关于热态弹性模量和冷态弹性模量的使用

CAESARII 软件在膨胀应力计算时使用冷态弹性模量，在计算 OPE 工况的时候软件缺省使用冷态弹性模量

关于冷态弹性模量的使用早在 2000 年江苏电力院和我们探讨 CAESARII 系列问题的时候就谈及过　江苏电力院提到的问题 6

COADE 公司的总裁 Tom Van Lan　曾经给过回答和承诺

回答是　如果您使用 4.5 版前的版本，您要用热态弹性模量计算推力和弯矩，另存一个文件，改变弹性模量的数值，仅仅利用热态弹性模量 OPE 工况计算推力和弯矩，不做其他用途

承诺在新版软件中添加该选项　CAESARII 5.0　已经添加该功能

热态弹性模量使用对端口推力和弯矩的具体影响

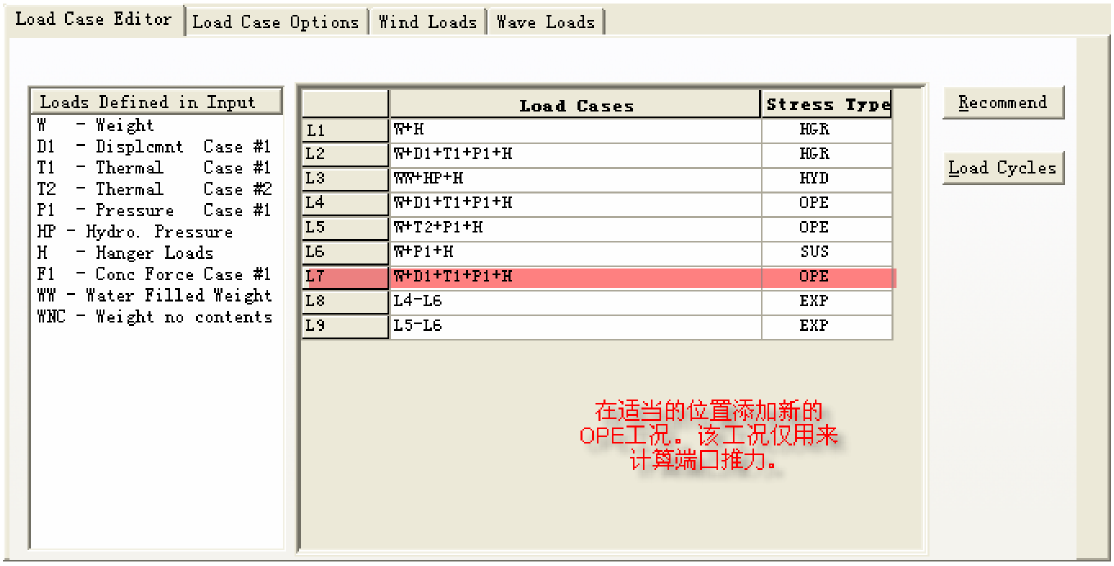
B31.1 并没有明确必须使用热态弹性模量来计算管口推力，目前，市面上的商业化管道应力软件普遍采用冷态弹性模量来计算应力和反作用力　从安全和保守角度来讲，计算结果更为保守，CII 计算出的端口推力和弯矩偏大，您必须保证您的管道柔性更好，方可满足管口受力要求

但针对 600MW/1000MW 超临界机组，管道尺寸大，温度压力高，管道材料价格昂贵，采用冷态弹性模量保守设计，带来太大的材料费用，同样走向和支架配置高温管道按热态弹性模量计算的推力和弯矩已经能够保证管道和汽机管口受力的条件要求　这正是部分电力设计单位工程师提出采用热态弹性模量计算推力的关键原因

如果您希望按此方法设计您的管线，您可以采用如下方法

1　正常建立您的分析模型

2　软件自动推荐工况，人工添加新的 OPE 工况



3 在工况选择栏中选择热态弹性模量

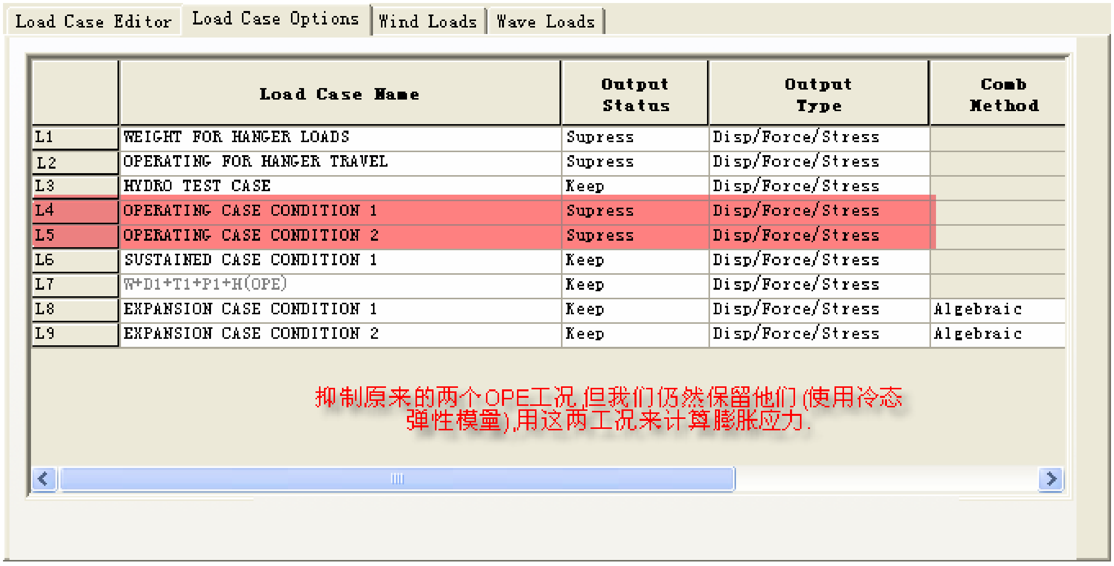
Load Case Editor | Load Case Options | Wind Loads | Wave Loads

	Load Case Name	Snubbers Active?	Hanger Stiffness	Elastic Modulus	Fri Mult
L1	WEIGHT FOR HANGER LOADS		Rigid	EC	
L2	OPERATING FOR HANGER TRAVEL		As Designed	EH1	
L3	HYDRO TEST CASE		Rigid	EC	
L4	OPERATING CASE CONDITION 1		As Designed	EC	
L5	OPERATING CASE CONDITION 2		As Designed	EC	
L6	SUSTAINED CASE CONDITION 1		As Designed	EC	
L7	W+D1+T1+P1+H(OPE)		As Designed	EH1	
L8	EXPANSION CASE CONDITION 1				
L9	EXPANSION CASE CONDITION 2				

从下面 3500 节点计算出来的推力可以看到，采用热态弹性模量的工况 7 的推力和弯矩比采用冷态弹性模量的工况减小了许多

NODE	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
3500		Displ. Reaction					
	4 (OPE)	-118405	-24415	-21942	-147196	260939	-243695
	5 (OPE)	-129844	-44920	-397573	538895	567865	-211768
	6 (SUS)	1875	-15494	-[illegible]509	-103802	-19213	-14432
	7 (OPE)	-90042	-18831	-25162	-121445	196681	-194061
	MAX	129844/ 5	44920/ 5	397573/ 5	538895/ 5	567865/ 5	243695/ 4

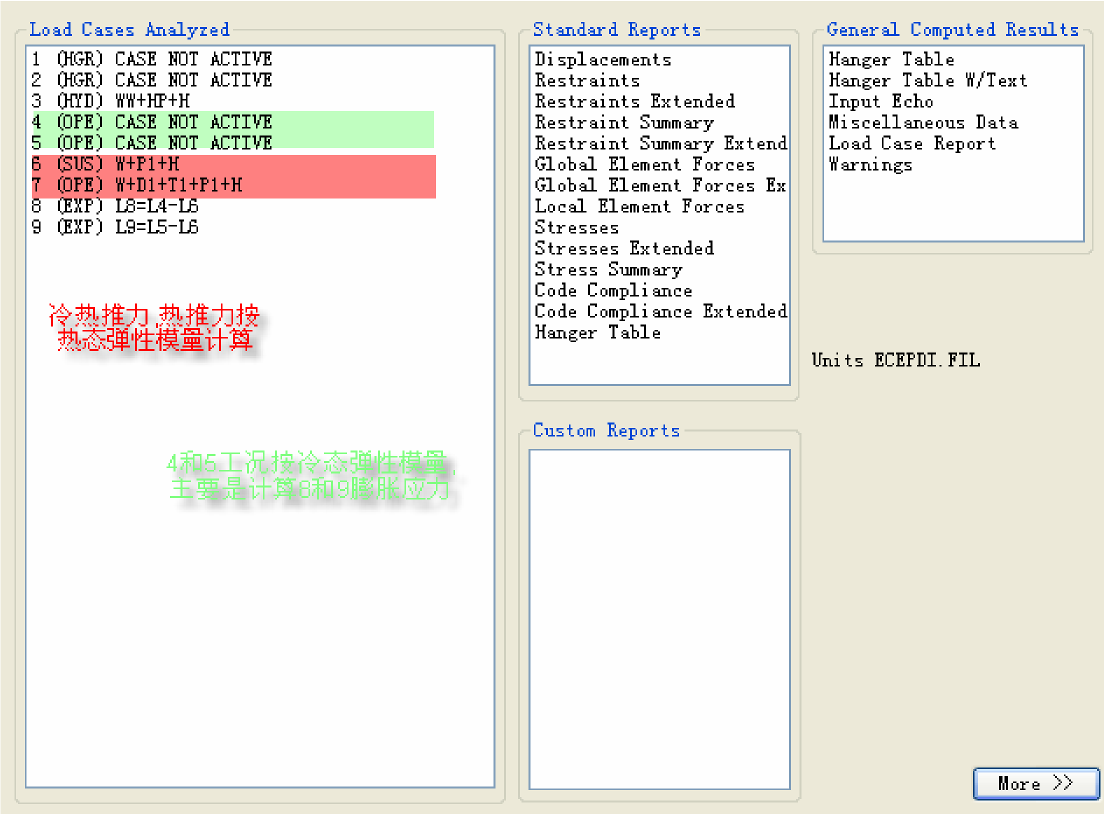
4 如果您决定采用该方法来设计您的高温管线系统，您不希望看到采用冷态弹性模量计算出来的热态推力，您可以在工况选择界面，将不希望看到计算结果的工况屏蔽掉



Load Case Editor | Load Case Options | Wind Loads | Wave Loads

	Load Case Name	Output Status	Output Type	Comb Method
L1	WEIGHT FOR HANGER LOADS	Supress	Disp/Force/Stress	
L2	OPERATING FOR HANGER TRAVEL	Supress	Disp/Force/Stress	
L3	HYDRO TEST CASE	Keep	Disp/Force/Stress	
L4	OPERATING CASE CONDITION 1	Supress	Disp/Force/Stress	
L5	OPERATING CASE CONDITION 2	Supress	Disp/Force/Stress	
L6	SUSTAINED CASE CONDITION 1	Keep	Disp/Force/Stress	
L7	W+D1+T1+P1+H(OPE)	Keep	Disp/Force/Stress	
L8	EXPANSION CASE CONDITION 1	Keep	Disp/Force/Stress	Algebraic
L9	EXPANSION CASE CONDITION 2	Keep	Disp/Force/Stress	Algebraic

5.这样您的最终计算结果中，您的全部报告就都符合电力使用热态弹性模量来计算的要求了



对您以往设计的影响和后果

如果您采用 5.0 以前的 CAESARII 软件版本，使用冷态弹性模量，计算出来的设备端口点的推力和弯矩偏大，计算结果偏保守，可能让您的管道绕一些，提高管道柔性，但增加些材料和施工费用　从运行角度来讲，更偏安全

美国 COADE 公司有关专家在热态弹性模量使用方面的具体回应是

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收件人地址　aecsoft@aecsoft.com.cn
抄送人名字　Richard Ay; Bill Evans; David Diehl
抄送人地址　ray@coade.com; bevans@coade.com; ddiehl@coade.com

Richard:

I am sorry that China Power is unhappy with our software.　We have never tried to give the impression that we implement 119.10.1.　I'm not sure how they might have gotten this idea that we would have done this automatically, since prior to version 5.00 there was no way to enter more than one elastic modulus into CAESAR II -- so where would we have gotten the ratio Eh/Ec from?). We thought we were adding a nice capability to the software and did not expect that it would cause (or highlight) an issue.

As I believe Rich mentioned to you, the requirements of 119.10.1 are not very reliable for real life systems. These requirements assume homogenous operating conditions (materials, temperatures, and cold spring) and totally linear boundary conditions throughout the entire system.

First, a brief summary of the requirements:

1. From an expansion stress point of view, the codes dictate that the cold modulus of elasticity must be used in order to ensure a conservative stress analysis result.

2. Seemingly not being concerned with conservatism with regards to the restraint and equipment loads, the code wishes to eliminate the conservatism through restoration of the most likely lower hot modulus of elasticity.

3. Expansion loads are based upon some factor (depending upon inherent system configuration flexibility) times A * E * alpha (where A = cross-sectional area, E = modulus used, and alpha = coefficient of thermal expansion between ambient and operating temperatures).

4. So if the analysis used the cold modulus (i.e., Rc = k*A*Ec*alpha) then multiplying by the ratio Eh/Ec gives Rh = k*A*Eh*alpha.

5. The second requirement (for cold reactions) is an attempt to capture the effect of shakedown/self-springing; I have no idea how accurate this really is.

Looking at item 4 above, it is apparent that the user must use care in applying this Eh/Ec factor to restraint loads -- they just cannot be applied to the operating loads! Why? Because weight loads are developed independent of the modulus of elasticity (as long as it is homogenous throughout) but rather via the laws of statics. So...if the user multiplied all operating loads times Eh/Ec, then the net total restraint loads would be less than the weight of the pipe!! So the actual process is:

1. Calculate weight reactions using any modulus of elasticity (Ec is easiest, since it is also used for stress results).

2. Calculate expansion reactions using Ec, since we need that case for stress results.

3. Multiply #2 by Eh/Ec and add those results to #1 to get the operating reactions.

Of course this all goes out of the window once we have non-homogenous operating conditions or materials and non-linear boundary conditions. At this point, the only way to approximate the "right" reactions in the operating case is to run an operating load case using the hot modulus.

This will correctly calculate and distribute both the weight and expansion reactions.

However, I know of no way of simulating the cold reactions, mentioned in 5 above, other than by hand. I have never seen a program that does this, and I am not aware of anybody who has ever done this calculation.

All that said, now to answer your specific questions:

1. Which of our customers use CAESAR II in the power industry? We don't really know, be cause we don't keep track of what our customers do with the product after buying it. By searching through the CAESAR II user list, I can guess that some of the following customers may be among those who use CAESAR II for power applications (and I am sure that there are many more):

ABB LUMMUS GLOBAL
BECHTEL, INC.
HALLIBURTON ENERGY SERVICES/KELLOGG BROWN & ROOT
INELECTRA S.A.
SHAW GROUP / STONE & WEBSTER
TOYO ENGINEERING CORP.
UHDE GMBH
WASHINGTON GROUP
ABB ALSTOM POWER
ADAM POWER & ASSCOC. NORFOLK, UK
ADENA UTILITIES ENGINEERING INC. CINCINATTI, OH
AMEC
AMERICAN ELECTRIC POWER
ARIZONA PUBLIC SERVICE PHOENIX, AZ
AUSATOM PTY LTD WEST MELBOURNE, AUSTRALIA
AUSTRALIAN NUCLEAR SCIENCE & TECH. LUCAS HEIGHT, AUSTRALIA
BLACK & VEATCH
BNFL ENGINEERING LTD.
BRUCE POWER LP TIVERTON, ON
BURNS & ROE ORADELL, NJ
CALENERGY OPERATING COMPANY CALIPATRIA, CA
CALPINE CORPORATION MAINEVILLE, OH
CANADIAN POWER ENGINEERING NEW WESTMINSTER, BC
COGENERATION PUBLIC CO. LTD. BANGKOK, THAILAND
DAIRYLAND POWER COOPERATIVE LA CROSSE, WI
DEPARTMENT OF ATOMIC ENERGY (BARC) INDIA
DLF POWER INDIA
ELECTRICITY GENERATING AUTH. OF THAILAND THAILAND
ELECTRICITY TRUST OF SOUTH AUSTRALI WEST MELBOURNE, AUSTRALIA
ELECTROBRAS THERMONUCLEAR RIO DE JANEIRO, BRAZIL

ELECTROWATT ENGINEERING U.A.E.
ELECTROWATT/GRANHERNE JOINT VENTURE RUWI, OMAN
ELEKTROWATT ING. GMBH MANNHEIM, GERMANY
ELF-ATOCHEM FRANCE
ENELPOWER ITALY
ENGEN SOUTH AFRICA
FRONEK POWER SYSTEMS LLC
FUJIAN ELECTRICAL POWER CHINA
GEA POWER COOLING SYSTEMS SAN DIEGO, CA
GENERAL ELECTRIC COMPANY
GENERAL PHYSICS CORPORATION
HEBEI ELECTRIC POWER DESIGN INSTITUTE BEIJING, CHINA
HYDRO QUEBEC MONTREAL, QC
>INDUSTRIAL POWER CORPORATION WOODINVILLE, WA
INSTITUTE OF NUCLEAR ENERGY RESEARCH TAIPEI, TAIWAN R.O.C.
INSTITUTE OF POWER STUDIES & DESIGN BUCHAREST, ROMANIA
INSTITUTO BRASILEIRO DA QUALIDADE NUCLEAR BRAZIL
KANSAS CITY POWER & LIGHT KANSAS CITY, MO
KENTUCKY UTILITIES CO. BURGIN, KY
KOREA POWER ENGINEERING SEOUL, KOREA
LAING UTILITIES LTD. U.K.
MINNESOTA POWER DULUTH, MN
NATIONAL POWER PLANT ENGINEERING UK
NEW BRUNSWICK POWER CORP. FREDERICTON, NB
NEW ENGLAND POWER CO. SOMERSET, MASS
NEW YORK STATE ELECTRIC & GAS CORP. BINGHAMTON, NY
NEWFOUNDLAND & LABRADOR HYDRO ST. JOHNS, NF
NOVA SCOTIA POWER PORT HAWKSBURY, NS
NUCLENOR SPAIN
PB POWER, INC. BOSTON, MA
PHIBRO USA, INC. HOUSTON, TX
POWER ENGINEERS HAILEY, ID
POWER ENGINEERING, INC. NEW ORLEANS, LA
POWER PIPING COMPANY PITTSBURGH, PA
PSE&G NEWARK, NJ
RELIANT ENERGY HOUSTON, TX
RENUSAGAR POWER NEW DELHI, INDIA
ROSS POWER SYSTEMS ST. LOUIS, MO
SALT RIVER PROJECT TEMPE, AZ
SASKATCHEWAN POWER REGINA, SASKATCHEW
SAUDI CONSOLIDATED ELECTRIC CO. SAUDI ARABIA
SCOTTISH NUCLEAR-AYRSHIRE UK
SCOTTISH POWER TECHNOLOGY UK
SIEMENS POWER CORP

SOUTHERN CALIFORNIA EDISON PARAMOUNT, CA
SOUTHWEST ELECTRICAL POWER DESIGN BEIJING, CHINA
THERMAL ENERGY SYSTEMS SOUTH AFRICA
THERMOELECTROPRO RUSSIA
THERMODYN-FRAMATON FRANCE
UTILITY ENGINEERING COPORATION
WEST VALLEY NUCLEAR SERVICES CO. INC. WEST VALLEY, NY
WESTINGHOUSE
WISCONSIN PUBLIC SERVICE CORP. KEWAUNEE, WI

2. How is the Eh application used ion the US and Europe? We do not know what our customers do. We did send out inquiries to two of our users in the power industry. One of them replied as follows:

"We did not use Eh to make our loads lower....

Using Eh by itself is non-conservative... because before the system softens at the operating temp it will be cold... and Eh probably will not decrease noticeably until I am guessing 75% of the thermal displacement strain is dialed in before E drops much....

So I guess I would plot Temp vs Exp coefficient vs E.... and try to get a feel as to what the maximum load would be based on a value for (E) would really be, or use the ratio method in 119.10....this of course is rather dicey, murky, and gray."

The other one told us that he never performed the 119.10 reduction on the nozzle loads, but always tried to fit the CAESAR II generated (i.e., using Ec) loads below the allowables.

Additionally I have checked all of my emails (going back at least 8 years) and have found only two user requests (written to me, there may be others to other people here at COADE) asking how to implement this portion of the B31.1 code -- one from China and one from Europe. At the time I stated that CAESAR II could not do this, so they would have to do a second analysis using the hot modulus of elasticity. This might indicate a lack of interest in making this adjustment among our users, or a lack of expectation that CAESAR II would be able do it.

All this is not to say that a stress analyst SHOULD NOT apply the adjustment, I think it just indicates that may not be very widespread.

3. Must Eh be used for OPE restraint force calculations for B31.1? The code says that the adjustment described in 119.10 "shall" be used, which usually means "must", but this calculation would normally give a less-conservative result than not applying it, and for reasons I state above, this adjustment shouldn't really be applied as described anyway. So I would think that in reality it should be optional at best.

4. Why has COADE used Ec for such a long time? In reality our analyses have always used a

single modulus of elasticity, per element, for all load cases. We have always defaulted to Ec -- because CAESAR II is primarily a stress analysis product, and Ec must be used for expansion stress calculation -- but the user could just as easily use Eh instead of Ec (as long as the same E is used for all load cases).

The reason we have stuck with this for so long is technological -- the original solver was written to work with a single stiffness matrix, which thus dictated one single modulus of elasticity. Going to a multi-modulus approach meant a total re-write of the solver, which was a lot of work (and dangerous) and which we resisted as long as there wasn't an overwhelming demand for it. We felt that sufficient demand was generated due to a) B31.3 recently suggesting that users might wish to run the operating case using the hot modulus in certain circumstances and b) the issuance of the EN-13480 code which requires use of the hot modulus with the operating cases. Following these developments we bit the bullet and rewrote the solver to accommodate a different modulus for each load case.

I did a check on various pipe stress programs popular in the power industry (admittedly the manuals that I have a from the old days when I worked in the industry). PIPESTRESS 2010 seemed to allow different modulus of elasticity for each load case, but ADLPipe and PipeSD did not (and did not support the Eh/Ec adjustment). Triflex, the most popular pipestress program in the US at the time when CAESAR II was created didn't allow either multiple moduli or Eh/Ec adjustment either. So I would say that CAESAR II was probably pretty much in compliance with the state of most of the industry at that time.

Please note that not even PIPESTRESS 2010 performed the correct calculation of the cold reactions.

5. The Load Case template is available -- what is not available is an easy to use Template Editor that the customer can use. Therefore we don't recommend that customers try to edit this template (even though they could). If worse comes to worse, I suppose that I could make them a special template that would automatically build these load cases.

Regards,

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-----Original Message-----
From: Richard Wang [mailto:aecsoft@aecsoft.com.cn]
Sent: Sunday, August 13, 2006 9:31 PM
To: Tom Van Laan
Cc: Richard Ay; Bill Evans
Subject: on Eh vs Ec

Dear Tom

On Eh vs Ec, right now, China Power is founding the great difference over the restraint force/movement at the steam turbine inlet & outlet.

even CII5.0 support adding a new OPE and get it as Eh, the user is still thinking that while they are selecting B31.1, this load case should be created there automatically. so their conclusion is that CII not follow B31.1 code totally.

Before 300MW power plant, even using Ec for restraint force, the nozzle load still could be satisfied, but for 1000MW power plant, the pipe

>size is much more bigger, the pipe is very expensive, for expansion loop to increase flexibility is not that possible. so they want to check the real restraint force base on Eh, and they found it's samller a lot and could be satisfied.

Base on this , we need COADE's help and support :

1.COADE offer us the application of CII over Power industries(how many years, how many users)

2.How is the Eh applicaion over OPE in the states or european countries? is it widely applied or only part of the user need this functions.

3.Is Eh must be used for OPE restraint force caculation base on B31.1?

4.why COADE has use Ec for such a long time?

5.For load case template, when this could be released? if this is available, then the user could define China Power template and get all load case setup base on their requirement or not?

Regards

Richard Wang

President

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Http://www.aecsoft.com.cn Email: aecsoft@aecsoft.com.cn

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Author	Topic: on Eh vs Ec in B31.1
richwang Member Member # 330	posted August 14, 2006 07:28 AM Dear Sir As CII5.0 allow user to choose Eh(hot elastic modulus) over load case option. for some China Power users are thinking that Eh should be used always while caculating restraint force over nozzle load rather than Ec(cold elastic modulus). the China Power in-house software GLIFF and 2010 are based upon Eh rather than Ec. As CII's OPE nozzle load is much higher than using Eh for caculation. so the user has to get more expansion loop to increase the flexibility, the the main steam pipeline is very expensive. by the user's experience, their steam turbine nozzles load could be satisfied via Eh caculation. so they insist on using Eh for restraint force caculation. certainly Ec is used for the stress caculation. so I want to get some comments on this, I want to know the opinions of peoples who is working over Power industries engineering. -------------------- Richard Wang Posts: 3 | From: Beijing China | Registered: Aug 2001 | IP: Logged | Report Post
John Breen Member Member # 95	posted August 14, 2006 11:00 AM Hello Richard, Always the first question: What Piping Code is to be applied? Assuming ASME B31 Pressure piping Code, if the purpose of the calculation is to evaluate stresses, the modulus of elasticity of the material at the ambient temperature must be used. This will result in an analysis of a less flexible (than it will actually be at operating temperature) system. So, the loadings on the terminal equipment will greater. It has always been my opinion that if the purpose of the calculation is to evaluate the loadings transferred from the piping to potentially strain sensitive terminal equipment, the modulus of elasticity of the material at the operating temperature should be used. This will result in an analysis of the system that will be closer to its actual flexibility at operating temperature. Regards, John. -------------------- John Breen Posts: 254 | From: Pittsburgh, PA (when I cannot be in Texas) | Registered: Mar 2000 | IP: Logged | Report Post

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探讨到最后，我想大家都明白了　通常情况下，我们可以不考虑热态弹性模量对热态推力和弯矩的影响　但在某些特定情况下，您还是要启用热态弹性模量的

新的电力应规即将推出，如果有必要，能够提供英文版的话，COADE 愿意将其纳入软件，完全符合国内电力的标准规范

最后，衷心感谢广大电力的专家对我们的一贯支持和厚爱　和我们探讨问题，我们和 COADE 公司一直本着“客户至上”的原则来进行我们的工作