

Mechanical Engineering News



For the Power, Petrochemical and Related Industries

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The COADE Mechanical Engineering News Bulletin is intended to provide information about software applications and development for Mechanical Engineers serving the power, petrochemical, and related industries. The Bulletin also serves as the official notification vehicle for software errors discovered in those programs offered by COADE.

presented a preview of what several of the redesigned modules will look like. Since that time additional improvements have been made to all areas of the program. This article will detail these improvements and give users an advanced look to what to expect when Version 4.00 ships.

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Compatibility: With each release of **CAESAR II**, users have questioned the issue of compatibility with previous versions of the software. COADE has always been committed to the usability of each software product. Each version is therefore tested using input streams generated from older versions. In the case of **CAESAR II**, Version 4.00 can read in and utilize an input file created by Version 1.00, circa 1984! (Due to enhancements made to the software, and additional *new* input items, the program can not maintain downward compatibility with prior versions.) This means that the Windows 95/NT version (Version 4.00) will also be capable of using an input file created by any previous version of the software.

Quality Assurance: As discussed in previous documents, COADE employs a Quality Assurance procedure to insure the software performs as expected and produces the correct results. This QA procedure involves (among other tasks) analyzing 200 previously checked jobs and comparing the results. (Interested users can purchase the **CAESAR II** Quality Assurance Manual which discusses these procedures and includes 40 of these QA jobs which can be used for in-house verification of the software.) Version 4.00 has been through this battery of test jobs and passed the QA check.

Another QA procedure is the *beta test* phase. This period involves distributing a limited number of advanced copies of the new release to current users willing to test and exercise the software. *Beta testing* is hard work, and involves utilizing the software in atypical ways, for the purpose of finding operational problems or areas of confusion. The number of *beta testers* is usually limited to about twenty users. However, for Version 4.00, a *beta* request form was posted on the COADE WEB site (<http://www.coade.com>) to allow interested users to sign up to assist in this *beta test* phase. Just under sixty users signed up to help test the software. We would like to once again thank all those

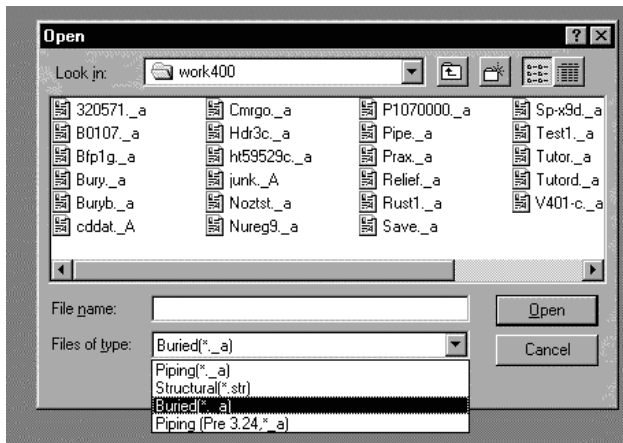
The Windows Version of CAESAR II

(by: Richard Ay)

CAESAR II Version 4.00 is nearing completion. Beta testing is scheduled to finish in early December, with final shipping scheduled to commence before the end of the year. The last issue of *Mechanical Engineering News* (June 1997) discussed some of the changes made to the software and

involved in the *beta test phase* for their efforts in helping to verify Version 4.00. (The winners of the cash prizes for the most helpful *beta* evaluation forms will be published in the next issue of *Mechanical Engineering News*.)

Common Controls: It is expected that current Windows programs conform to a set of common controls and operations. Windows 95 and Windows NT 4.00 have improved these common controls and their usability. Examples of the controls include: file management dialog boxes, tabbed dialog boxes, tool bars, and tool tips. **CAESAR II** Version 4.00 takes advantage of all of these controls to enhance the overall operation and navigation of the software. One example is the use of the standard Windows File Manager. The figure below shows the File Open dialog of the Main Menu, with the available file types expanded.



Note that the controls in this dialog allow the complete traversing of the local hard disk as well as the entire network. Using this dialog, users can select piping, structural, or pre-3.24 piping files for subsequent usage.

Tool Bars provide experienced users with a shortcut method to activate commonly used commands. Two of the most frequently used tool bar icons are the diskette (to save the current file), and the printer (to print the current file). **CAESAR II** Version 4.00 takes advantage of this tool bar idea to offer the most often used features to the user in an easily reached graphical manner. The figure below shows the piping input spreadsheet, with the tool bar just below the menu.



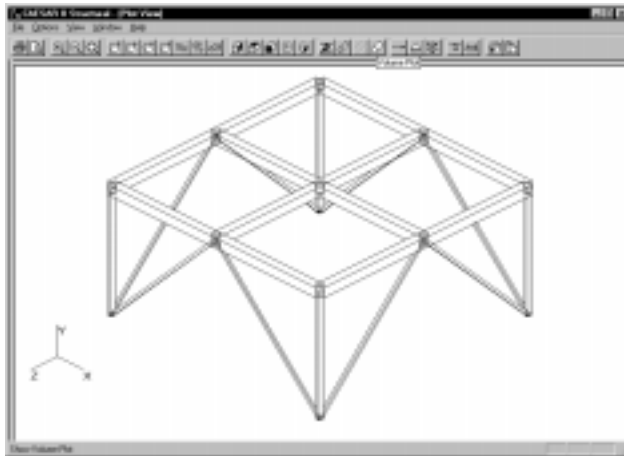
Starting at the right of the tool bar, the icons activate: continue to a new spreadsheet, plot, include structural files, include piping files, special execution parameters, bend SIF scratchpad, intersection scratchpad, spring hanger design control data, title page, expansion joint modeler, valve & flange data base, break, list, distance between nodes, node increment, loop closure, global coordinates, delete spreadsheet, insert spreadsheet, find, batch run, run, and archive. The six remaining icons (on the left) represent standard Windows icons.

Tabbed Dialog boxes provide an intuitive, logical way to group items. Many of the program modules in **CAESAR II** Version 4.00 rely on tabbed dialogs to associate common input parameters. As an example, the figure below shows new layout for the WRC-107 module.



Each of the tabs in this figure presents a different input spreadsheet to the user. The particular tab shown allows the specification of loads from the Sustained load case. (Note that the button at the bottom allows these loads to be acquired directly from the piping output file!)

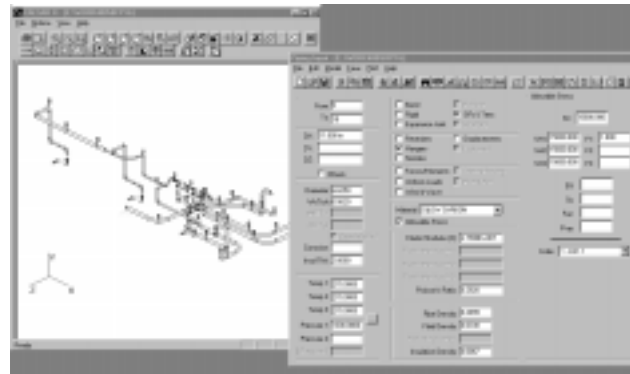
Tool Tips are a necessity now that Windows programs utilize tool bars with many icons. It is often difficult to immediately associate a particular icon with the function the button performs. As an aid to the usability of the software, tool tips are available for each icon on the tool bar. A tool tip is a small text window which appears when the mouse is held stationary over a button for a second or two. This text window describes the function of the icon under the mouse pointer. The figure below shows the new structural input processor, in plot view, with a tool tip for the volume plot button.



General Enhancements: In converting CAESAR II to the Windows environment, opportunities existed to simplify certain operations for the user. One area of simplification involves the Main Menu. The cascading pull down menus now replace the nested architecture of the DOS version. The new Main Menu also includes a Diagnostic menu and an ESL menu. These options had to be manually invoked in the DOS version.

In the piping input module, the specification of nozzles and hangers has been moved to the spreadsheet level (which is more intuitive) in the form of additional auxiliary areas. Additionally, the [F12] key can be used to toggle through all of the auxiliary areas, prior versions required you to set the focus (on the Y/N fields) to see a particular auxiliary). To avoid repeated "help" requests via the [F1] key, the input spreadsheet provides combo boxes (drop down lists) for the selection of materials, piping code, and restraint types.

Another enhancement made to the piping input processor is the ability to view the spreadsheet and the graphics plot simultaneously. From the plot view, selecting the spreadsheet icon on the tool bar will bring the spreadsheet back. Properly positioning both windows on the desktop allows the plot to be updated as data is entered on the spreadsheet, as shown in the figure below.

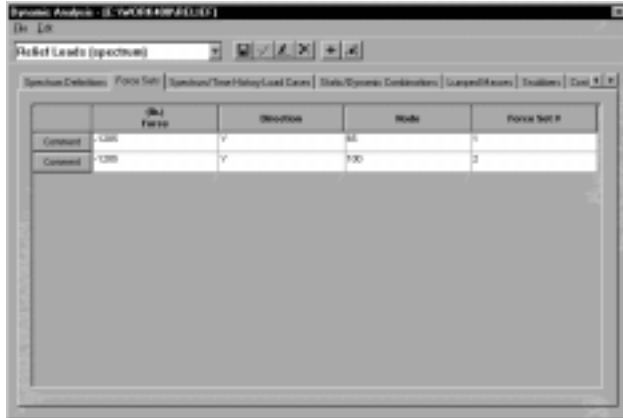


The piping error checker has been improved with additional items checked, and some rephrasing of text messages. One nice new feature here is a switch to turn off a particular error or warning. For example, in large models where dummy rigid elements have been used, each will generate a warning that the weight has not been specified. This may result in the display of forty or more messages, none of which are pertinent after the first run. This switch allows the user to disable this message after the first display.

The static load case editor has been improved to provide a more intuitive method of viewing and modifying load cases. Load cases are recommended for new jobs, and the user is automatically placed on the editing dialog. Starting a previously run job also places the user on the load case editing dialog, effectively eliminating the need for the old DOS menu. From the load case editing dialog, load cases can be added or deleted using the tool bar icons. Load cases can be constructed by either typing in the necessary components, or by dragging and dropping the components from the available list onto the appropriate load case. The redesigned load case editing dialog is shown in the figure below.



The specification of dynamic input has been simplified greatly. Based on the type of analysis to be performed (selected from a combo box on the dialog), only the necessary input tabs are available. The figure below shows the "Force Set" specification dialog, as well as the other necessary tabs needed to perform a relief load analysis.



Note that in instances where the tabs extend off of the available dialog area, a spin control is provided to slide the tabs left or right as needed. (The spin control is the double arrow pair at the upper right of the figure above.)

The static output processor presents a dialog similar in appearance to the DOS version. The tool bar at the top provides quick navigation of available options, including the animation viewer and the input processor. One of the nicer enhancements here is the ability to view, on screen, the output in 132 column mode, which has been previously available only if the results were printed.



The figure above shows the static output menu with a view of the Restraint Summary report, in 132 column mode. This view shows the displacements of the restrained nodes, as well as the forces and moments acting on the restraint. Note that this summary also includes a line for each restraint indicating the maximum force, moment, or displacement.

Each of the **CAESAR II** modules was converted into a Windows program with the intent of improving the usability of the software. There are many more improvements throughout the package. We sincerely hope users find that **CAESAR II** Version 4.00 provides additional capabilities towards their solution to pipe stress problems.

Updating COADE Software Products

(by: Richard Ay)

This article first appeared in the October 1996 issue of Mechanical Engineering News. At that time, intermediate maintenance releases were referred to as "patches" and labeled "A", "B", etc. Since that time, many other software vendors have standardized the terminology used to describe maintenance releases. Currently, maintenance releases (bug fixes) are referred to as "Builds". **In order to follow current industry trends, all new versions of COADE products will also employ this terminology.**

This article (which is a revision to the original published in October of 1996) describes the procedures whereby users can insure that they are using the latest revision to the current versions of COADE software products. Obtaining, installing, and archiving software "builds" are discussed in the following paragraphs.

COADE software products are not static, they are changed continually to reflect: Engineering Code Addenda, operational enhancements, user requests, Operating System modifications, and corrections. New versions are planned and targeted for a specific release date. However, there may be corrections necessary to the "currently shipping" version, before the next version can be released. When this occurs, a correction to the "currently shipping" version is made. This correction is referred to as a "Build". (Other vendors also use the term Service Pack. As an example, the Microsoft Windows NT 4.00 operating system is currently at Service Pack 3, while the Windows 95 operating system is currently at Service Pack 2. This information is usually displayed at system boot time.)

When COADE software is modified for a specific user, the change is made available for that user immediately. The change is either sent directly on diskette, or E-Mailed directly to the user.

Changes and corrections are accumulated until an error producing incorrect results is found. When this occurs, the build is finalized, announced, and posted to the BBS and WEB sites. Most builds contain only those files that have been modified since the previous build. Some COADE users have expressed concern over tracking, archiving, and

distributing the various builds generated between major releases. **In order to alleviate this problem for our users, all maintenance builds for new releases will contain all previous builds.** In other words, Build "Y" will contain Build "X". This will increase the download size and time required to obtain the Build, but only one will be required at any given time.

How Are Builds Identified?

When posted on the WEB or BBS, builds will be identified with the program identifier and the date the build was generated. Internally, the individual components of the build will continue to be identified with single letters: A, B, C, etc. The first build (to a specific version) will be Build A, the second Build B and so on. The builds will be distributed as self-extracting .ZIP archives (which means they have a .EXE suffix). Once on a users computer, the .EXE file can be run to extract and install the modified files. (Additional details on installing builds can be found below.)

Builds have a naming convention, as follows. The first character(s) of the file name represent the COADE program being updated; C2 for **CAESAR II**, CC for **CODECALC**, PV for **PV Elite**, TK for **TANK**, P for **CADWorx/PIPE**, and F for **CADWorx/P&ID**. These identifying characters are then followed by six digits representing the date of the build. The next character is a single letter representing the ESL version (the ESL is the External Software Lock used by the programs). The character U represents an unlimited or full run version, L is an execution limited version, D is a dealer version. The following examples illustrate this naming convention.

<u>Build Name</u>	<u>Correlation</u>
C2101597U.EXE	CAESAR II Build of Oct 15, 1997, full run users
C2101597D.EXE	CAESAR II Build of Oct 15, 1997, dealers
P111797D.EXE	CADWorx/PIPE Build of Nov 17, 1997, dealers

Insure you obtain the correct ESL version of a particular build. If the build does not match your ESL, and you install it, the software will not function. You will receive error messages that the ESL can not be found, or you have an improper version.

Can Builds Be Applied to Any Version?

NO! As new versions are released, additional input items become necessary and must be stored in the program data files. In addition, file formats change, data bases grow, and so on. A Build is intended for one specific version of the software. Using a Build on a different version (with out specific advice from COADE personnel) is a sure way to cripple the software.

How Are Builds Announced?

When a Build becomes available, the NEWS file maintained on the BBS and WEB sites is updated. All entries in this news file are dated for ease of reference. Users should check one of these news files at least once a month to insure they stay current with the software.

Corrections and Builds are also published in this newsletter, *Mechanical Engineering News*.

How Are Builds Obtained?

Builds are posted to both the COADE Bulletin Board System (BBS) and COADE's Internet WEB site (<http://www.coade.com>). The Builds are arranged in subdirectories by program. Each file contained in the directory includes a description defining what it contains, its size, and the date it was created.

Decide which Build file you need, and simply download it.

What Is Contained in a Specific Build?

Each patch file contains a file named BUILD.TXT. This is a plain ASCII text file. It can be viewed with any text editor or simply printed to the system printer. This text file contains a description of all corrections and enhancements made, which are contained in the current patch. When necessary, additional usage instructions may be found in this file.

How Are Builds Installed?

For COADE DOS Applications:

As discussed above, the Build files are self-extracting programs. Simply running this .EXE file will extract the modified files. Usually, there is nothing else to do. However, you should always review any .TXT files included in the patch. When running the .EXE patch file, you should include the "-O" command line argument. This will run the archive in "overwrite" mode, which will avoid prompting you for permission to replace exiting files.

Sometimes a Build will be posted which exceeds 1.5 Mbytes — too large to move between machines on 1.44 Mbyte floppy diskettes. When this occurs, the archive file extracts smaller archives, which are all less than 1.44 Mbytes. The README.TXT file explains that the sub-archives contain the actual updates to the software, and any additional instructions which may be necessary.

For COADE Windows Applications:

Builds distributed for Windows applications will use a Windows installation procedure. The EXE will still be a self extracting archive, which will extract to a number of sub-directories, each containing sufficient files to fit on a 1.44 diskette. The first diskette (directory) will contain a standard SETUP.EXE program to actually install the Build. This procedure insures that necessary files are registered with the system and that the “UnInstall” utility will perform its task.

How Can Builds Be Detected / Checked?

When a Build is ready to be released, the Main Menu module is revised to reflect the Build level. This allows the user to see, on the Main Program Menu, which Build is in use. To see which program modules have been modified, you can run a COADE utility program from within the program directory.

From the Utility/Tools menu, select the option for “COADE EXE Scanner”. This option will scan each of the EXE modules in the program directory and list its size, memory requirements, and Build Level. A sample display from this utility is shown in the table below.

Program Name	Open Sys File Type	File Size	DOS Min Memory	Windows Memory	Build
CC-MATL.DLL	W/BLNT	1327158	1688	2157240	CC 4.00 111207
CDINPROL.DXE	W/BLNT	24054	1688	40058	CC 4.00 111207
RCUT.DXE	W/BLNT	1994516	1688	2063280	CC 4.00 111207
BDSPRT.DXE	W/BLNT	1395008	1688	1403832	CC 4.00 111207
PLMSET.DXE	W/BLNT	1889512	1688	2009888	CC 4.00 111207
MASLINT.DXE	W/BLNT	4886016	1688	1052632	CC 4.00 111207
ACCTNG.DXE	W/BLNT	2812782	1688	2861488	CC 4.00 111207
COADNG.DXE	W/BLNT	28636	1688	49056	CC 2.00 111207
ENPROUTL.DXE	W/BLNT	1687048	1688	1726744	CC 4.00 111207
DIN.DXE	W/BLNT	1476588	1688	1548396	CC 4.00 111207
ENINOUTL.DXE	W/BLNT	1389008	1688	1377888	CC 4.00 111207
DISENG.DXE	W/BLNT	1342976	1688	1386736	CC 4.00 111207
CS.DXE	W/BLNT	2488884	1688	3186720	CC 4.00 111207
ARC.DXE	W/BLNT	136968	1688	148344	CC 4.00 111207
CADPRF.DXE	W/BLNT	138688	1688	148380	CC 4.00 111207
WPLANT.DXE	W/BLNT	127524	1688	143820	CC 4.00 111207

Reviewing this table shows which modules have been patched and to what level.

CADWorx/PIPE displays the version and build information in the AutoCAD command line when the program boots up.

Archiving and Reinstalling an Old, Patched Version?

When a new version of the software is released, what should be done with the old, existing version? The distribution disks sent from COADE should obviously be saved. Additionally, any Builds obtained should also be archived with the original diskettes. This will allow full usage of this version at some later time, if it becomes necessary.

To reinstall an older version of the software, the distribution diskettes from COADE should be installed first. Then, the last Build should be installed. Each Build will include the modifications made in all prior Builds. This procedural change (previously, patches did not contain prior patches) is the result of user requests. While this will make the download files bigger, and require more time, only the last Build needs to be archived. In addition, users can update their installation by applying a single Build, even if they have not been following developments and modifications detailed in the NEWS files (on the WEB and BBS sites).

The COADE WEB Site

(by: Richard Ay)

Many COADE clients have noticed the changes taking place on our WEB site. We have switched Internet Service Providers and completely redesigned the operation of many of the WEB pages. The Home Page has replaced the graphics images with a button bar to ease navigation through the site. In addition, the Home Page also automatically reports the date it was last modified and whether it has changed since your last visit. The Home Page also presents a scrolling banner with the latest news and tips for using the site. The revised Home Page is shown in the figure below.



One new option is the "Site Map", a hierarchical view the pages on the site. This view of the site presents an efficient way to navigate, avoiding the up and down movement typical of most WEB visits. All tables have been reformatted for a cleaner appearance and more manageable performance.

Users will also notice that forms are checked for completeness before being submitted. This insures sufficient data to satisfy the request being made. Additional enhancements will be made as necessary to keep the COADE WEB site useful. Usage continues to increase, the site is now receiving over 2000 hits per month.

One area of the WEB site which does not receive enough attention from users is the Discussion Forum. This area of the site was discussed in the last issue of *Mechanical Engineering News* also. Basically, the Discussion Forum is a general bulletin board area, where users can post questions and or discuss problems. It is hoped that other users will contribute by posting suggestions to the same thread. The **CAESAR II** user base is very large and varies widely in application. There is a wealth of information available and no one should be shy about contributing.

When contributing to the Discussion Forum, please try to respond to the proper message. You will notice that the messages have their responses indented, to show the ownership and history of the discussion. When all responses to a message are beneath the initial posting, the thread of discussion is much easier to follow.

The Year 2000 Issue

(by: Richard Ay)

COADE receives many requests from clients requesting verification that our software is "Year 2000" compliant. This article (which has been available on our WEB site since June 1997) serves to explain this issue and the steps we have taken to avoid problems at the turn of the century.

Is COADE software "Year 2000" compliant? As of Spring 1997, all products released by COADE are "Year 2000" compliant. Versions of our products released before Spring 1997 are not "Year 2000" compliant.

What date formats are used by COADE Software products?

Except for a few instances, all dates carried by the software are for reporting purposes only and therefore have no bearing on the operation of the software. In all instances where the date is actually used, (such as internal accounting or sequence checking), a full four digit year is used or explicit steps have been taken to handle to roll-over into the next century.

Is "Year 2000" compliance dependent on specific versions of operating systems or other products? No.

Does COADE insure that components from other suppliers are "Year 2000" compliant? Yes. The only components that would be affected deal with the External Software Locks (ESLs), and these components have been tested by COADE to insure compliance.

Can "Year 2000" compliance be demonstrated by COADE software? Yes. While this is not recommended (since it will change data on the ESL and require a reset procedure) changing the CPU date to any time after December 31, 1999 will show that the software still functions properly.

ASME Section VIII Division 2 Nozzle Reinforcement Calculations

(by: Scott Mayeux)

In previous newsletters we have examined some aspects of nozzle reinforcing calculations per the ASME code. The ASME Code Section VIII is divided in the 3 sections, Section VIII Division 1, Division 2 and an upcoming Division 3. Beginning in paragraph UG-36 of Section VIII Division 1, the Code outlines the method for performing nozzle reinforcement calculations. Most of the equations are presented in paragraph UG-37. The premise for performing these calculations is fairly simple. When an opening is cut in a vessel there is a stress intensification produced at the hole. A hole in a fairly large cylinder is roughly the same as a flat plate loaded in plane. Stress intensification factors for these cases are:

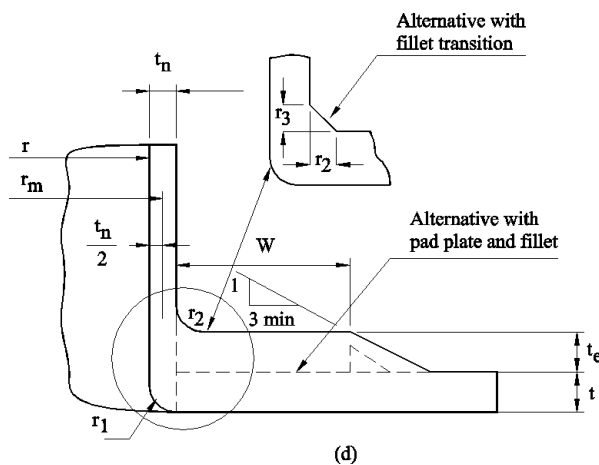
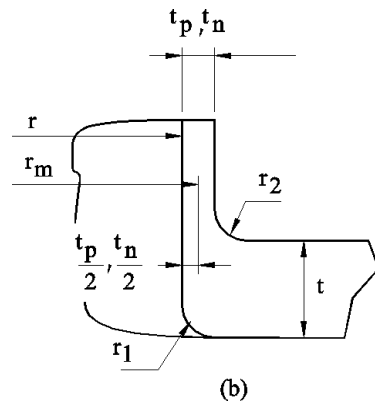
Axial Load only	3.00
Cylinder	2.50
Sphere	2.00

The Code implements these equations based on an "area of replacement" concept. Near the opening, there should be "extra" metal provided equal to the area of the required metal missing due to the presence of the opening. This extra metal should be within one decay length in both the vertical and horizontal directions to be effective. In COADE's vessel design software, these values are referred to as the effective material diameter and thickness limits. These limits are normally computed unless overridden by the user.

Another consideration in nozzle design is accounting for materials of differing strengths. If the nozzle or reinforcing element material is of lower strength than the vessel material the strength reduction factors used on those areas is reduced by the appropriate strength reduction factor.

With the given vessel design data, the various required thicknesses, thickness and diameter limits can be computed. Next the required area to be replaced would then be computed. After that, the areas available in the nozzle wall, welds, shell, pad and inside projection would be computed. The area available must be greater than the area required.

In 1968 Section VIII Division 2 was issued. This Code is titled **Alternative Rules**. This section to the Code is typically used to design high pressure, lower operating temperature vessels or very heavy vessels (usually in excess of 100 tons). In some cases, Division 2 vessels require special analysis (FEA), extensive testing, fatigue analysis and more extensive record keeping than Division 1 vessels. As a result, fewer Division 2 vessels are designed and fabricated than Division 1. Division 2 has a similar set of design requirements pertaining to reinforcement of nozzles. These rules are found in Article D-5. Paragraph AD-540 deals with limits of reinforcement. These formulae are different than their counterparts in UG-40. The interesting paragraph to AD-540 is AD-540.2, **Boundary Normal to the Vessel Wall**. This paragraph computes the vertical thickness limit for available reinforcement. This paragraph is subdivided into three subsections (a), (b) and (c). Subparagraph (a) refers to sketches a and b on the following page of the Code. These arrangements are shown below.



Note that this geometry is for smooth contoured connections with a radiused transition. Sketch (d) shown below shows a similar sketch as (b) above but contains a sketch for an alternative fillet transition. One may assume for a typical pipe nozzle, sketch (d) would be the proper figure to use for determining the vertical thickness limit. Indeed in **PVELite** this is the default. Not entirely to my surprise others do not agree with my assessment of the use of sketch (d) for a pipe nozzle arrangement. Instead they prefer to use sketch (b). We should probably ask ourselves why, and what is the difference. Lets begin by examining the equations for determining the vertical thickness limit. From Ad-540.2 (a)(1) we see that:

When $h < (2.5 * t_n + K)$, the limit is the larger of :

$$0.5 * \text{sqrt}(r_m * t_n) + K \quad \text{or} \quad 1.73 * x + 2.5 * t_p + K$$

but this limit cannot exceed $2.5 * t$ or $L + 2.5 * t_p$.

When h is greater than or equal to the quantity $(2.5 * t_n + K)$, the limit is the larger of :

$$0.5 * \text{sqrt}(r_m * t_n) + K \quad \text{or} \quad 2.5 * t_n$$

but this limit cannot exceed $2.5 * t$, where

- r = inside radius of the nozzle
- t_n = nominal nozzle thickness
- r_m = mean nozzle radius
- r_2 = transition radius between nozzle and vessel wall
- t_p = nominal thickness of the connecting pipe
- t = nominal vessel thickness
- L = length along nozzle with thickness of t_n plus transition length, in.
- K = $0.73r_2$, when a transition radius r_2 is used and the smaller of the two legs when a fillet weld transition is used.
- x = slope offset distance

For subparagraph (c) which refers to sketch (d), the limit is the larger of :

$$0.5 * \text{sqrt}(r_m * t_n) + t_e + K \quad \text{or} \quad 2.5 * t_n + t_e + K \leq 2.5 * t$$

The paragraph goes on to state that in no case can the thickness t_e used to establish the limit exceed $1.5 t$ or $1.73W$, where:

- W = width of the added reinforcing element
- t_e = thickness of added reinforcing element

On inspection it would seem that sketch (d) with no reinforcing element and fillet weld transition would reduce to sketch (b) with fillet transition. But we see this is not the case. This is especially evident if h (what we would term the outside projection) is greater than $2.5tn + K$. If that is the case and sketch b is selected and the term $2.5tn$ is greater than $0.5\sqrt{rm*tn}$ then we miss out on adding K (the weld leg) to the thickness limit. The practical outworking of this is that using sketch (b) is the conservative decision. If a hand calculation was made using sketch (b) and compared to the output from PVELite, the difference in the vertical thickness limit would be noted. In PVELite version 3.1 we allow the user to analyze the geometry according to sketch (b) by placing the text "#B" in the nozzle description field. An example is shown below:

The following example illustrates the use of the #B directive. Note that the thickness limit is 2.5 inches. Without the #B the same computation would have yielded 3.0 inches and as a result we would have more area available in the nozzle wall. The area available in the nozzle wall would increase 0.738 sq. inches.

```

INPUT VALUES, Nozzle Description: MANWAY #B      From : 20
Design Internal Pressure ( Case 1 )              P      700.00  psig
Temperature for Internal Pressure                TEMP   500.00  F
Design External Pressure ( Case 2 )              PEPT    15.00  psig
Temperature for External Pressure                TEMPEX  500.00  F

Shell Material                                   SA-516 70
Shell Allowable Stress at Temperature            S      20500.00  psi
Shell Allowable Stress At Ambient               SA      20500.00  psi

Inside Diameter of Cylindrical Shell            D      41.8750  in.
Design Length of Section                        L     126.4792  in.
Actual Thickness of Shell or Head               T       1.5000  in.
Corrosion Allowance for Shell or Head           CAS      .0000  in.

Distance from Bottom/Left Tangent              3.2500  ft.
User Entered Minimum Design Metal Temperature  -20.00  F

Nozzle Material (Normalized)                    SA-516 70
Nozzle Allowable Stress at Temperature          SN     19400.00  psi
Nozzle Allowable Stress At Ambient              SNA    21600.00  psi

Diameter of Nozzle                             DIA     12.0000  in.

Nozzle Size and Thickness Basis                 IDBN      Actual
Actual Thickness of Nozzle                     THK      1.0000  in.
Corrosion Allowance for Nozzle                 CAN      .0000  in.
Joint Efficiency of Shell Seam at Nozzle       ES        1.00
Joint Efficiency of Nozzle Neck                 EN        1.00

Outward Projection of Nozzle                   HO       9.0000  in.
Weld leg size between Nozzle and Pad/Shell    WO       .5000  in.
Groove weld depth between Nozzle and Vessel  WGNV     1.0000  in.
Inside Projection of Nozzle                    H        5.0000  in.
Weld leg size, Inside Nozzle to Shell         WI       .0000  in.
ASME Code Weld Type per UW-16.1               None

NOZZLE CALCULATION, Description: MANWAY #B
ASME Code, Section VIII, Division 2, 1995, A-96 AD-510,520,530,540,551

Actual Nozzle Diameter Used in Calculation      12.000  in.
Actual Nozzle Thickness Used in Calculation     1.000  in.

Required thickness per AD-201 of Nozzle Wall:CASE 1
= (P*(D/2+CA))/(S-0.5*P) per AD-201
= ( 700.00*(12.0000/2+.0000))/(19400-0.5*700.00)
= .2205 in.
    
```

```

Required thickness of Nozzle under External Pres.      .0388  in.

AD-540, Thickness and Diameter Limit Results : CASE 1
Effective material diameter limit,                D1     24.0000  in.
Effective material thickness limit, no pad        Tlnp    2.5000  in.

RESULTS of NOZZLE REINFORCEMENT AREA CALCULATIONS:
AREA AVAILABLE, A1 to A5                          Design External Mapnc
Area Required (Full Lim.) AR                      8.806    1.370    NA  sq.in.
Area in Shell A1                                  9.189    15.147    NA  sq.in.
Area in Nozzle Wall A2                            3.688    4.548    NA  sq.in.
Area in Inward Nozzle A3                          4.732    4.732    NA  sq.in.
Area in Welds A4                                  .237     .237    NA  sq.in.
Area in Pad A5                                    .000     .000    NA  sq.in.
Area Available (Full Lim) ATOT                     17.846   24.664    NA  sq.in.

Pressure Case 1 Governs the Analysis

Area Required (2/3 Limit) Ar23                    5.871     .913    NA  sq.in.
Area Available (2/3 Lim) At23                     12.981   16.644    NA  sq.in.

Nozzle Angle Used in Area Calculations            90.00  Degs.

The area available without a pad is Sufficient.

Reinforcement Area Required for Nozzle:
Ar = Dlr*Tr + 2*(Thk-Can)*Tr*(1-Fr) per AD-520 & AD-551
Ar = 12.0000*.7274+2*(1.0000-.0000)*.7274*(1.0-.9463)
Ar = 8.8063 sq.in.

Areas per AD-550 but with DL = Diameter Limit DLR = Corroded ID:
Area Available in Shell (A1):
A1 = (Dl-Dlr)*(T-Cas-Tr)-2*(Thk-Can)*(T-Cas-Tr)*(1-Fr)
A1 = (24.000-12.000)*(1.5000-.000-.727)-2*(1.000-.000)
    *(1.5000-.0000-.7274)*(1-.9463)
A1 = 9.1888 sq.in.

Area Available in Nozzle Wall, no Pad:
A2np = ( 2 * Min(Tlnp,Ho) ) * ( Thk - Can - Trn ) * fr
A2np = (2*Min(2.500,9.000))*(1.0000-.0000-.2205)*.9463
A2np = 3.6885 sq.in.

Area Available in Nozzle Penetration:
A3 = 2*(Tn-Can-Can)*(MIN(H-Can,Tl))*fr
A3 = 2 * ( 1.0000 ) * ( 2.5000 ) * .9463
A3 = 4.7317 sq.in.

Area Available in Welds, no Pad:
A4np = WO^2 * fr + (Wi-Can/0.707)^2 * fr
A4np = .5000^2 * .95 + ( .0000 )^2 * .9463
A4np = .2366 sq.in.

M.A.W.P. RESULTS FOR THIS NOZZLE GEOMETRY
Approximate M.A.W.P. for given geometry          AMAP    1042.0  psig
Nozzle is O.K. for the External Pressure         AMAPEXT  15.0  psig

Min. Metal Temp. per Fig. AM-218.1 Nozzle Group IV  -22  F

WELD SIZE CALCULATIONS, Description: MANWAY #B

Results Per Art. D-2, Required Thickness Actual Thickness
Nozzle Weld .2500 = Min per Code .3500 = 0.7 * Wo
in.

PV Elite Version 3.1, (c)1995-97 by COADE Engineering Software
    
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Conclusions

ASME Section VIII Division 2 provides two calculations for the vertical thickness limit for the case of a normal inserted pipe nozzle. It does not explicitly inform us which one to use. When h exceeds $2.5 * tn + K$ and we are looking at figure (b) the weld leg is not added to the overall thickness limit. In our opinion this is probably an omission in the equation. If figure (d) is used, the dimension K is added and the net result is more available area in the nozzle wall.

Pipe Stress Analysis of Fiberglass Reinforced Plastic (FRP) Piping (Part 1: Underlying Theory)

(by: Tom Van Laan)

(This article is being presented in two parts – in the first, the theory of stress analysis of fiberglass reinforced plastic pipe is presented on the micro-, mini-, and macro-analytical levels; with the discussion of macro-analytical level covering the implementation of the most prominent FRP piping codes. The second part of this article, to be presented in the next issue of Mechanical Engineering News, details the specific use of the CAESAR II software in the analysis of FRP piping.)

Introduction: The behavior of steel and other homogeneous materials has been long understood, permitting their wide spread use as construction materials. The development of the piping and pressure vessel codes (Reference 1) in the early part of this century led to the confidence in their use in piping applications; the work of Markl et. al. in the 1940's and 1950's was responsible for the formalization of today's pipe stress methods, leading to an ensuing diversification of piping codes on an industry by industry basis. The advent of the digital computer, and with it the appearance of the first pipe stress analysis software (Reference 2), further increased the confidence with which steel pipe could be used in critical applications. The 1980's saw the wide spread proliferation of the micro computer, with associated pipe stress analysis software, which in conjunction with training, technical support, and available literature, has brought stress analysis capability to almost all engineers. In short, an accumulated experience of close to 100 years, in conjunction with ever improving technology has led to the utmost confidence on the part of today's engineers when specifying, designing, and analyzing steel, or other metallic, pipe.

For fiberglass reinforced plastic (FRP) and other composite piping materials, the situation is not the same. Fiberglass reinforced plastic was developed only as recently as the 1950's, and did not come into wide spread use until a decade later (Reference 3). There is not a large base of stress analysis experience, although not from a lack of commitment on the part of FRP vendors. Most vendors conduct extensive stress testing on their components, including hydrostatic and cyclic pressure, uniaxial tensile and compressive, bending, and combined loading tests. The problem is due to the traditional difficulty associated with, and lack of understanding of, stress analysis of heterogeneous materials. First, the behavior and failure modes of these materials are highly complex and not fully understood, leading to inexact analytical methods, and a general lack of agreement on the best course of action to

follow. This lack of agreement has slowed the simplification and standardization of the analytical methods into universally recognized codes (**BS 7159 Code (Design and Construction of Glass Reinforced Plastics Piping Systems for Individual Plants or Sites)** and **UKOOA Specification and Recommended Practice for the Use of GRP Piping Offshore** being notable exceptions). Secondly, the heterogeneous, orthotropic behavior of FRP and other composite materials has hindered the use of the pipe stress analysis algorithms developed for homogeneous, isotropic materials associated with crystalline structures. A lack of generally accepted analytical procedures has contributed to a general reluctance to use FRP piping for critical applications.

Stress analysis of FRP components must be viewed on many levels. These levels, or scales, have been called "Micro-Mini-Macro" levels, with analysis proceeding along the levels according to the "MMM" principle (Reference 4).

Micro level analysis: Stress analysis on the "Micro" level refers to the detailed evaluation of the individual materials and boundary mechanisms comprising the composite material. In general, FRP pipe is manufactured from laminates, which are constructed from elongated fibers of a commercial grade of glass (called E-glass), which are coated with a coupling agent or sizing prior to being embedded in a thermosetting plastic material, typically epoxy or polyester resin.

This means, on the micro scale, that an analytical model must be created which simulates the interface between these elements. Since the number and orientation of fibers is unknown at any given location in the FRP sample, the simplest representation of the micro-model is that of a single fiber, extending the length of the sample, embedded in a square profile of matrix (Figure 1).

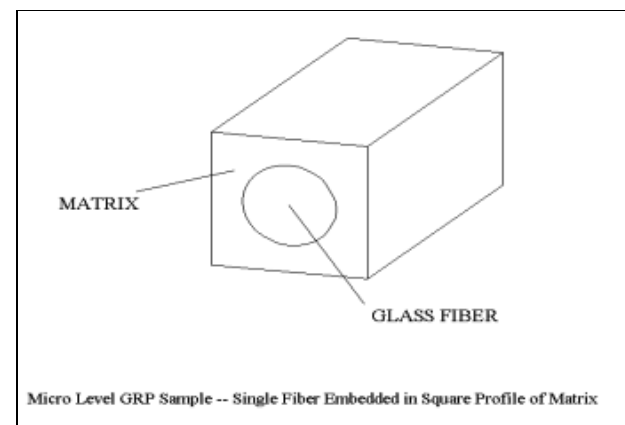


Figure 1

Evaluation of this model requires use of the material parameters of:

- 1) the glass fiber
- 2) the coupling agent or sizing layer (normally of such microscopic proportion that it may be ignored)
- 3) the plastic matrix

It must be considered that these material parameters may vary for an individual material based upon tensile, compressive, or shear applications of the imposed stresses, and typical values vary significantly between the fiber and matrix (Reference 5):

Material	Young's Modulus tensile (MPa)	Ultimate Strength tensile (MPa)	Coefficient of Thermal Expansion m/m°C
Glass Fiber	7.25×10^4	1.5×10^3	5.0×10^{-6}
Plastic Matrix	2.75×10^3	7.0×10^1	7.0×10^{-5}

The following failure modes of the composite must be similarly evaluated:

- 1) failure of the fiber
- 2) failure of the coupling agent layer
- 3) failure of the matrix
- 4) failure of the fiber-coupling agent bond
- 5) failure of the coupling agent-matrix bond

Due to uncertainties of the degree to which the fiber has been coated with the coupling agent, and the lack of a full understanding of the failure modes of items 2, 4, and 5 above, this evaluation is typically reduced to:

- 1) failure of the fiber
- 2) failure of the matrix
- 3) failure of the fiber-matrix interface

Stresses in the individual components can be evaluated through finite element analysis of the strain continuity and equilibrium equations, based upon the assumption that there is a good bond between the fiber and matrix, resulting in compatible strains between the two. For normal stresses applied parallel to the glass fiber:

$$\begin{aligned} \epsilon_f &= \epsilon_m = \sigma_{af} / E_f = \sigma_{am} / E_m \\ \sigma_{af} &= \sigma_{am} E_f / E_m \end{aligned}$$

Where:

- ϵ_f = strain in the fiber
- ϵ = strain in the matrix
- σ_{af} = normal stress parallel to fiber, in the fiber
- E_f = modulus of elasticity of the fiber

- σ_{am} = axial normal stress parallel to fiber, in the matrix
- E = modulus of elasticity of the matrix

Due to the large ratio of the modulus of elasticity of the fiber to that of the matrix, it is apparent that nearly all of the axial normal stress in the fiber-matrix composite is carried by the fiber. Exact values are (Reference 6):

$$\begin{aligned} \sigma_{af} &= \sigma_L / [\phi + (1-\phi)E_m/E_f] \\ \sigma_{am} &= \sigma_L / [\phi E_m/E_f + (1-\phi)] \end{aligned}$$

Where:

- σ_L = nominal longitudinal stress across composite
- ϕ = glass content by volume

The continuity equations for the glass-matrix composite seem less complex for normal stresses perpendicular to the fibers, since the weak point of the material seems to be limited by the glass-free cross-section shown in Figure 2.

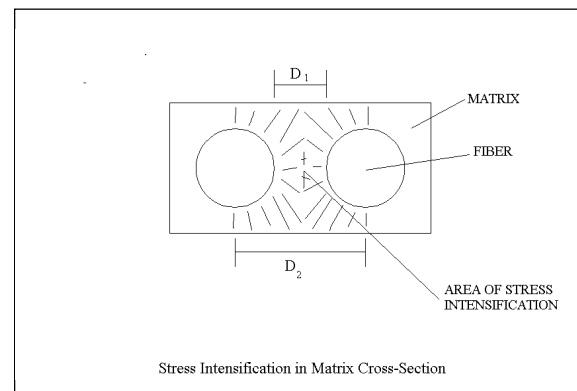


Figure 2

For this reason, it would appear that the strength of the composite would be equal to that of the matrix for stresses in this direction; in fact, its strength is less than that of the matrix due to stress intensification in the matrix caused by the irregular stress distribution in the vicinity of the stiffer glass. (Since the elongation over distance D_1 must be equal to that over the longer distance D_2 , the strain, and thus the stress at location D_1 must exceed that at D_2 by the ratio D_2/D_1 .) Maximum intensified transverse normal stresses in the composite are:

$$\sigma_b = \frac{\sigma_{\perp} [(1-\phi)^{1.25} + \phi(E_m/E_f) / (1-V_m^2)]}{(1 + 0.85\phi^2)[1 - \sqrt{(2\phi\sqrt{3}/\pi)} (1 - (E_m/E_f) / (1-V_m^2))]}$$

Where:

- σ_b = intensified normal stress transfer to the fiber, in the composite
- σ_{\perp} = nominal transverse normal stress across composite
- V = Poisson's ratio of the matrix

Note that due to the Poisson effect, this stress produces an additional σ'_{am} equal to:

$$\sigma'_{am} = V_m \sigma_b$$

Shear stress can be allocated to the individual components again through the use of continuity equations; it would appear that the stiffer glass would resist the bulk of the shear stresses; however, unless the fibers are infinitely long, all shears must eventually pass through the matrix in order to get from fiber to fiber. Shear stress between fiber and matrix can be estimated as:

$$\tau_{ab} = \frac{T (1-\phi)^{1.25} + \phi(G_m/G_f)}{(1 + 0.6\sqrt{\phi}) [(1 - \sqrt{(2\phi\sqrt{3}/\pi)} (1 - (G_m/G_f))]}$$

Where:

- τ_{ab} = intensified shear stress in composite
- T = nominal shear stress across composite
- G_m = shear modulus of elasticity in matrix
- G_f = shear modulus of elasticity in fiber

Determination of the stresses in the fiber-matrix interface is more complex. The bonding agent has an inappreciable thickness, and thus has an indeterminate stiffness for consideration in the continuity equations. Also, the interface behaves significantly differently in shear, tension, and compression, showing virtually no effects from the latter. The state of the stress in the interface is best solved by omitting its contribution from the continuity equations, and simply considering that it carries all stresses which must be transferred from fiber to matrix.

Once the stresses have been apportioned, they must be evaluated against appropriate failure criteria. The behavior of homogenous, isotropic materials such as glass and plastic resin, under a state of multiple stress is better understood. A failure criterion for isotropic material reduces the combined normal and shear stresses ($s_a, s_b, s_c, t_{ab}, t_{ac}, t_{bc}$) to a single stress, an "equivalent stress", which can be compared

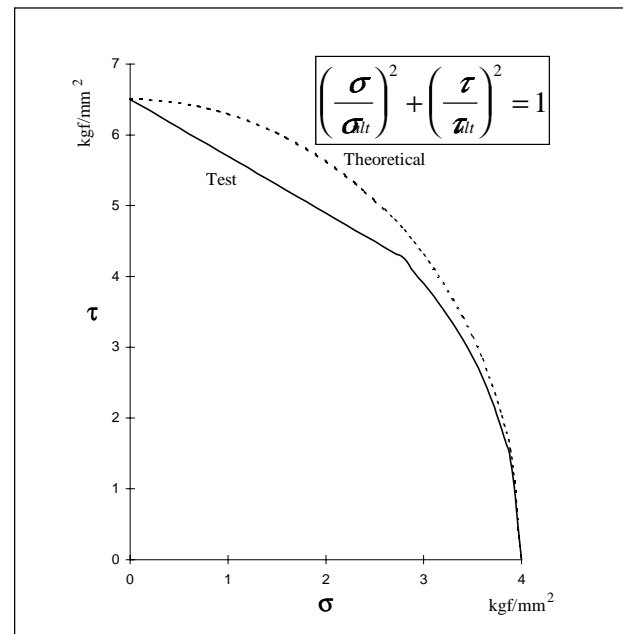
to the tensile stress present at failure in a material under uniaxial loading, i.e. the ultimate tensile stress, S_{ult} .

Different theories, and different equivalent stress functions $f(s_a, s_b, s_c, t_{ab}, t_{ac}, t_{bc})$ have been proposed, with possibly the most widely accepted being the Huber-von Mises-Hencky criterion, which states that failure will occur when the equivalent stress reaches a critical value – the ultimate strength of the material:

$$\sigma_{eq} = \sqrt{\{1/2 [(\sigma_a - \sigma_b)^2 + (\sigma_a - \sigma_c)^2 + (\sigma_b - \sigma_c)^2] + 6(\tau_{ab}^2 + \tau_{ac}^2 + \tau_{bc}^2)\}} \leq S_{ult}$$

This theory does not fully cover all failure modes of the fiber, in that it omits reference to direction of stress (i.e., tensile vs. Compressive). The fibers, being relatively long and thin, predominantly demonstrate buckling as their failure mode when loaded in compression.

The equivalent stress failure criterion has been corroborated (with slightly non-conservative results) by testing. Little is known about the failure mode of the adhesive interface, although empirical evidence points to a failure criterion which is more of a linear relationship between the normal and the square of the shear stresses. Failure testing of a composite material loaded only in transverse normal and shear stresses are shown in Figure 3; the kink in the curve shows the transition from the matrix to the interface as the failure point.



Combined Stresses s and t at failure: Araldite CY232

Figure 3

Mini level analysis: Although feasible in concept, micro level analysis is not feasible in practice. This is due to the uncertainty of the arrangement of the glass in the composite — the thousands of fibers which may be randomly distributed, semi-randomly oriented (although primarily in a parallel pattern), and of randomly varying lengths. This condition indicates that a sample can truly be evaluated only on a statistical basis, thus rendering detailed finite element analysis inappropriate.

For mini-level analysis, a laminate layer is considered to act as a continuous (hence the common reference to this method as the “continuum” method) material, with material properties and failure modes estimated by integrating them over the assumed cross-sectional distribution, i.e., averaging. The assumption regarding the distribution of the fibers can have a marked effect on the determination of the material parameters; two of the most commonly postulated distributions are the square and the hexagonal (Figure 4), with the latter generally considered to be a better representation of randomly distributed fibers.

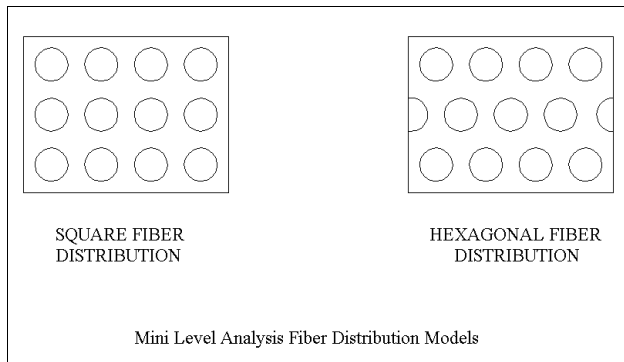


Figure 4

The stress-strain relationships, for those sections evaluated as continua, can be written as:

$$\begin{aligned} \epsilon_{aa} &= \sigma_{aa}/E_L - (V_L/E_L)\sigma_{bb} - (V_L/E_L)\sigma_{cc} \\ \epsilon_{bb} &= -(V_L/E_L)\sigma_{aa} + \sigma_{bb}/E_T - (V_T/E_T)\sigma_{cc} \\ \epsilon_{cc} &= -(V_L/E_L)\sigma_{aa} - (V_T/E_T)\sigma_{bb} + \sigma_{cc}/E_T \\ \epsilon_{ab} &= \tau_{ab} / 2 G_L \\ \epsilon_{bc} &= \tau_{bc} / 2 G_T \\ \epsilon_{ac} &= \tau_{ac} / 2 G_L \end{aligned}$$

Where:

- ϵ_{ij} = strain along direction i on face j
- σ_{ij}, τ_{ab} = stress (normal, shear) along direction i on face j
- E_L = modulus of elasticity of laminate layer in longitudinal direction

- V_L = Poisson’s ratio of laminate layer in longitudinal direction
- E_T = modulus of elasticity of laminate layer in transverse direction
- V_T = Poisson’s ratio of laminate layer in transverse direction
- G_L = shear modulus of elasticity of laminate layer in longitudinal direction
- G_T = shear modulus of elasticity of laminate layer in transverse direction

These relationships require that four moduli of elasticity ($E_L, E_T, G_L,$ and G_T) and two Poisson’s ratios (V_L and V_T) to be evaluated for the continuum. Extensive research (References 4 - 10) has been done to estimate these parameters. There is general consensus that the longitudinal terms can be explicitly calculated; for cases where the fibers are significantly stiffer than the matrix, they are:

$$\begin{aligned} E_L &= E_F \phi + E_M(1 - \phi) \\ G_L &= G_M + \phi / [1 / (G_F - G_M) + (1 - \phi) / (2G_M)] \\ V_L &= V_F \phi + V_M(1 - \phi) \end{aligned}$$

Parameters in the transverse direction cannot be calculated; only their upper and lower bounds can. Correlation with empirical results have yielded approximations (Reference 5 and 6):

$$E_T = \frac{E_M (1 + 0.85\phi^2)}{(1 - V_M^2) [(1 - \phi)^{1.25} + \phi (E_M/E_F) / (1 - V_M^2)]}$$

$$G_T = G_M (1 + 0.6\sqrt{\phi}) / [(1 - \phi)^{1.25} + \phi (G_M/G_F)]$$

$$V_T = V_L (E_L / E_T)$$

Use of these parameters permits the development of the homogenous material models which facilitate the calculation of longitudinal and transverse stresses acting on a laminate layer. The resulting stresses may be allocated to the individual fibers and matrix using relationships developed during the micro analysis.

Macro level analysis: Where Mini level analysis provides the means of evaluation of individual laminate layers, Macro level analysis provides the means of evaluating components made up of multiple laminate layers. It is based upon the assumption that not only the composite behaves as a continuum, but that the series of laminate layers acts as a homogenous material with properties estimated based on the properties of the layer and the winding angle, and that finally, failure criteria are functions of the level of equivalent stress.

Laminate properties may be estimated by summing the layer properties (adjusted for winding angle) over all layers. For example:

$$E_{LAMI} = (1 / t_{LAMI}) \sum_k (E_{jk} C_{ik} + E_{lk} C_{jk}) t_k$$

Where:

- E_{LAMI} = Longitudinal modulus of elasticity of laminate
- t_{LAMI} = thickness of laminate
- E_{jk} = Longitudinal modulus of elasticity of laminate layer k
- C_{ik} = transformation matrix orienting axes of layer k to longitudinal laminate axis
- C_{jk} = transformation matrix orienting axes of layer k to transverse laminate axis
- t_k = thickness of laminate layer k

Once composite properties are determined, the component stiffness parameters may be determined as though it were made of homogenous material – i.e., based on component cross-sectional and composite material properties.

Normal and shear stresses can be determined from 1) forces and moments acting on the cross-sections, and 2) the cross-sectional properties themselves. These relationships can be written as:

$$\begin{aligned} \sigma_{aa} &= F_{aa} / A_{aa} \pm M_{ba} / S_{ba} \pm M_{ca} / S_{ca} \\ \sigma_{bb} &= F_{bb} / A_{bb} \pm M_{ab} / S_{ab} \pm M_{cb} / S_{cb} \\ \sigma_{cc} &= F_{cc} / A_{cc} \pm M_{ac} / S_{ac} \pm M_{bc} / S_{bc} \\ \tau_{ab} &= F_{ab} / A_{ab} \pm M_{bb} / R_{ab} \\ \tau_{ac} &= F_{ac} / A_{ac} \pm M_{cc} / R_{ac} \\ \tau_{ba} &= F_{ba} / A_{ba} \pm M_{aa} / R_{ba} \\ \tau_{bc} &= F_{bc} / A_{bc} \pm M_{cc} / R_{bc} \\ \tau_{ca} &= F_{ca} / A_{ca} \pm M_{aa} / R_{ca} \\ \tau_{cb} &= F_{cb} / A_{cb} \pm M_{bb} / R_{cb} \end{aligned}$$

Where:

- σ_{ij} = normal stress along axis i on face j
- F_{ij} = force acting along axis i on face j
- A_{ij} = area resisting force along axis i on face j
- M_{ij} = moment acting about axis i on face j
- S_{ij} = section modulus about axis i on face j
- τ_{ij} = shear stress along axis i on face j
- R_{ij} = torsional resistivity about axis i on face j

Using the relationships developed under macro, mini, and micro analysis, these stresses can be resolved back into local stresses within the laminate layer, and from there, back into stresses within the fiber and the matrix (Figure 5).

From these, the failure criteria of those microscopic components, and hence, the component as a whole, may be checked.

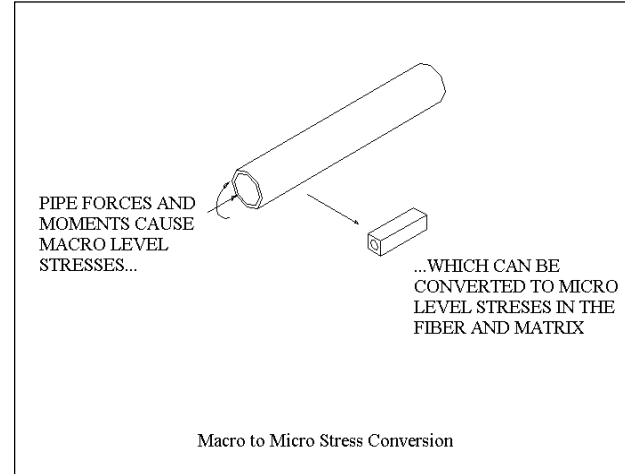


Figure 5

Implementation of Macro level analysis for piping systems: The Macro level of analysis described above is the basis for the preeminent FRP piping codes in use today, including the **BS 7159 Code (Design and Construction of Glass Reinforced Plastics Piping Systems for Individual Plants or Sites)** and the **UKOOA Specification and Recommended Practice for the Use of GRP Piping Offshore**.

BS 7159 uses methods and formulas familiar to the world of steel piping stress analysis in order to calculate stresses on the cross-section, with the assumption that FRP components have material parameters based on continuum evaluation or test. All coincident loads, such as thermal, weight, pressure, and axial extension due to pressure need be evaluated simultaneously. Failure is based on the equivalent stress calculation method; since one normal stress (radial stress) is traditionally considered to be negligible in typical piping configurations, this calculation reduces to the greater of (except when axial stresses are compressive):

$$s_{eq} = \sqrt{(s_x^2 + 4t^2)} \text{ (when axial stress is greater than hoop)}$$

$$s_{eq} = \sqrt{(s_h^2 + 4t^2)} \text{ (when hoop stress is greater than axial)}$$

A slight difficulty arises when evaluating the calculated stress against an allowable, due to the orthotropic nature of the FRP piping – normally the laminate is designed in such a way to make the pipe much stronger in the hoop, than in the longitudinal, direction, providing more than one allowable stress. This is resolved by defining the allowable in terms of a design strain e_d , rather than stress, in effect

adjusting the stress allowable in proportion to the strength in each direction – i.e., the allowable stresses for the two equivalent stresses above would be $(e_d E_{L\text{AMX}})$ and $(e_d E_{L\text{AMH}})$ respectively. In lieu of test data, system design strain is selected from Tables 4.3 and 4.4 of the Code, based on expected chemical and temperature conditions.

Actual stress equations as enumerated by the **BS 7159** Code are shown below:

- 1) Combined stress: straights and bends:

$$\sigma_C = (\sigma_\phi^2 + 4\sigma_S^2)^{0.5} \leq \epsilon_d E_{L\text{AM}}$$

or

$$\sigma_C = (\sigma_X^2 + 4\sigma_S^2)^{0.5} \leq \epsilon_d E_{L\text{AM}}$$

Where:

- σ_C = combined stress
- σ_ϕ = circumferential stress
- σ_S = torsional stress
- σ_X = longitudinal stress
- $\sigma_{\phi P}$ = circumferential pressure stress
- $\sigma_{\phi B}$ = circumferential bending stress
- M_S = torsional moment on cross-section
- D = internal pipe diameter
- t_d = design thickness of reference laminate
- I = moment of inertia of pipe
- m = pressure stress multiplier of component
- P = internal pressure
- M_i = in-plane bending moment on cross-section
- $SIF_{\phi i}$ = circumferential stress intensification factor for in-plane moment
- M = out-plane bending moment on cross-section
- SIF_ϕ = circumferential stress intensification factor for out-plane moment
- σ_{XP} = longitudinal pressure stress
- σ_{XB} = longitudinal bending stress
- SIF = longitudinal stress intensification factor for in-plane moment
- SIF = longitudinal stress intensification factor for out-plane moment

- 2) Combined stress: branch connections:

$$\sigma_{CB} = ((\sigma_{\phi P} + \sigma_{bB})^2 + 4\sigma_{SB}^2)^{0.5} \leq \epsilon_d E_{L\text{AM}}$$

Where:

- σ_{CB} = branch combined stress
- $\sigma_{\phi P}$ = circumferential pressure stress
- σ_{bB} = non-directional bending stress
- σ_{SB} = branch torsional stress
- t_M = thickness of the reference laminate at the main run
- SIF_{Bi} = branch stress intensification factor for in-plane moment
- SIF_B = branch stress intensification factor for out-plane moment

- 3) When longitudinal stress is negative (net compressive):

$$\sigma_\phi - V_{\phi X} \sigma_X \leq \epsilon_\phi E_{L\text{AM}\phi}$$

Where:

- $V_{\phi X}$ = Poisson's ratio giving strain in longitudinal direction caused by stress in circumferential direction
- ϵ_ϕ = design strain in circumferential direction
- $E_{L\text{AM}\phi}$ = modulus of elasticity in circumferential direction

The **BS 7159** Code also dictates the means of calculating flexibility and stress intensification (k- and i-) factors for bend and tee components, for use during the flexibility analysis. These factors are shown in Figures 6 and 7.

Bends	Type					
	Smooth			Mitred		
Pipe factor	$\lambda_b = \frac{t_2 R}{r^2}$ (7.6)*					
Flexibility factor	$k = 7\alpha_1 \lambda^{1/2} (\epsilon^{-0.5})$ (7.5)*			$k = 7\alpha_1 \lambda^{1/2} (\epsilon^{-0.83})$ (7.5)*		
Laminate type	1	2	3	1	2	3
α_1 In-plane	1.0	1.0	0.7	0.9	0.9	0.64
Out-of-plane	1.0	1.0	0.7	0.9	0.9	0.64
Correction factor	$\gamma = (1 + 2.53\epsilon_0 R^{1/2} r t_2^{-0.2})^{-1}$ (7.7)*					
Stress intensification factor	$SIF = (\delta_x \text{ or } \delta_\theta) \alpha_2 \lambda^{1/2} (\epsilon^{-2.0})$ (7.9)*					
Laminate type	1	2	3	1	2	3
α_2 In-plane Long.	0.96	0.96	0.76	0.65	0.69	0.5
In-plane Circ.	1.84	1.60	1.60	1.47	1.37	1.2
Out-of-plane Long.	1.1	1.03	0.56	0.86	0.86	0.51
Out-of-plane Circ.	1.8	1.42	1.58	1.72	1.4	1.53
Correction factor Long.	$\delta_x = (1 + 2.53\epsilon_0 R^{1/2} r t_2^{-0.2})^{-1}$ (7.10)*					
Correction factor Circ.	$\delta_\theta = (1 + 1.1\epsilon_0 R^{1/2} r^{1/2} t_2^{-0.2})^{-1}$ (7.11)*					
Pressure stress multiplier <i>m</i>	1.0 or $0.83(1 - r/2R)/(1 - r/R)$ whichever is the greater (see 7.3.1.7)			1.3		

BS 7159 Bend k- and i- Factors

Figure 6

The **BS 7159** Code imposes a number of limitations on its use, the most notable being the limitation of a system to a design pressure of 10 bar, the restriction to the use of designated design laminates, and the limited applicability of the k- and i- factor calculations to pipe bends (i.e. mean wall thickness around the intrados must be 1.75 times the nominal thickness or less).

This code appears to be more sophisticated, yet easy to use, than any available alternative, so it is recommended here that its calculation techniques be applied even to FRP systems outside its explicit scope, with the following recommendations:

- 1) Pressure stiffening of bends should be based on actual design pressure, rather than allowable design strain.
- 2) Design strain should be based on manufacturer's test and experience data wherever possible (with consideration for expected operating conditions).
- 3) Fitting k- and i- factors should be based on manufacturer's test or analytic data if available.

The **UKOOA** Specification is similar in many respects to the **BS 7159** Code, except that it simplifies the calculational requirements in exchange for imposing more limitations and more conservatism on the piping operating conditions.

Rather than explicitly calculating a combined stress, the specification defines an idealized envelope of combinations of axial and hoop stresses which cause the equivalent stress to reach failure. This curve represents the plot of:

$$\left(\frac{\sigma_x}{\sigma_{x-all}}\right)^2 + \left(\frac{\sigma_{hoop}}{\sigma_{hoop-all}}\right)^2 - \left[\frac{\sigma_x \sigma_{hoop}}{\sigma_{x-all} \sigma_{hoop-all}}\right] \leq 1.0$$

Where:

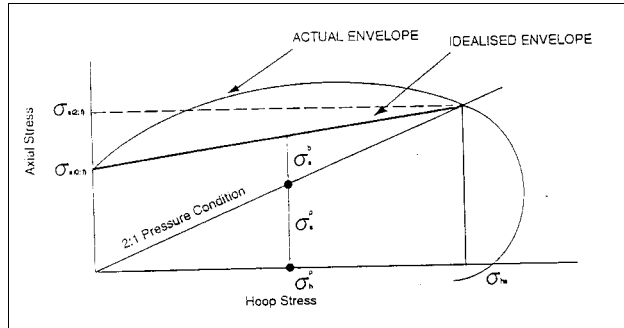
- σ_{x-all} = allowable stress, axial
- $\sigma_{hoop-all}$ = allowable stress, hoop

The Specification conservatively limits the user to that part of the curve falling under the line between s_{x-all} (also known as $s_{a(0:1)}$) and the intersection point on the curve where s_{hoop} is twice s_x (a natural condition for a pipe loaded only with pressure), as shown in Figure 8.

Tees	Equal		Unequal
Moulded			
Fabricated (set-on or set-in)			
Flexibility factor	1.0		
Stress intensification factor (see 7.3.2.2)	$SIF = 0.66\lambda^{-0.5}$ (7.12)*		
Pipe factor	$\lambda_T = \frac{2t_m}{D_1}$ (7.13)*		
Pressure stress multiplier	$m = 1.4\lambda_T^{0.25}$ (7.15)*		
Pipe factor	$\lambda_1 = \frac{D_1}{2t_m}$ (7.16)*	$\lambda_2 = \left(\frac{D_2}{2t_2}\right)^2 \cdot \left(\frac{2t_m}{D_m}\right)$ (7.17)*	

BS 7159 Tee i- Factors

Figure 7



UKOOA Idealized Stress Envelope

Figure 8

An implicit modification to this requirement is the fact that pressure stresses are given a factor of safety (typically equal to 2/3) while other loads are not. This gives an explicit requirement of:

$$P_{des} \leq f_1 f_2 f_3 \text{ LTHP}$$

Where:

- P_{des} = allowable design pressure
- f_1 = factor of safety for 97.5% lower confidence limit, usually 0.85
- f_2 = system factor of safety, usually 0.67
- f_3 = ratio of residual allowable, after mechanical loads
 $= 1 - (2 \sigma_a^b) / (r f_1 \text{ LTHS})$
- σ_a^b = axial bending stress due to mechanical loads
- r = $\sigma_{a(0:1)} / \sigma_{a(2:1)}$
- $\sigma_{a(0:1)}$ = long term axial tensile strength in absence of pressure load
- $\sigma_{a(2:1)}$ = long term axial tensile strength in under only pressure loading
- LTHS = long term hydrostatic strength (hoop stress allowable)
- LTHP = long term hydrostatic pressure allowable

Note that this has been implemented in the **CAESAR II** pipe stress analysis software as:

Code Stress	Code Allowable
$\sigma_a^b (f_2 / r) + PD_m / (4t)$	$\leq (f_1 f_2 \text{ LTHS}) / 2.0$

Where:

- P = design pressure
- D = pipe mean diameter
- t = pipe wall thickness

and i-factors for bends are to be taken from the **BS 7159** Code, while no such factors are to be used for tees.

The UKOOA Specification is limited in that shear stresses are ignored in the evaluation process; no consideration is given to conditions where axial stresses are compressive; and most required calculations are not explicitly detailed.

References:

Cross, Wilbur, An Authorized History of the ASME Boiler and Pressure Vessel Code, ASME, 1990

Olson, J. and Cramer, R., "Pipe Flexibility Analysis Using IBM 705 Computer Program MEC 21, Mare Island Report 277-59", 1959

Fiberglass Pipe Handbook, Composites Institute of the Society of the Plastics Industry, 1989

Hashin, Z., "Analysis of Composite Materials – a Survey", Journal of Applied Mechanics, Sept. 1983

Greaves, G., "Fiberglass Reinforced Plastic Pipe Design", Ciba-Geigy Pipe Systems

Puck, A. and Schneider, W., "On Failure Mechanisms and Failure Criteria of Filament-Wound Glass-Fibre/Resin Composites", Plastics and Polymers, Feb. 1969

Hashin, Z., "The Elastic Moduli of Heterogeneous Materials", Journal of Applied Mechanics, March 1962

Hashin, Z. and Rosen, B. Walter, "The Elastic Moduli of Fibre Reinforced Materials", Journal of Applied Mechanics, June 1964

Whitney, J. M. and Riley, M. B., "Elastic Properties of Fiber Reinforced Composite Materials", AIAA Journal, Sept. 1966

Walpole, L. J., "Elastic Behavior of Composite Materials: Theoretical Foundations", Advances in Applied Mechanics, Volume 21, Academic Press, 1989

BS 7159 : 1989 – British Standard Code of Practice for Design and Construction of Glass Reinforced Plastics (GRP) Piping Systems for Individual Plants or Sites

UK Offshore Operators Association Specification and Recommended Practice for the Use of GRP Piping Offshore — 1994

*Tippett & Gee Success Story,
Using the Bi-directional Power of
CADWorx/PIPE and CAESAR II*

(by: Vornel Walker)

Tippett & Gee, an engineering company based in Abilene, Texas has successfully used the bi-directional capabilities of **CADWorx/PIPE** and **CAESAR II** to complete a 10 million dollar piping project for which they were the design engineering firm.

Tippett & Gee were engineering consultants for Sweeny Co-generation Limited Partnership. The project was installed on the existing Phillips Petroleum Site at Sweeny, Texas.

Beating out other tenders, Tippett & Gee was able to demonstrate that they could complete the project on time and within budget. This was based on their 40 years of experience and the continued use of tried and tested design software.

The project consisted of linking a new co-generation facility with new gas compressor and water treatment facilities to the existing Phillips Petroleum refinery. The interconnection of these facilities comprised approximately 20 different piping systems routed over existing and new pipe racks.

The co-generation and water treatment units were at diagonally opposed corners of the 1-mile square site with the existing gas compressor unit in between.

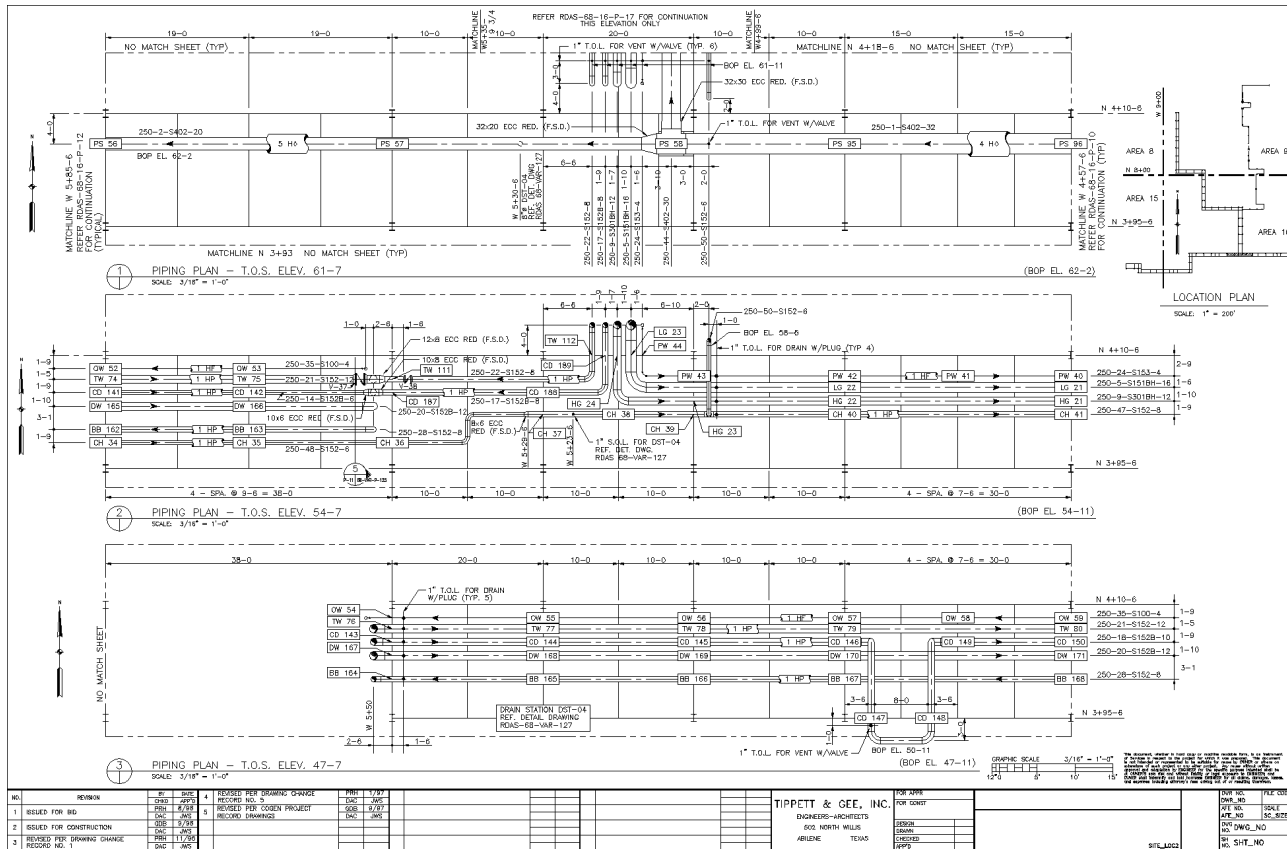
The 34,000 ft. of new pipe was equally divided between 5,500 ft. of new and existing piping racks. The 32-inch steam header line was the largest pipe run on the rack with 30 in. and 20 in. branches separately supported.

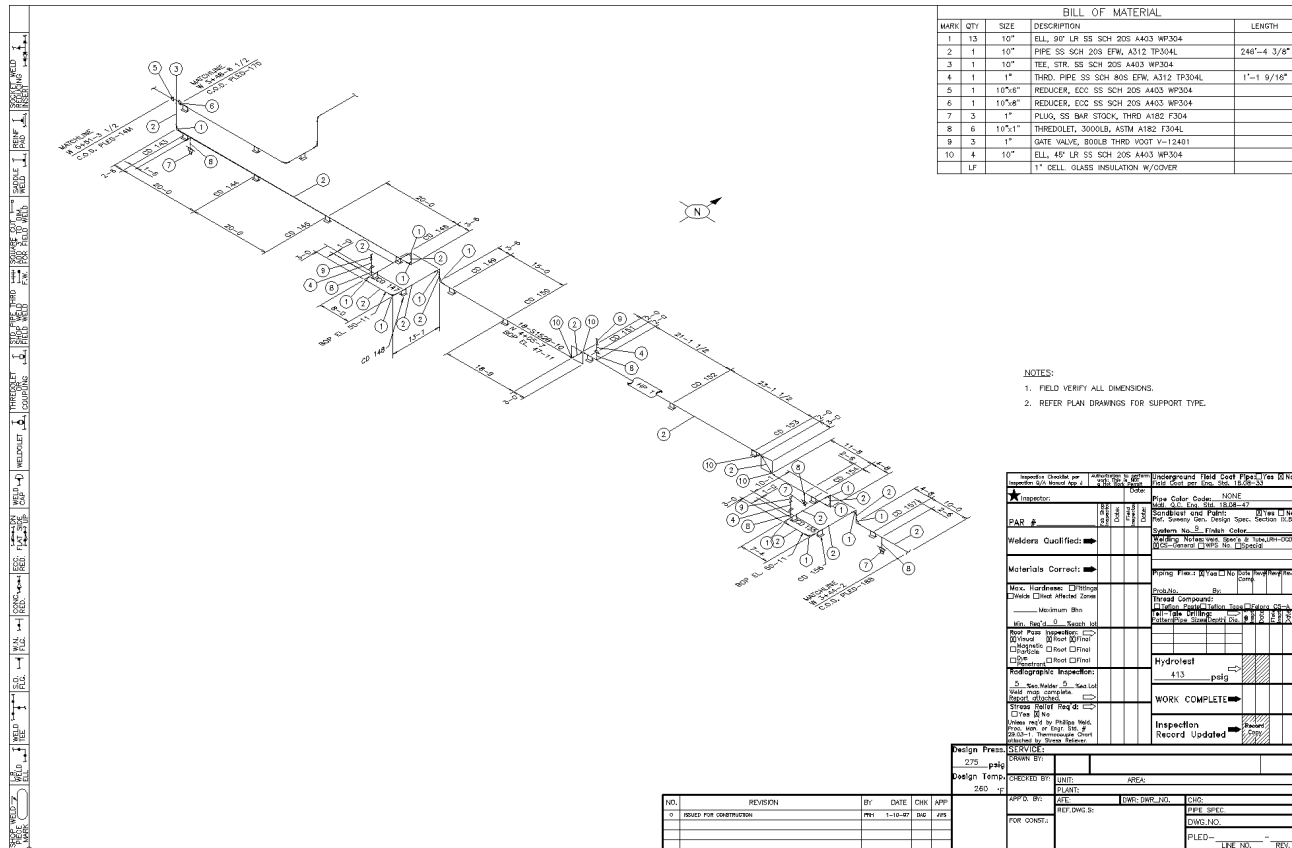
In May 1996 at the start of the project a team of eight engineers was dispatched to the site. Over the next two weeks they had to identify several alternative points for each tie-in to the existing piping systems and route the 20 different interconnecting pipe systems through the existing plant rack system.

The new pipe work had to be connected to the existing plant with over 30 new tie-ins and an additional 50 tie-ins to the newly installed units.

The installation of the tie-ins had to be undertaken during regular shutdowns. This increased the pressure on making sure that an already tight schedule was closely followed and maintained.

An additional requirement of the tie-in work was to make sure that any items that were added had no adverse impact





on existing pipe work. They took the tie-in information gained on site and included it in the **CAESAR II** stress analysis model. They then determined that the new pipe system, including the tie-in to existing pipe, was to code and that they indeed did not compromise the integrity of the existing pipe work.

The information was transferred back to the Head Office where the analyzed information was transferred in the form of a 3D model from **CAESAR II** to **CADWorx/PIPE**.

Another problem that was eloquently solved was that each of the engineers was responsible for a number of piping systems. This meant that the design was divided into systems and not areas. Therefore for each line an X-Ref was created to the new existing and piping, steelwork and electrical systems on the project. This ensured that no system was designed in a vacuum.

CADWorx/PIPE enabled Tippett and Gee to work fully in 3D to modify and reach the final routing. Even though they chose to work in 3D the client deliverables were 2D drawings. One aspect of **CADWorx/PIPE** that made this easy was that they were able to just window around any piping item and it would be instantly converted to 2D.

The design phase of the project took four months from May 1996 to Aug 1996. Throughout this period Tippett & Gee used the following packages to produce their clients deliverables.

CAESAR II
 – Piping stress analysis

CADWorx/PIPE
 – For 405 mechanical and piping drawings including; layouts of new pipe work, layouts, tie-in drawings, fabrication isometrics and bills of material.

In addition to these piping deliverables were a total of 126 civil, steel framing and fabrication drawings, structural analysis plus electrical and instrumentation drawings.

The designed items were to be installed during the regular shutdown periods between December 1996 and July 1997. Rework during that period was at a very low level, less than 0.5% for the project!

The project was completed below budget and ahead of schedule.

PC Hardware & Software for the Engineering User (Part 24)

(by: Richard Ay)

This installment will focus on keeping your system up to date, since most competent software vendors provide maintenance releases of their products. What are the things you need to know about updating your system, where do you go to get the updates, and how often are they available?

The first thing to know about your system is that the software installed is not static. Application software is updated, drivers are updated, and operating system components are updated. These updates may encompass bug fixes, enhanced capabilities, or address usability issues raised by users. One of the often addressed issues in maintenance releases is incompatibility – the installation of Product B corrupts or disables a certain feature of Product A. This problem is especially prevalent now that application products routinely update system DLL components.

In maintaining your system, the foremost issue is to insure that you have a backup before making any changes or updates. This is especially true of operating system components. The update may not perform as stated, the update file could be corrupt, or a new conflict may be encountered. A reliable backup is a must at all times.

How do you know when updates are available? Usually you have to check the vendors' WEB site. Occasionally, for more well known software packages, you may see a notice or article discussing an update in the trade press. You will rarely get notified directly from the vendor. A few of the more prominent WEB sites to watch are listed in the table below.

Vendor	WEB Site Address	Downloads
Cannon	www.ccsi.cannon.com	Printer drivers
COADE	www.coade.com	Piping, Pressure Vessel, Drafting, & Tank Software
Compaq	www.compaq.com	System drivers & BIOS updates
Dell	www.dell.com	System drivers & BIOS updates
Gateway	www.gateway.com	System drivers & BIOS updates

Vendor	WEB Site Address	Downloads
Hewlett Packard	www.hp.com	Printer drivers
Microsoft	www.microsoft.com	Operating system updates
Netscape	home.netscape.com	WEB Browser update
Novell	www.novell.com	Network updates

Once you locate a WEB site which is of importance to you, you should bookmark the address for future access. Each such site should be checked at least once a month to see what new items have been posted. If the site contains a "news" file, check this out also. You will be surprised to see the available information and software updates are available from vendor WEB sites. WEB distribution of news and updates is the most cost effective and uniform way to reach users. If you don't have WEB access, you are on the road to being obsolete. If you have a major vendor who is not providing maintenance releases of their products, you should question this policy – you are probably running out-of-date software.

How do you acquire these maintenance releases? The best way is from the vendors' WEB site. When an update is available, there will be some sort of notice on the WEB site. Usually there is a link, in this notice, to the download area of the site. It is usually just a matter of clicking the link to start the download process. The file acquired is either the installation program, or a self-extracting archive with instructions for installing the update. (Remember to back up your system before installing updates. You may also want to setup some sort of procedure to check files acquired electronically for viruses.)

What are some of the current, more important updates to be concerned with? The list below details what you may have missed.

Windows 95: In the Spring of 1996, Microsoft released Service Pack #1 for Windows 95. This maintenance release corrected a number of problems with the initial version of Windows 95. In the Summer of 1997, Microsoft made available to OEMs (Original Equipment Manufacturers) Service Pack #2. This maintenance release corrected additional problems with Windows 95. Unfortunately, this update can not be acquired unless you purchase a new computer. However, components of this service pack are available from Microsofts' WEB site.

Are these service packs important? One system level DLL that has been updated is COMCTL32.DLL. This file is used by Windows software implementing "common controls". The original version would cause such software to abort – an example of this is the new Windows version of **CAESAR II**, Version 4.00. The proper version of this DLL is dated August 1996 (or later) and is at least 379 Kbytes in size.

Windows NT 4.00: The current version of NT 4.00 is Service Pack #3. One problem that exists with N4.00 Service Pack 3 is that there is a bug in the file WIN32K.SYS, which will cause the GDI to lock up the Java engine for both Explorer and Communicator. There is a fix available for this. Download "admnfixi.exe", from "www.sousystems.com/faq/commonly/java_remedy". A temporary workaround for this problem is to drop to 16-bit colors, or reduce the color depth of the system.

Office 97: In the fall of 1997, Microsoft released Service Pack #1 for Office 97. Shortly after this, an update to Service Pack #1 was released. Currently purchased packages should have "SR1" on the box, indicating that it includes the Service Pack #1 updates.

Communicator 4.00: Netscape has released several updates to its WEB browser (previously known as Netscape Navigator). The current version is 4.04. This browser also had problems loading WEB sites incorporating JAVA applets. The fix for this is "signedapplets.zip", and can be obtained from "www.sousystems.com/faq/commonly/java_remedy".

Internet Explorer 4.00: The new WEB browser from Microsoft also has a few problems loading WEB sites incorporating JAVA applets when run under Windows NT. The fix for this problem is discussed under Windows NT above.

These are just a few examples of the updates to system level software that are available directly from the Vendors' WEB site. You should make it a habit to check sites important to your productivity.

CAESAR II Notices

Listed below are those errors & omissions in the **CAESAR II** program that have been identified since the last newsletter.

- 1) **Material Data Base Editor:** An error was found in the Material Data Base Editor which sometimes prevented the value of Poisson's ratio from being changed. This error was corrected in Patch C to Version 3.24, and posted to the BBS and WEB sites.

An error was discovered in the interpolation code for the Modulus of Elasticity, *when the ambient temperature had been changed*. This error was corrected in Patch C to Version 3.24, and posted to the BBS and WEB sites.

- 2) **Analysis & Load Case Setup:** An error was found in this module which caused incorrect handling of wind data *when bringing in jobs from pre-3.24 versions when using metric units*. This error was corrected in Patch D to Version 3.24, and posted to the BBS and WEB sites.

- 3) **Input PreProcessor:** A typo-graphical error caused the label "FZ" to appear where "FY" should be on the Force input auxiliary screen, for the second node. This error was corrected in Patch C to Version 3.24, and posted to the BBS and WEB sites.

Corrected a problem where the "LIST" screen did not display allowable stress data if the material was acquired from the data base. This error was corrected in Patch C to Version 3.24, and posted to the BBS and WEB sites.

Corrected a problem where "G" loads were shown on the "LIST" screen with units of "force/length" for vectors 2 and 3. This error was corrected in Patch C to Version 3.24, and posted to the BBS and WEB sites.

Corrected several inconsistencies with the display of the allowable stresses on the screen and in the "LIST" options. This error was corrected in Patch D to Version 3.24, and posted to the BBS and WEB sites.

- 4) **Equipment Module:** An error was found in the "printed report" for API-610 8th Edition. The equation in F.1.2.3 for MYCA was reported as MZCA (which is correct for the 7th Edition). This error was corrected in Patch D to Version 3.24, and posted to the BBS and WEB sites.

- 5) Structural PreProcessor: An error was discovered in the initialization of the "element orientation" value which affected multiple structural file combinations. If the ANGLE or ORIENT commands were used, and not reset to zero (by generating at least one element), subsequent files included into the same job assumed the last orientation angle. This error was corrected in Patch E to Version 3.24, and posted to the BBS and WEB sites.
- 6) WRC-107 Module: An error was discovered in the application of the ASME Section VIII Division 2 stress indicies, the longitudinal and circumferential directions were reversed in the application of these indicies. This error was corrected in Patch E to Version 3.24, and posted to the BBS and WEB sites.
- 7) UK.BIN File: An error was discovered in the UK structural steel data base. The depth of the UB686X254X140 shape was incorrectly specified. This error was corrected in Patch E to Version 3.24, and posted to the BBS and WEB sites.
- 2) Vessel Calculation Module: For multi-chambered vessels, the program was using too high of a MAWP for the nozzle design. Typically in this case the nozzle analysis would not run because the computed shell thickness was inadequate.
- 3) Component Processor: While running tubesheets in the component processor, the program would display an error message that the TEMA number was not valid. Also, in some cases the material database could not be accessed.
- 4) Input Processor: For Division 2 custom flange design, the stress values from the Div. 2 tables were being used instead of the stress values from the Division 1 tables.
- 5) Input Processor: When the design temperature was too high and the Code was Division 2, the input processor would abort.
- 6) Vessel Calculation Module: For BS-5500 the program would generate a warning about the material density being out of range when it was not.
- 7) ASMETubeSheet Module: Same error as noted in the CodeCalc Notices Section.

TANK Notices

Listed below are those errors & omissions in the **TANK** program that have been identified since the last newsletter.

- 1) Structural Steel Data Bases: Several problems were found in the overseas structural data bases added to Version 1.51. These problems were corrected in Build 110197 and posted to the BBS and WEB sites.

PVElite Notices

Listed below are those errors & omissions in the **PVElite** program that have been identified since the last newsletter. These patches are available for download from our BBS and WEB sites.

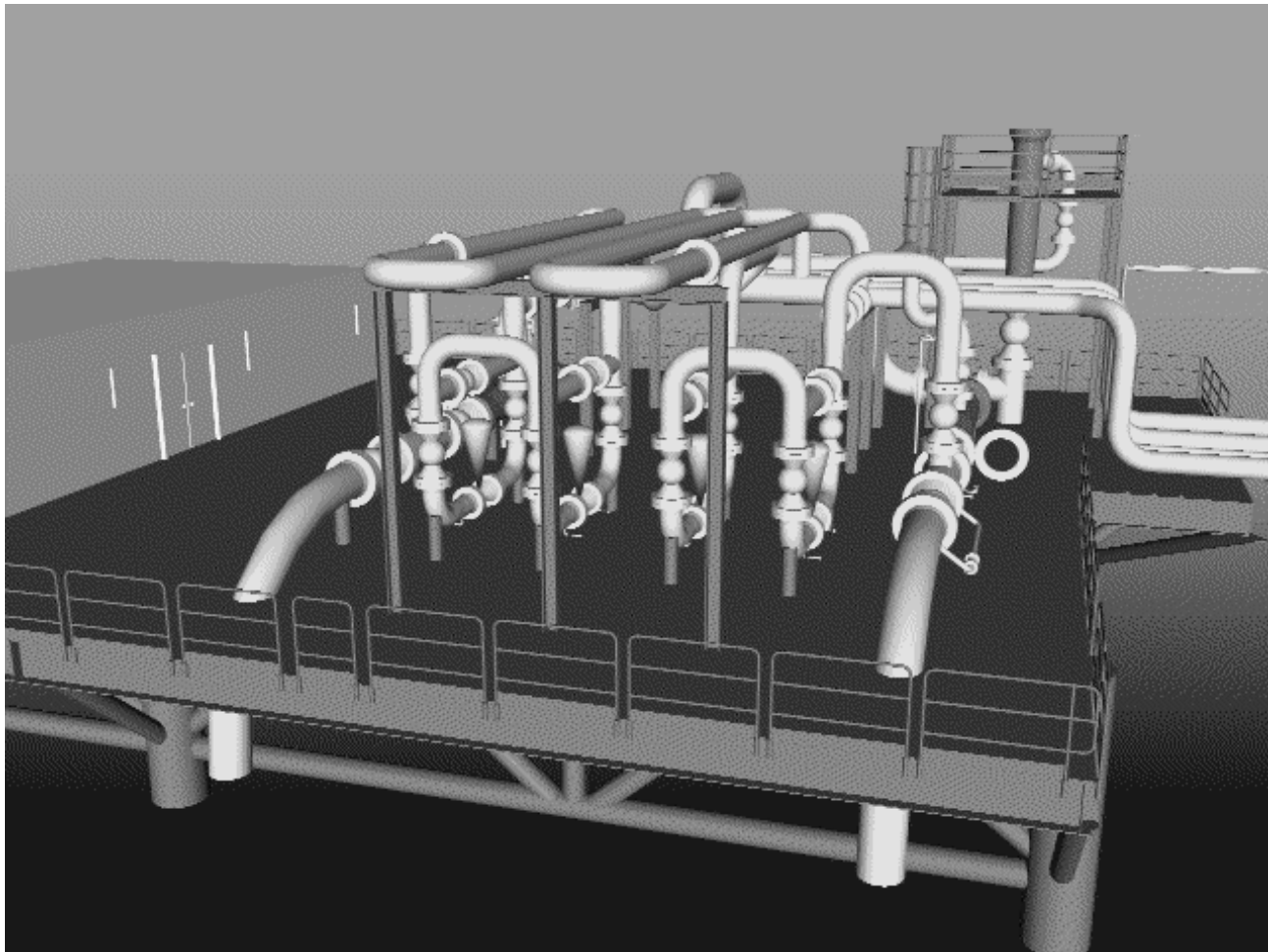
- 1) Vessel Calculation Module: In some cases the values for the vertical reinforcement limit were in error. Also there were some unit conversion errors found. When the thickness limit cut through the bevel transition, the area in the bevel was not computed correctly.

CODECALC Notices

Listed below are those errors & omissions in the **CODECALC** program that have been identified since the last newsletter. These corrections are available for download from our BBS and WEB sites.

- 1) NOZZLE: This is the program for Nozzle calculations. For small nozzles, with external pressure, in some cases the iterative result shows a false "Nozzle fails" message when it may not have failed.
- 2) ASMETUBE: This is the program for Tubesheet design per ASME VIII Div. 1, Appendix AA. Fixed a calculation for the required thickness for the tubesheet flanged portion (per TEMA RCB7.1341).
- 3) NOZZLE: This is the program for Nozzle calculations. When analyzing flat heads, if the dimension basis was ID, in certain cases the corrosion allowance was not properly considered in the computation of the head diameter.

- 4) WRC-107: This is the program for WRC-107 calculations. The pressure stress intensification factors were not properly incorporated in one case.
- 5) NOZZLE: This is the program for Nozzle calculations. For App 1-7 calculation: even if the new and cold case governs, the calculation shall still be made for the operating case.



Project Created with CADWorx/Pipe — Drawn by F. Salehi

COADE Thanks

Everyone at COADE would like to thank all of our customers and dealers for making possible our best sales year ever. Sales figures this year have far exceeded those of last year, with a record setting month in May, followed by another in November. November 1997 sales were double November 1996 sales.

We appreciate the confidence which our customers have placed in us, and the efforts of our dealers in selecting COADE as their software vendor for piping and pressure vessel applications. We look forward to continuing to provide the best software and solutions to the engineering community in the coming years.

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