STANPIPES MOVES TO THE WINDOWS ENVIRONMENT

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Abstract

STANPIPES is the software embodiment of the design environment within which Ontario Power Generation personnel perform piping analysis. Its various programs and supporting utilities, interfacing with commercial finite element packages are geared to design and fitness for service calculations for all classes of nuclear piping and B31.1 conventional piping. Historically, STANPIPES resided on a (Compaq Alpha) Virtual Memory System (VMS) platform. The past year has seen its transition to the Windows environment. With this transition, it has acquired graphics capabilities and a user friendly interface. This paper show-cases its present form and capabilities.

1. Introduction

This paper is the companion of a presentation to be given at the 2008 CNS Annual Conference to showcase the package of piping analysis software known as STANPIPES. The bulk of the presentation is expected to be a demonstration of the software in the Windows environment: its user interface, its graphic representation of piping models, utilities and a few of its key utilities to perform complementary tasks.

Here, we shall describe the program in general terms, give a brief history and discussion of how it is structured and where we perceive it to be going.

2. A brief history of STANPIPES

STANPIPES began in the early 1970's as a loose collection of programs designed to perform very specific (and relatively simple) nuclear class 1 piping analysis tasks. It resided on a (Sperry Corporation) UNIVAC 1100 series computer. Simple static analyses were done, where possible, using (internally developed) GPE or (externally purchased) PIPEFLEX [1] piping programs. Seismic analysis made use of an early edition of the finite element package Cosmic NASTRAN [2] to perform a modal analysis after which a very simple response spectrum analysis could be performed. Multiple thermal transient thermal expansion analysis was done approximately by scaling the design temperature thermal expansion analysis. The applicable code was the 1974 edition of ASME Section III NB-3600 code [3]. Software maintenance and development was performed in the Engineering Systems Department of the Information Services Division.

When Darlington was conceived, the code effective date was the 1980 edition of the ASME Boiler & Pressure Vessel code up to and including Summer 1980 Addenda. Cosmic NASTRAN gave way to MSC NASTRAN (offered by the then MacNeal-Schwendler Corporation) [4].

Experience with NASTRAN in modal analysis suggested its use in static analysis too. GPE and PIPEFLEX became historic foot-notes. Control over programming came over to us. (In those days, we were the Mechanical Design Department of the Design and Development Division of Ontario Hydro.)

As need dictated, STANPIPES evolved. Water hammer was added to its capabilities. Seismic analysis embraced multipoint excitation. Seismic analysis could be done by time history. Piping models could embrace multiple piping classes, an important feature as it would often be found that various classes would be dynamically coupled; separated perhaps by an unanchored valve. Forecast thermal transients in the primary heat transport system became more complex and the need to accurately analyze many of them gave rise to the current Multiple Thermal Transient capability.

The Three Mile Island event of 1981 resulted in interest in new instructions regarding primary heat transport pump operation for CANDU stations. They were to be kept operating even if in a state of cavitation. Tests to see whether *pumps* could withstand this punishment revealed that *pipes* were also an issue. From this, came a "steady state response" capability in STANPIPES. This is discussed extensively in [5]. Here, it suffices to say that experimental data determines the amplitude of pressure waves sent down the flow path and is assumed to induce a fully developed steady state resonance response in the piping.

As time moved on, design of new stations gave way to maintenance. New code editions came out and with them new code effective dates for upgrade work. So STANPIPES became capable of breaking up a model into various code segments. The "old" piping might apply the 1980 code and new piping the 1997 code. At the time of writing, there are three ASME code editions fully established in STANPIPES: S80 (1980 + S summer1980 Addenda), A97 (1997 code up to and including 1997 Addenda) and 2004 code. Changes to our regulation CSA N285.0-06 [6] - expected to be mandatory within OPG by mid 2008 - gives rules as to which ASME code edition to use and as the "latest code" designates the 2004 ASME code. So new code editions will be added as necessary to keep up with changes to CSA N285.0.

Fortuitously – in retrospect – we had only modest resources in manpower to devote to software maintenance and development. It was out of the question to develop our own structural solver. NASTRAN had its own DMAP (Direct Matrix Abstraction Programming) language available enabling us to intervene in solution execution - usually to pull out specific information - with a minimum of programming effort on our part. So NASTRAN became our central solver; most of our own programming effort aimed at enabling our engineers to communicate with it and to interpret the results of its calculations. (This was to be managed without their necessarily being expert NASTRAN users.) This communication, as we shall see, entailed pre and post processors whose respective functions are to create NASTRAN analysis input files and to read the results of these analyses from output (binary) data blocks. These results are sometimes tabulated directly for immediate user perusal. They are usually also written to STANPIPES "result" files [7].

A fortunate consequence of the use of a finite element program solver is the flexibility it supplies. One can use STANPIPES to generate a NASTRAN model for one of its usual applications and can then manipulate the finite element model to do something quite different;

outside the realm of current STANPIPES activities. New capabilities to STANPIPES often began with such manual input file construction. Then, as the need dictated, the enabling software would be developed to automate it as a regular STANPIPES feature. This is how seismic analysis by time history, multiple thermal transient and steady state response analysis came to STANPIPES.

Some analyses remain special manual applications; never part of formal STANPIPES. They may have STANPIPES origins – but evolve beyond anything envisioned for automation. So important has this aspect become that STANPIPES now routinely generates neutral files for the mesh generation program FEMAP [8]. Starting with what STANPIPES provides, embodying a one-dimensional centre-line model, one can move to much more detail and local sophistication. The target analytical result can be any of the finite element packages FEMAP supports: ANSYS, ABAQUS, H3DMAP and NASTRAN to name four routinely used at OPG. FEMAP has proven useful too within STANPIPES as a means of visually post-processing results, pictures often revealing details one would be unlikely to spot in tables of numbers.

The latest major issue for STANPIPES has been formal documentation and governance. In the earliest days, STANPIPES could casually acquire new features by accretion. Reports validating the results were always written – but these tended to be self-contained; not usually part of a master structure. The emergence of CSA Standard N286.7 [9] and its OPG spin-off governance made a much more formal strategy necessary. There is a five year plan to supply all the documents now deemed relevant in light of current governance.

Computer use underwent a parallel evolution with STANPIPES. In 1986, Sperry merged with Burroughs to become UNISYS. The final iteration of that architecture used by STANPIPES was the UNISYS 1192. In 1983, the Mechanical Design Department acquired a DEC (Digital Equipment Corporation) VAX 780 mini-computer and STANPIPES migrated to it in 1988. The UNISYS command language was replaced by DEC’s Virtual Memory System (VMS). In 1998, Digital Equipment Corporation was purchased by Compaq which was, in turn, acquired in 2002 by Hewlett-Packard. The most sophisticated computer used by STANPIPES, employing the VMS system was a Compaq Alpha.

The VMS platform has served us well over the years. However, it became something of a dead-end when the purveyors of NASTRAN stopped providing the latest versions of their software for it. All versions of NASTRAN beyond version 68 (released in 1994) required a UNIX or a WINDOWS operating system. The decision was made to go to the latter for ease of use and transition. The earlier transition to VMS from UNISYS had occasioned significant upheavals as personnel adapted to the new system and its enabling software (text editors and command language). A switch from VMS to UNIX would have been at least as significant as had been that to VMS while personnel at OPG all use Windows applications routinely for business purposes. There would have been a speed advantage in going to UNIX which was relinquished reluctantly.

That decision made, the use of Visual Basic Scripts (*.vbs) and batch files (*.bat) made the entire software package functionally much as it had been on VMS. Most STANPIPES command procedure files (*.com) on VMS got their *.vbs or *.bat counterparts – depending on whether they were to interact with the user or execute as fragments of batch runs. Fortran programs were rewritten to the Fortran 90/95 standard (from the Fortran 77 in which most had been written) to facilitate the Windows transition. This would all be transparent to the user except for the opportunities which came with the switch to Windows to make STANPIPES more user-friendly. One could use visual basic "forms" for data entry (sparing the user having to worry about such details as whether numbers were in the right columns). One could use "tool-tip" messages to informally prompt or advise the user (reducing the number of routine consultations of the Users' Manual [10]). And one could provide interactive visual display previously unexplored with STANPIPES.

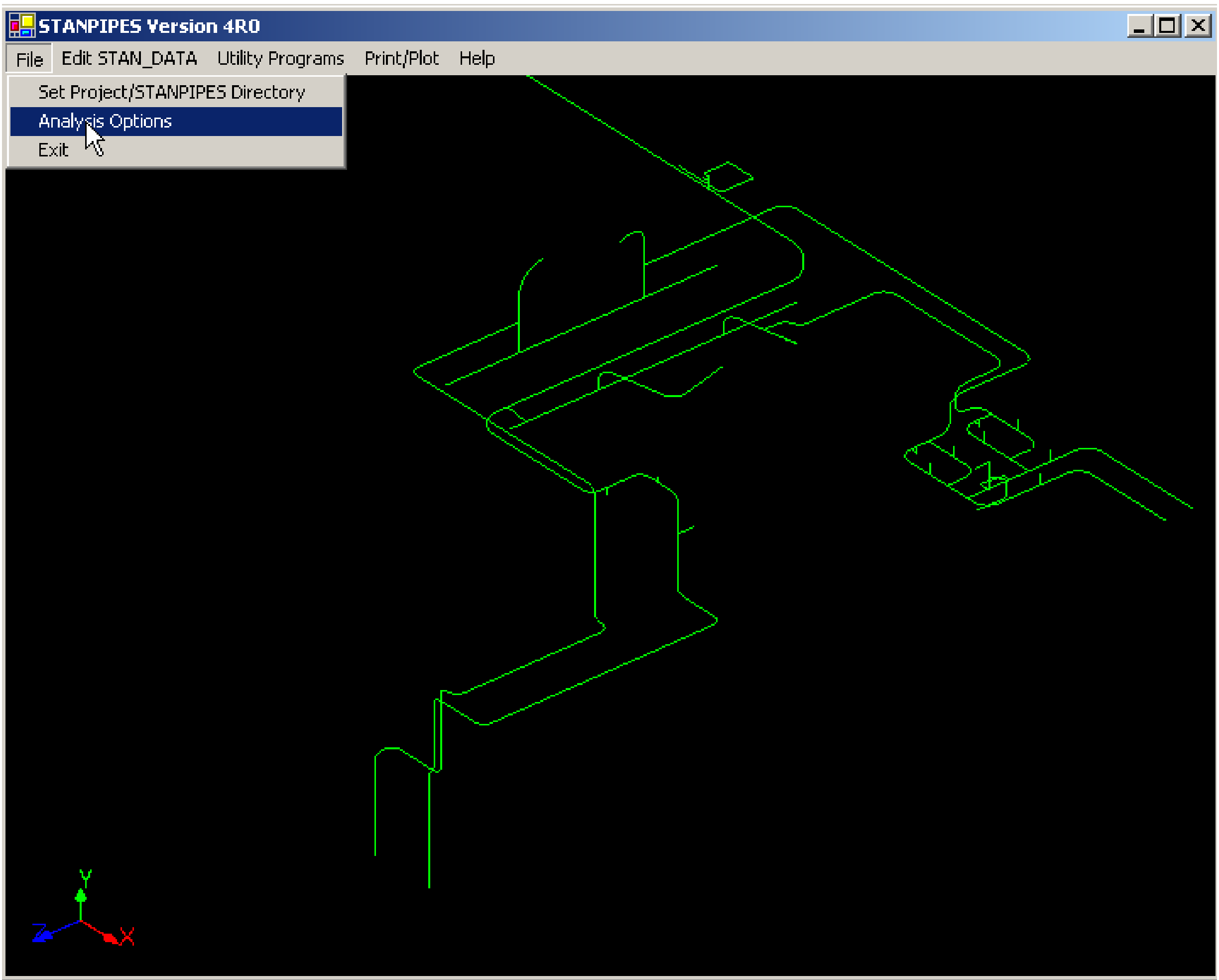

Figure 1: STANPIPES Display of a Typical Model

3. Present Structure of STANPIPES

STANPIPES consists of a collection of executable programs and their enabling scripts. The user interacts with the entire package via a Visual Basic interface executing various analytical "steps" as befits the case. The user works within a "project" folder for a given piping model. The interface can be used to construct user data files for the various steps within this project; given filenames of the form STAN_DATA.*. (Not all steps normally require special data.) In the course of execution of its programs, STANPIPES generates and populates various binary "result" files. STANPIPES programs may create result files, consult them for information or write to them as befits their nature.

Central to the collection of STAN_DATA files is STAN_DATA.model from which all else flows. Once such a file exists, the user can display its model. Figure 1 shows the model representing the NE quadrant of the primary heat transport system of a Darlington unit. Displayed is the picture as initially loaded, the user about to explore analysis options. We can rotate the image about any of the coordinate axes, make the display solid (thereby seeing relative pipe sizes), show node locations and numbers, colour code the piping by material or pipe class and zoom in or out to get a better look at a region of interest.

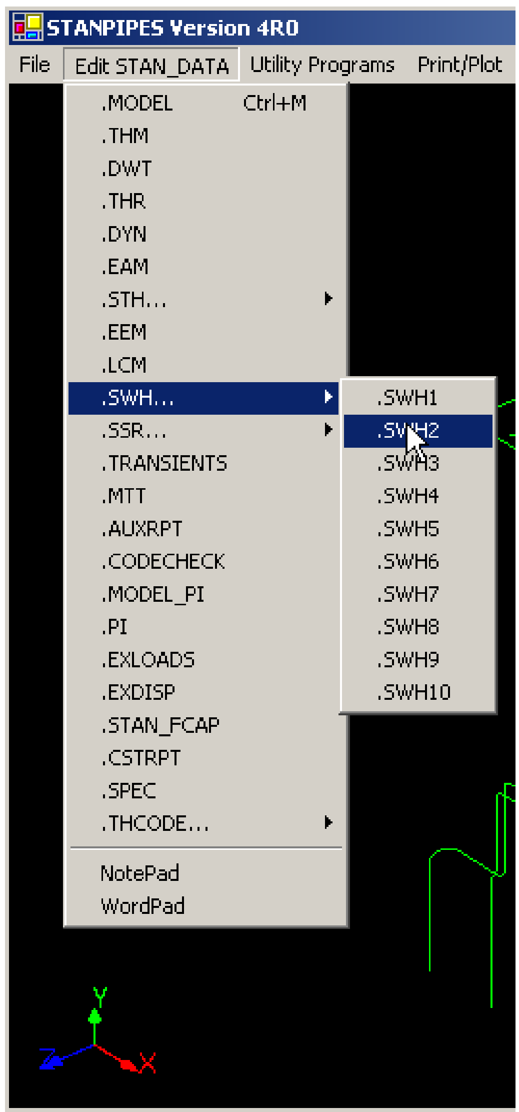

Figure 2: Creating or Editing STAN_DATA.SWH2

Note that the menus of the STANPIPES interface include "Edit STAN_DATA". Any of the STAN_DATA files can be edited here. STAN_DATA.model tops the list; the others providing loading or directions for other steps a user may run. Figure 2 shows the menu selection a user would make to edit a file STAN_DATA.SWH2 providing loading for a water hammer analysis which has been designated (by the user) as load case number 2.

Having selected the file to edit, the user may exploit the various forms consistent with the applicable data images. Figure 3 depicts the editing of a MAT (material) data image within STAN_DATA.model. Having selected the line in question (or choosing MAT from the insert menu) the user will load the MAT form. Note how floating the cursor over a given data field will briefly announce its physical content and expected units.

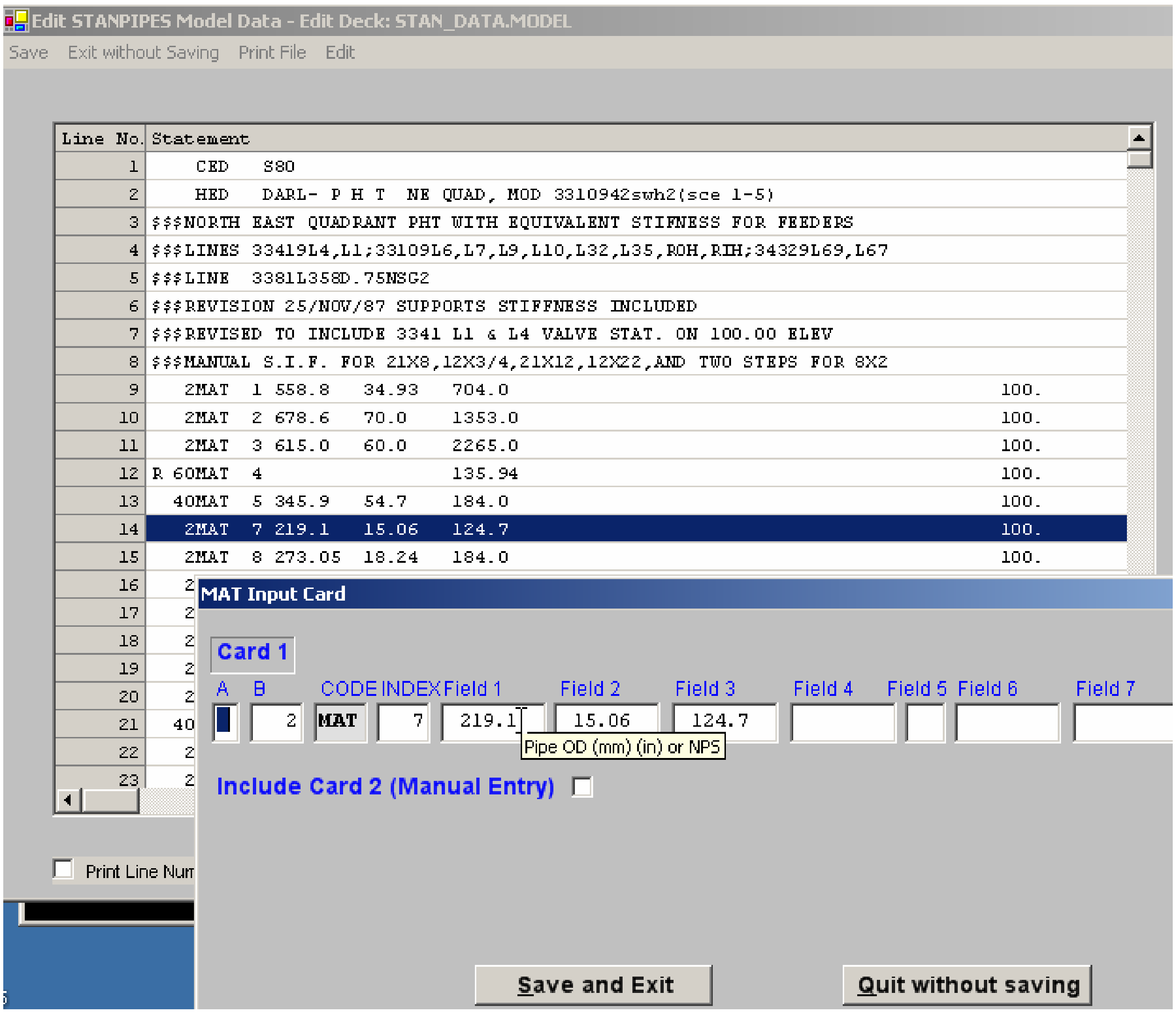

Figure 3: Editing a Material Data Image

When the necessary data is constructed, the user will execute an analysis step. Figure 1 showed how a user calls up the Analysis Options form (Figure 4) to select the step(s) to be run.

The first step a user *must* run after having constructed STAN_DATA.MODEL is the "validation" step. This step checks over the data and issues any relevant messages. FATAL messages – in validation or in any other step - stop execution cold! WARNING messages indicate that assumptions are implicit in the way the program proceeds *which may not be what the user had in mind*. It behoves the user to rerun validation – leaving nothing to the imagination - until all warnings have disappeared and only INFORMATION messages remain. Validation also prepares several of the "result" files to receive data from subsequent steps notably the MASTER file which holds properties for all structural "members" (prospective finite elements) and MEMBER_TBL which stores over-all project parameters.

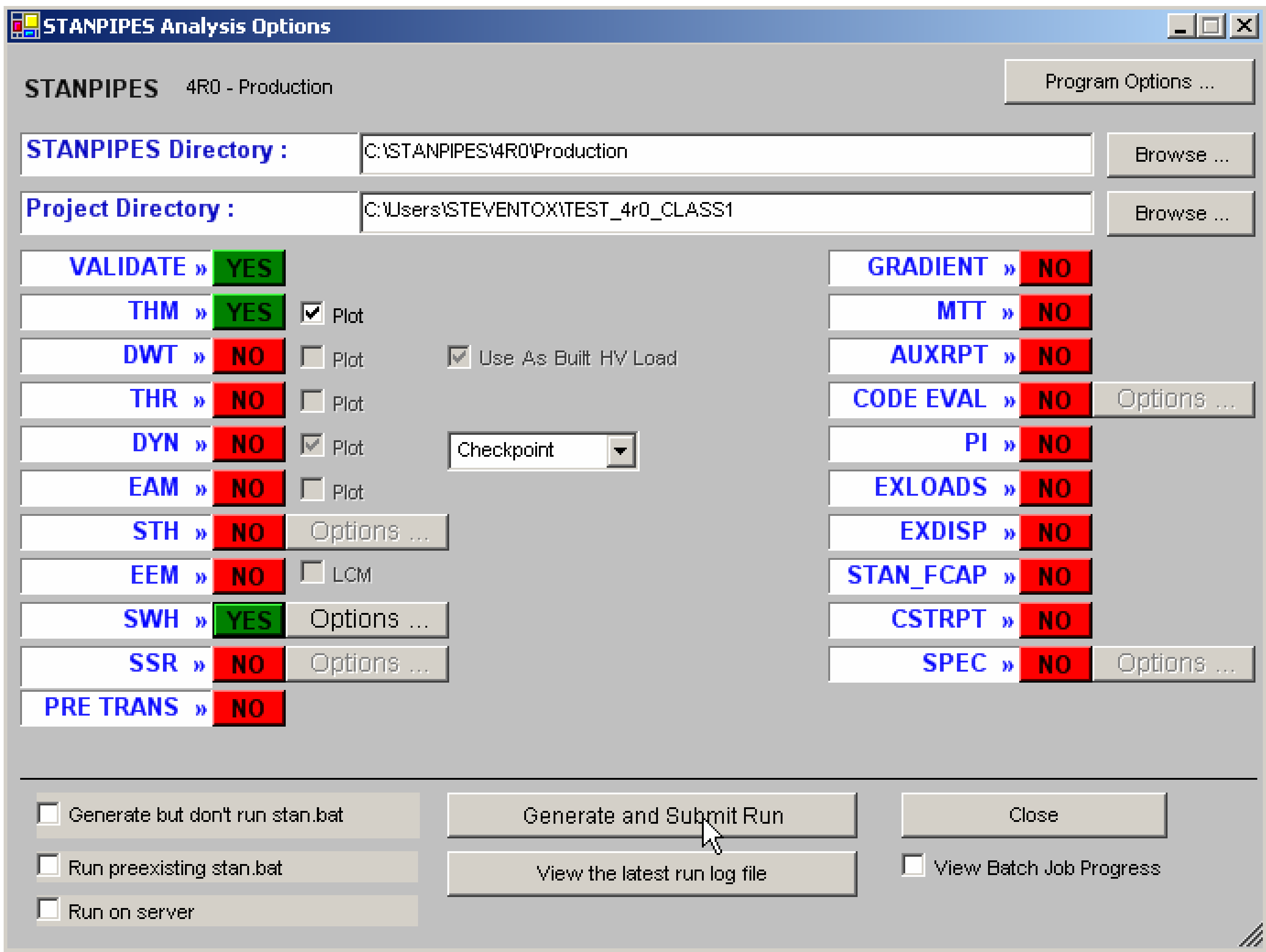

Figure 4: Select Validation, Thermal and Steam/water Hammer Analysis Steps

Normally, the user will proceed with other steps: thermal (THM), dead-weight (DWT), thrust (THR), modal (DYN), earthquake anchor movement (EAM), emergency earthquake motion

(EEM), seismic time history (STH), steam/water Hammer (SWH), steady state response (SSR), preliminary transient Data processing (PRE-TRANS), thermal gradient analysis (GRADIENT), multiple thermal transient (MTT), auxiliary (support forces) report (AUXRPT), code evaluation (CODE EVAL), periodic inspection (PI), extraction of details regarding loads (EXLOADS), extraction of data regarding displacements (EXDISP), STANPIPES fatigue crack growth in piping components pre-processor (STAN_FCAP), custom (support loads) report (CSTRPT), (secondary) spectrum generation and decoupling assessment (SPEC).

Note at the top of the Analysis Options form of Figure 4 that there is a button "Program Options" for fine tuning the use of finite element programs used on the various steps. Figure 5 shows the Program Options form, the user in the process of selecting NASTRAN version 2005 in lieu of the default version 70.7 for thermal analysis. (Note that H3DMAP version 6.2 and 3 other versions of NASTRAN were alternatives for simple thermal analysis.)

By judicious selection of check-boxes and slider control, the user can also:

- Change the number of lines per page of printed output from the default 97.
- Run selectively, pre-processors, finite element programs and post-processors. The default shown is that *all* are run.
- Invoke files which will automatically edit finite element input files generated by calling up EDIT_NASTRAN_DECK.* files. Default is not to have any such files but if they do exist, the deck will be edited *on the fly* during the sequence: pre-processor, finite element, post-processor executions.
- Prepare neutral data files for FEMAP to provide visual post-processing of finite element results.
- Perform specialist functions: "Dump Binary Files" and "Compare with Archived Results" are benchmarking activities when new versions of STANPIPES are being tested. "All Finite Element Choices" over-rides default restrictions on which finite element programs are permitted for the various steps. This enables us to try new development initiatives which, by their nature, do not yet have adequate quality assurance to be used for production work.

In addition to regular steps, STANPIPES has a number of utilities which it has acquired through accretion as need has dictated over the years. On VMS, users were given "symbols" (short acronyms) to call up the most popular. In the Windows environment, all those of interest to users are available through the interface.

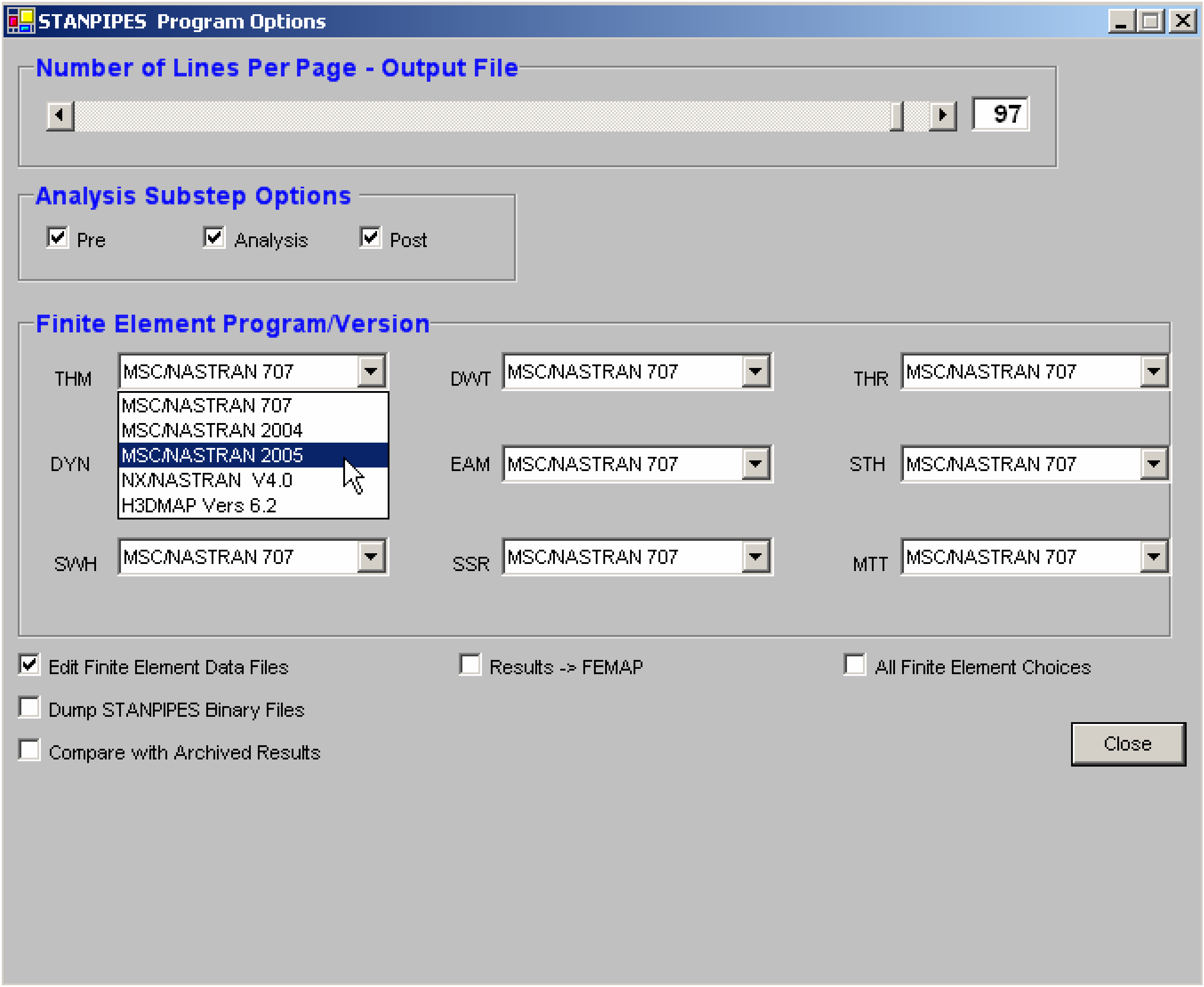

Figure 5: Program Options Selection of Version 2005 for Thermal Analysis

To illustrate the calling up of a utility, the menu selection of the Dump Utility (used to review the contents of the binary result files) is illustrated in Figure 6.

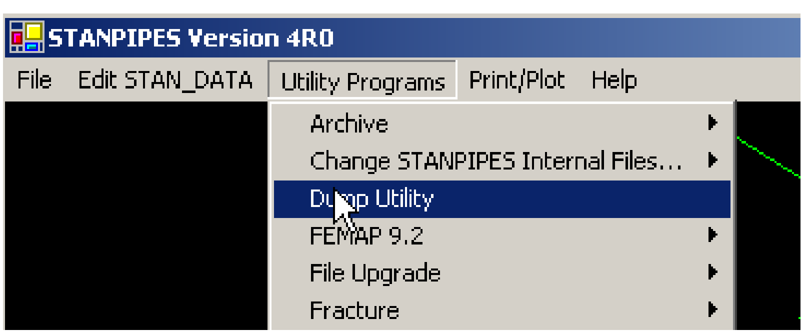

Figure 6: Calling Up the Dump Utility

Figure 7 shows the consequence of that call, a window opened with its own menu in which the user begins by identifying the desired binary file and proceeding from there responding to navigational and information display queries.

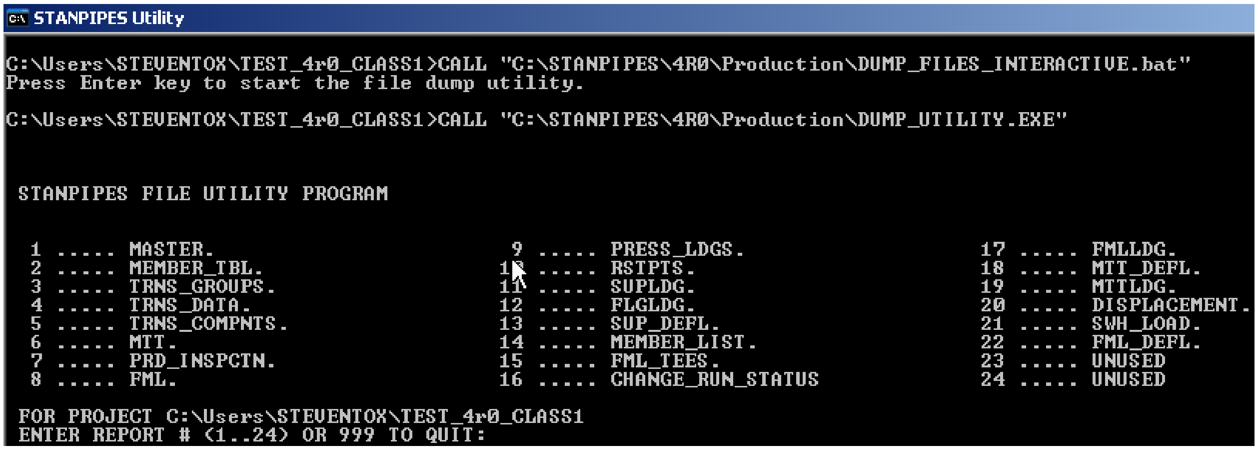

Figure 7: Executing the Dump Utility

4. Special STANPIPES analyses

The use by STANPIPES of finite element programs has facilitated its use in special applications. Each could of itself be the subject of a presentation. Here, we are content to list a few with a brief description to give an indication of what can be done.

4.1 The shift/window feature

This capability evolved to enable a user to get around the STANPIPES piping model limitations of 1000 or fewer nodes and 1400 or fewer elements. The user creates a number of smaller models, uses the pre-processor to generate a NASTRAN model, applies a shift utility to map default NASTRAN ID numbers generated by STANPIPES into small model specific ranges (to make them unique). A knowledgeable NASTRAN user then melds them to create a large composite model for running NASTRAN. The postprocessors are applied within each of the original sub models and given the shift data to window on that part of the composite representing the given sub model; feeding the applicable responses to its result files. From there, each sub model has its pipe stresses and support load checks done exactly as if it were the entire self-contained model.

The shift/window feature was crucial in the dynamic modeling of large banks of (dynamically coupled) Darlington NGS feeders. Well over 100 feeders may be required to embrace a dynamically complete collection.

4.2 Non-linear analyses

There have been a number of instances where the usual linear modeling of piping has had shortcomings. STANPIPES then required special hands-on intervention by skilled finite element analysts. The point in mentioning them is to note that it could be done starting – if not finishing the appraisal - using conventional STANPIPES modeling and utilities.

4.2.1 Stuck feeder hangers

The lower feeder hangers on a number of CANDU stations were designed with suspension points expected to slide within a groove as channel creep occurred over the life of the plant. It was found that some slid only under protest. NASTRAN static analysis allowing large angular displacement showed that only modest stresses could arise even with a lot of frictional sticking.

4.2.2 Darlington hot water hammer

As part of Darlington's safety analysis, serious events such as 100% breaks in the pump suction header were postulated. The TUF program predicted very large (void collapse) pressure pulses. Usual STANPIPES analysis suggested this would engender permanent deformation of the beleaguered piping. However, through the FEMAP interface, H3DMAP models were generated crediting material non-linearity in piping and supports and the energy dissipation their deformation would entail. With its explicit solver, H3DMAP could simulate this event and show that piping and support integrity would be maintained.

4.2.3 Gaps

Most of the time, a piping analyst ignores gaps arising from construction tolerance etc. However, on occasion, the NASTRAN CGAP element has proven useful. CGAP's enable one to introduce friction in (say) sliding supports or simulate "one-way" restraint action from a thermal stop or a buckled "rigid" hanger rod.

5. Future plans for STANPIPES

As has been noted, STANPIPES has grown over the years by accretion of capabilities and utilities to make the analyst's task easier. It has adapted to the availability of more powerful computers and other supporting hardware. It will always, however, be a work in progress. Following completion of the five year plan to bring its documentation in line with current OPG governance, various other possibilities may be explored:

- H3DMAP has a release (version 7) which is to be incorporated into STANPIPES enabling routine use of that program for almost all regular STANPIPES applications. (Currently, straight-forward use of H3DMAP is available for simple static analysis.)

- NASTRAN has a "superelement" capability which might facilitate the shift/window feature and facilitate more sophisticated substructure modeling (of, say, a damaged feeder).

- Random analysis is expected to become increasingly more important. NASTRAN has that capability and we could exploit it.

These are just a couple of the possibilities that we could mention. What we wished to announce here is that the program is now fully implemented in the Windows environment and OPG is willing to entertain external interest in its application and development.

6. References

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[2] MacNeal, R. H.; McCormick, C. W. "The NASTRAN Computer Program for Structural Analysis", Computers and Structures, Vol. 1, No. 3, pp. 389-412, 1971

[3] ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, Division 1, Subsection NB, 1974

[4] The MacNeal-Schwendler Corporation, "MSC/NASTRAN Demonstration Problem Manual", Los Angeles, California, November, 1978

[5] Stevens T., "Post-LOCA Vibrational Analysis in CANDU Primary Heat Transport Systems", CNS 22nd Annual Conference, June 10-13, 2001

[6] Canadian Standards Association "General Requirements for Pressure Retaining Systems and Components in Nuclear Power Plants" CSA Standard N285.0 January, 2006

[7] Sy A, "STANPIPES File Descriptions", January 11, 2007 (internal OPG document N-DD-04973.28-10001-R000)

[8] UGS Corporation FEMAP – Finite Element Modeling and Postprocessing V9.10 2005

[9] Canadian Standards Association "Quality Assurance of Analytical, Scientific, and Design Computer Programs for Nuclear Power Plants" CSA Standard N286.7 March, 1999

[10] Sy A, STANPIPES User's Manual Revision 17, September, 2007 (internal OPG document N-USR-04973-0001-R017)