REFINED ANALYSIS OF PIPING SYSTEMS ACCORDING TO NUCLEAR STANDARD REGULATIONS

N. BISCONTI, L. LAZZERI, P.P. STRONA

SAIGE, Società di Architettura Industriale per gli Impianti di Generazione di Energia, Genova, Italy

SUMMARY

The problem of analyzing a piping system for a nuclear power station is generally faced by means of the ASME 3 code and its implication and problems have been discussed by others (see papers F 8/1, F 3/2 of the 2nd SMIRT conference). The problem, the authors have tried to resolve is how actually perform all the required analysis and handle the tremendous amount of data which is involved.

A number of programs have been selected to perform particular analyses partly coming from available libreries such as SAP 4 for static and dynamic analysis, partly directly written such as TRATE (for thermic analysis), VASTA,VASTB (to perform the analysis required by ASME 3 for pipings of class A and class B), CFRS (for the calculation of floor response spectra etc.). A large amount of work is still to be done in the area of transferring the data from one program to another, this is automatically done by a group of small programs which combine and reordinate the data (such as the COMBIN and RIORD series).

All the programs are automatically linked and directed by a general program (SCATCA for class A and SCATCB for class B pipings).

The starting point is a list of the fabrication, thermal, geometrical, and seismic data. The geometrical data are plotted (to check for possible errors) and fed to SAP for static and dynamic analysis together with seismic data and thermal data (average temperatures) reelaborated by TRATE 2 code.

The raw date from SAP (weight, thermal, fixed points displacements, seismic, other dynamic) are concerned and reordered and fed to COMBIN 2 program together with the other data from thermal analysis (from TRATE 2). From Combin 2 program all the data are listed; each load set to be considered is provided, for each point, with the necessary data (thermal moments, pressure, average temperatures, thermal gradients), all the data from seismic, weight, and other dynamic anlysis are also provided. All this amount of data is stored on a file and examined by VASTA code (for class A) or by VASTB (for classes B, C) in order to make a decision about the acceptability of the design.

Each subprogram may have an independent output in order to check partial results. Details about each program are provided and an example is given, together with a discussion of some particular problems (thermohydraulic set difinition, fatigue analysis, etc.).

1. Introduction

The problem of analyzing a piping line to nuclear standard regulations has been widely discussed in the open literature (see e.g. reg 1,2). The following problems will be discussed :

a) to analyze the piping under various loading conditions both static (dead weight, thermal movements etc.) and dynamic (sismic, steam hammer etc.)

b) to analyze the piping from the regulatory point of view to show its acceptability and conformance to the applicable rules (generally ASME 3).

c) to handle a very large amount of data and to transfer them from one program to another

d) to compute some data necessary for the analysis from the ones available in the specifications (e.g. to convert data on thermal transitories into transitories on the pipe wall or to compute floor response spectra from data on sismic analysis of applicable buildings floors)

e) to check for possible errors mainly in the description of the geometry

These problems belong to different fields (structural, sismic, thermal, computer programming) and their solution requires a combination of efforts of people with different experience.

2. Input data

2.1 General

The input data may be divided in the following main categories:

a) technological data: they are required by the applicable ASME 3 code in order to compute s.c.f. (stress concentration factors)

b) geometry: a careful numbering of nodes is generally required in order to keep the problem bandwidth as low as possible

c) thermal pressure transitories: they are generally given in the data as transitories of the fluid and required to be converted into transitories on the pipe wall

d) sismic data: they may be given under the form of maximum accelerations for each mode of the building (if a modal analysis with response spectra is used) or of time histories of displacement or accelerations (if a time history analysis is used); in both the cases further elaborations may be required

e) other transitories: they may include forces due to particular accidents (valve blowdown, steam hammer etc.)

2.2 Thermal pressure transitories:

The derivation of transitories in the pipe wall from the ones in the fluid requires the availability of an ad hoc code; the authors have used a one dimension time step integration procedure using an application of Dusinberre method (3).

The ASME 3 sub NB (class 1 piping) requires the computation of the following data (4):

a) average temperature Tm

b) equivalent linear gradient ΔT1

c) equivalent non linear gradient ΔT2

d) average temperatures on each side of a joint (Ta-Tb) such differences may result as a consequence of differences in the thermal properties or thermal transitories

The TRATE 3 code computes the maxima and minima for each of the given data (Tm,ΔT1, ΔT2,Ta - $\frac{Eb}{Ea}$ Tb (Ea Eb modulus of elasticity)and the corrispondent times. A somewhat fast transitory is considered and depicted in fig. 1

2.3 Floor response spectra

The various tecniques used to derive the floor response spectra have been widely discussed (see e.g. ref 5) ; the authors currently use the modified white noise tecnique (in the CFRS code) as described in ref 6.

A typical examples of FRS is shown in fig.2.

The authors wish to stress the point that quite high accelerations (of the order of a few gs) may result in the peak region, while they are much more limited if certain "frequency regions" are precluded; this may require certain particular requisites on the stiffnesses of the hangers, bracings, restraints, etc. Besides this concept may be more or less easily applicable, depending on the eigenfrequenties of the building in which the piping is located (from this point of view low eigenfrequencies in the building may be desirable)

3. Piping structural analysis

The analysis of a piping generally requires the following analysis:

a) static analysis: dead weight, thermal dilatations (RFE), pressure, sustained mechanical loads

b) dynamic analysis: eigen values and eigen frequencies analysis is generally required for sismic analysis; further analyses may be necessary for particular problems (steam hammer, valve blowdown etc.)

A general purpose structural program is required; among the different programs available the authors have selected the SAP 4 (7),

4. ASME 3 Compliance

The compliance of a piping to the rules of ASME 3 sub NB,NC,ND must be generally demonstrated in order to show the acceptability of the piping.

Two programs (VASTA and VASTB) have been written in order to perform the analyses requested by ASME 3 for class 1 and class 2 and 3 pipings.VASTA accepts the following inputs:

a) dead load and other sustained loads.

b) sismic loads (for OBE and SSE)

c) thermo hydraulic sets (for each set pressure, thermal data (ΔT1, ΔT2,Tm,Ta-Tb)and corresponding moments are specified

d) transitories between specified sets, with the indications of number of cycles and classification (normal, upset,emergency,faulted) .

The code computes all the primary stresses and compares the obtained values with the allowable ones; for each thermo hydraulic set all the applicable transitories are considered and the most severe classification (normal,upset,emergency,faulted) is associated and the allowable values are consequently evaluated.

To compute the secondary and the peak stresses only the transitories classified as normal or upset are considered; the others are disregarded. All the applicable sets are coupled (two by two) and the maximum difference in the secondary stresses is computed and compared with the allowable values. A similar procedure is used for the peak stresses: an "equivalent number of cycles" distribution is generated, which associates the maximum possible numbers of cycles to the largest differences in the peak stresses. Possible short comings (e.g. to associate the total number of cycles to the worst possible cycle) are included in order to keep the computation time as low as possible.
A procedure according to ASME 3 is used for the analysis of class 2/3 pipings too
A computation example is given in table 4.1

5. Data handling

The amount of data which must be processed even for a single line analysis is tremendous, so that authomatic procedures are absolutely necessary. Besides it may be desiderable to keep each program as an indipendent unit in order to be able to directly evaluate each output, to minimize the effort in adapting each program, to be able to substitute any unit, if it becomes obsolecte or if a better program becomes available.
A number of programs (RIORD 1 - COMBIN 1 - COMBIN 2 - COMBIN 3) have been consequently written in order to store the information in each output and to reordinade and combine the available information to make them compatible with the following programs.

6. Integrated procedures

Two different integrated procedures have been written: one for the design of class 1 pipings (SCATCA) and one for design of class 2/3 pipings (SCATCB).
Their flow charts are shown in the figs 3,4,5.
Here the single units have been identified and their possible connections have been considered, multiple options are available depending on the size and type of the problem, which is found.

./.

References

1) Watwood Chow "Combined analysis and evaluation of piping systems using the computer" paper F3/1 2SMIRT Conf,1973

2) Landers "Problems occurring in nuclear piping systems analysis and operation" paper F3/2 2SMIRT Conf,1973

3) Mc Adams "Heat transfer" Mc Graw Hill

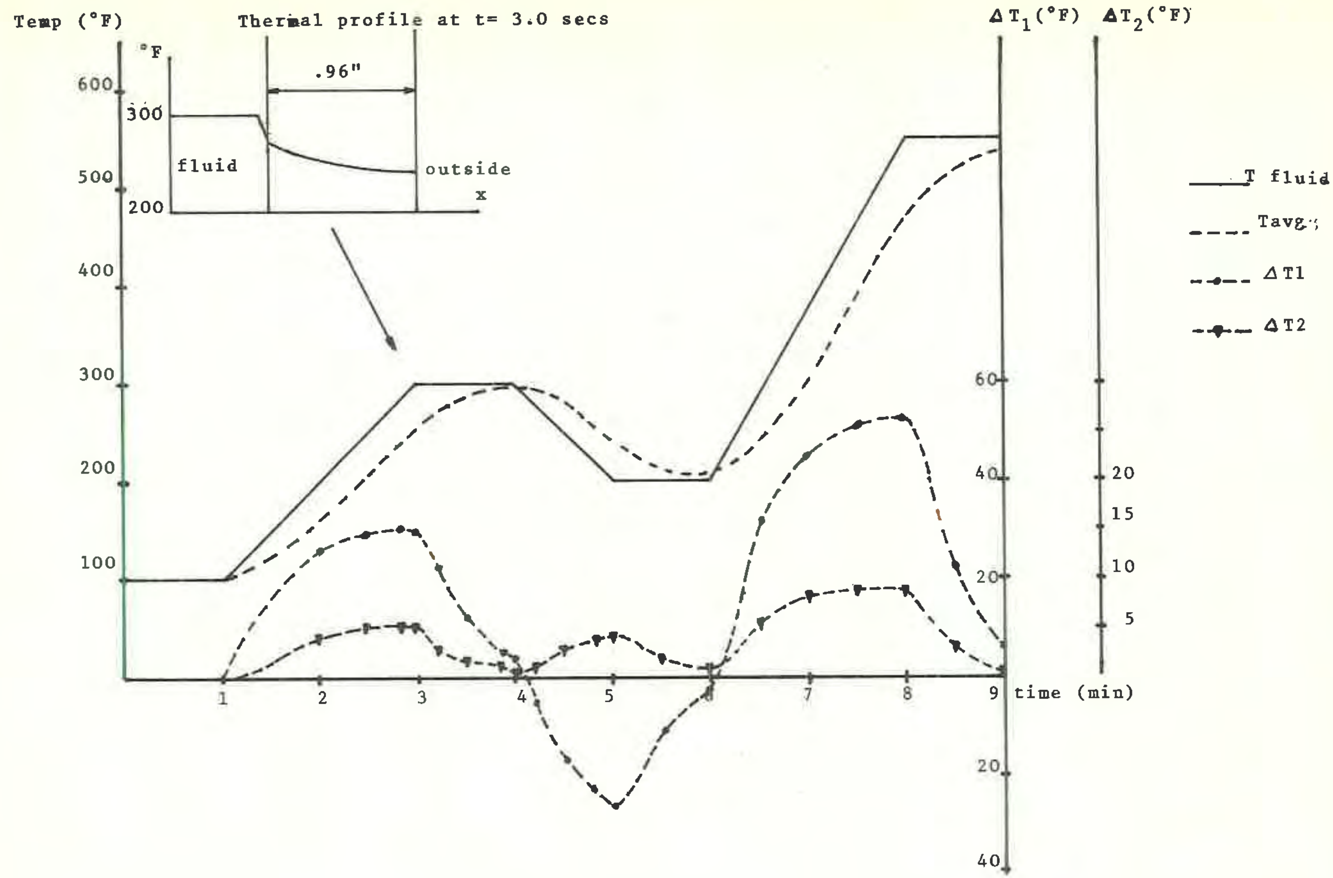
4) ASME 3 Nuclear power components ed 1974

5) Castellani "On design criteria for equipment mounted on massive structure" V WCEE, Rome, June 1973

6) Lazzeri "Floor response spectra by the use of a modified white noise tecnique" paper K 4/2, 2 SMIRT Conf, 1973

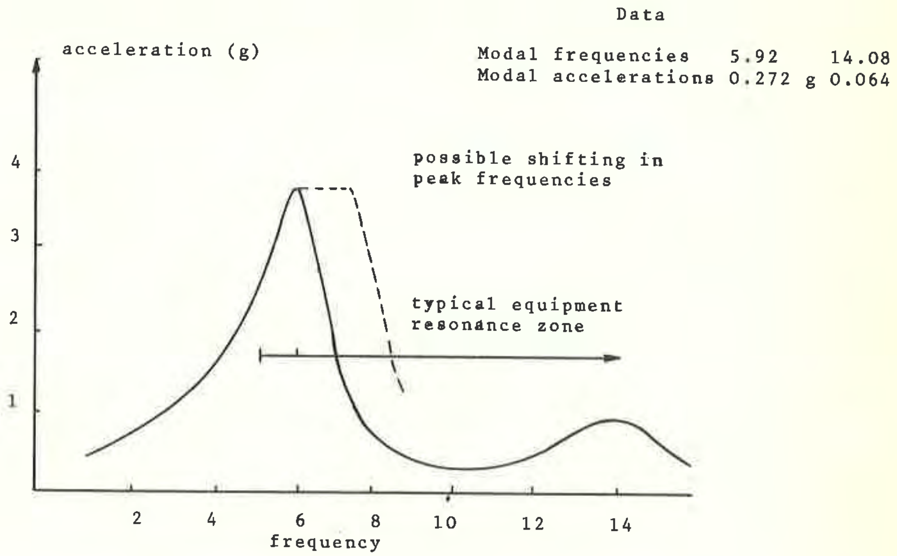
7) Bathe Wilson Peterson "SAP IV a structural analysis program for static and dynamic analysis of linear structural systems" EERC 73/11, 1973.

F3/3

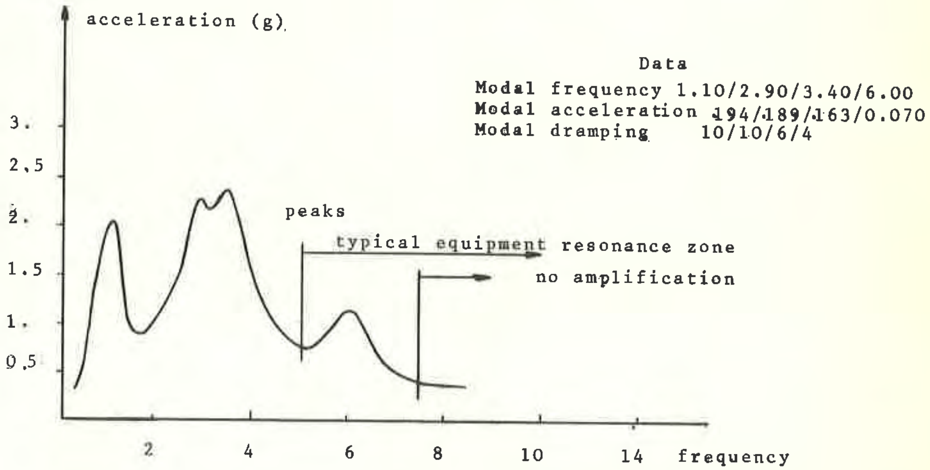


Temp (°F)
Thermal profile at t= 3.0 secs
°F
300
200
fluid
outside
x
.96"
600
500
400
300
200
100
1
2
3
4
5
6
7
8
9
time (min)
ΔT_1(°F)
ΔT_2(°F)
60
40
20
20
40
20
15
10
5
T fluid
Tavg
ΔT1
ΔT2

fig. 1



high frequency response spectrum



low frequency response spectrum

fig. 2

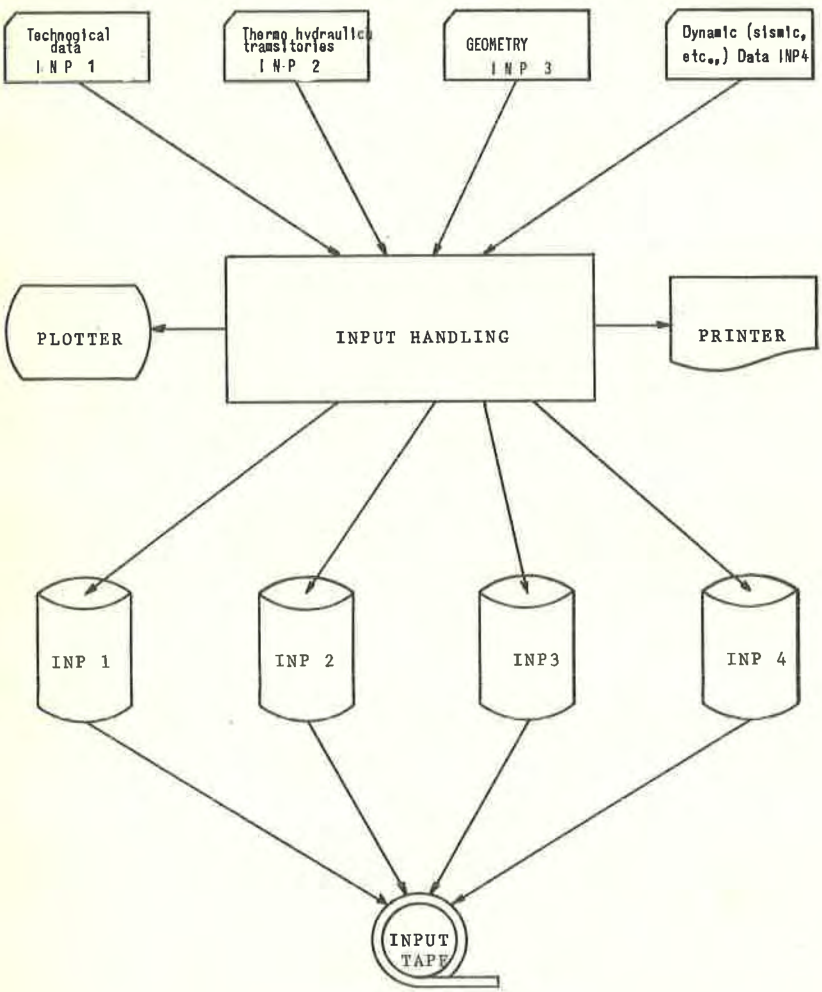
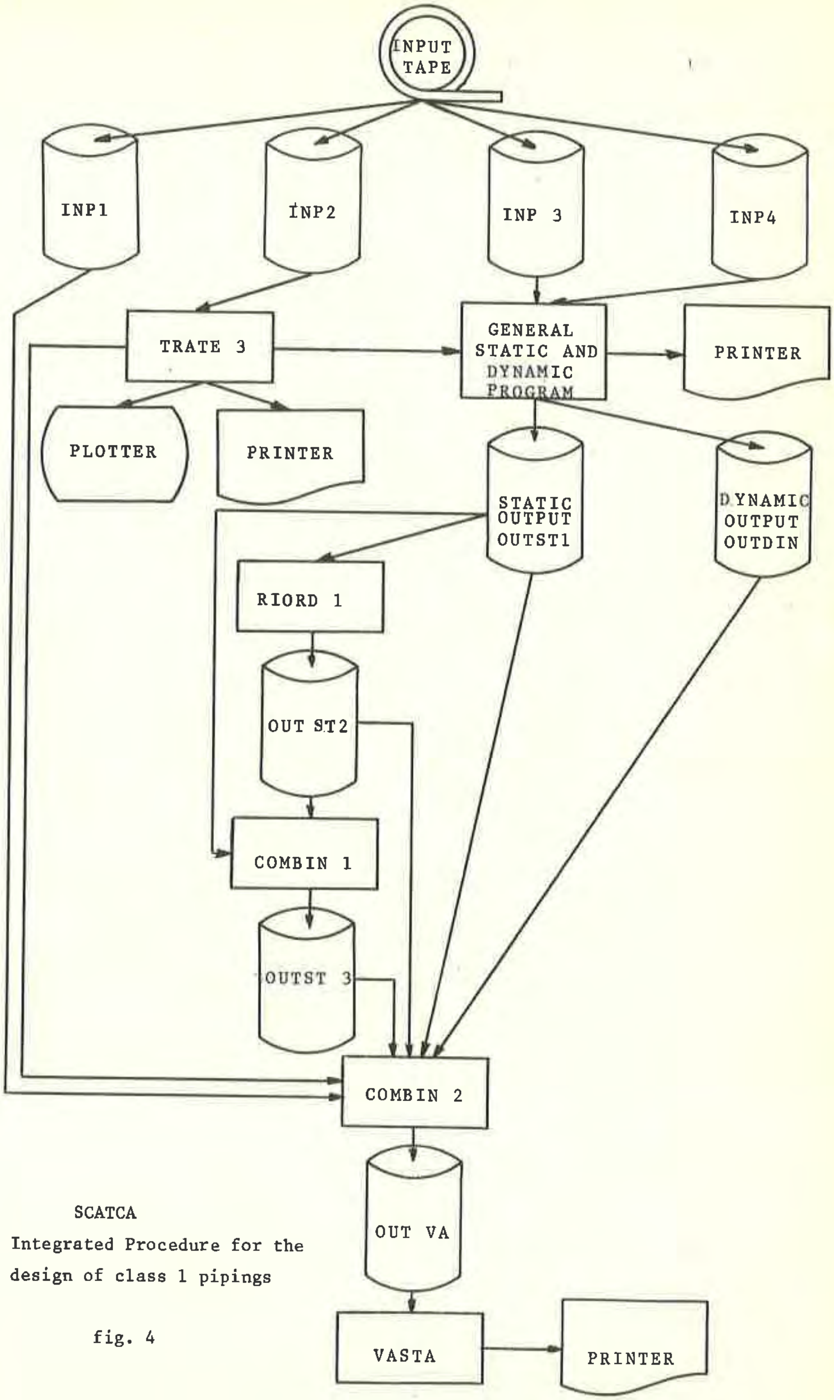
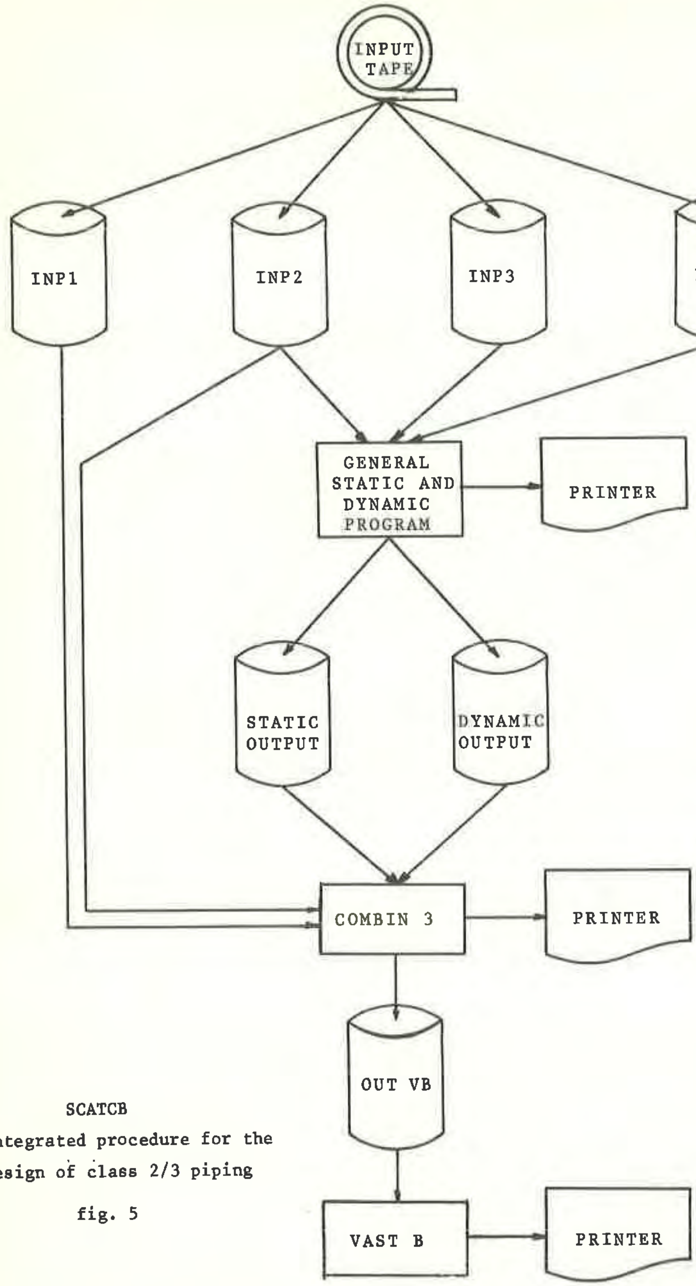

Technogical data
I N P 1
Thermo hydraulics
tramsitories
I N P 2
GEOMETRY
I N P 3
Dynamic (sismic, etc.,) Data INP4
PLOTTER
INPUT HANDLING
PRINTER
INP 1
INP 2
INP3
INP 4
INPUT
TAPE

fig. 3



SCATCA
Integrated Procedure for the design of class 1 pipings

fig. 4



SCATCB

Integrated procedure for the design of class 2/3 piping

fig. 5

TABLE 4.1.

DATI DI CALCOLO (UNITA' DECIMALI)

SEZIONE N. 1 TIPO 1
ACCIAIO AUSTENITICO

TEMPERATURA DI PROGETTO	=	0.1CCC0E C3
TOLLERANZA LAVORAZIONE	=	0.238C0E C0
RAGGIO MEDIO DEL TUBO	=	C.1C440E C2
SPESSORE DEL TUBO	=	C.1C310E 01
TENSIONE AMMISSIBILE	=	0.10550E C4
COEFF.DI DILATAZIONE 1	=	C.120C0E-04
COEFF.DI DILATAZIONE 2	=	0.120C0E-C4
MODULO DI YOUNG	=	C.210C0E C7
MODULO DI POISSON	=	0.300C0E 00
N.DI SEZIONI DA VERIFICARE	=	12
N.DI SET TERMO-IDRAULICI	=	6
N.DI TRANSITORI	=	7

TIPO DI CARICO	MOMENTO 1	MOMENTO 2	MOMENTO 3
PESO PROPRIO	0.0	C.0	C.829E 03
OBE SENZA SPOST.DIF.	0.C	C.137E C2	C.2C6E C2
OBE SOLO SPOST.DIF.	C.C	C.137E 02	0.206E C2
DBE SENZA SPOST.DIF.	0.C	C.274E C2	C.413E C2
DBE SOLO SPOST.DIF.	0.C	C.274E 02	0.413E 02

CONDIZIONI TERMOIDRAULICHE

SET	PRESSIONE	DT.LIN.	DT.NON LIN.	TEMP.A	TEMP.B	MOM.TUB. 1	MOM.TUB. 2	MOM.TUB. 3
1	0.0	0.0	0.0	C.380E 02	0.380E C2	C.0	0.C	-.485E 03
2	C.717E C2	0.424E 01	C.7CCE CC	C.279E 03	0.279E C3	C.C	C.C	-.357E C4
3	0.790E 02	0.110E 00	C.200E-C1	C.296E 03	0.296E 03	C.C	C.C	-.378E C4
4	0.717E 02	C.858E 01	0.148E C1	C.271E 03	C.271E C3	C.C	0.C	-.347E C4
5	0.717E 02	0.154E 01	C.170E CC	C.283E 03	0.283E 03	0.C	0.C	-.362E C4

F3/3

** S.A.I.G.E. S.P.A. ** PROGRAMMA VER.TUBAZIONI CLASSE A * 025ABC0CC8 * 2.

TABLE 4.1. (continue)

CONDIZIONI TERMOIDRAULICHE

SET	PRESSIONE	DT.LIN.	DT.NON LIN.	TEMP.A	TEMP.B	MOM.TUB. 1	MOM.TUB. 2	MOM.TUB. 3
6	0.0	-.335E 01	0.470E 00	0.430E 02	0.430E 02	0.0	0.0	-.550E 03

TRANSITORI CONSIDERATI

TRANS.	1	DA SET	1	A SET	2	N.CICLI	120	TIPO COND.	0	NORMAL
TRANS.	2	DA SET	3	A SET	4	N.CICLI	180	TIPO COND.	1	UPSET
TRANS.	3	DA SET	5	A SET	6	N.CICLI	111	TIPO COND.	3	FAULTED
TRANS.	4	DA SET	2	A SET	3	N.CICLI	100	TIPO COND.	2	EMERGENCY
TRANS.	5	DA SET	3	A SET	5	N.CICLI	150	TIPO COND.	3	FAULTED
TRANS.	6	DA SET	1	A SET	4	N.CICLI	200	TIPO COND.	1	UPSET
TRANS.	7	DA SET	1	A SET	6	N.CICLI	130	TIPO COND.	0	NORMAL

SET N.	VERIFICA PRESSIONE PRESSIONE	PRES.AMM.	ESITO	VERIFICA TENS.PRIMARIA TENSIONE	TENS.AMM.	ESITO
1	0.0	0.10317E 03	O.K.	0.25194E 01	0.15825E 04	O.K.
2	0.71700E 02	0.10317E 03	O.K.	0.38346E 03	0.15825E 04	O.K.
3	0.79000E 02	0.10317E 03	O.K.	0.42225E 03	0.15825E 04	O.K.
4	0.71700E 02	0.10317E 03	O.K.	0.38346E 03	0.15825E 04	O.K.
5	0.71700E 02	0.20633E 03	O.K.	0.38353E 03	0.31650E 04	O.K.
6	0.0	0.10317E 03	O.K.	0.25194E 01	0.15825E 04	O.K.

VERIFICA CAUTELATIVA PRELIMINARE O.K.

TENS.SEC.	AMM.	T.PICCO	AMM.	N.CICLI	F.FATICA
0.993E 03	0.317E 04	0.514E 03	0.656E 04	630	0.630E-03

F3/3