The AP Graphs: A Preliminary Discussion

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(These slides are an expanded version of a set that was part of a recent power point presentation on recent developments in Iran's nuclear program. I would like to thank those who commented on these slides and made suggestions to improve them.)

Associated Press Graphs

- The Associated Press recently received a figure from a country that purportedly showed an Iranian calculation of the explosive yield rate and yield of a simulated nuclear explosion. (It should be noted that the AP showed only two graphs in one figure; the other graphs in the possession of the International Atomic Energy Agency (IAEA) were not shown to the AP).
- One of the graphs, the yield rate, had a major error in its units, which was very embarrassing to the AP. Subsequently, the AP moved quickly to correct this error, and in the process reported that the graph's incorrect units had been deliberately changed to ease the understanding of the graph by an Iranian non-technical audience. The underlying spreadsheet in the possession of the IAEA has the correct units and numbers, adding plausibility to this explanation.
- The purpose of this presentation is to discuss these graphs, their possible meaning, and explore their shape and their similarity to graphs generated by a Los Alamos computer code used to model nuclear explosions.

Rushed, Faulty Public Analysis

- Despite the AP's error, some of public attacks on the AP were excessive and unfair, and apparently motivated by ideological reasons rather than scientific analysis.
- In particular, assertions made in the Bulletin of Atomic Scientists that "This diagram does nothing more than indicate either slipshod analysis or an amateurish hoax," seem particularly unsupported by any facts or analysis, even accounting for the mistake in the units.
- Determining the truth in leaks like this is usually very complicated and rushing to judgment often results in mistaken analysis.
- Moreover, the IAEA has a substantial amount of information to support its suspicions about nuclear explosive yield calculations by Iran, much more than just the AP graphs. Thus, using this AP graph to try to judge the quality or quantity of all the IAEA's information is unwarranted.
- For example, a mistake by some in the public debate has been to assume that if the AP graph has this error then all the IAEA information, and hence its assessments, must also be wrong. Likewise, efforts to find a similar graph in the open literature and assert it was copied by the leaking country and leaked to the AP (and given to the IAEA earlier) also seem far-fetched, given the length and care exercised by the IAEA in its investigations of information relevant to the possible military dimensions of Iran's nuclear program. Such claims are likely wrong and are misleading about IAEA's information on this important topic. Mostly what these assessments accomplish is to confirm that indeed the AP graph represents a calculation of a nuclear explosion without providing any credible analysis of its source or insight into the information possessed by the IAEA.

The IAEA Needs Answers from Iran

- Despite the limits of public information, it is essential to urge the Iranians to cooperate with the IAEA in its effort to find answers to its questions about the possible military dimensions of Iran's nuclear program.
- It is important to recognize that the information in the IAEA's hands is sufficient for raising questions and to support the IAEA in asking Iran for clarifications.

IAEA Information

- The AP reported and no one has challenged that the IAEA has these graphs in a collection of other information about possible Iranian work on calculating the yield of a nuclear explosive from the late 2000s.
- The next slide is a statement by the IAEA that appears to be linked to this set of information.

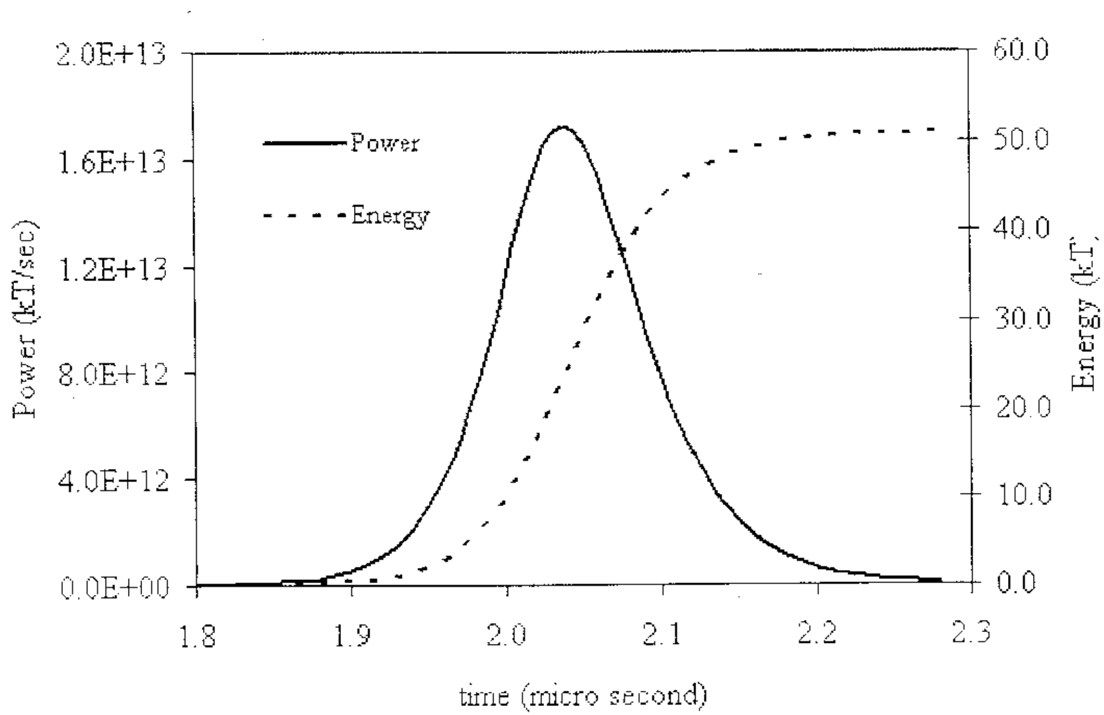
Excerpt from 8 November 2011 IAEA Iran Safeguards Report (GOV/2011/65)

- [annex, para 52] Information provided to the Agency [IAEA] by two Member States relating to modelling studies alleged to have been conducted in 2008 and 2009 by Iran is of particular concern to the Agency. According to that information, the studies involved the modelling of spherical geometries, consisting of components of the core of an HEU nuclear device subjected to shock compression, for their neutronic behaviour at high density, and a determination of the subsequent nuclear explosive yield. The information also identifies models said to have been used in those studies and the results of these calculations, which the Agency has seen.
- [annex, para 52] The application of such studies to anything other than a nuclear explosive is unclear to the Agency. It is therefore essential that Iran engage with the Agency and provide an explanation.

Background

- Just prior to the AP's publication of the first article, I was asked to comment on the graphs by the AP (see next slide). I have often assessed leaks to the media about the Iranian nuclear program and am skeptical about these leaks. I said that the explosive yield appeared too high to reflect an actual Iranian nuclear weapon design, assuming that such a design existed.
- Upon learning after the publication of the error in the units, I analyzed the graph confirming the error but also I calculated that correct units were "joules per 10 nanoseconds" or "joules per shake." A shake is a term from the Manhattan Project and refers to the short time frame between neutron generations in a nuclear explosion.
- With those units, I estimated the area under the yield rate curve and derived an answer close to the total yield of about 50 kilotons (see two slides down).
- The AP published my results in its second story along with a correction of its original claim.

Graph Published by AP



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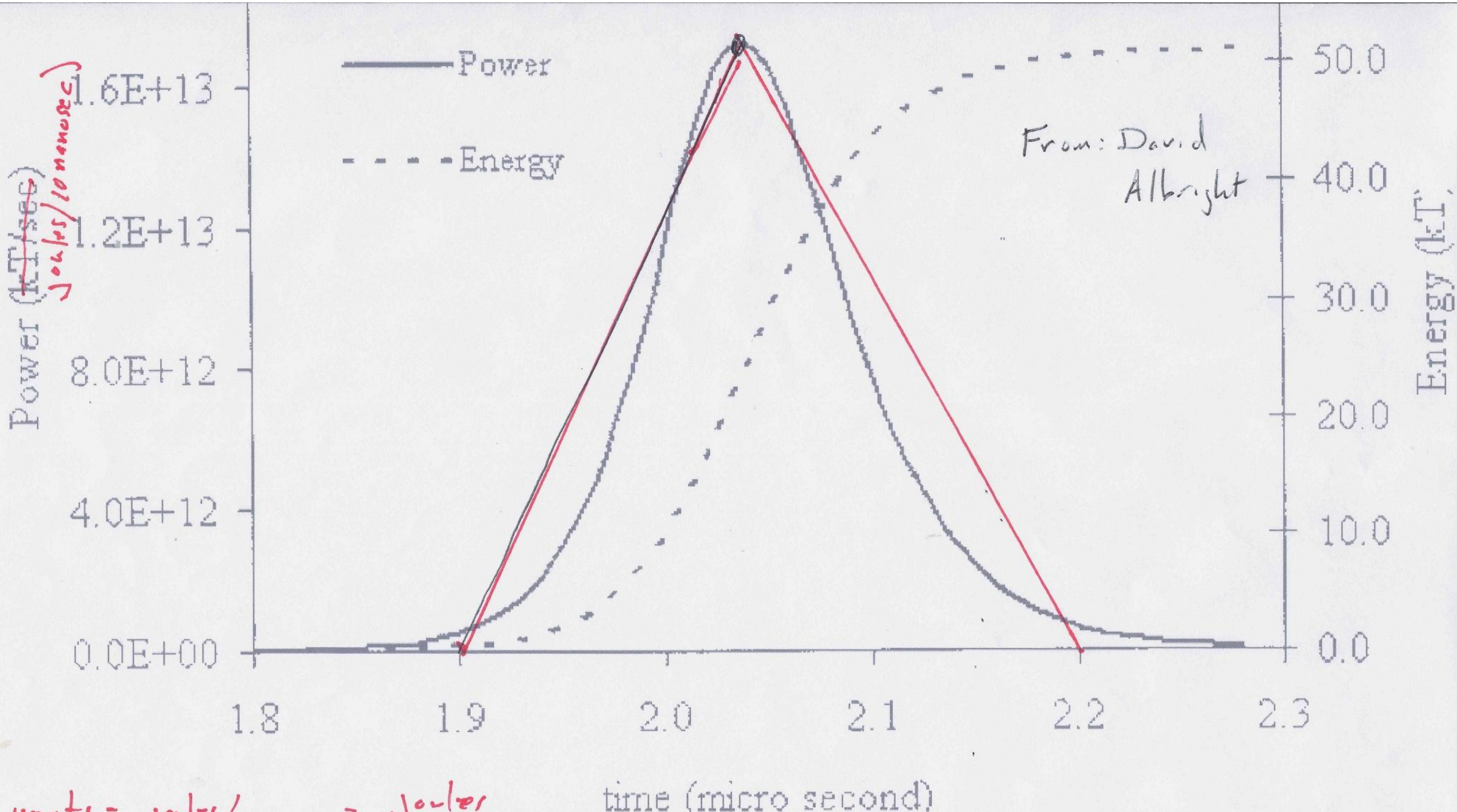

units = joules/10 nanosec = joules/shake

$$\text{Energy} \approx \frac{1}{2} b \cdot h = \frac{1}{2}(1.7\times10^{13})\left(\frac{\text{joules}}{10^{-8}\,\text{sec}}\right)(.3\times10^{-6}\,\text{sec}) = 2.55\times10^{14}\ \text{joules} = 61\ \text{ktons}$$

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Subsequent Developments

- Some also asserted that even though the units can be fixed, the shapes of the graphs are wrong for nuclear weapons calculations or that the graphs can be easily explained away as graphs produced by scholarly unclassified "toy models" of a nuclear explosion. The first claim is widely accepted as wrong, and the second is little more than uninformed speculation.
- Soon after I first talked to the AP about the graphs, I asked an ISIS consultant, Mark Gorwitz, about the graphs and what he thought. Mark, who is a world-class expert in open source nuclear technical literature, subsequently sent me the following article to demonstrate his point that the graphs likely represent a calculation of a nuclear explosion and that the calculation could be sophisticated.
  – H.A. Sandmeier,, S.A. Depree, and G.E. Hansen, "Electromagnetic Pulse and Time-Dependent Escape of Neutrons and Gamma Rays from a Nuclear Explosion," Nuclear Science and Engineering, 48, 343-352, (1972). Hansen and Sandmeier were at Los Alamos Scientific Laboratory in Los Alamos and Dupree was at Nuclear Weapons Evaluation Facility, Kirtland Air Force Base, Albuquerque
- This article applies a Los Alamos Scientific Laboratory coupled hydrodynamic-neutronics code, called HENRE, to estimate the time dependent release of gamma rays and neutrons in the course of a nuclear explosion and the resulting electromagnetic pulse of a ground detonation. It does so for what they call the S-device, a 24 kiloton implosion device with a core of plutonium surrounded by high explosives.
- A major result is that the "gamma leakage rate was found to follow closely the fission rate in the core of the S-device, and thus to provide an excellent source of information which could be used for diagnostic analysis of a nuclear explosion."
- The first part of this article discusses the HENRE code and provides graphs of the yield rate and yield of the S-device.

LASL's coupled hydrodynamics-neutronics computer code HENRE

- According to the authors, "HENRE calculates accurately the production and material motion and density within an exploding nuclear device. However, the details of the escape of neutrons and gamma rays during a nuclear explosion are usually of secondary interest to the explosive designer using HENRE." The authors then applied an additional code to better estimate the escape of nuclear radiation.
- The authors imply by this statement that HENRE is a realistic estimator of key behavior of a nuclear explosion and that it is used by those who design nuclear weapons.

HENRE graphs

- The paper has two graphs that are similar in shape to the AP graphs.
- Figure 1, on the next slide, are graphs of alpha and yield. The yield graph becomes significant at the time of the explosion, or the time of the outward expansion of the core.
- Figure 2 shows the yield rate.

Figure 1 from Sandmeier, et al

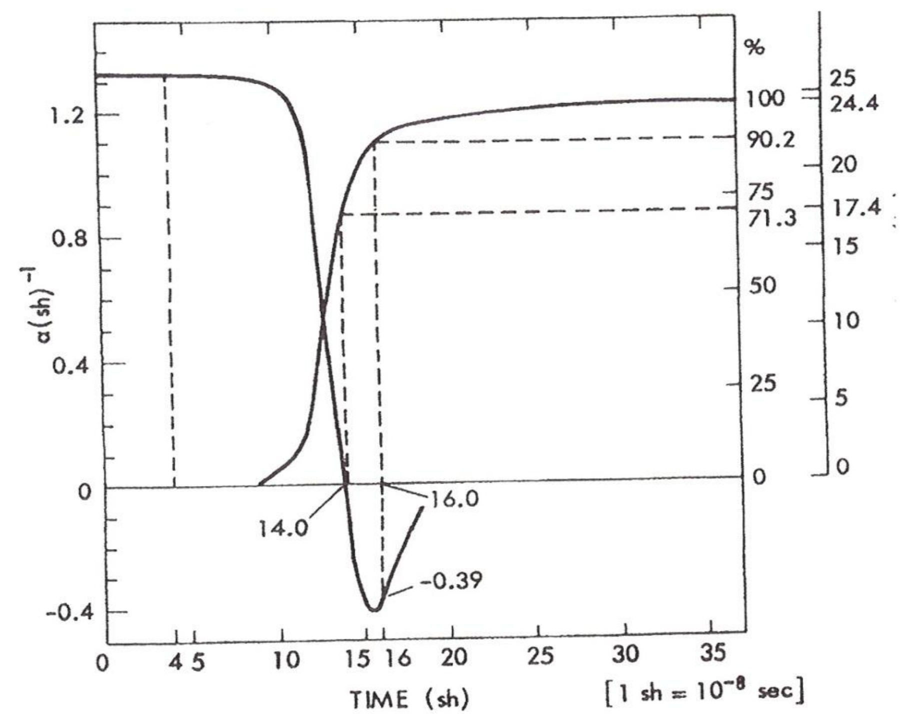


Fig. 1. Dynamic HENRE explosion response $\alpha(t)$
$Y(t)$ for 24 kt S-device.

Figure 2: Yield Rate from HENRE

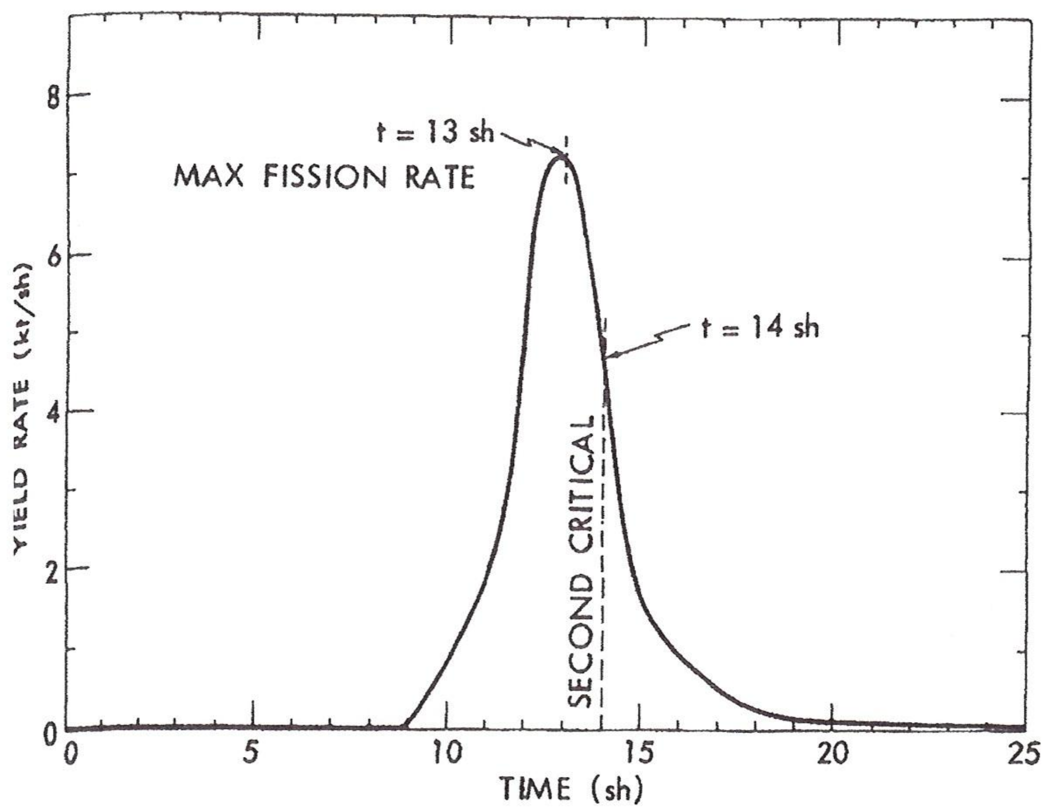


Fig. 2. Dynamic HENRE explosion yield rate for 24 kt S-device.

Fission Yield Rate

- Sandmeier, et al also provide a graph of the estimated fission yield rate of the S-device in fission per shake. This graph shows one of the fundamental results of their paper quoted above, namely the correlation between time dependent gamma ray emissions and fission yield.
- The next slide shows this figure from their paper.
- It has a shape, as expected, related to the yield rate graph but also different in shape. One difference is that the yield rate graph is a better indicator of the start of the explosion than the fission rate graph.
- Thus, this graph is less useful in making comparisons to the AP graphs.

Figure 8

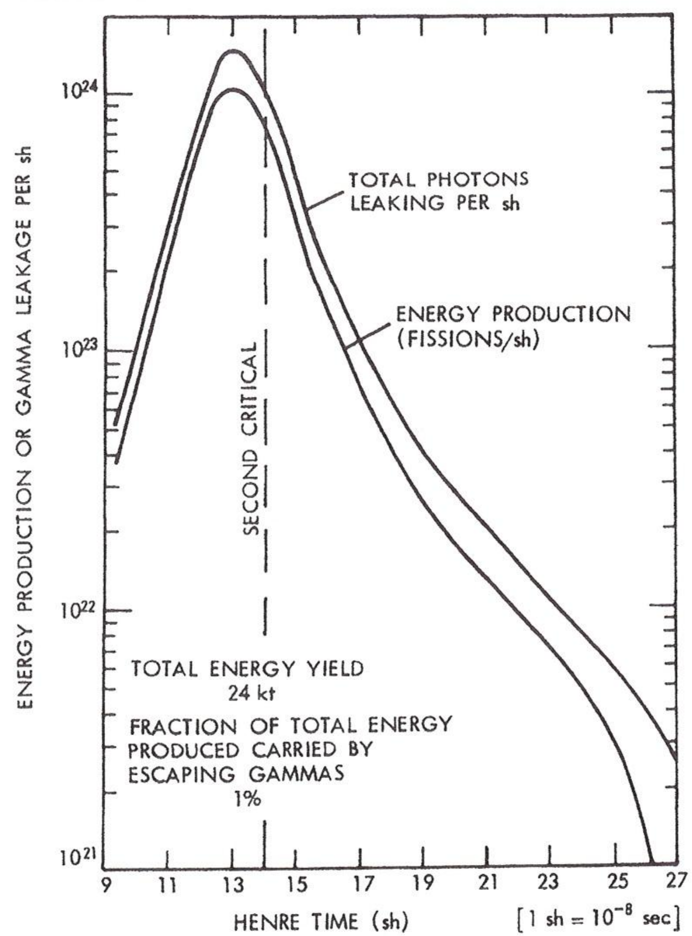


Fig. 8. Total time-dependent gamma leakage and fission rate for 25 kt S-device.

Composite Graphs

- I roughly hand drew the yield from figure 1 onto figure 2, the yield rate, which can be seen in the next slide.
- The subsequent slide presents the AP graphs and HENRE graphs side-by-side to ease comparison.

Combined yield rate and yield graphs (yield hand drawn from figure 1)

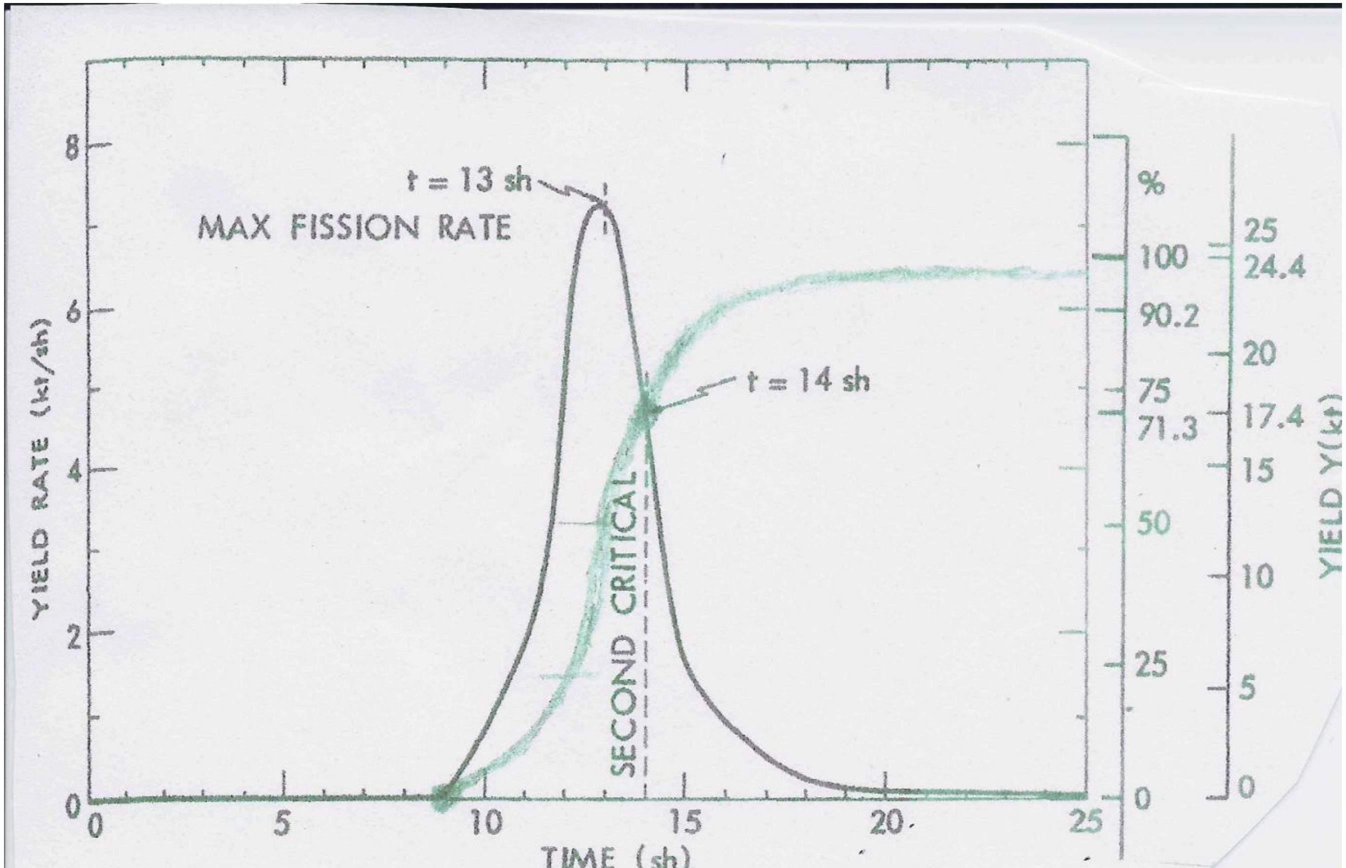
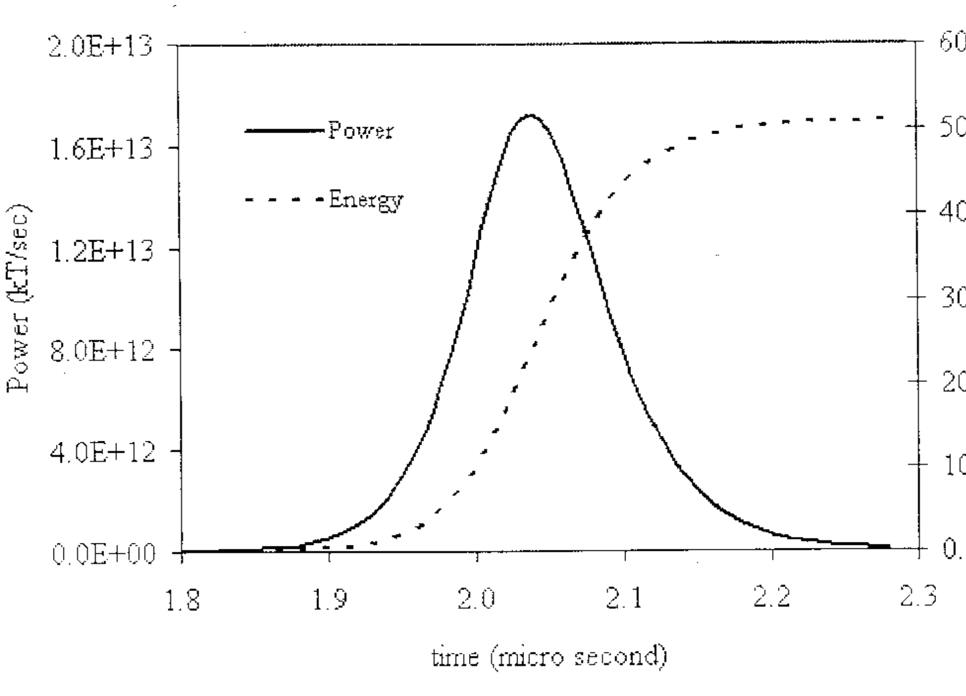


Fig. 2. Dynamic HENRE explosion yield rate for 24 kt S-device.

Graph Published by AP



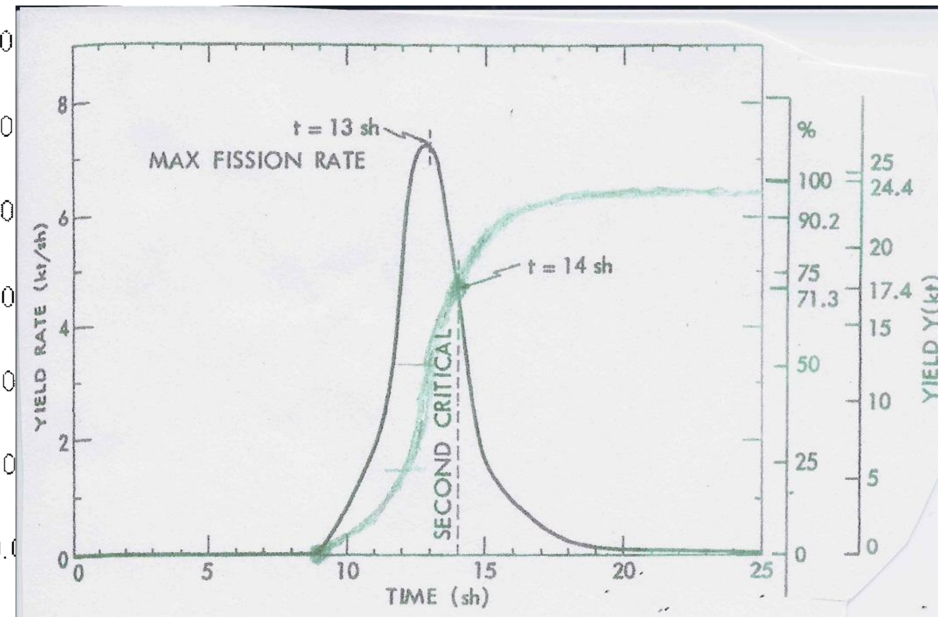


Fig. 2. Dynamic HENRE explosion yield rate for 24 kt S-device.

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Discussion and Findings

- The HENRE graphs are similar in shape to those reported by the AP. Thus, the AP graphs appear consistent in shape with graphs generated by advanced codes used to predict the behavior of a nuclear explosion.
- They differ in that the width of the AP yield rate graph is greater than the one generated by HENRE. One partial explanation is that the yield of the explosion in the AP graph is double the size in the HENRE calculation, e.g. about 50 kilotons vs. 24 kilotons, but this is not sufficient to explain the difference in the width of the graphs. Is the difference due to the use of weapon-grade uranium rather than plutonium in the core? Are the compressions significantly different? This difference in width needs further examination.
- Other differences in the shape would tend to rule out that the graphs are generated by the HENRE code. The AP reported that the IAEA has a spreadsheet that was used to generate the graphs but it did not report what generated the values in that spreadsheet.
- It should be emphasized that this exercise is not to determine if Iran used the HENRE code or similar neutronic codes later developed by other countries. Iran likely did not. Moreover, Iranian military and civilian entities, such as the Physics Research Center (PHRC), have bought many unclassified computer codes that are or can be related to nuclear calculations, including nuclear explosions. Many were bought years ago; for example, the purchases by the PHRC date to the early 1990s. Based on this information, Iran would have had ample time to modify these unclassified codes for use in nuclear weapons calculations. Based on Iraq's declaration to the IAEA Action Team in 1996, such a strategy was straightforward to pursue.

Discussion and Findings (cont.)

- This analysis:
  - should dispel those claims that the AP graphs have shapes that have nothing to do with nuclear explosions; and,
  - refutes those who would claim that an examination of the AP graphs shows them to be slipshod analysis or an amateurish hoax.
- I welcome comments on the similarities and differences in the graphs.

Summary

- The AP graphs are consistent in terms of basic calculus, namely the energy graph appears that it can be differentiated to give the shape of the energy yield graph and the integrated AP power curve precisely overlaps the AP energy curve.
- With a relabeling of the vertical axis to the units of joules/shake, the units are consistent and the area under the AP yield rate graph gives the predicted total explosive yield.
- In addition, the shapes of the AP graphs of the estimated yield rate and yield are consistent with those derived from a coupled hydrodynamic-neutronics computer code called HENRE.
- An examination of the AP graphs cannot determine their authenticity or origin with the information available publicly.

Summary (cont.)

- The IAEA has much more information about this subject, as exemplified by its statement in the November 2011 safeguards report.
- Based on publicly available information, it is too early to conclude who did the calculations or for what purpose, and to the calculations' relationship to a wide body of evidence collected by the IAEA about the possible military dimensions of Iran's nuclear program. The AP graphs are only one page of a set of information in the hands of the IAEA. Before forming a conclusion based on public information, it is necessary to learn the actual content of this information and the scope of the work.
- Despite the limits of public information, it is essential to urge the Iranians to cooperate with the IAEA, recognize that the information in the IAEA's hands is sufficient to raise questions, and support the IAEA in asking Iran for clarifications.

Last Word from Olli Heinonen

- Olli Heinonen, former DDG of the IAEA, has offered some useful advice about this leak and the much broader set of information held by the IAEA:
- "Let us, however, look at facts. The graphs are just part of the information. We should not conclude too much from them. The graphs are part of a report. It would be good to know what is the actual content and text of that report, the scope of it, authors, etc. Then one can put such a report into its right context.
- Then the report, including its contents, authors, and timing, has to be compared against other information, which is available (e.g. to the IAEA). This other information includes other reports, documents, publications, procurements, other individuals and known organizations, all of which give a broader picture of activities going on in Iran. Some of it is hard verifiable facts, and some of it is information which requires clarifications. The key question is then, does this information point in the direction of undeclared nuclear activities or non-peaceful use of nuclear energy? The IAEA conclusion has been for years that the information in its hands is sufficient to raise such questions with Iran, and ask them for clarifications. Some of the activities, perhaps even the graphs, can be explained by work to protect people, including in the military, from nuclear fall-out. But there are many items, such as the detonation experiments, work on neutron sources, the missile reentry vehicle, and uranium metallurgy, which do not serve radiological defense purposes."