Mechanical Engineering News

The COADE Mechanical Engineering News Bulletin is published periodically from the COADE offices in Houston, Texas. The Bulletin is intended to provide information about software applications and development for Mechanical Engineers serving the power, petrochemical, and related industries. Additionally, the Bulletin will serve as the official notification vehicle for software errors discovered in those Mechanical Engineering programs offered by COADE. (Please note, this bulletin is published only two to three times per year.)

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PC Hardware & Systems for the Engineering User (Part 19)

Summer 1994 brought about a new release of all COADE software products. In addition to supporting a *local* ESL from a new vendor, these releases also support a *network* ESL. Additionally, the SYSCHK (system check) program

has been updated to reflect the variety of different operating environments under which users run COADE software. The new SYSCHK main screen is shown in the figure below:


```
                  CAESAR II System Check
                 COADE Engineering Software

                   Graphics Device Information
Primary Board   : VGA              Secondary Board  :    None
Primary Monitor : VGA Color        Secondary Monitor:    None

        Environment Data               Memory/Processor Data
Variable        : CAESAR         Installed RAM   :   655344   bytes
Value           : G:\C2TEST      Free RAM        :   589344   bytes
DOS Version     : 6.00, HIGH     Processor       :   80486
Windows Version : Not Loaded
Network Loaded  : Yes            Math Chip       :   80487
                                 NDP Status      :   already Enabled
Current Drive   : G              NDP Accuracy    :   Passed
Drive Size      : 124602368 bytes
Drive Free Space: 21571584 bytes  Expanded RAM   :   7733248  bytes
Disk Compression: None            Free Exp RAM   :   6520832  bytes
SmartDrv Loaded : Yes             Extended RAM   :   6422528  bytes

System Date/Time: 09/24/94  12:07     Strike any key to continue.
[ B ]
```

The major changes/enhancements to this program are:

- A revised detection method for the DOS SHARE utility is implemented. This is necessary because it is illegal to load SHARE once Windows is loaded. Therefore Windows always patched the standard detection method to *lie* about the existence of SHARE. SYSCHK can now detect if SHARE is loaded, even from a DOS box under Windows.

- The new SYSCHK checks to see if DOS is loaded in high memory.

- The new SYSCHK checks to see if Windows is loaded, and if so what version is running.

> ***CAESAR II*** *celebrates 10 years
> of industry leadership
> this December*

- The new SYSCHK checks to see if a network redirector is running.

- The new SYSCHK also checks to see if disk caching or disk compression have been implemented.

The main purpose of SYSCHK is to provide a concise summary of the machine environment - as an aid to the COADE support staff. The machine environment can be altered by modifying the CONFIG.SYS and AUTOEXEC.BAT files, used during system startup.

What are some of the "more important" items on the main SYSCHK screen? First and foremost is the presence of a math coprocessor. All COADE products require the math chip (shown on the right side of the screen, near the middle). *This means that 486/SX processors can not be used by COADE software. These chips have the math coprocessor disabled!*

The second most important item is the amount of low, free, DOS RAM. The User's Manual for each COADE program specifies the amount of free RAM required to run the software. Attempting to run the software with less than this amount results in an abort condition. (A related item necessary for **CAESAR II** is the amount of free *extended* memory. Version 3.21 of **CAESAR II** requires 2.3 Mbytes of free extended memory to run the input processor.)

Another important item on the SYSCHK screen is the setting of the environment variable (on the left side of the screen). If the environment variable for the program is not set, you must run out of the program installation directory, *and the "switch directory/drive" feature of the file manager is disabled.*

Pathworks Network Users: A major incompatibility problem between Pathworks and the **CAESAR II** graphics hardcopy drivers has been resolved. Updated modules are available from the **CAESAR II** file area of the COADE BBS. The necessary changes are being distributed as "Patch B". The file to download is B321_U.ZIP.

> *Some users have asked about the operation of COADE software on Pentium processors.*
> *COADE has tested all software products on a Pentium/90 without any problems.*

TANK Enhancements

Work is progressing for the version 1.2 of the **TANK** program. One item added for this release will be the ability to plot the interaction diagrams for the API-650 Appendix P limiting nozzle loads. Nozzle loads are indicated on the plot as an asterisk, easily showing whether the loads are within or exceed the code allowables. An example plot is shown in the figure below.
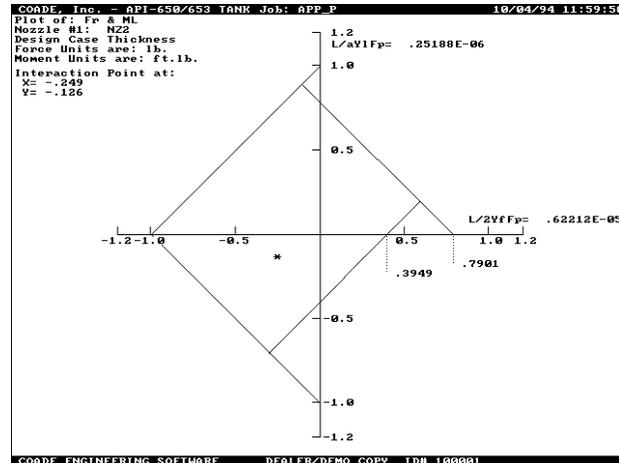
The most important item added for the next version will be the ability to perform a roof design, according to the procedures outlined in Brownell & Young. This will provide the number and size of rafters, girders, and columns for supported cone roofs. Other enhancements include: additional input specification for anchor bolts, settlement parameters, more nozzles, external nozzle loads and weight.

CAESAR II Version 3.21 Released in July

In late July, **CAESAR II** Version 3.21 began shipping to all users current on the update/maintenance plan. Besides the major enhancements (see box), there were several smaller changes (many a direct result of user suggestions and requests) aimed at increasing ease-of-use, which were not given as much attention in the update documentation. These subtle changes are discussed below.

Graphics File Viewer: Many times users find themselves staring at a directory of job files wondering what is in each file or which version of a particular job contains a certain modification. Entering the input processor and plotting the model is a slow and tedious process - when looking for a specific job or modification. If the selected job is not the one desired, the input must be exited, then another job selected, and the input/plot procedure repeated.

To aid in this job file search, Version 3.21 incorporates a graphics file viewer directly into the File Manager of the Main Menu. From the job file list, the job currently selected can be viewed by simply pressing **[P]**. The job is plotted showing restraints, valves, rigids, and expansion joints. The next keystroke returns control back to the File Manager where another job file can be selected. The entire procedure takes approximately three seconds.

Note that there are no graphics controls built into the viewer distributed with Version 3.21. This decision was made to keep the viewer program as small as possible, which reduces the load time. Once the desired job is found, the input processor should be used to access the other graphics functions. (A full featured viewer was developed, but the load/display time approaches six seconds - for this reason the small viewer was released.)

Major 3.21 Enhancements

- Low RAM requirement reduced to 475K
- Input model size limited only by amount of extended memory
- B31.5 piping code added
- UBC earthquake spectra added
- Direct network support and network ESL

Input Echo Report Selection: From either the static or dynamic output menus, a user can request an input echo of the current job. This report was automatically generated based on what was in the input file. Many users requested additional control over the input echo, to deactivate certain reports. As a result, Version 3.21 incorporates into the Input Echo module the same report selection menu found in the input processor.

CAESAR II Tutorial: Included in the update notes for the Version 3.21 release is a one hundred page tutorial. This tutorial (Chapter 4 of the Applications Guide) covers model building, static analysis, and interpretation of results.

Network Drive Access: The File Manager incorporated into the Main Menu and both the static and dynamic output processors has been enhanced to search out and subsequently access all network drives. (Previous versions of the software would access all drives up to the first nonexistent drive. This caused non-contiguous network drives to be invisible to the software.) Version 3.21 specifically searches for all drives from A to Z, and maintains a list of valid drives discovered.

Note that the installation program (INSTALL) also incorporates this enhancement, to facilitate installation on network drives.

Accounting: The Accounting Module has been completely replaced for Version 3.21, to streamline the operation of the system. The initial release of this module allowed the generation of accounting reports to a disk file (C2ACCT.OUT) only. At the request of several users, this module has been modified to send the reports to the terminal screen or the active printer. This new module is available from the BBS, in the **CAESAR II** download area. The file name is ACCOUNT.EXE.

Seminar Schedules for 1995

Our seminar schedule for 1995 has been set. It appears below. We will again have five piping analysis seminars and two pressure vessel courses. These are our open attendence courses held here in our training room. Other, in-house, training can be held at any time, anywhere, by appointment.

The **CAESAR II** courses will be held here every other month except for July. Our entire support staff pitches in as instructors for these courses so you get to understand several different approaches to system analysis. There is also ample time to meet with other students during lunch and other breaks to discuss common issues in engineering, analysis, and construction.

One change for 1995 is the elimination of the three day introductory course to pipe stress analysis. Even though the people who attended the course saw the value in it, participation was light. To bring new **CAESAR II** users up to speed, we will offer an optional Monday evening session to review and explain **CAESAR II** basics.

Class size is currently limited to 17 students and most classes are fully booked. Sign up early to lock in your dates. We find that this is an excellent opportunity for all engineers and designers, both new and experienced users alike, to spend a few days on the subject without interruption. Understanding the concepts in modeling and analysis will produce better design strategies, more efficient use of time, and greater confidence in the results.

Piping Seminars in Houston, Texas

January 23-27	Statics & Dynamics
March 20-24	Statics & Dynamics
May 15-19	Statics & Dynamics
September 11-15	Statics & Dynamics
November 13-17	Statics & Dynamics

Pressure Vessel Seminars in Houston, Texas

February 6-8

October 16-18

German Language Files Available for CAESAR II

As of November 1994, the language text files utilized by **CAESAR II** have been translated into German. These new language files provide German users the same presentation abilities as has been available to Spanish and French users.

The German language files are available for download from the COADE BBS, as GERMAN.ZIP in the **CAESAR II** file area. This file has also been forwarded to the COADE dealer in Germany.

> *For users running COADE software from a DOS box under Windows/NT, ESL drivers are available for download from the BBS.*
> *The necessary file is WIN_NT.ZIP, located in the "Miscellaneous" file area. This file contains drivers and instruction files for all ESLs supported by COADE software. These drivers will be part of subsequent software releases.*

Caution When Moving COADE Programs

Most users eventually have the need to *move* a software program, either from one machine to another, or from one disk drive to another. Up until the Summer 94 releases, this was a rather simple affair for COADE products. However, as of the Summer 94 releases, there are two new traits of COADE software products that may hamper the simple "copy from here to there" scenario.

First, the products are no longer managed by a .COM program. The old .COM loader/manager has been replaced by a more powerful .EXE loader/manager. What does this mean to the user? By default, DOS looks for .COM files before .EXE files. Therefore if one of the products is *moved* to a location where DOS finds an old .COM before the new .EXE, the program will not run. Instead, the user will receive an error message that the Main Menu module could not be loaded. (Using INSTALL instead of a COPY procedure eliminates this problem, since INSTALL cleans up the installation directory.)

This switch from a .COM to a .EXE can also cause the same error to occur if more than one version of the software exists on the computer. DOS will find and execute whichever loader it finds first when it walks down the PATH. Users with multiple versions of the same product, on the same machine, must adjust the AUTOEXEC.BAT file to correctly run the programs.

The second change in the Summer 94 releases is that all products now reference a SYSTEM subdirectory (beneath the installation directory) for certain data files, *which may be subject to alteration by the user.* These files are now located in SYSTEM to allow network installations the option of *"write protecting"* the program directory. If the software is *moved*, the SYSTEM subdirectory must be moved also in order for the software to find the necessary data files.

Notes on Insulation Densities (Calcium Silicate)

As most users know, **CAESAR II** allows the specification of insulation density as an elemental property. The **CAESAR II** help facility offers suggested values of insulation density based on the type of insulation. If the value of insulation density is not specified by the user, **CAESAR II** will default to calcium silicate, and assume a density of 11 lb/ft^3.

Recently, a user pointed out that ASTM-533 states that the density of calcium silicate insulation is 15 lb/ft^3. This statement is in fact true. However, several other references were checked, and the following density values for calcium silicate obtained.

Source	Density
Grinnell Catalog	11 lb/ft^3
The Piping Guide	11 lb/ft^3
Intro to Pipe Stress Analysis	11 lb/ft^3

Users should be aware of the default data used for engineering computations, its origin, and other possible values.

Local Coordinate Systems - Revisited

By Richard Ay

The December 1992 issue of *Mechanical Engineering News* contains an article discussing the "Global" versus "Local" coordinate systems implemented in **CAESAR II**. This article explains what each coordinate system represents and how they can be determined. Many users have requested additional information on this subject, especially for bends and skewed sections of a piping model. This article is intended to provide this information.

The figure below shows a small piping system with the local coordinate system for each elbow sketched near the element. The local element coordinate system for an elbow can be determined as follows: local "x" is directed along the incoming

tangent, in the From-To direction; local "z" points towards the center of the circle described by the bend; local "y" can be found by applying the right hand rule.
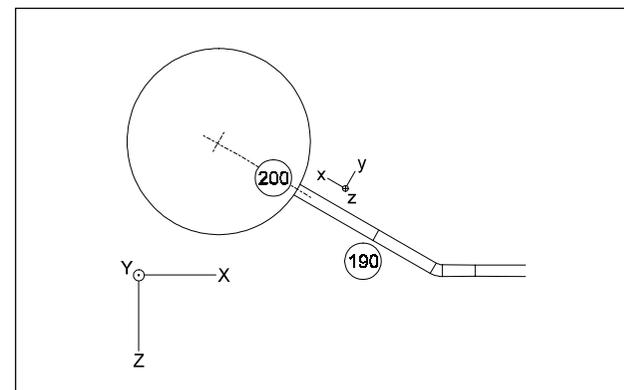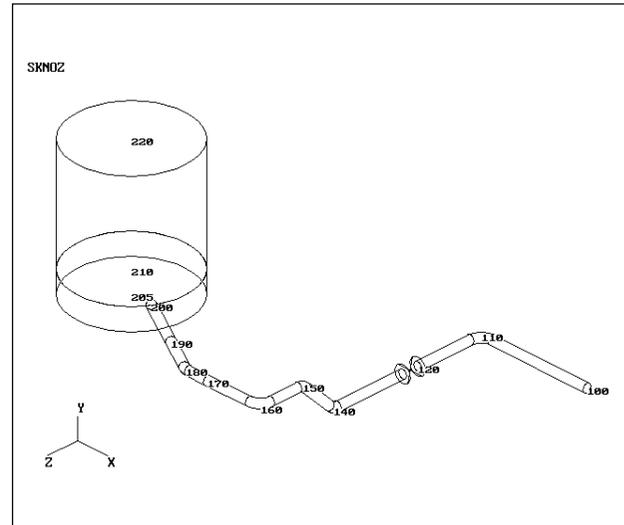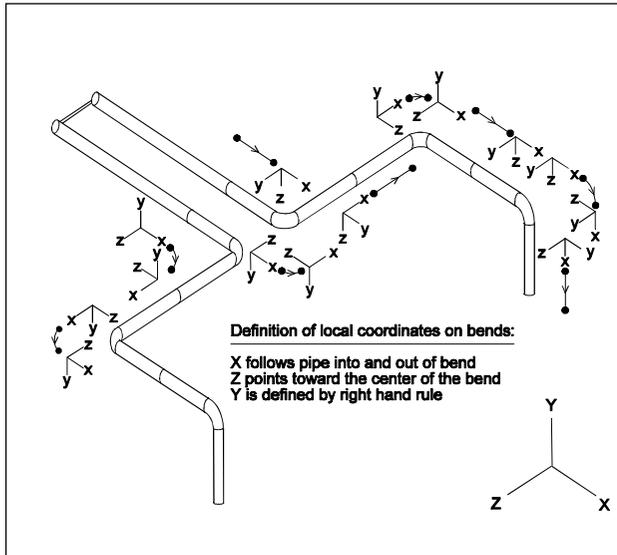
Note that the figure above and the figures from the 12/92 article all represent systems aligned with the Global coordinate system. How can the system forces and moments for skewed piping be resolved? The figure below shows a portion of a line which terminates at a vessel nozzle. The pipe running into the nozzle makes an angle of 150 degrees with the Global "X" axis. (Note that the pipe nodes are *from* 190 *to* 200, which defines the direction of the Local "x" axis. The angle *from* the Global "X" axis *to* the Local "x" axis is 150 degrees.) We need to know the loads imposed on the nozzle for a WRC-107 analysis, which means radial, circumferential, and longitudinal directions. (If the pipe element had been aligned with the Global "X" or "Z" directions, it would be a simple matter to obtain the forces and moments from the restraint report. However, for a skewed system, the forces and moments must be obtained from the element force/moment report - with a change in sign.)

The figure below shows both the "Global" and "Local" coordinate systems for the pipe element 190-200. Below the figure are the Global and Local Force reports for this element for the Operating case, and the Restraint report for node 200.


```
RESTRAINT REPORT, Loads on Restraints
CASE 3 (OPE) W+T1+P1+FOR

        — Forces(lb.) —      — Moments(ft.lb.) —
NODE    FX      FY      FZ      MX      MY      MZ      TYPE

200    -302.   -234.   564.    57.    -6352.   -3.     Rigid ANC

FORCE/STRESS REPORT, Forces on Elements
CASE 3 (OPE) W+T1+P1+FOR

DATA    —Forces(lb.)—        —Moments(ft.lb.)—
POINT   FX      FY      FZ      MX      MY      MZ

190    -302    -87    564    -345   -3153    693
200     302    233   -564     -56    6351      3

LOCAL FORCE REPORT, Forces on Elements
CASE 3 (OPE) W+T1+P1+FOR

DATA     —Forces(lb.)—             —Moments(ft.lb.)—
POINT    fx      fy      fz        mx       my       mz

190     -20.   -640.     88.     -47.5   -773.2   3153.5
200      20.    640.   -234.      47.5    -31.0  -6351.9
```

The radial force needed for the WRC-107 analysis is simply the "negative" of the local "fx" at node 200, or -20.0 pounds. The circumferential moment is the "negative" of the local "mz" at node 200, or 6351.9 foot-pounds. The longitudinal moment is the negative of the local "my" at node 200, or 31.0 foot-pounds.

These Local forces and moments can be related to the Global forces and moments at node 200 by applying the "coordinate system rotation" matrix. This transformation matrix (for a two-dimensional system) is shown below.

$$\{f\}=[M]\{F\}$$

$$\begin{Bmatrix} fx \\ fz \end{Bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & +\cos\theta \end{bmatrix} * \begin{Bmatrix} FX \\ FZ \end{Bmatrix}$$

For this system, the angle theta is 150 degrees. This results in the following matrix equation, based on the forces and moments from the "Global Force/Moment" report.

    fx = (-.866)(302) - (.5)(-564) = 20.5
    fy = (.5)(302) + (-.866)(-564) = 639.4

    mx = (-.866)(-57) - (.5)(3) = 47.9
    my = (.5)(-57) + (.866)(3) = -31.1

Note that for this system, the Global "Y" direction corresponds to the Local "z" direction, and the Global "MY" corresponds to the Local "mz".

The resulting "local" forces and moments agree with those reported in the "Local Force/Moment" report. These forces and moments represent the loads acting **on** the end of the pipe element. To use these values in the WRC-107 analysis, the signs must be reversed, since the forces **on** the vessel are needed.

More information on local-global transformations can be found in most graphics texts, and in texts on matrix solutions to engineering problems.

> *The COADE BBS has recently been upgraded to the latest version of PCBOARD. Suggestions from the users of the BBS are welcome. Users desiring additional information about using this BBS can download the file BBS_INFO.ZIP from the "Information" file area.*

Fine Tuning & Sensitivity Studies – Added Benefits of Piping System Analysis
By David Diehl

With today's software-based analysis tools so quick and convenient, their application has been expanded to include "what-if" analysis. For example, "what-if" a support is moved down the line a few feet or "what-if" the spared pump is not heat traced. One change of the input data and a few more seconds of analysis will allow the engineer to evaluate the reliability of the system under variations in installation and under unexpected operating conditions. Within minutes, and without paper, the results from a base model's analysis can be compared to those of a modified model.

When only small, simple model changes are made in each design iteration, these modifications could serve two purposes. First, if the model is accurate, the modification can push the design closer to the desired value. This will be called fine tuning the design. Second, the modification is made only to test the impact of the change in the results. This will be called a sensitivity study. Both fine tuning the design and the sensitivity study are a natural outgrowth of computer simulation.

Fine tuning has a specific goal in mind. For example, if pump loads must be reduced then intelligent changes are made to the model and the results are examined to see if that goal is approached. Of course, fine tuning is only valid if the model itself is "fine" or detailed in the first place. The sensitivity study is more of a discovery process. The model is "tweaked" to see how sensitive the results are to the change. For example, if pump loads are low in a model where all rack piping supports are modeled as "rigid Y restraints" (with a stiffness of 10^6 lbf./in.) but pump loads are high when these rack supports are modeled with structural steel elements, the model is sensitive to the support stiffness and accurate restraint stiffnesses are then important in this design. The figure below exemplifies this process. The three lines signify the limits on typical pump/piping systems. The area bounded by these limits indicates safe and reliable operation while results falling outside are not acceptable. If a user is uncertain about some aspect of the model, a second job is analyzed which changes that aspect. If the results move from #1 to #2, the uncertainty has no great impact. If, however, the results move from #1 to #3, than the user should take the time to research the issue and build a more accurate model. This sort of investigation was not feasible with earlier analysis methods due to the inherent inaccuracies or because of the large commitment in time.
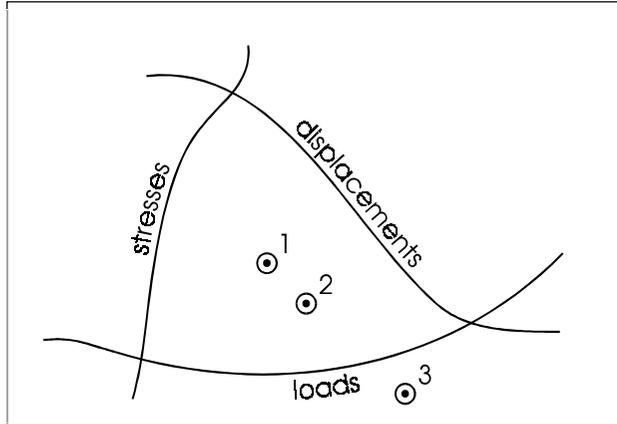
Figure 1

This sensitivity study serves several purposes. First of all it can identify critical design parameters in the model analysis and in the actual layout. A sensitivity study is used to find significant design modifications and study their impact on the piping system. Another advantage to this approach is the investigation into the variability between the "as designed" system and "as built" system. Troubleshooting possible variations in installation requires anticipation of possible differences but, when uncovered, these critical construction guidelines can be established before the line is built rather than when the line is shut down for repair. Finally, this sort of study can actually simplify the analysis by revealing model details which prove to have no impact on results; a simplification that saves modeling time and effort and improves comprehension. Again, this sort of analysis technique does not replace experience but works well with design experience to develop a feasible and reliable layout. In many ways, a sensitivity study is a cost effective check on piping systems with their tight load restrictions around rotating equipment.
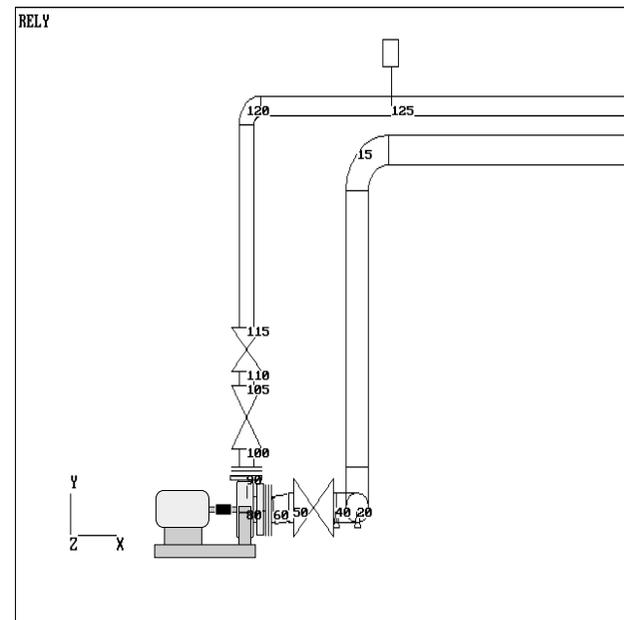
An Example

Figure 2

To illustrate the concepts promoted here and to provide an example of this sensitivity study a pump system will be analyzed using **CAESAR II**. The system shown in Figure 2 illustrates the piping around the 10 inch suction and 8 inch discharge lines. Figure 3 shows the entire 26 element system with node numbers and several of the supports. The suction side runs from node 5 to node 70, the pump is constructed of rigid elements 70 to 90, and the discharge pipe carries on from node 90 to node 145. The boundary conditions are set at nodes 5 and 145 with a known operating position of node 5 and an immovable point at 145. With the drawing prepared with all the required data, an experienced user can produce a first pass analysis in under 15 minutes. The program selects the spring for installation at node 125 (in this case from the Grinnell catalog) and then calculates the system loads and displacements for the operating and installed conditions and the B31.3 sustained and expansion stresses. The pipe stresses are well within the B31.3 limits.
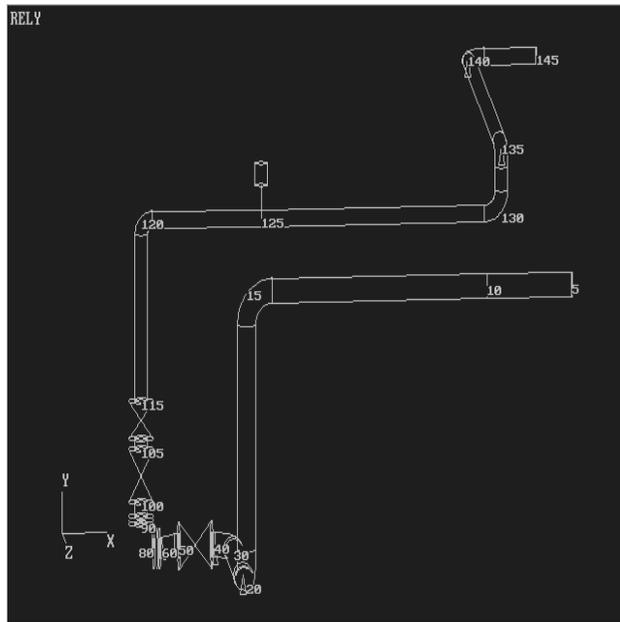
Figure 3

The calculated pump nozzle loads are compared to the limits defined in API Standard 610. The simple check compares the component loads on the nozzle to values based on nozzle size and orientation. If the nozzle loads are below these limits (specified in Table 2 of the standard), then the pump alignment is assured. A second test is available for pumps if the Table 2 limits are exceeded. This secondary check is defined in Appendix F of the standard. Appendix F has three checks:

F.1.2.1 - the component loads on each nozzle (which can be as large as twice the Table 2 limits),

F.1.2.2 - the resultant forces and moments on each nozzle, and

F.1.2.3 - the resultant forces and moments and the moment about the local Z axis of all loads resolved to the center of the pump

The example here generates pump loads that exceed the API 610 Table 2 limits. It is necessary, then, to examine the Appendix F limits defined in that standard. The **CAESAR II** API 610 processor collects the definition of the pump along with the nozzle loads to check the Appendix F criteria. The API 610 report (shown in Figure 4) confirms that the 10 inch end suction nozzle and the 8 inch top discharge nozzle meet the Appendix F criteria; the pump is OK.

```
API Standard 610 1989 7th Edition        File  : RELY
                                         Date  : SEP 1,1994
User Entered Description :                Time  : 11:42 am


AS DESIGNED




                  Node #      Orientation     Nominal Diameter
 Suction Nozzle     70            End              10
 Discharge Nozzle   90            Top               8

 Table 2 Allowable ( ratio )      =      2

 Pump Axis is in the "X" direction.

                Suction       Table 2    Force & Moment   Status
                               Values        Ratios

X Distance  =     10.5   in.
Y Distance  =       .0   in.
Z Distance  =       .0   in.

X Force  = -1522.0   lb.    1500           1.01       Passed
Y Force  = -1931.0   lb.    1000           1.93       Passed
Z Force  =  -674.0   lb.    1200            .56       Passed

X Moment =  4270.0  ft.lb.  3700           1.15       Passed
Y Moment = -5152.0  ft.lb.  2800           1.84       Passed
Z Moment =  3110.0  ft.lb.  1800           1.73       Passed


               Discharge     Table 2    Force & Moment   Status
                               Values        Ratios

X Distance  =       .0   in.
Y Distance  =     15.0   in.
Z Distance  =     12.3   in.

X Force  =  -313.0   lb.     850            .37       Passed
Y Force  = -1499.0   lb.    1100           1.36       Passed
Z Force  =   279.0   lb.     700            .40       Passed

X Moment =  3596.0  ft.lb.2600            1.38        Passed
Y Moment = -2099.0  ft.lb.1900            1.10        Passed
Z Moment =  2526.0  ft.lb.1300            1.94        Passed

Check of Condition F.1.2.2            Requirement      Status

(FRSa/1.5FRSt2) + (MRSa/1.5MRSt2) = 1.756  < or = 2.00 Passed
(FRDa/1.5FRDt2) + (MRDa/1.5MRDt2) = 1.593  < or = 2.00 Passed

 Check of Condition F.1.2.3           Requirement
Status

1.5 ( FRSt2 + FRDt2 )  = 5640. >  3910.   (FRCa)    Passed
2.0 ( MZSt2 + MZDt2 )  = 6200. >  4338.   (MZCa)    Passed
1.5 ( MRSt2 + MRDt2 )  = 12750. > 12748.  (MRCa)    Passed

Overall Pump Status Passed
```

Figure 4

With the calculated pump loads so close to their limits it is wise to take a much closer look at the model to confirm it is correct. Any questionable input items could be "tweaked" to examine their impact on the results. If the results do not suffer, no additional investigation into these model details is necessary.

If the system is built as it was designed the pump should operate without difficulty. To illustrate an additional benefit of this analysis, four variations on this design will be used to determine how sensitive the pump is to the hanger load and position. As it is initially designed, the hanger (at node 125) is placed 7 feet from the discharge riser. It is a Grinnell

Figure B-286 (mid range) spring with a spring rate of 260 lbf./ in. The spring's load is set to 1200 lbf. when the system is in operation. Since the spring moves 1/3 inch to its operating position, the installation load on the spring is set to 1286 lbf. Four additional analyses will be made to test the significance of common installation variations. All four involve the spring and are very simple to run through the program. The changes are:

• Set the spring load to reach only 70% of the operating load,

• Set the spring so that the spring load is 130% the design value,

• Move the spring towards the discharge riser by 3.5 feet, and

• Move the spring 3.5 feet away from the discharge riser.

In each case the suction loads on the pump are the same. The pump discharge loads (in pounds and foot-pounds) for each variation are shown in Table 1 below. The final column (% of allowable) lists the maximum ratio of the Appendix F criteria.

Case	FX	FY	FZ	MX	MY	MZ	% of allowable
1 - light load	-315	-1745	279	3620	-2093	2172	100.74
2 - heavy load	-312	-1252	278	3571	-2105	2882	111.00
3 - closer	-313	-1318	278	3619	-2084	2166	98.01
4 - farther	-316	-1696	281	3592	-2118	2562	101.39

Table 1

Only one of these variations — moving the spring closer to the riser — passes the API 610 check; the loads here are much better than the original design. The other three cases fail for the following reasons:

Case 1 - The moments resolved at the pump's base point exceed the allowable limit (Condition F.1.2.3),

Case 2 - The bending moment about the Z axis at the pump discharge nozzle exceeds the two times the Table 2 value, and

Case 4 - The moments resolved at the pump's base point exceed the allowable limit.

Again, why were these analyses made? The analysis of the original layout showed that the pump was very close to its maximum rated loads. The model was first examined to determine whether or not modeling shortcuts might have produced low values for these loads. This initial review

could have indicated that model modification – "fine tuning" – was necessary. But here the model looked fine so the model was manipulated in the second fashion — a "sensitivity study" was made. This sensitivity study did not focus on variations in design layout but instead on variations on the hanger installation. The study clearly illustrates that the layout is sensitive to the spring; the spring load and position must be properly set for reliable pump operation. It is noteworthy that the spring, which in so many cases is used to improve system loads, can also harm the design. Man time for the four analyses in this study is minimal, about ten minutes, but the benefits may be great. Not all systems require this sort of study, but here, where the pump loads are very close to their limits, such an examination plus a close review of the model definition is warranted. If these pump loads are not reduced, it would be wise to give close attention to this pump at startup.

This sort of formal analysis can confirm a good piping design and can assist the engineer in redesigning the piping system when it is required. When used as a tool for sensitivity studies, piping analysis software can indicate critical installation parameters so that safe and reliable operation is ensured.

The CAESAR II Pulse Table Generator
By Thomas Van Laan and Richard Ay

The *Force Spectrum* solutions offered by **CAESAR II** (for simulation of relief valve, water hammer, slug flow, etc.) use a frequency domain model based on a Dynamic Load Factor (DLF) vs. natural frequency response spectrum. Dynamic Load Factor is defined as the ratio of the system response (i.e., deflection, force, stress, restraint load) during dynamic application of a load to the system response which would have resulted from the static application of the same load.

The DLF response spectrum for a given load is generated by solving the dynamic equation of motion for a single degree of freedom system:

$$Ma(t) + Cv(t) + Kx(t) = F(t)$$

Where:

M = mass of system, slug
$a(t)$ = acceleration of system (as a function of time), in/sec^2
C = damping of system, slug/sec or lb-sec/in
$v(t)$ = velocity of system (as a function of time), in/sec
K = stiffness of system, lb/in
$x(t)$ = displacement of system (as a function of time), in
$F(t)$ = applied force (as a function of time), lb

For an idealized system, where the system damping is near zero, and the loading takes the form of an instantaneously applied constant force of infinite duration, the system displacement solution is:

$$x(t) = (F/K) \ (1\text{-}\cos \omega t)$$

Where:

- $x(t)$ = system displacement (as a function of time), in
- F = magnitude of applied force, lb
- ω = system angular natural frequency, rad/sec
 = $(K/M)^{\frac{1}{2}}$
- t = time, sec

Since the maximum static deflection of the system under load F is calculated as F/K, the Dynamic Load Factor (or the ratio of the dynamic to static response) is therefore $(1 - \cos \omega t)$. This DLF varies in magnitude from a value of zero to a value of 2.0, where the maximum and minimum values fluctuate along the time axis with the natural period (the engineer is, of course, most interested in the maximum value of the DLF). The response spectrum for this load is generated by plotting the maximum DLF that occurs throughout the load duration (2.0) vs. the natural frequency ω. Obviously, ω drops out of the equation, so the DLF response spectrum for an instantaneously applied constant load of infinite duration is a flat value of 2.0:

Once the Dynamic Load Factor is known, a static analysis of the system (or of each mode of vibration, when considering multiple degree-of-freedom systems) can be done, with the static results then being multiplied by the DLF to yield the dynamic results. *Note that the DLF is a non-dimensional value that is independent of the applied load.*

Expanding this discussion to loads of different shapes and durations allows the application of a force spectrum solution to *impulse* loads of different types (technically, an <u>impulse</u> is defined as the area under the force-time profile). The dynamic response of a system to an impulse load is dependent upon the ratios of the load duration and rise/fall rate to the

natural period of the system. (For an *instantaneous* rise time, and an *infinite* load duration, the ratios to all natural periods are the same, which explains why the DLF was constant for all frequencies in the example discussed above). A review of the textbook **Introduction to Structural Dynamics**, by John M. Biggs, shows several plots of maximum DLF curves as a function of the ratio of load duration to system natural period.
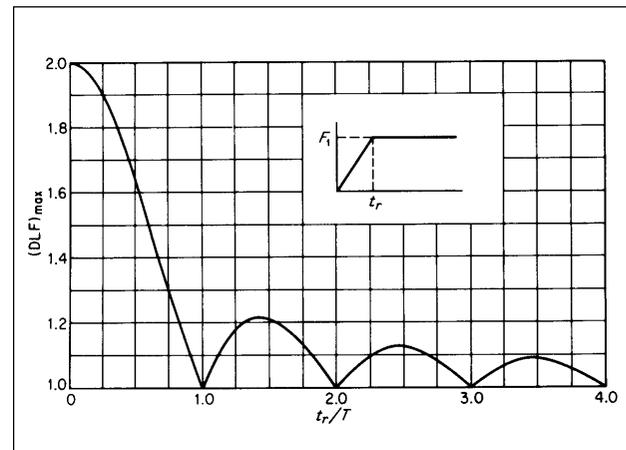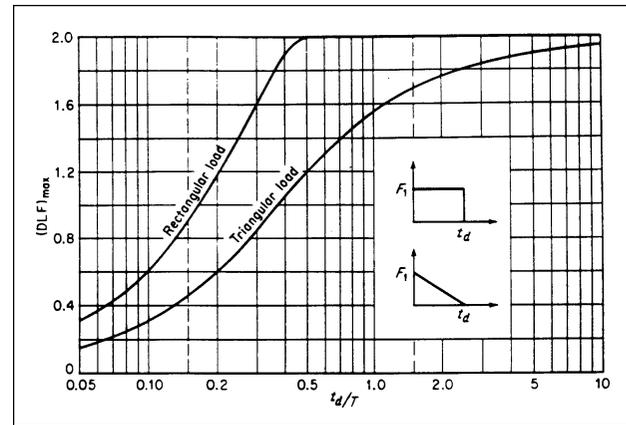
How is this information useful to the pipe stress engineer who has a specific dynamic problem to solve? Usually, the shape of the pulse load profile is trapezoidal, with the duration of each segment known. For example, for a relief valve load, the segments of the trapezoid consist of the load rise (with a duration equal to the opening time of the valve), the relatively constant jet load (with a duration equal to the time required to vent the excess mass from the system), and the load fall (with a duration equal to the closing time of the valve). This type of load can be converted to a response spectrum by solving the dynamic equation of motion through each of the load segments, dividing the maximum displacement throughout by the static displacement under the maximum magnitude of the load, and then plotting the result vs. natural frequency.

According to the textbook **Structural Dynamics (Theory and Computation)**, by Mario Paz, the displacements of a system due to any arbitrary load can be calculated through the application of Duhamel's integral, as shown below:

$$X(t) = X_0 \cos \omega t + \frac{v_0}{\omega} \sin \omega t + \frac{1}{M\omega} \int_0^t F(\tau) \sin \omega(t-\tau) \, d\tau$$

Where:

t   = time for which displacement is solved, sec

τ = time at which force is applied, sec

When the arbitrary load can be broken into discrete, linearized segments, the force function can be fairly easily integrated using Simpson's rule, permitting the solution of the system displacements at any point throughout the duration of the load.

CAESAR II provides the user with a **Pulse Table/DLF Spectrum Generator**, which performs the automatic integration of Duhamel's integral. This module takes a user supplied, segmented pulse, and creates the appropriate equation for each segment. Displacements are calculated at each terminus of the segment, and the equation is differentiated in order to locate any displacement minima or maxima ocurring within the interior of the segment (this assures that the maximum displacement is found, without using a hit-or-miss approach). The absolute maximum dynamic displacement is then selected from the largest of the segmental values, and the DLF calculated from that. This process is repeated for the number of natural frequencies specified by the user, which, when plotted, create the response spectrum.

Response spectra for the same load profiles as shown in the theoretical plots above have been generated using the **CAESAR II Pulse Table/DLF Spectrum Generator**, and are shown below, demonstrating the accuracy of **CAESAR II**'s algorithm:
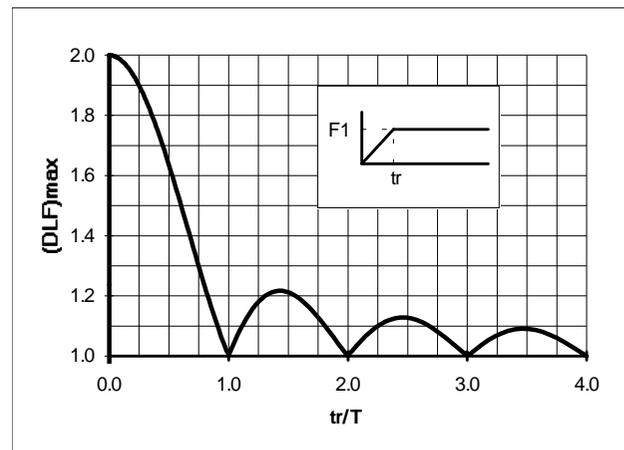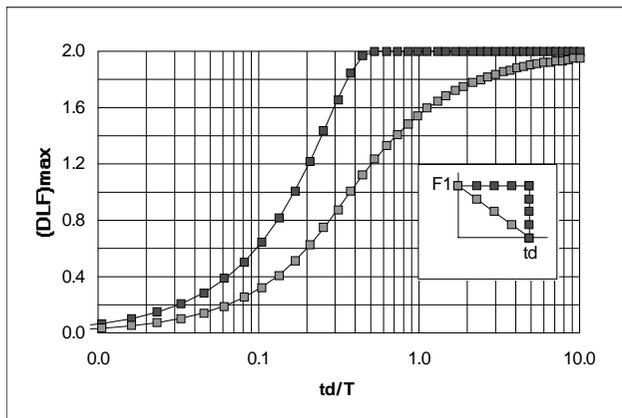
The ASME B31.1 Power Piping Code, in Section 3.5.1.3 of Appendix II (**Nonmandatory Rules for the Design of Safety Valve Installations**), presents a discussion on dynamic load factors, including a DLF curve, adapted from the Biggs text. Here, the Code uses t_o (the opening time of the relief valve) to represent the rise time of the loading. The figure below demonstrates how the ASME Code curve, which is based upon an infinite load duration, envelopes the DLF curves generated by **CAESAR II** for various finite load durations.
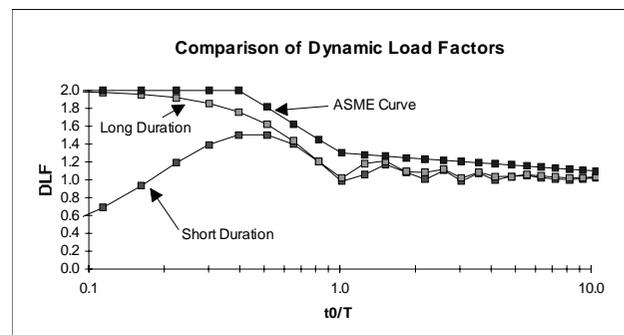
In general one can reach the following conclusions about Dynamic Load Factors and impulse loading:

• The magnitude and shape of the DLF curve is independent of the magnitude of the applied force, but dependent on the shape of the normalized load profile. Therefore the **CAESAR II** user may specify the actual load, or a normalized value of 1.0 as the pulse magnitude.

• If the rise time is much greater than the natural period of the system, the system response approaches the static response to the applied load - the dynamic effects (and thus the DLF) are negligible.

• The shorter the rise time of the load profile is, the greater the DLF will be. If the rise time (for a load of infinite duration) is less than approximately one quarter of the natural period, the response approximates that for an instantaneously applied load — i.e., the DLF is 2.0.

• As the duration of the load increases, peak dynamic response (higher DLFs) will shift toward the systems with longer natural periods (smaller natural frequencies).

Commonly Asked CAESAR II Questions

By Tim Curington

The following begins a Question & Answer series that will be continued in subsequent newsletters. In addition, these and other Q & A entries can be found in the subsequent editions of the program documentation, and on the COADE BBS. The series is intended to provide an additional reference source from which to obtain answers to **CAESAR II** questions.

1) Why are the allowable stress values zero for the operating condition?

Operating stresses are not considered by the Power and Petrochemical Codes. Therefore, when reviewing operating stresses, the user will first be confronted by the message that states 'NO CODE STRESS CHECK PROCESSED', and then the user will notice that all of the allowable stress values are set to zero. This is not the result of incorrect data input, but rather a result of whether the individual Code being used reviews operating stresses or not.

2) What is the difference in the expansion case D1 - D2 and just running a T case?

The expansion case is described in the Codes as the differential between extreme conditions of the piping system (i.e., normally cold and operating cases). If, for example, the operating load case is W + P + T and the sustained (cold) load case is W + P, by subtracting the sustained loads from the operating loads we are left with the temperature effects T. So are the results acquired from the difference of the two loads the same as just running a T case? In the event of a completely linear system the answer would be yes. If, however, there are any nonlinear effects in the system (friction, gaps, single directional supports, etc.) these two results could vary.

In the latest addenda to B31.3, Interpretation 12-06 acknowledges that the maximum and minimum operating temperatures should be considered as one of the "ranges" in computing the expansion case. This is in agreement with the article "Expansion Case For Temperatures Below Ambient", published in *Mechanical Engineering News*, May 1993.

By examining a pipe resting on a pipe rack, this variance can be seen. In the sustained (cold) condition, the pipe is resting on the rack, and there is a deadweight load imposed on the rack. In order for the pipe to move off of the rack, the forces due to expansion must first overcome the deadweight load. Therefore, the loading on the pipe will be the difference between the deadweight load and the forces due to the expansion of the pipe. If instead of reviewing the difference, the user looked at the temperature case only, the deadweight effects would be ignored. In order to adhere to one code's definition of secondary loadings (loadings due to expansion, weight stress variation, differential settlement, movements in the supports, etc.) these deadweight effects must be considered.

3) I have entered wind/uniform loads in the job, but my results have not changed?

NO OCCASIONAL LOADS ARE INCLUDED IN THE **CAESAR II** RECOMMENDED LOAD CASES. Although COADE has suggested guidelines (Chapter 5 of the User's Manual) on setting up load cases for occasional loads, **CAESAR II** does not recommend them automatically. It is the user's responsibility to edit the recommended, or existing, load cases in order to include these occasional effects in the analysis. Additionally, if wind has been included in the input, the user must define the wind loading. Upon entering the static processor, the user will first edit the wind loading data, and then edit the load cases to include the wind effects.

4) How can I get **CAESAR II** to create larger printed plots?

The size of the **CAESAR II** printed plots is determined by your graphics resolution. LaserJet printer resolution is typically 100 dots/inch in the horizontal direction and 75 dots/inch in the vertical direction. Knowing this, you can determine the size of the expected plot based on your individual graphics resolution. For example, a Color Graphics Adapter (CGA) has a resolution of 640 X 200 dots. Therefore, a horizontal plot would yield 6.4 inches in the horizontal by 2 inches in the vertical (based on the horizontal printer resolution of 100 dots/inch). Similarly, a vertical plot would yield 8.53 X 2.67 inches (based on the vertical printer resolution of 75 dots/inch). The largest available plot is going to be with VGA graphics (640 X 480 resolution) in the vertical direction, which yields a plot 8.53 inches X 6.4 inches.

CAESAR II Specifications

Listed below are those bugs/errors/omissions in the **CAESAR II** program that have been identified since the last newsletter. These items are listed in two classes. Class 1 errors are problems or anomalies that might lead to the generation of erroneous results. Class 2 errors are general problems that may result in confusion or an abort condition, but do not cause erroneous results.

Class 1

1) Hanger Design Modules: An error has been discovered in the computation of the "Actual Installed Load" on Variable Spring Hangers when more than one hanger is specified at the location. This error was an output error only and involved the application of the spring rate of the total installation to each individual spring. This did not cause an error in spring selection, calculation of hot or cold load, or subsequent load case results. This error exists in all versions of **CAESAR II** prior to Version 3.21, and was corrected in Version 3.21a, which was sent to all current users.

2) Refractory Lined Pipe: An oversight was discovered in the element generator when generating the mass matrix for dynamic jobs. The presence of refractory lining was not considered.

   This error exists in Versions 3.19, 3.20, and 3.21, and is corrected in Version 3.21a.

Class 2

1) Analysis Setup Module: A file management error has been discovered in the setup of the wind loading data for "structural only" jobs. For these jobs, if an attempt was made to adjust the ASCE #7 wind data, the program aborted back to DOS. This error exists only in Versions 3.19 and 3.20. This error was corrected for the Version 3.21 release.

2) WRC-107 Module: A units conversion problem was discovered in the WRC-107 module which was activated *if the user made an input error.* When the program detected the input error, it returned control to the input routine, by passing the units conversion step. This error is only apparent for non-English operation. This error, corrected for Version 3.21, is in all other 3.x versions of the program.

3) Pen Plot Module: A plotting error was discovered in the Pen Plot module which caused all elements of the model to be plotted as expansion joints - when the job included thermal bowing. This error exists in Versions 3.19, 3.20, and 3.21. This error also exists in the Animation Module in Versions 3.19 and 3.20. This was corrected in 3.21a.

4) Static Output Module: An error has been discovered in the static output module which could cause the restraint/hanger symbol plotting to put the symbols at incorrect locations. This problem only occurred if the "restraint summary" report was previously requested, resulting in a restraint nodal sort. This plotting error exists in Versions 3.19, 3.20, and 3.21. This was corrected in 3.21a.

5) Graphics File Saves: A compiler conversion problem was discovered which prevents "appending" to graphics image files. This problem exists in Versions 3.20 and 3.21 in the following modules: piping input, structural input, dynamic animation, static output. This was corrected in 3.21a.

6) Documentation, Technical Reference Manual: On page 3-27 of this document, reference is made to using the **[Alt]** key to plot node numbers with hangers, supports, anchors, and nozzles. This is an error, the proper key to use is **[Shift]**.

   On page 6-20, the Expansion case is defined as D1-D2. This is incorrect, it should be D3-D4.

7) Piping Error Checker: Two errors have been discovered in the piping error check module. The first error occurs when the "INCLUDE" feature is used with the "N" (no) option, and the second intersection field of the SIF auxiliary field is used. The node number increment is not applied to this second intersection node, resulting in a fatal error. This error exists in all **CAESAR II** 3.x versions.

   The second error limits the number of intersections to 200. This limit should have been removed in Version 3.21. This was corrected in 3.21a.

8) Piping Input Module: An error has been discovered in the input module when attempting to use Stainless Steel pipe schedules. The addition of the half-pipe sizes (in Version 3.21) caused the access routine to overlook the stainless thicknesses, resulting in an error notification during input. This was corrected in 3.21a.

9) Piping Input Module: A change has been made in the ordering of the bend node numbers during the node number increment. Versions prior to 3.21A incremented the auxiliary bend nodes backwards, causing the new nodes to be ordered incorrectly. This was corrected in 3.21a..

10) Input Listing Module: A memory management error has been discovered Version 3.21 in the Input Listing Module. This error causes some input data to be omitted from the listing report, for jobs that exceed roughly 1000 elements. This was corrected in 3.21a.

11) Documentation, Applications Guide: Pages 3-93 through 3-96 should have been reprinted for the 3.21 update. This is necessary since the echo of two elements moved from 3-92 to 3-93.

TANK Specifications

Listed below are those bugs/errors/omissions in the **TANK** program that have been identified since the last newsletter. These items are listed in two classes. Class 1 errors are problems or anomalies that might lead to the generation of erroneous results. Class 2 errors are general problems that may result in confusion or an abort condition, but do not cause erroneous results.

Class 1

1) Appendix E Seismic Computations: An error has been discovered in the Appendix E seismic calculations regarding the usage of the "percentage of roof weight supported by the shell". This user specified percentage value (entered on the Roof Details Spreadsheet) should have been divided by 100.

   This error exists in Versions 1.00 and 1.10 of **TANK**. The error was corrected and Version 1.10A was shipped to all users.

2) Appendix E Seismic Computations: An error has been discovered in the Appendix E seismic calculations in the determination of the required anchor bolt size. The bolts were oversized by a factor of approximately SQRT(pi/4). This error exists in Version 1.10, and was corrected in Version 1.10C and shipped to all users.

3) Appendix P Nozzle Computations: A data management error prevented the computation of nozzle stiffnesses and limiting loads for any nozzles after the first one specified. The results for subsequent nozzles are identical to those for the first nozzle. This error exists in both Version 1.00 and 1.10 of **TANK**. This problem was corrected in Version 1.10C and was shipped to all users.

Class 2

1) Input Module: An error has been discovered in the Version 1.10 input module regarding the automatic specification of elastic modulus and expansion coefficient for the Appendix P nozzles. The data provided is correct, however for nozzles 2 through 5 this information is placed in the wrong input cells. This error is obvious to the user when specifying the remaining nozzle data. This problem is corrected in Version 1.10C.

2) Output Generation Module: Several conversion errors were discovered in the output preprocessor which affected the display of "user input". The values of: design temperature, bottom plate yield stress and bottom plate thickness were not converted from the English system properly. This error exists in Versions 1.00 and 1.10 of **TANK** and is corrected in Version 1.10C.

3) Output Generation Module: An error exists in Version 1.10 which prevents the nozzle input text labels from being associated with the proper input data. This error produces incorrect input listings. This problem is corrected in Version 1.10C.

CodeCalc Specifications

Listed below are those bugs/errors/omissions in the **CodeCalc** program that have been identified since the last newsletter. These items are listed in two classes. Class 1 errors are problems or anomalies that might lead to the generation of erroneous results. Class 2 errors are general problems that may result in confusion or an abort condition, but do not cause erroneous results.

Class 1

1) The UCS-66.1 MDMT reduction was off for vessels whose required thicknesses were between .4 and .5 of the actual thickness. This problem was corrected in Version 5.30A and was shipped to all users.

2) The piping materials used by the Pipe&Pad program were updated to the latest edition of the B31.1 piping Code. These were updated in 5.30A.

3) The tubeside corrosion allowance was not being added to the flange thickness in the Floating Heat program. This was corrected in 5.30A.

4) The allowable stresses in the summary of shellside pressure for primary type stresses were modified in the Thick Joint program. The computation for the factor theta B at X=YB was also corrected. These were corrected in 5.30A.

Class 2

1) A file sharing conflict was discovered which kept more than one user from using the input processor at the same time on Pathworks Networks. This problem was resolved in 5.30A.

2) The occasional load factor was not being used for computations involving angles in the Leg&Lug program. This was corrected in 5.30A.

Compuserve Access to COADE

Due to the increased usage of our Bulletin Board (BBS), and the needs of our overseas users, COADE is establishing both a *forum* and a *mail address* on Compuserve. This service will be available to upload or download files, or to post general questions and answers. (Users will need to have their own Compuserve account to take advantage of this service. In the U.S., this costs $8.95 per month plus any service charges.) Most users will be able to access Compuserve via a local telephone call.

The COADE mail address is 73073,362.