From Slide Rule to Computer: Forgetting how it is used to be done.

By Henry Petroski (notes on the article)

I was advised along with all the other freshmen to get, right at the start, a good slide rule with all the scales I would ever need.

What our engineering instructors were interested in teaching us was not all the grand things that our various models of rules could do, but their common limitations. We were expected to know that we could only report answers accurate to three significant digits from our rules.

The result of a calculation could not have a greater accuracy than the least accurately known input number.

We also learned how to estimate the order of magnitude of our answers.

As late as 1967 Keuffel & Esser did not predict the demise of the slide rule within five years.

In 1968 "if this hand-size calculator ever becomes commercial, the conventional slide rule will become a museum piece." In 1968: "Only the digital readout still poses a problem, since at present there are no low-cost miniature devices available."

In 1974 there were price breakthroughs with the Commodore model SR-1400, a "37 –key advanced math, true scientific calculator".

We faculty were thus faced with the question of whether students with electronic slide rules had an unfair advantage on quizzes and examinations over those with the traditional slip sticks.

By 1976 Keuffel & Esser consigned to the Smithsonian Institution the machine it once used to carve the scales into its wooden slide rules.

By the mid-1970's calculator manufacturers were making fifty million units a year, and soon just about everyone, including engineers who went through school in the old days, had a calculator.

A decade after the calculator displaced the slide rule, we are beginning to ask these questions (and we are still asking them), but we are asking them not about the calculator but about the personal computer.

Some structural failures have been attributed to the use of and misuse of the computer.

Each revision of one part of a structure could affect the stresses in every other part. If that were the case, the entire stress analysis would have to be repeated. In the days of manual calculation with the slide rule, such a process would be limited by the sheer time it would consume, and structures would be generally over designed from the start and built that way.

The computer can be used to analyze structures that engineers of slide rule era found too complex

Since the engineer himself presumably has no feel for the structure he is designing, he is not likely to notice anything suspicious about any numbers the computer produces for the design.

While the computer works very quickly as a file clerk, it cannot work very quickly when it is asked to analyze certain engineering problems.

The computer does not work with ideas but with numbers, and it can only solve a single problem at a time.

The computer is both a blessing and a curse for it makes possible calculations once beyond the reach of human endurance while at the same time also making them virtually beyond the hope of human verification.

Unfortunately, nuclear plants and other complex structures cannot be designed without the aid of computers and complex programs that work the problems assigned them. The analysis of the many piping systems in nuclear plants seems to be especially prone to gremlins, and one computer program used for calculating the stresses in pipes was reportedly using the wrong value of ?. Another incident with a piping program occurred several years ago when an incorrect sign was discovered in one of the instructions to the computer. Since the computer results had been employed to declare several nuclear plants earthquake-proof, all those plants had to be rechecked with the corrected computer program. This took months to do.

Even if a computer program is not in error, it can be improperly employed. The two and a half acres of roof covering the Hartford Civic Center collapsed under snow and ice in January 1978; only hours after several thousand fans had filed out following a basketball game.

Apparently, the original designers were so confident of their own oversimplified computer model (and that they had asked of it the proper questions) that when workmen questions the large sag noticed in the new roof they were assured that it was behaving as it was supposed to.

Because the computer can make so many calculations so quickly, there is a tendency now to use it to design structures in which *every* part is of minimum weight and strength thereby producing the most economical structure. This degree of optimization was not practical to expect when hand calculations were the norm, and designers generally settled for an admittedly over designed and thus a somewhat extravagant, if probably extra-safe, structure.

The Electric Power Research Institute (EPRI) has been sponsoring a program to test the ability of structural analysis computer software to predict the behavior of large transmission towers. A full-size giant tower has been constructed and the actual structure can be subjected to carefully controlled loads as the reaction of its various members is recorded. The results of such real-world tests were compared with computer predictions of the tower's behavior, and the computer software did not fare too well.

It is only the factor of safety that is applied to transmissions towers that appears to have prevented any number of them from collapsing across the countryside.

Thus, while the computer can be an almost indispensable partner in the design process, it can also be a source of overconfidence on the part of its human bosses. When the computer is relied upon for the design of innovative structures for which there is little experience of success, let alone failure, then it is as likely, perhaps more likely, for the computer to mistaken as it was for a human engineer in the days of the slide rule.

Canadian Concrete Code Committee – "changes have occurred so rapidly that the profession has yet to assess and allow for the implications of these changes." In the design office the reduction in computation time will free the engineer to spend more time in creative thought – or it will allow him to complete more work with less creative thought than today. Because the computer analysis is available it will be used. Because the answers are so precise that is a tendency to believer them implicitly.

The American Society of Civil Engineers – "Should the computer be registered?"

Computers, while really no more than elaborate electronic slide rules and computation pads, enable anyone, professional engineer or not, to come up with a design for anything from a building to a sewer system that looks mighty impressive to the untrained eye. Is it becoming easy to take on design work outside of the engineer's area of expertise simply because of software page is available? How can civil engineers guarantee the accuracy of the computer program that the engineer is qualified to use it properly?

This is one of the most significant developments in the history of structural engineering