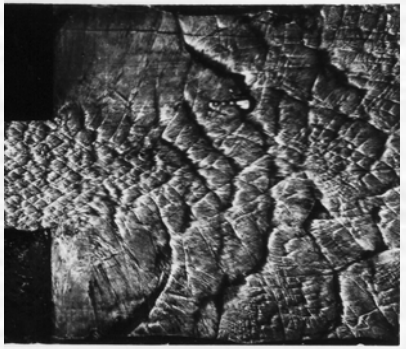


The initial study was later extended to study detonation transmission across inert regions and concentration gradients

Detonation diffraction I

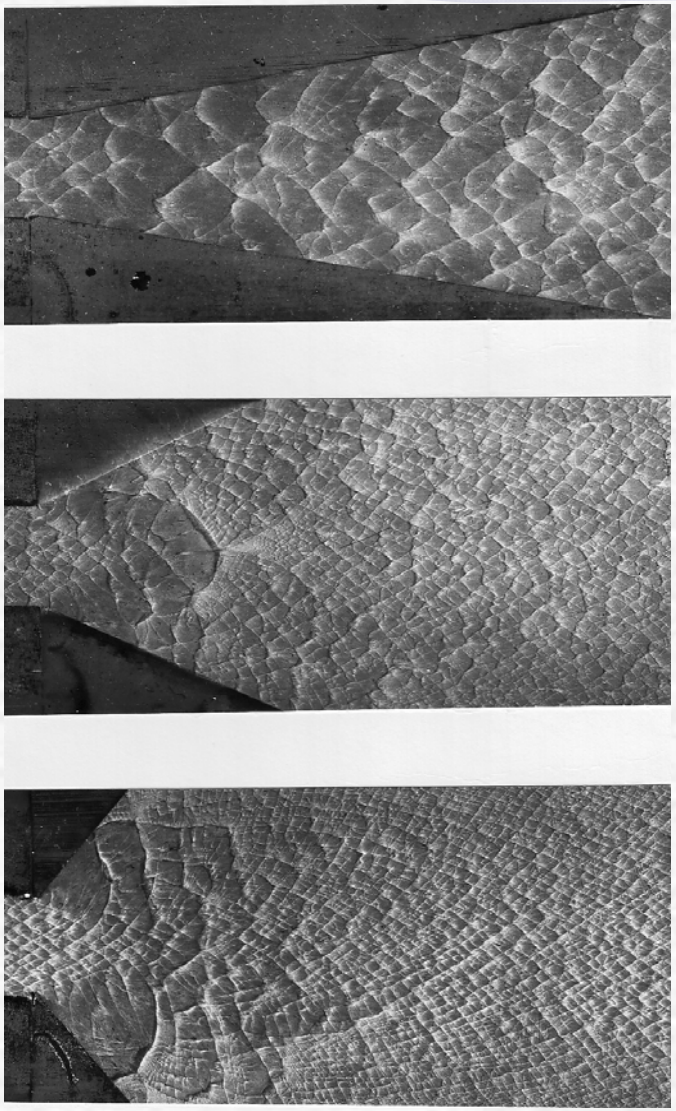
Returning to the study of detonation propagation and initiation Huw instigated and supervised a number of experiments on the diffraction of detonation at abrupt area changes. Extending the earlier work by Solukhin from circular to rectangular area changes the observations showed that the critical number of cells (13) required at the round pipe exit for successful propagation through the area change, was reduced to 10 for a rectangular geometry





Detonation diffraction II

Additional work done in collaboration with Lee and Knystautus in McGill showed that the propagation mechanisms for successful transition became more complex for less abrupt area changes and that transverse wave interactions with the wall were crucial. Other work with the McGill team showed that the "regularity" of the original detonation structure also influenced the transmission processes



Other miscellaneous studies I

- Together with David bull, the complex flows behind a reflected shock wave in a shock tube were investigated by using infra-red tagging of gases to look at mixing

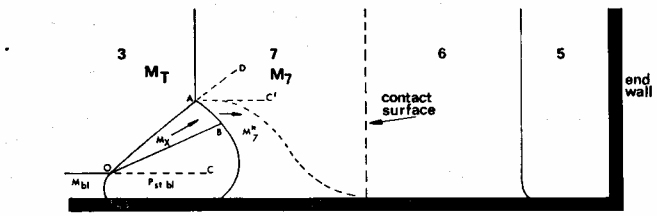


Fig. 1 Sketch showing bifurcation of the shock transmitted through the contact surface.

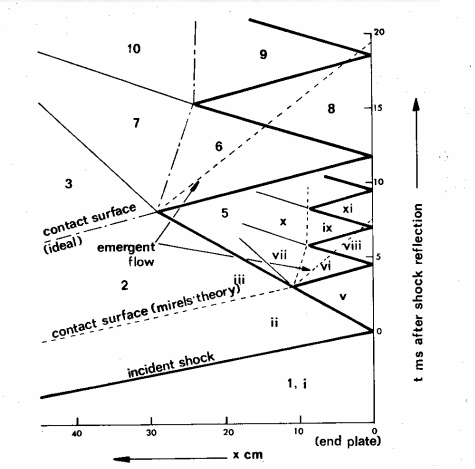


Fig. 3 Computed x-t diagram of the reflection of a shock normally incident on the closed end of a shock tube and the subsequent interaction with the contact surface, $M_s = 3.00$, $M_i = 2.17$.

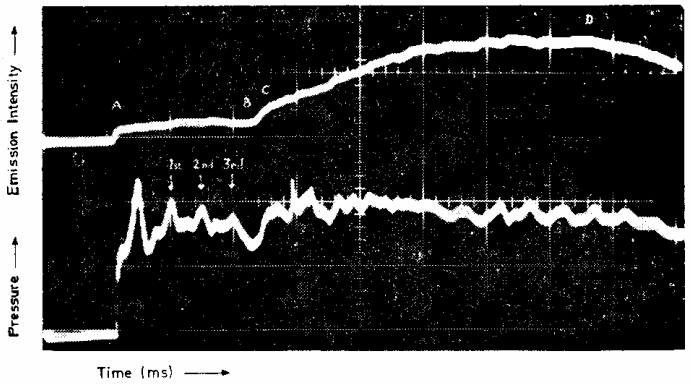
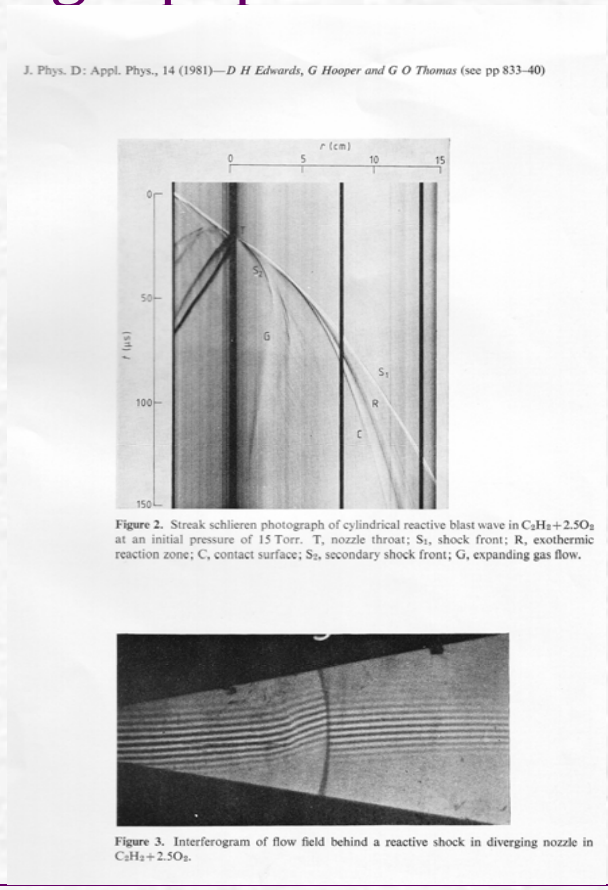


Fig. 7 Infrared emission record at 2.7μ (upper trace) and pressure variation recorded at end wall of shock tube (lower trace). Test gas: nitrogen; driver gas: 80% H_2 + 20% CO_2 $M_s = 2.78$.

Other miscellaneous studies II

- Innovative adaptations of existing equipment allowed him to investigate other ideas

- e.g. The propagation of reactive diverging blast waves: In an attempt to simulate the incident shock wave within a detonation cell, he engineered and observed the motion of a detonation incident on a converging-diverging nozzle. Again schlieren optical visualization techniques were used effectively



Other miscellaneous studies III

- Detonation mitigation by metal foils was studied
- As was the effectiveness of water sprays.

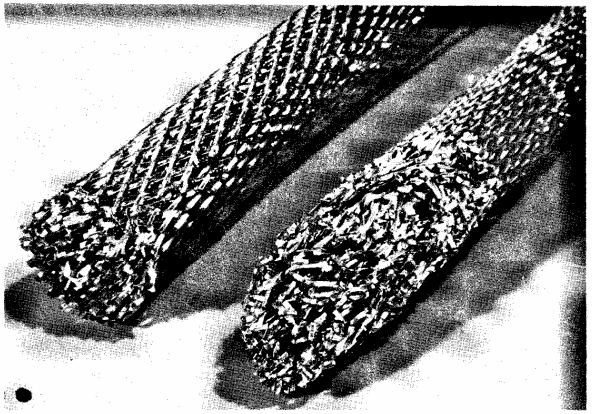


Fig. 1 Perforated foil used to pack the 50 mm diameter detonation tube.

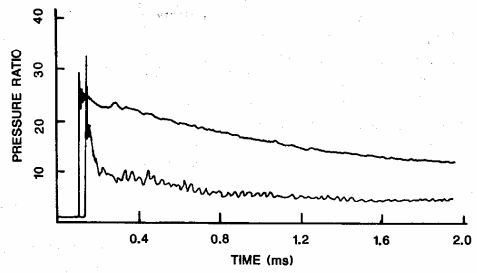
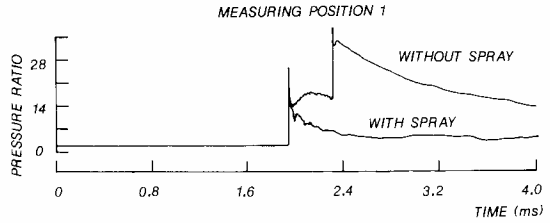
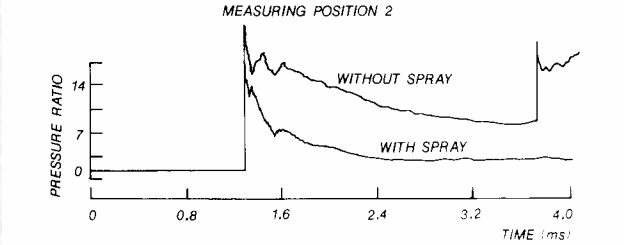


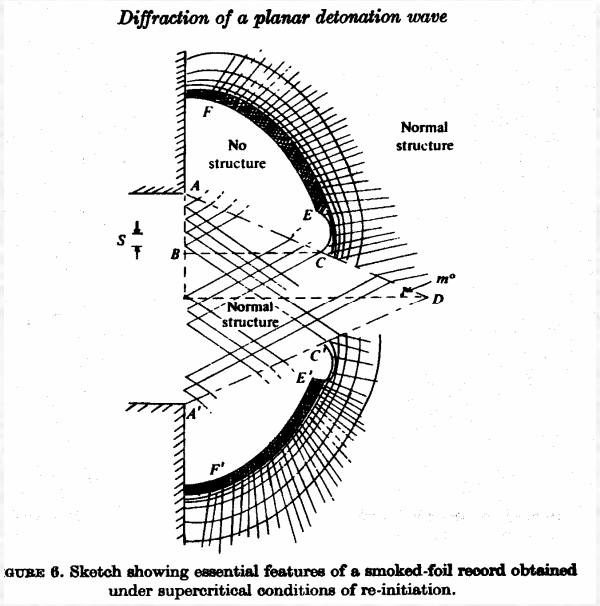
Fig. 2 Static pressure records obtained in the 50 mm diameter tube for tests with and without foil packing.



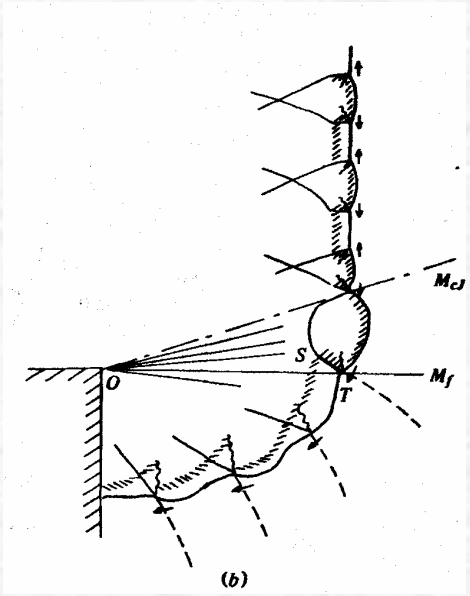


The contemplative Huw Edwards I

Huw's research papers were notable for the care exercised in obtaining the required experimental data and, even more importantly, the time and thought devoted to careful interpretation and analysis; Anyone reading his collected papers should notice his use of sketches that illustrate and explain phenomena of particular interest: as with these sketches of detonation diffraction. Presented with a new and perhaps unexpected result in the afternoon Huw would go home to think about it and return to the lab next morning with an explanatory sketch

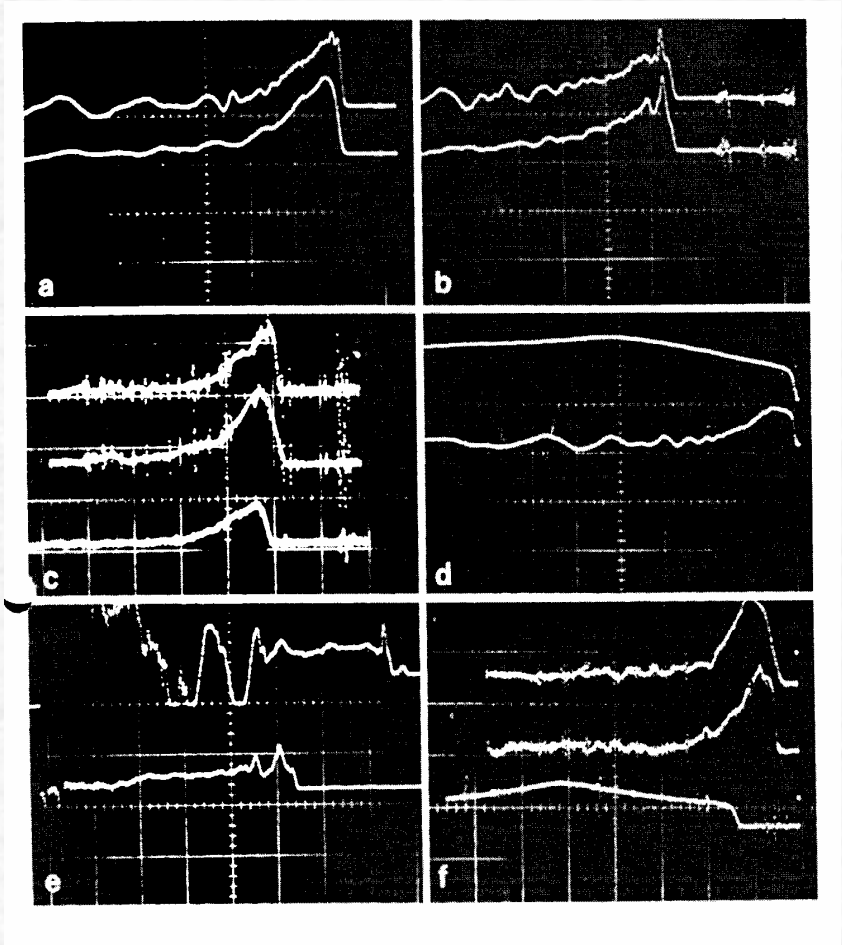


GURE 6. Sketch showing essential features of a smoked-foil record obtained under supercritical conditions of re-initiation.

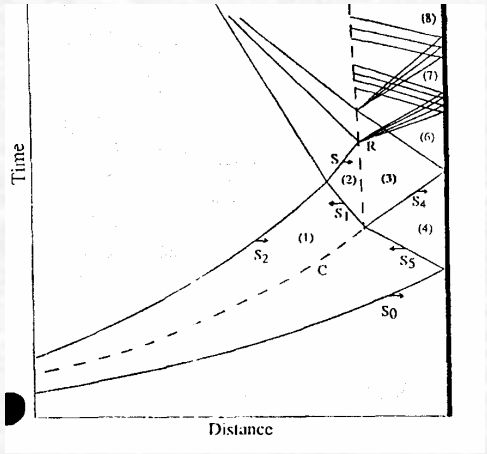


The contemplative Huw Edwards II

An impressive example of his deductive powers drawing on a detailed understanding of gas dynamics was his interpretation of pressure records obtained from measurements extremely close (~cms) to1-8Kg solid TNT charges using a custom designed pressure bar arrangement,

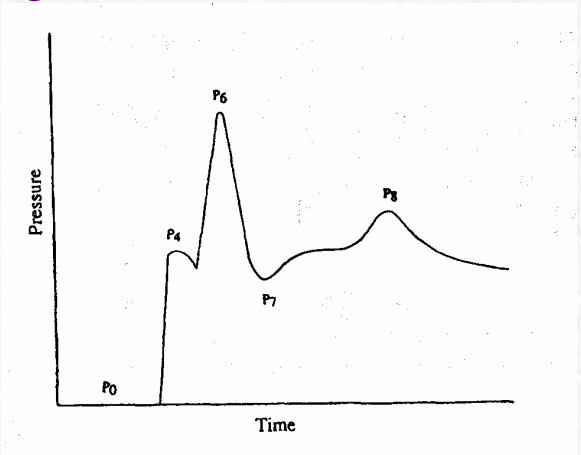


The contemplative Huw Edwards II

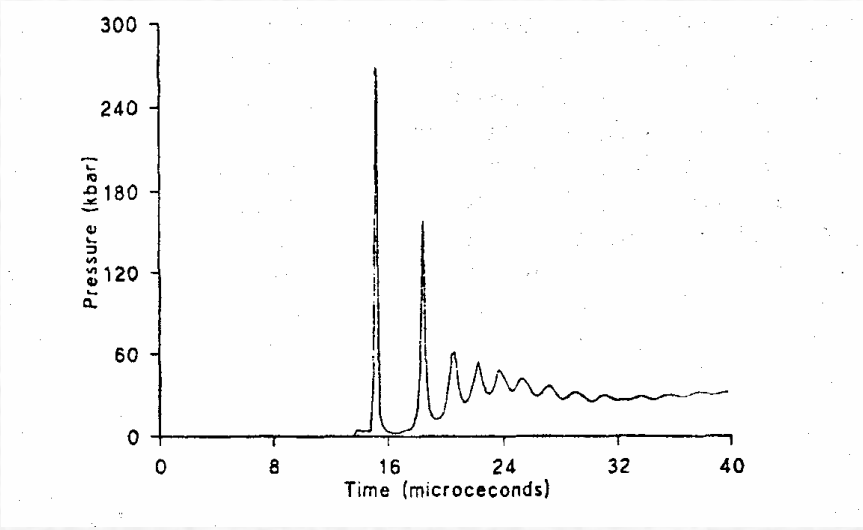


After viewing the records he sketched the wave interactions that would give rise to the observed pressure waveforms and these were later confirmed in numerical simulations, by Alec Milne

Qualitative sketch



Quantitative C.F.D



Other key persons I

- It would be unfair to complete a review of Huw's career without making reference to key friends and colleagues
- Research students
- Huw had a close personal and working relationship with his many postgraduate research students (ca. 30, of whom only one did not submit a successful thesis) who found employment across a diverse range of major industries as well as the MOD and defence sectors. Most students continued in fields where their research was relevant and many sectors of UK industry benefited from the training and insight gained by their employees initially under his tutelage. Several have established notable careers overseas
- Whilst under his supervision students were treated within beneficial tolerance, as if members of his family. Indiscretions were readily overlooked and in several instances recounted with what was close to pride and joy.
- Workshop technicians
- Huw was always appreciative and supportive of the workshop technicians who transformed his experimental ideas into mechanical realities in metal and glass

Other key persons II

- **Beti, Huw's wife**: A compact bundle of energy who supported Huw in all he did and who took equal delight in the successes and antics of Huw's students.
- She was as much loved and respected by friends around the world as Huw and during visits to other detonation laboratories by Aberystwyth students the opening pleasantries always included the sincere question
- "and how are Huw and Beti?"

Mike Nettleton: An employee of the Central Electricity Generating Board at their Leatherhead research laboratory Mike was in some respect an unlikely candidate as a collaborator with Huw, so different were their characters. However, over the years they worked closely and productively together seeking solutions to the practical explosion and detonation problems Mike came across during his daily duties.

It was Mike therefore that prompted the study of detonation diffraction as well as studies of detonation propagation over wedges and through bends.

Huw in return encouraged Mike with the preparation of his valuable book on detonation. And I suspect Mike was instrumental in encouaging Huw's involvement with Euromech and later UKELG

Summary of final career achievements

- 1979 :appointed Reader, university of Wales Aberystwyth
- 1983:awarded the Numa Manson Gold Medal for ”outstanding contributions to Gas Dynamics of Explosions and Reactive systems, especially towards advances in the knowledge of Shock and Detonation Waves"
- Please note: This was the first and to date the only time that the medal has been awarded to a UK scientist

- D.Sc from Cambridge university.
- personal chair in physics, University of Wales Aberystwyth,
- co-organiser of Euromech 139, the precursor to UKELG

- 54 published peer reviewed papers:

- It is a measure on the stature of his scientific contributions is that amongst all his 54 publications there is not a single instance where a paper required correction or a statement or assertion had to be withdrawn

- 29 successful PhD theses supervised