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The Early Days in the development of thermal-hydraulic reactor analysis computer codes.

I'm not really sure what "early days" mean but will assume that this refers to the time frame of the 1960's through the mid 1970's covering the development of the various computer codes leading to the first RETRAN version sponsored by EPRI. Also there were ~~hundreds~~ many of people involved with both the experimental as well as theoretical work so it's very difficult to give extensive credits in this presentation.

Background (Broad brush without details of most dates and efforts.)

First of all I need to tell you briefly about the area where a great deal of this work was done. The Department of Energy (DOE) operates this area that has had several names but is now called the Idaho National Engineering and Enviornmental Labartory. It is an area of about 700 square miles and sits west of Idaho Falls about 35 miles. It was started in the late 1940's by the Atomic Energy Commission (AEC) as a remote area to build and study the then unknown details of nuclear reactors. Through the 1950's to the 1980's many experimental versions of nuclear reactor designs were built and studied as well as experiments involving the effects of radiation on various materials. Argonne National Laboratory (University of Chicago) studied reactor designs cooled with liquid metals, the organization (operated by several contractors to the AEC) that I worked for was mostly involved with water cooled designs, and several other projects were military including a facility operated by Westinghouse for the Navy to train nuclear submarine crews. There was also a reprocessing plant to handle used military fuel. Now most of these facilities and reactors (about 70 or so) are now shutdown and some have been completely removed.

LOFT

Jim/LOFT 1968

In the late 1960's and 1970's much of our work was concentrated on understanding the safety aspects of operating commercial power plants. In particular, an experimental reactor called LOFT (Loss of ~~Coolant~~ Flow Test) was built to be similar to a commercial Pressurized Water Reactor but on a much smaller scale. At that time some of the most severe accident scenarios were thought to be involved with a loss of cooling of the reactor fuel leading to severe consequences such as core meltdown. Thus LOFT was designed to study experimentally some of these scenarios especially the Large Break Loss of Coolant accident (LOCA).

Both input to The 650 was punched paper cards & 90 was the output.

When the LOFT project began, I had been working at this site as an engineer for about 8 years in analysis, design, and simulation of various reactors using both digital and analog computers. The first digital computer that I used in the late1950's was an IBM 650. This was a vacuum tube design using lots of electric power and filled a rather large room. Programming it involved coding in basic machine languages and wiring patch boards to activate various circuits. Later the 650 supported an early version of the FORTRAN language but program complexity was still limited to about 2000 computer words. Later in the 1960's we obtained an IBM 7040 computer and eventually IBM 360 series of machines. Today those computers pale in comparison to my current personal PC and they cost millions of dollars. In any case that was the leading edge of technical analysis.

My first involvement with the LOFT project was an assignment to study and develop a computer code to aid in its design. I started with a computer code called FLASH that was developed by Westinghouse (Margolis and Redfield) for admiral Rickover's submarine projects. We called our code RELAPSE, an acronym for REactor Leak And Power Safety Excursion as well as a pun on what the computer bill would cause. RELAPSE was like FLASH in using only three regions (volumes) to model the primary cooling system, one for the heated water from the core, one for the cold water entering the core, and one for the pressurizer with very simple models for other components.

(I think Porshing came later)

Over the next few years, a team of three to five other engineers expanded the capability of RELAP generating several more versions. With RELAP3 (1970) the analyst could describe the reactor primary system in more detail with up to 20 volumes. This was the first version to have non-trivial analysis capability but was still inadequate in a number of ways including more complex constitutive relations and generalized geometry with the number of volumes limited only by the computer.

As I remember, Jim McF ~~was~~ was part of the LOFT program.

The efforts leading to RELAP4 (1973) involved this rather small team but a large number, 30 or so, people doing analysis for LOFT as well as experiments from other laboratories and vendors. We maintained control over each of the many development versions of the code, often a new one each day, but also allowed the analysts to use even the latest one. This resulted in long lines of people outside my office each morning wanting to know why they obtained pecular results. Today's standards for code development, control and maintanence were obviously non-existant since we usually did whatever we deamed necessary to improve the models. All of this work was done in an environment much different from the desktop computers of today. We had to hand write each line of the Fortran code which was then processed by other people on key-punch machines similar to a typewriter producing cards that were the input to the computer. The card deck for RELAP4 occupied a rather large brief case.

Some ~$100k at commercial rates

It was common for detailed analyses to use many hours of computer time and this really cost the projects lots of money. Initially the only output from the computer was an on-line printer and if the computer crashed, you had to completely redo the analysis. We eventually used magnetic tape to record the analysis results allowing a lot more flexibility to ~~on~~ printi~~ng~~ results and also restarti~~ng~~ an analysis in mid-stream.

RELAP4 had the capability to analyze both PWR's and BWR's for various accident scenarios including large breaks. While a lot of worthwhile results were made with this code, the very complexity of real reactor systems was beginning to show up as difficult problems to analyze. The basis for all RELAP codes to that date was one-dimensional hydraulics and to approximate real three-dimensional regions such as reactor cores was at best an art.

All of that said, many engineers used RELAP4 to analyze and predict a number of experiments funded by the government (NRC, AEC) as well as experiments developed by the vendors of nuclear plants. My coworkers and I were involved with some of these including a pre-prediction of a General Electric experiment that was a "Standard Problem" for the NRC. We did our best to model this experiment with RELAP4 providing the results to higher-ups in the company. That person then went to a meeting at GE and came back with the information that out results were all wet. After a number of modifications of our model, we still came up with essentially the same results and refused to "match" the perceived answer. It turned out that this perceived answer was wrong and we did get it right. In the end RELAP helped design LOFT but the LOFT experiments helped redesign the next generations of reactor accident analysis codes. & CONTEMPT

all these were from the same organization INEL

Sullivan
Lauben

In this era, a new regulation, 10CFR50, for power plant licensing was being adapted and the NRC wanted codes that implemented these regulations. The main codes used as the basis for this were RELAP4, MOXY and TOODEE but these had to be significantly modified to implement 10CFR50. This effort involved about a dozen people from the Idaho site as well as several from the NRC. Many of the 10CFR50 requirements were intended to be "conservative" and as such were not in the realm of real physics but simple edicts such as throwing away cooling water. Implementing these requirements was probably the most difficult of all of our efforts. We had to use a great deal of the government's computer resources, especially at Argonne Chicago. They complained loudly about our ~~hogging~~ excessive use of their IBM 360/195 and threatened to throw us out. Washington sent them a directive saying we should have unlimited access on the night shifts even to the point of shutting their own projects down. This then was the level of pressure brought to bear to develop WREM (Water Reactor Evaluation Model) for the NRC and was my last project for the government. In fact, the President of Aerojet Nuclear Company addressed ~~the employees~~ us (~~including me~~) in 1973 that ".. we will go on from the present series of computer codes … but we've completed their (the present series) which many of you know as the RELAP series." Its odd but almost 30 years latter the same and related computer projects are still around. ~~This~~ and this was one of the considerations to go find another job.

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I then joined a new company in 1974, Energy Incorporated, where we had the good timing to associate with the newly formed utility organization called the Electric Power Research Institute. Most of the RETRAN team today came from this group.
It was obvious to us as well as EPRI that the utility industry also needed an independent capability to analyze various scenarios. While RELAP4 did a reasonably good job for large breaks, it was not designed to analyze more realistic scenarios such as small breaks and operational transients. Large break accidents are very violent and are over in a matter of minutes whereas these more mild transients produce conditions inside the reactor system significantly different from the large break conditions. With the sponsorship of EPRI, we set out to develop a new series of codes called RETRAN (REactor TRANsient) starting from RELAP4. The EPRI project manager for this first version (Jan 1977) was Lance Agee with a team of about 14 people from EI including Jim McFadden, Mark Paulsen and Craig Peterson and myself.

Gary Gose

While EPRI continued to sponsor RETRAN through the next decade and EI eventually grew to several hundred people, in the mid 80's EI went bankrupt and ceased to exist. Then in 1988, ~~four of us~~ (Jim, Mark, Craig, myself) and later Gary formed Computer Simulation and Analysis (CSA) with the specific intent of continuing the RETRAN work for EPRI.
I find it interesting that my work on the RELAP and NRC codes covered about eight years whereas EPRI has been funding RETRAN one way or another since the mid 70's.