

**Observations and some preliminary conclusions relating to the
Corrib Project Documents
including the Advantica Safety Review Draft Report.**

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Conclusions

- A. *The Rossport 5 are fully and completely vindicated by the contents of Advantica Safety Review Draft Report, despite the terms of reference placing severe limitations on the reviewers in relation to scope. Advantica have stated that the onshore part of the Corrib up-stream pipeline as described in QRA version F, is an unacceptable risk that is it is UNSAFE due to the extreme pressure it is likely to be subject to, some 5000psi 345 bar. I do not believe that “tinkering” with the flawed design of the “Corrib Project” can render it safe since “pressure reduction systems” will fail and the outcome would still be as described in my worst case scenario. A very big bang!*
- B. *PEGG and others, who still think the Rossport 5 have no basis for their claims that this pipeline is not safety should note well; that if such an explosion as described here happens. The area around Rossport and Struwaddacon Bay will look like Groznyy after the second battle or as if a “7 Kiloton Tactical Nuclear Weapon” had detonated. Despite the differences between Nuclear, High Explosives and Gas-Air explosions, the end result would be pure devastation. Not something a few thousand or even a few million Euros could fix.*

Preliminary

- 1) I call on the Minister to place all the documents relating to this project believed to amount to more than 150 in total, together with the detailed calculations and modelling performed, supplied to or by TAG and produced by Advantica, immediately into the public domain. And to extend the consultation period by a further 60 days in 2006 to permit this draft report together with those documents to be properly evaluated. There appears to be an excessive haste in closing off the consultation period amounting to a lack of a provision for real public consultation as was stated by various parties in Balmullet at the launch of this draft report.

- 2) There must be a serious question concerning the terms of reference and scope of the review as well as the separation of the Corrib Project into three parts for Quantified Risk Assessment that has resulted in conclusions that are of questionable validity if not fundamentally flawed. The key questions that have been excluded are; (a) why is the gas not to be processed out at sea, (b) why the current pipeline route and (c) why a land based “plant” to process the gas was even contemplated, (d) the legality of the shenanigans that allowed this project to receive a string of approvals without proper oversight (as stated by Advantica)?

- 3) At the Planning Enquiries it was established that the Quantified Risk Assessment for the “Terminal” did not address the “worst case scenarios with very low probability of occurrence but extreme consequences”. In view of the common authorship of the Upstream Pipeline QRA, and the Terminal Quantified Risk Assessment a similar philosophy of discarding very low probability of occurrence events with extreme consequences, is apparent. This is a fundamental as such “impossible events” (together with O&M deficiencies) and lack of safety culture (as stated by Lord Cullen) produced major disasters of which Piper-Alpha and Flixbrough are but two (relevant) incidents since they both involving VCEs although the size and mass of the cloud is dwarfed by the estimated size for Rossport.

- 4) The deficiencies in both the QRA under review (failure to address true worst case low probability events including domino effects) and those parts of the Corrib Project design looked at by Advantica are such as provide absolutely zero confidence that the design of this project is not seriously flawed. On that basis a total rethink of the whole project is required, not just if the Corrib gas should be processed offshore. A far more fundamental question is how this project, described by Inspector Moore as, “An inappropriate industrial development in a remote and un-serviced part of North Mayo”, was permitted to get this far with such serious flaws as to design and proof of its safety still outstanding? That this pipeline would have been built but for the valiant efforts of the Rossport people spearheaded by the Rossport 5 who’s lives would have been subject to the highest levels of risk from it. Must worry all right thinking people the length and breadth of Ireland. Thus the question of a failure of official oversight to date, leads to a call for a full public debate and public oversight both for any future design as well as the safety aspects. And is a major issue for the people of Ireland and not just those public representatives in the Dail.

In respect of the comments made by Advantica concerning my original report.

- 5) First unlike J.P.Kenny and Shell I was and am not involved in developing a detailed design for the Corrib Field. Being retired I have access to neither the kinds of resources required to do this, not only man power (bodies) but also simulation packages and the powerful machines to run them. The results of the calculations I performed were intended to answer the questions Hazard or not?, and what sort of sized bang? In relation to the pipeline. It is ludicrous to expect to subject my figures to the same rigor as those of the designers. In addition Shell despite their protestation of an “open door policy” and “all questions answered” refused to engage with me when I started to ask serious technical questions related to the failure rated and modes of the sub-sea valves and their control systems, as well as asking for a check of my figure for gas density at 345 bar and 5°C, since my data was created with a “free” from the Internet “tool”.
- 6) Since I am retired I do not have the engineering reference books I require for accurate calculations. I had to grub around on the Internet and as I stated in my report, resort to calculations from first principles quite literally “on the back of an envelope” to produce “engineering grade ball-park figures”, where the accuracy was expected to be no better than +/-5%, probably 10% worst case. To ease the calculation load, and my memory, I employed what tools I could find on the Internet and took them as giving good answers. One of those tools I managed to drive outside it’s design range, which gave me” for the gas speed in the pipe a “funny answer. Rather than investigate it then and there, I stated my answer looked imposable in the report and pressed on with completing it. Using a tool off the Internet was a known problem. With more time a replacement tool was found and after being subject to a sanity check it’s answers showed the original figure was around 100 times too high.
- 7) My conclusion that all the gas in this pipeline would be involved in an UVCE (Unconfined Vapour Cloud Explosion) has been challenged by both Shell and Advantica on the basis the gas would not collect but not disperse and burn rather than detonate. For my calculations I use the figure of the total pipeline length from wellhead to plant ESDV of 93000 meters rather than just the 9000 meter on-shore section, since I conclude that the hand operated valve on the beach would not be

closed soon enough to play any part in a worst case release at 345 barg (worst case).

- 8) The “worst case scenario” I described in my original report and still believe is worse than those in the various versions of the pipeline QRA, started off with the Ballanaboy plant performing a rapid trip to full shutdown so called ESDzero. In the QRAs it is stated that the inlet ESDV would close in 60 seconds. I believe this would cause a pressure surge in the pipeline. With no better data I considered from first principles two possible mechanisms at work, a) the equivalent of water hammer for pressure pulse transit time, and b) stagnation pressure similar to that at a leading edge of a wing. From these two I conclude that a pressure pulse 1.5 times the pipeline pressure would be produced if the valves close quicker than 7.5 minutes.
- 9) It was on this basis that I calculated the release time for the pipeline contents of just over 8 minutes. Subsequently I have increased the total amount of gas that would be released (over a longer period) approaching two pipeline inventories providing the sub-sea valves seal or reduce the leakage rate from the wells, the probability of which Shell refused to state but in view of Advantica’s comments of the inadequacies of the sub-sea system suggests is not vanishingly small. I further concluded that the effects of any kind of leak from the pipeline would rapidly escalate to a full-bore rupture, as escaping gas expanding to atmospheric pressure would be subject to Joule-Thompson cooling and regardless of the pressure involved over the range 80 to 345 bar the resultant temperature would be well below the NDTT [Non Ductile Transition Temperature] for steel of -20 to -27°C. The pipeline can be expected to fail by brittle fracture due to being cooled, resulting in disintegration of a length of pipeline (100 meters?) with ejected chunks (missiles) hurled by the released pressure energy over an estimated radius of 300 meters.
- 10) The transition to a full-bore rupture would have a high probability of severing the umbilical and Advantica have stated ,(as I had already concluded), the wellhead valves are likely to fail to close. The Gas issuing from the seaward or pressurized end of the pipeline can be expected to flow at around 8100 kg/s, that is 200 m/sec all the time one or more wellhead valve is open and be very cold (-40 to -140°C). The crater formed by the escaping gas is likely to be well in excess of 100 meters (peat is soft) and the momentum is likely to entrain up to 50% air into the cloud

with the inversion limiting the height of the air/gas cloud to 7 meters as it gathers in the lowest point Struwaddacon Bay and gradually fills the valley spreads in the form of a “pancake” (rather than the plume postulated by Advantica). The gas cloud it’s flammability modified by the presence of methanol which would either liquefy or freeze at such low temperatures, probably carried along as fine “snow”, would be of the order of more than twice the density of air so would tend to sink and travel down, hill freezing all before it. The most likely place for the gas to gather is Struwaddacon Bay and on the presumption that only one pipeline inventory escapes, the gas cloud presumed to be 7 meters high and to have entrained 50% air would have reached 220 meters diameter if perfectly circular after only 5 seconds, 700 meters diameter after approximately 50 seconds and after just over 8 minutes be some 1.8 kilometres diameter. If the sub-sea valves either fail to seal fully or worse case not close, the original figure of 3954.8 Tonne of TNT based on a 10% “Yield Factor” advised by the US DOE (White Sands Test facility, Los Alamos national Lab, and Lawrence Livermore National Lab) as well as the British HSE. This value now looks very conservative, with 7000 Tonne of TNT being a more likely minimum figure reached after just under 15 minutes and 14.4 kilotons after a 30 minutes release, based on ten times that amount of gas being consumed in the resultant VCE type detonation.

- 11) While the flame speed of a mixture of Corrib gas and methanol with air is not likely to exceed 24% of that of TNT (2000 m/sec), and a Chapman-Jouguet or CJ-pressure of around 20 bar (2.0 MPa), the blast wave is likely to be sustained for much longer than four times the duration of the impulse from TNT implying that the total impulse energy will be greater and produce just as serious damage to humans and property. The distances to the various overpressure levels in my original report has been rechecked and confirmed with better DOE simulation tools which produce a spread of values within +/-2.5%.
- 12) I have serious reservations that the result of Advantica’s release simulation is correct. They have modelled a release as “an upward plume”, while the reality of the low temperature and high density of any release due to J-T effects suggests that the gas, not just Corrib gas but with methanol and other “inhibitors added”, will form a creeping mass close to the ground slithering down hill until it reaches the waters of Struwaddacon Bay where it will slowly fill the whole valley. This gas is asphyxiating and will kill any living thing in its path despite entraining air as it travels and warms. It will spread until it reaches a source of ignition: car, tractor,

range, cooker or open fire in a house. On this basis the “plume” model is hardly likely to give true answers for the mass of the gas involved and be inapplicable for the full-bore release case.

- 13) The resultant combustion of this gas may depending on the exact location of the source of ignition but is likely to be a mixture of Vapour Cloud Fire (VCF) and Vapour Cloud Explosion (VCE) with some characteristics of BLEVE, but dominated by those of an Unconfined Vapour Cloud Explosion (UVCE). It is the valley of Struwaddacon Bay rather than the inversion that are likely to enhance a VCF and promote it to a UVCE. See notes at end.

- 14) . This effect has been observed previously during incidents in the Mid-East. The following description of the Port Hudson and two other incidents is quoted direct from the source document as an example of an incident in which a VCE detonation occurred as an unconfined vapour cloud in air with the valley provided a questionable degree of confinement: “It was found that the vapour, heavier than air, tended to flow under the influence of gravity into low-lying areas. The most extreme example of this was at Ruff Creek, where the vapour drifted down a valley for 1200m, producing a very long but narrow area of burn. The Franklin County report describes a large explosion that was the result of a pipeline rupture. In the Brenham and the Franklin County incidents, the explosion was significantly more hazardous than the flash-fire. A map showing both the burn area and the location of damaged buildings appear in the Brenham report; the burn area is considerably smaller than the area damaged by explosion. In the Franklin county case an aerial photograph is overlaid with a marked burn area of 3,716m²; houses within a 2-mile radius (32,500,00m²) were extensively damaged. All of these were the result of vapours finding sources of ignition *inside buildings*. In all three cases, they produced fatalities.” The similarity of the incident at Port Hudson to that described above at Rossport is obvious and the British HSE have stated that ALL persons within such a VCE/VCF can be expected to perish, that is there would be 100% casualties every time and for Rossport this would be on both sides of Struwaddacon Bay.

- 15) My worst case scenario with the full-bore rupture at the second crossing of Struwaddacon Bay suggests that, when the “plant” at Ballanaboy is hit with the a (7.0+ Kilotons of TNT equivalent) blast, the methanol tower and storage tanks will be damaged leading to a BLEVE the details of which I do not have time to

work on but exceeding what is described in the Terminal QRA, with much of the pine forest around” the plant” burning.

References and Notes

- a. The TNT method (the use of which was criticized by Shell) is described by Gugan in Unconfined Vapour Cloud Explosions (IchemE, 1978).
- b. Concerning my statement that the 3954.8 tonne of can would detonate is based on the fact that Moen et al. (1985 [c] and 1989 [d]) have observed transition to detonation due to jet flames. In one test they reported transition to detonation in a lean mixture of acetylene-air (5% C₂H₂) in an essentially unconfined situation. The transition to detonation was caused by a jet-flame shooting into the unconfined cloud. These experiments demonstrated that detonations can be induced in an unconfined fuel-air cloud with moderate reaction rates **as long as the size of the cloud is large than 50 tonne.**
- c. **Moen, I.O., Bjerketvedt, D., Jenssen, A. and Thibault, P.A.** (1985) *"Transition to detonation in a large fuel-air cloud"*. Combustion and Flame 61.
- d. **Moen, I.O., Bjerketvedt, D., Engebretsen, T., Jenssen, A., Hjertager, B.H. and Bakke, J.R.** (1989) *"Transition to detonation in a flame jet"*. Combustion and Flame 75.

My use of the term "Detonation"

Detonation is a process of supersonic combustion that involves a shock wave and a reaction zone behind it. The shock compresses the material thus increasing the temperature to the point of ignition. The ignited material burns behind the shock and releases energy that supports the shock propagation. This self-sustained detonation wave is different from a deflagration that propagates with a subsonic speed and without a shock. Detonations generate high pressures and are usually much more destructive than deflagrations, detonations and deflagrations being the categories of explosions. Detonations can be produced by high explosives, reactive gaseous mixtures, certain dusts and aerosols.

My use of the term "Fireball"

The use of the term fireball rather than VCF and the model used in my original report came from the HSE research Report 036 which gave the formula used and stated it was used in HSE "MISHAP98" and had existed in standalone form in HSE for some time, under the name "FLAMCALC".

Table 1 *CJ-pressure and CJ-detonation velocity for some fuel-air mixtures.*

Initial conditions 25°C and 1.013 bar (Baker et al. 1983).

| | Hydrogen | Ethylene | Propane | Methane |
|-------------------|----------|----------|---------|---------|
| CJ-Pressure (bar) | 15.8 | 18.6 | 18.6 | 17.4 |
| CJ-Velocity (m/s) | 1968 | 1822 | 1804 | 1802 |