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Copy

FAX MESSAGE

TO: **Mr. Ronald Wray/ASME - Dynamics and Extreme Loads**

Teledyne Engineering Services

FAX NO: (617) [illegible] **DATE:** May 20, 1993

Pages (including cover sheet): 20

SUBJECT: "The Correct Way to Handle Transient Loads"

Dear Mr. Wray:

I have looked over my write-ups on the transient loading subject to find some 20 pages that will highlight the problem, particularly, in pressure vessels, including, nuclear reactors as we discussed yesterday. Most of the papers are lengthy, with greater emphasis on the same problem in aerospace systems, and include specific numerical examples from real systems. I believe the enclosures and the following commentary will provide a glimpse of how the transient loads have been [mis]handled in nuclear reactor pressure vessels and related hardware. I will be glad to answer your, or other experts', questions.

1- I have just completed the enclosed article with the above title and submitted it for publication in a general engineering magazine. The article is intended for general engineering readers, and not only to the experts. The modified Fig. 6a is meant to clearly show why sensitive pressure transducers cannot measure nor detect the transient response. I hope you will find the article useful.

2- I have selected just a few sheets from some papers that dealt with the transient problems associated with nuclear reactors. I will identify the Proceedings, main author, page number, and other information; and I will write some thoughts as they come to mind in the process. The objective is to provide you with examples that show how the "pressure," which is strictly the forcing function in transient conditions, has been habitually and widely mistaken to be the response in transient conditions.

SOURCE 1: **"Reliability of Reactor Pressure Components,"** Held in Stuttgart, March 1983, International Atomic Energy Agency (IAEA), Vienna, 1983. Proceedings Series

A Collier et al., U.K., **"Fracture Assessment of A PWR Pressure Vessel,"** pp. 192-193

The paper deals with transients. Only rapid pressure rise or fall is shown or treated. Stresses are based on maximum steady-state value. Calculated stresses are increased "*by 10% prior to fracture analysis*." Note: The 10% factor is also used in aerospace systems, where instead of calculating the correct overshoot (70% to 100%), the 10% factor is randomly selected and used.

B Kussmaul et al., Germany, **"Ruling-out of Fractures in Pressure Boundary Pipings,"** pp. 217, 224

Page 217; Figs. 5 and 6; data based on pressure profiles. There is no indication whatsoever that the pressure-time profiles are the forcing function in transient conditions.

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Page 224; Figs. 14 and 15; distinctly show how the PRESSURE and the STRESS track —— No stress transient. Notice how the pressure and the stress drop at about 10 to 15 seconds. Also, notice that the transients happen in the first fractions of a second (say, 200 milliseconds). Of course, there is no pressure overshoot, because pressure does not overshoot. But notice, there is no stress overshoot! This is what I mean by "***simple conversion of pressure to stress***," or to force. This paper applies an external dynamic bending moment, which has nothing to do with the transient dynamics due to rapid pressure build-up.

SOURCE 2: "**TRANSIENT TWO-PHASE FLOW**," Proceedings, the Third CSNI Specialist Meeting, Pasadena, 1981, Hemisphere Publishing Corporation, 1983.

C Hsu et al., NRC, USA, "**Modern Measurement Techniques for Inadequate Cooling of Nuclear Reactor Core,**" p. 7

Page 7: Monitoring techniques show "*Parameters Measured*," including, "*Direct*," "*Indirect*," and "*Derived*" parameters. Notice that for pressure, it is stated that the parameter "*can be obtained from sensors without interpretation.*" This is fine if the transient is measured separately and directly. But, the transient parameters are not even included. The pressure measurement is strictly the "forcing function" and it must be used to derive the transient response analytically, which then requires interpretation.

D Wallis et al., USA, "**Transient One-dimensional Flow of an Evaporating Mist**"

Page 429: This paper discusses something called, "***pressure responses***," see Fig. 1. The pressure fluctuates during rapid start-up, and it is well to study its fluctuation, i.e., the forcing function's fluctuation or behavior. But strictly, one must speak of the fluctuation ***of*** the forcing function (the pressure), or the responses ***to*** the forcing function; but not of the response ***of*** the forcing function (i.e., pressure response).

This is the only paper that I have seen that clearly shows a significant departure from the applied maximum steady-state pressure and from the predicted analytical and computer schemes; See Fig. 2 (a) and (b), **p. 443**. The measurements show what seems to be a transient response, **an unexpected overshoot.** Actually, the "*trough*" is a special case of what I call "pressure fluctuation," or fluctuation in the forcing function. It is not a transient response, unless we change the definition and meaning of the term.

Notice how the appearance of the "*trough*" in the measurements confounded the authors because it did not "track" the Computer Code predictions, "***None of the EVET models predict the experimental pressure trough.***" **(Last paragraph, p. 442)**.

While most the other papers that I have reviewed show simple conversion of pressure to stress, this paper shows that the "transient" concept is very seriously muddled.

The ASME, ASTM, IAEA, and other Committees may want to look very carefully at this paper to see **(1)** why the measured "*trough*" is a special case of pressure, or forcing function, fluctuation, **(2)** why the measured peak, or "*trough*," is absolutely not a "**transient response**," **(3)** why this kind of *trough* cannot exceed **50%** of the maximum applied steady-state pressure, **(4)** why the correct transient "peak" can be as great as 100% of the maximum applied steady-state pressure, etc.

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I am including **pp. 444-445 (Fig. 5)** to show how a new Computer Code, called **EVUT** (instead of **EVET**), was developed to track the observed data, particularly, the *trough*. Here, only the "fluctuation" was matched. Remember the fluctuation can only rise 50% above the suddenly applied steady-state unit-step function. **The real transient problem, with its distinct 100% peak, is not even mentioned.**

E **Pages 543 and 575** (from two different papers): Figs. 9 and 1, respectively, show how the existing Computer Codes (TRAC-PIA, TRAC PD2, etc.) track the measured pressure build-up, or causal parameter, or transient forcing function, in time. There is no response, or desired effect. Remember, the response cannot be in pressure units.

Similar curves are very popular in aerospace systems. Actually, they are the only kind available for rocket engines and motors, jet engines, etc. The measured pressure very nearly tracks some computer predictions. Well of course they should. **The two are the same parameter!** The only way that the response can track the forcing function so closely is when the forcing function is applied very very slowly. The pressure build-up in the two figures above happens in less than 10-milliseconds. This is almost a perfect, or ideal, unit-step-function!

I recommend that you do not accept the common clichés; We know about transients; We always take the forcing function and derive the response; etc. If the forcing function and the response look like the curves shown in the enclosures, then the transient is not understood, let alone derived.

F **"PANEL DISCUSSION: HOW GOOD DO CODES HAVE TO BE?"**

Pages 693-694 (not faxed): Under the subject of the Codes, it was stated that, "***To reduce the uncertainties we have used measurements obtained during start-up and operation of nuclear power plants and measurements obtained from special experiments*** ...;"

Yet, not one single paper presented a true "transient response." I emphasize again that a pressure measurement shown to be similar to some computer code, or vice versa, is not a transient analysis. It is the same parameter shown to equal itself, which it should.

And then, "***These accidents are mainly governed by the system design and in many cases by <u>transient two phase flow conditions in the reactor, loops, pressurizer and also the secondary side</u>*** (Original underline). ***There "Transient Two-Phase Flow Best Estimate Codes" with adequate verification are <u>urgently needed</u>*** (Emphasis added) ***which include sufficient secondary side modeling and control system logic.***

The transient loading conditions are indeed vital, and treating these conditions correctly is *urgently* and immediately needed.

Finally, **Pages 698-699** identify a distinct need: The need for global and local "**EMPIRICISM**" to better deal with the transient problems. Empirical or conjectural methods may be used when categorical and unequivocal methods do not exist. But, when definite methods are available, then there is no place for empiricism. Every expert should be able to look at a forcing function that rises to a maximum in less than 10 milliseconds and immediately recognize the magnitude of the overshoot involved. The fact that we do not measure the overshoot does not mean that it is not there. This is like the *modern digital weight scale* mentioned in my article.

The above is an infinitesimal sample. The dynamic transient problem in nuclear reactors have been treated very seriously after Three Mile Island, and there are many papers by worldwide experts on the subject. The Proceedings I mentioned above, and several others, and textbooks on Reactor Dosimetry, Design, and Standardization all compare the pressure build-up, as measured with (sensitive) pressure transducers, with the analytical or computer code predictions of the same pressure build-up. This is like measuring the input, and then predicting it; or vice versa. But, even if you go through all the above references, it is still an infinitesimal sample. Pick up at random any textbook on propulsion in a technical library, or your own propulsion textbook, and look for the transient response to the rapid pressure build-up in an engine or a motor. It simply isn't there. You can then move on to other mechanical engineering textbooks on theory of elasticity, machine design, etc. There is no overshoot, just like the modern digital weight scale.

An aircraft enters suddenly a dangerous wind shear zone. What happens. We use the *drag equation* to calculate the force. We use wind tunnels (in *steady-state flow*) to confirm the calculated force. We place hundreds of *pressure transducers* around airports and measure the pressure accurately. But, there is no mention whatsoever of something called overshoot in this and similar critical transient situations. At the speed an aircraft approaches an airport, it will be in the midst of the shear zone in some 200 milliseconds. This is a near unit-step forcing function.

It is not enough that we know about forcing functions, transient responses, and how to do the transient analysis. The transient analysis must be done correctly. In most cases, it has not.

Sincerely yours,

Ali F. AbuTaha

See also, "Radiation Embrittlement and Surveillance of Nuclear Reactor Pressure Vessels: An International Study," Conference sponsored by IAEA, ASTM Committee E-10, 1981; and similar references.

cc:

S. FABIC

1. The fewer the number of fields i. e., fluid phases and components, and the fewer the number of degrees of freedom (dimensions) considered in the analyses, the larger is the demand on global empiricism. In that case the system components are viewed either as black boxes, or very simplistic models are employed to rely on empirically determined coefficients for simulation of the overall behavior. Demand on global empiricism, in the course of simple modeling, is stronger in the case of severe accident scenarios, as contrasted to a weaker deman (e. g. 1-D modeling) for milder transients. This is illustrated in Figure 1.

2. The reverse situation exists concerning the demands on the local empiricism, as illustrated in Figure 2. Complex models require a large amount of local empiricism (e. g. for local exchanges of mass, momentum, and energy between fluid phases and/or components, as functions of the flow topology).

3. Extensive use of global empiricism greatly constrains the domain of the code applicability. Extensive use of the local empiricism is aimed at extending the code applicability to a greater variety of system geometries and physical processes. However, the existing data base useful for generating the needed local empiricism is not adequate. This, in fact, has been the main criticism of the advanced codes. One of the main drawbacks in such codes is the use of flow regime maps to define the flow topology in complex geometries, even though they were obtained only for simple and steady-state pipe flows. This speaker feels that if more fields are considered (perhaps in the far future) it may be easier to define the exchange processes (local empiricism) because of dealings with physically identifiable entities (e. g. vapor bubbles vis-a-vis liquid droplets, vis-a-vis continuous vapor or liquid fields) rather than some amorphous mixtures. More importantly, consideration of more fields and their interactions has a chance of eliminating the need for flow regime maps.

4. The bottom part of Figure 3 shows a qualitative relationship between accident probability, consequences, and the risk (defined as the product of the former two). If the "consequence" absicssa is regarded synonymous with the accident severity, it can be concluded that the scenarios involving highest risk do not involve transients/accidents of highest severity, such as the large break LOCA.

The upper half of Figure shows the qualitative relationship between the severity of transients/accidents and the required complexity for the best estimate modeling. It can be seen that while the realistic analysis of the large break LOCA requires considerable modeling complexity, analyses of transients/accidents within the high risk domain are not so demainding.

Since most of the previous work on code development was focussed on the Design Basis Accident (Large Break LOCA), the advanced codes designed to handle DBA contain a certain amount of "overkill" with respect to the required complexity for modeling of the high risk accident/transients scenarios. The important consequence of this overkill is the large cost of computation involved with the B. E. LOCA codes.

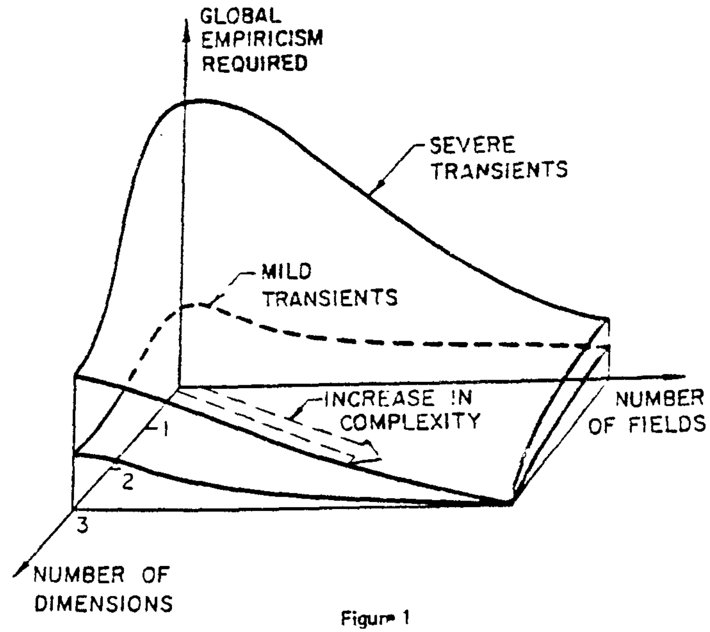

Figure 1

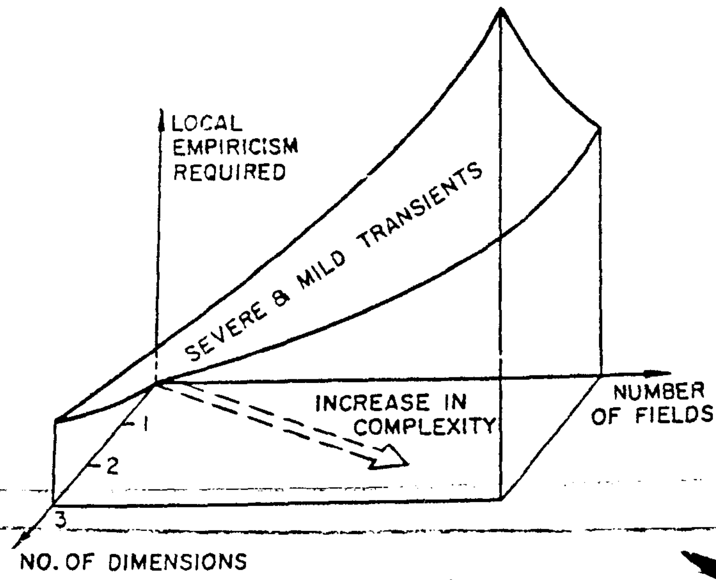

Figure 2