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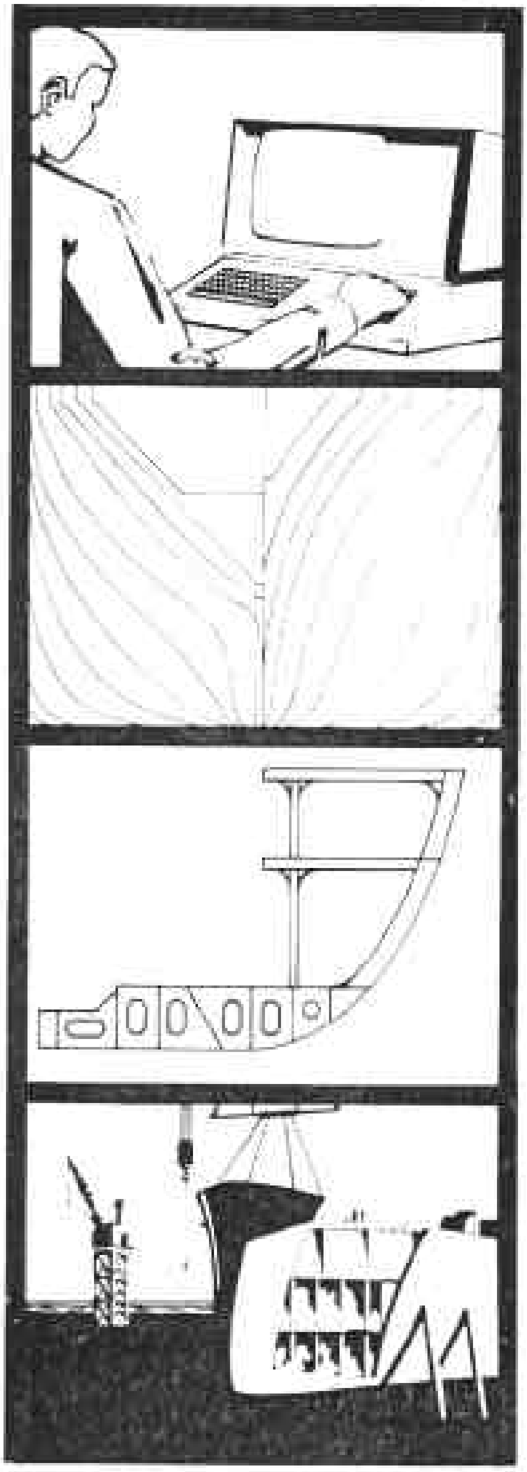

R ESEARCH
AND
E NGINEERING
FOR
A UTOMATION
AND
P RODUCTIVITY
IN
S HIPBUILDING

Proceedings of the REAPS Technical Symposium

September 11-13, 1979

San Diego, California

A PROGRESS REPORT ON THE CNC SHIP FRAME BENDER

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Mr. Wall is Project Manager for the CNC frame bender at the National Steel and Shipbuilding Company. He has a degree in mechanical engineering, and is currently pursuing a masters degree in business administration. His previous experience includes steel mill maintenance supervision, air pollution research and equipment design.

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Since the founding of Cali and Associates Inc, Mr. Cali has directed the continuous development of the SPADES system, and expanded the company to provide complete N/C lofting services to the shipbuilding industry, with particular emphasis to the small and medium size shipyards. He has an engineering degree from the Italian Naval Academy.

Mr. Cali has over 30 years experience in all phases of shipbuilding. Prior to founding Cali and Associates, Mr. Cali held the positions of Vice-President for Engineering at Avondale Shipyards, and Director of Engineering at Litton Ship Systems.

The U.S. Navy and National Steel and Shipbuilding Company in San Diego are cooperating to build and test a new and more efficient machine for forming ship's frames. The device is a CNC Ship's Frame Bender. The frame bender is a hydraulically powered, computer controlled machine which will cold form typical angle and "Tee" shapes used in the hulls of ships.

There are several unique features of this machine. It will eliminate labor and energy intensive hot forming processes now in use. The computer control features "adaptive feeback" which will automatically compensate for variations in the properties of a beam being formed. The desired curvature of the beam will be "read in" via a paper tape supplied by an existing computer at NASSC0. The need for templates and human judgement will be eliminated by the computer. The bender will form beams by developing a pure bending moment rather than *a* combination of moment and shear, within the work section of the beam.

The frame bender concept, and a working model, were developed at Case Western Reserve University by Dr. H. W. Mergler. The U.S. Navy's Manufacturing Technology division and NASSCO are funding the construction, installation and testing of a prototype capable of handling beams up to 8" flange by 25".web and 42 feet in length. Construction was begun in late 1978 with all parts delivered to San Diego in July of this year. Installation is presently underway working toward a demonstration date later this year.

The frame bender shapes a beam by progressively forming short sections as the beam is fed through the bender. A Work section of 14 to 48 inches in length is clamped at each end by the fixed head and the moving head. A pure bending, moment is then exerted on the work section by rotating the moving head in a horizontal plane relatively to the fixed head. The forces applied and resulting deformation are monitored by various transducers which feed information back to the computer. After making a bend the beam is allowed to spring back. The curvature is then compared to the desired curvature by the computer. If the bend is not within tolerances the same section is rebent using the results of the previous bend to recalculate the properties of the section. Once the bend is within tolerances the beam is advanced through the heads to the next work section and the process is repeated.

The frame bender is presently being assembled and installed in the Plate Shop at NASSCO in San Diego. All of the major components have been set in place on special footings and electrical and hydraulic installation is being performed; Assembly is scheduled for completion late September, 1979 with shakedown and "debugging" to be complete by late October.

After the demonstration date additional support equipment will be fabricated and installed to bring the machine into full production. An automated system is being developed to transfer beams directly from the beam welder to hold tables at the entry end of the Frame Bender. Each beam will then be hoisted to a feed in table by a remotely controlled "picker" on a dedicated semi-gantry crane. The feed in table will be capable of handling--all cross sections and lengths of beams. It will grasp the end of the beam, raise and properly orient the beam then charge it into both heads of the Frame Bender; All this will be; controlled remotely from the operator's platform allowing full visibility of all operations. After a beam has been formed it will be extracted from the bender by the picker and crane while another beam is being charged into the bender. Finished beams will be stacked downstream of the bender for later distribution.

All of this support equipment is scheduled to be in operation in early 1980. At that point the CNC ship's Frame Bender will be fully integrated into the production line at NASSCO and will be helping to reduce costs and conserve energy in the production of ships.

PART II - SOFTWARE AND DOCUMENTATION
BY FILIPPO CALI, PRESIDENT, CAL1 AND ASSOCIATES, INC.

This part of the paper has been written with two goals in mind:

1. Report on the state of developement of Host Software;
2. Provide a preliminary documentation for the system programmer to be able to link the software with any system other than "SPADES".

It is appropriate at this point to give Mr. K. W. Cheng of Cali and Associates, most of the credit for the development of the "Host" Software described in this paper.

STATE OF SOFTWARE DEVELOPMENT

The basic design criteria for the Host Software were described in the 1978 SNAME Paper, "Development and Application of a Computer-Controlled Ship's Framebender in the Automated Shipyard," to which the reader is referred.

These criteria have essentially remained unchanged and the development was done accordingly. The software is, at the present time, ready and paper tapes can be generated directly from the ship's geometry definition as it exists in the "SPADES" Database.

The portion of the program dealing with the computation of the length of the work sections was the most difficult in view of the conflicting requirements.

The geometry of the beam requires certain work lengths to better approximate the desired curvature

Efficiency of operation (i. e. minimum cycle time) requires the longest work length allowable by the Framebender

Use of the stabilizers and the operational requirement of not wanting to change the number of stabilizers during the bending of a beam dictate a minimum work length

These often conflicting requirements have been taken into account, but provisions have been made to easily bypass one of them or change the priority, based on the feedback of the forthcoming tests. It is my opinion, for instance, that total elimination of the use of the stabilizers in conjunction with appropriate selection of work lengths will result in a better overall cycle time.

The portion of the software dealing with checking beam geometry with physical machine parameters has been left incomplete pending determination of these parameters after installation.

The bender is now in the final phase of installation and testing will soon commence. We all expect that a certain amount of tuning of Host Software, Mini-Computer Software and Bender itself will be required. The area requiring the most tuning will be measuring of the vertical (in the Z-X plane) bending, existing in the beam being processed in order to eliminate it and for the purpose of refining the out-of-plane compensation ratio.

In order to achieve the required capability to link it with any N/C Lofting system other than "SPADES", the software has been organized in two FORTRAN SUBROUTINE CALLS. A separate driver program that reads manual type input data and calls these two subroutines has also been provided for those potential users who do not use any data base for N/C lofting. (See Fig. II-l)

The First Subroutine Call is:

CALL FRBNDR (Argument List)

This subroutine receives through the argument list the lofted contour of the neutral axis of the beam and the necessary physical and geometrical characteristics of the beam.

After operating on the above data to create the numerical model required by the framebender, the subroutine returns, through one of the arguments, an array to be used in the subroutine call:

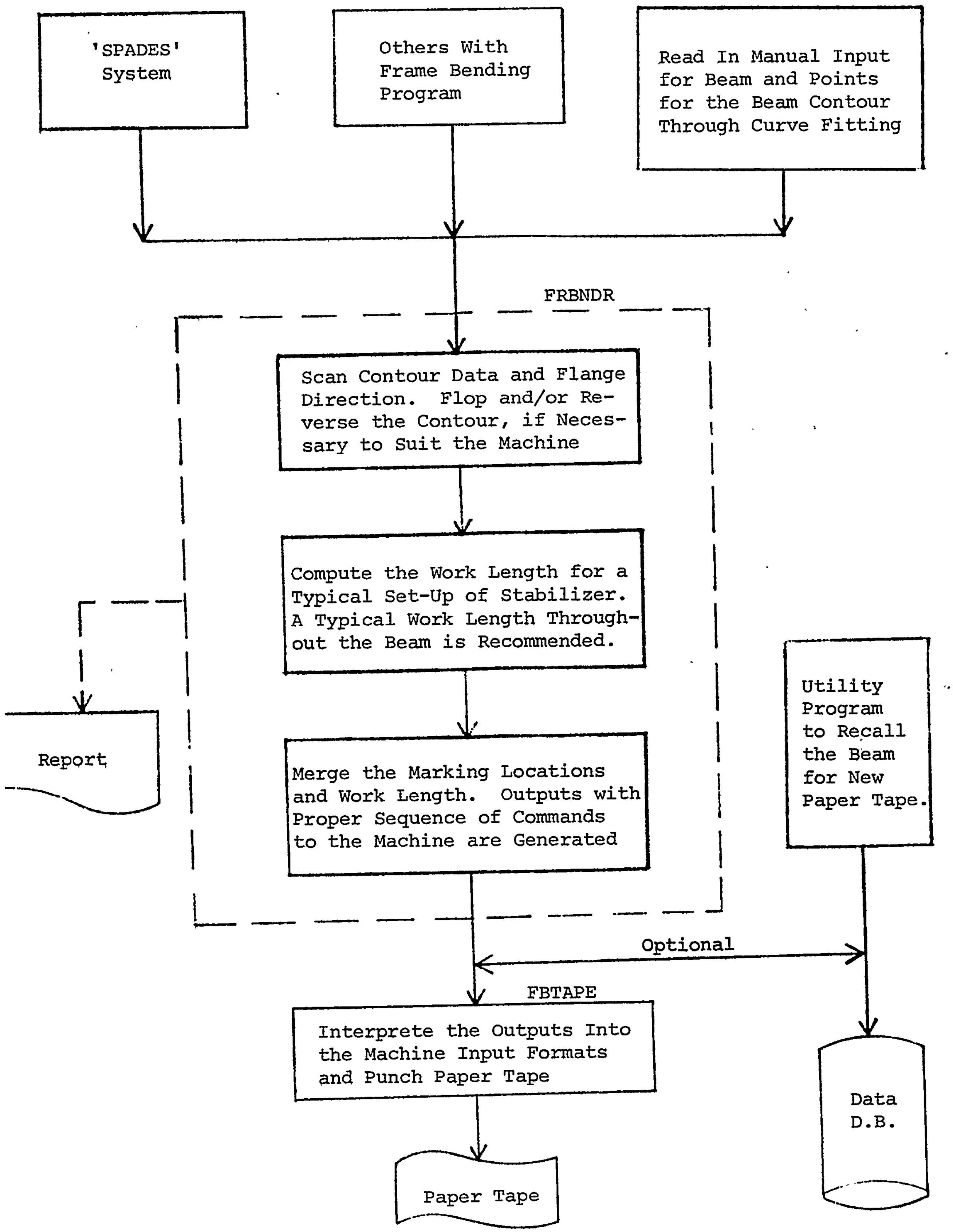
CALL FBTAPE (Argument List)

Subroutine 'FBTAPE' translates the array generated by 'FRBNDR' into the paper tape image required by the framebender's controller.

The software was set up on purpose with these two calls so that a user that wishes to store the array generated by 'FRBNDR' in a database can do so and have a utility program to recall the array and regenerate the paper tape image for punching or 'DNC' without calling 'FRBNDR'

For further details on the use of these two subroutines, see the following 'Preliminary Software Documentation".

FIG. II - 1


'SPADES'
System
Others With
Frame Bending
Program
Read In Manual Input
for Beam and Points
for the Beam Contour
Through Curve Fitting
FRBNDR
Scan Contour Data and Flange
Direction. Flop and/or Re-
verse the Contour, if Neces-
sary to Suit the Machine
Compute the Work Length for a
Typical Set-Up of Stabilizer.
A Typical Work Length Through-
out the Beam is Recommended.
Report
Merge the Marking Locations
and Work Length. Outputs with
Proper Sequence of Commands
to the Machine are Generated
Utility
Program
to Recall
the Beam
for New
Paper Tape.
Optional
FBTAPE
Interprete the Outputs Into
the Machine Input Formats
and Punch Paper Tape
Data
D.B.
Paper Tape

Linkage Procedure With a Lofting "N/C System"

In order to properly link the software, the following must be done:

A - Initialization (for the entire program)
The initialization procedure must contain the FORTRAN statement:

```
CALL FBSTCM
```

A common must be included and initialized as follows:

```
COMMON/MISCS/IUNIT(6), NERR(4), TOLER(25), IDTR(6)

IUNIT(1) = FORTRAN UNIT FOR PRINTER FILE
IUNIT(3) = FORTRAN UNIT FOR PAPER TAPE IMAGE FILE
```

The remaining variables in the common are initialized by the call to 'FBSTCM'

B - Initialization for Each Beam
The variables array 'NERR' in COMMON/MISCS/ must be re-initialized as follows:

```
NERR(l) = 0
NERR(2) = 0
NERR(3) = User ID for associating diagnostic error messages
NERR(4) = 0 When set to greater than 0, it triggers a trace printout
```

Two additional commons require re-initialization for each beam.

```
COMMON/SHAPE/ NSHAP, KTEXT(lO), ITYS, SEMB(24)
```

Prior to the call to 'FRBNDR' the following variables in the common must be initialized as follows:

NSHAP	SHPAE NO. (INTEGER 501-1499)
KTEXT(7-10)	ALPHABETIC DESCRIPTION OF SHAPE
ITYS	TYPE OF SHAPE
	1 - Flat Bar 2 - Angle Bar 3 - T-Beam 4 - Bulb Angle 5 - Not applicable 6 - Not applicable 7 - NASSCO special built-up angle bar

SEMB(1)	Area of cross section in IN2
SEMB(2)	Weight per Foot in LBS
SEMB(3)	Web depth in Feet
SEMB(4)	Flange width in Feet
SEMB(5)	Web thickness in Feet
SEMB(6)	Flange thickness in Feet
SEMB(7)	Moment of Inertia about major axis in IN^4
SEMB(8)	Section of modules in IN^3
SEMB(9)	Not used in this program
SEMB(10)	Distance from centroid to flange (Feet)
SEMB(11)	Moment of Inertia about minor axis in IN^4
SEMB (12)	Section of modules in IN^3
SEMB(l3)	Not used in #is program
SEMB(14)	Distance from centroid to web if X-section of beam is not symmetrical (Feet)
SEMB(l5)	Tangent of separation angle
SEMB(l6)	Not used in this program
SEMB(17)	Not used in this program
SEMB(l8)	Amount of recess (NASSCO special built-up type) (Feet)
SEMB(19)	Material code (Integer O-9)
SEMB(20)	Young's module lbs/in^2
SEMB(21)	Yield stress lbs/in^2
SEMB(22)	Density of material lbs/ft^3 (used when unit weight is not given)
SEMB(23-24)	Not used in this program

The program will compute the data in SEMB(7) through SEMB(17) if SEMB(7) is set to zero.

The data in SEMB(1) and SEMB(2) will be calculated if they are set to zero.

The data in SEMB(l9) through SEMB(22) will be set to the default values for mild steel.

SEMB(19)	= 0
SEMB (20)	= 30 x 10^6 LBS/IN^2
SEMB(21)	= 35,000 LBS/IN^2
SEMB(22)	= 490 #/Ft^3

COMMON/TEMP/IDN, ITYPE, ITEXT(26), OPEN(l0)

Some of the variables in this common are set by the calls to 'FBSTCM' and 'FRBNDR'. The following variables should, however, be set by the calling program.

IDN — An integer value representing the assigned identification number of the paper tape within any one ship (JOB).
The value is a seven digits number with the format TPPNNNNN where:

T = 4 For a paper tape to bend or straighten specific beam in the ship
  = 5 For straightening a stock beam

Paper tapes for straightening stock beams (T=5) are recognized as such by the mini-computer in the framebender and no error is given when the end of the beam is detected by the limit switch on the feed side of the machine, since stock lengths can vary. The mini-computer allows also the storing in core of a number of these tapes for easy recall by the operator.

PPNNNN — = Arbitrary six digits number. Within the "SPADES" system, PPNNNN is controlled by the system.

ITEXT(1) — Integer value of Julian Date (YYDDD)

ITEXT(3)* — Integer value of time of day (HHMMSSS) where:

HH = Hour (O-23)
MM = Minutes
sss = Tenths of seconds

ITEXT(5) — Ship (Job) ID number (integer 1 to 99)

ITEXT(6) — Rev. number of tape (integer 1 to 99)

ITEXT(7)* Ship name (A4 Format)

ITEXT(8-9)* Ship account (2A4 Format)

ITEXT(11-14)* Piece mark (T=4) or stock number (T=5) (4A4 Format)

*Note: Setting of these variables is recommended but not mandatory.

OPEN(l) Real number of format MOSSSS.0 where:

M = Material ID (O-9)
ssss = Beam ID (501 to 1499)

OPEN(2) Minimum required cut length of beam (internal units)

OPEN(5) Total weight of beam

OPEN(6-8) Three dimensional center of gravity Qf the beam in the ship

These values in ARRAY 'OPEN' are also optional. Within the "SPADES" system they are set to 1000000.0 when not used as in the case of a tape for straightening a stock beam.

c - Call of subroutine 'FRBNDR'

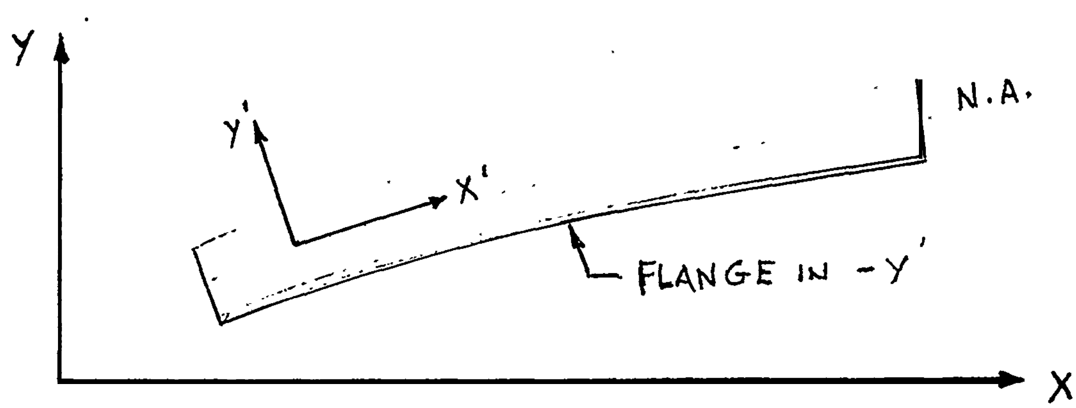
CALL FRBNDR (IOP, IDS, FBCNR, NCFB, FBXY, NAMREF, IRRAY)

INPUT ARGUMENTS:

IOP Operation Control Word
= 1 Bend Beam
= 2 Straighten Beam

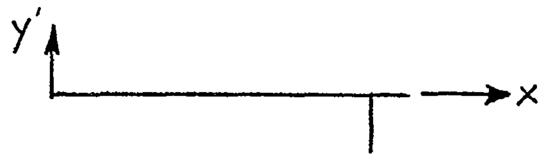
IDS(7) Control Words

IDS(l) Flange Location Relative to the COntOUr
= +1 Flange in positive y' of contour
= -1 Flange in negative y' of COntOUr



IDS(2) Flange Orientation for Unsymmetrical Shape
= +l Flange in positive y' direction

= -1 Flange in negative y' direction



IDS(3) Total no. of segments of contour (INA)

IDs(4) Total no. of marks on the beam (INM)

IDS(5) Index of mark array for fwd. end cut template ref. mark

IDS(6) Index of mark array for aft end cut template ref. mark

IDS(7) Total no. of words in IRRAY at return (NWD)

FBCNR(4,INA) Contour geometry at N. A. in absolute coordinates in 'ESSI' format

1 - X-coord. of starting point
2 - Y-coord. of starting point
3 - X-coord, of center
4 - Y-coord. of center

NCFB(INA) Indicator of 'ESSI' segment

0 - Straight line
1 - Positive rotation
2 - Negative rotation

Note: FBCNR (1,INA) and FBCNR(2,INA) contain the end point of segment (INA-l), i.e. the contour is defined by 'INA-1' segments.

FBXY(2,INM) Marking location on N. A. contour sorted in sequence along the contour

1 - X Abs.
2 - Y Abs.

NAMREF(3,INM) Names of marks

OUTPUT' (return) ARGUMENTS:

IRRAY(NWD)	"FRBNDR" returns in this array the data required for calling 'FBTApE'. The array size (NWD) provided by the calling program should be 500 words.
IDS(7)	The contents of this variable in the input argument 'IDS' is set up to the actual no. of words used in ARRAY 'IRRAY'. The calling program should check this value for not equal to zero. A zero value indicates an error condition.

D - Call of Subroutine 'FBTAPE'

CALL FBTAPE (IRRAY)

INPUT ARGUMENT:

IRRAY	The ARRAY generated by 'FRBNDR'

Upon return from "FBTAPE" the variable OPEN(4) should be checked for the following values:

OPEN(4)	0 Paper tape image generated without errors
	8 System logic error - No P/T
	9 User errors ocurred. Paper tape should not be used in the framebender.

The identification number assigned to the paper tape will be as follows:

JJNNNNTPP-RR where:

JJ	= Value assigned to ITEXT(5)
NNNNTPP	= As defined in "IDN"
RR	= Rev. no. as assigned to ITEXT(6)

In order to avoid duplication of names of both subroutines and commons between the calling program and the software a list of the names used is included.

LIST OF COMMON AND SUBROUTINE NAMES USED

The following names have been used in the software and therefore cannot be duplicated within the calling program.

NAMES OF SUBROUTINES

ABTOIN
AFORMT
ARCLNG
AXES
BPCALC
CHKPRT
CIRCEL
CIRCFT
COSCAN
CURVES
PATE
ERR1
FBCHR
FBFEED
FBLABL
FBSTCM
FBTAPE
FRBNDR
FRBNIT
FRBOUT
FTTOHD
GETBYT
GLRMRK
GRPNT
GRSEG
IEBCDC
IGERR
INTFRC
INTOAB
ISGATN
ITOALF
IVSRAY
JASCII
MORAY
NCFBIN
NCFRPT
COMTIM
OPDRTN
OUTAPE
PACK
PRINTP
PRTERR
PRTVAL
SEARCH
SETCTL
SLOPEA
SNCS
STBREQ
STPC
STOBYT
SPDVAL
SWAP
UNPKD
WINDW
WTCALC
ZFORMT

NAMES OF COMMONS

/ALFBET/
/BLTKNT/
/CNVRT1/
/CNVRT2/
/DELET1/
/ESSEIA/
/FBWORK/
/FBNDCT/
/IGERR1/
/LPRP1/
/MISCS/
/MISCS2/
/FOSTBF/
/TEMP/
/SHAPE/

STAND ALONE PROGRAM FOR MANUAL INPUT

As mentioned earlier this program was conceived to give the user, who does not have a databased oriented N/C Lofting capability, a relatively easy way to generate paper tapes for the N/F Framebender.

The type of input data needed can be divided as follows:

- DESIRED BENDING
  This can be given by the use of a discrete number of points along the desired curvature or by a series of straight line and circular segments.

  If points are used the "SPADES" curve fitting routine is used to generate the contour. Flags to indicate tangency conditions and change of curvature are allowed. In either of the above cases the given data can be for the neutral axis or for the trace of the beam.

- DESIRED MARKING
  This is indicated by giving a series of points, where marking is desired, in the same coordinate system used to define the bending.

- PHYSICAL PROPERTIES OF BEAM
  This type of data describes the cross-section of the beam. The material is assumed to be mild steel if not otherwise specified.

- ADMINISTRATIVE DATA
  This includes the desired tape no. and rev. The piece mark of the beam or the stock no. of the beam in the case of a tape for straightening.

When this program is used to generate the standard tapes for straightening stock beams, there is no need to provide any bending and marking data. The only data needed is the properties of the beam, the number of the beam (501 to 1499), the stock number, and tape revision. The tape number is assigned by the program.

Within the "SPADES" environment only the beam number and stock number are needed, with everything else provided from the database,

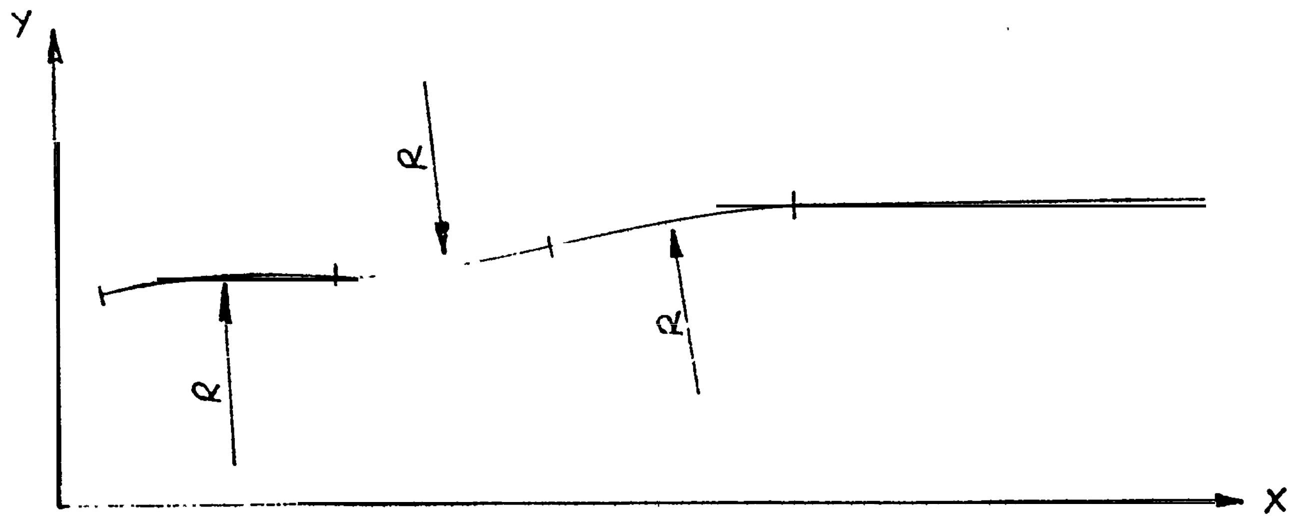
A user manual is being prepared giving detailed instruction on the format of the input data required in each case.

Figs. (II-2) through (II-10) have been included for general information.

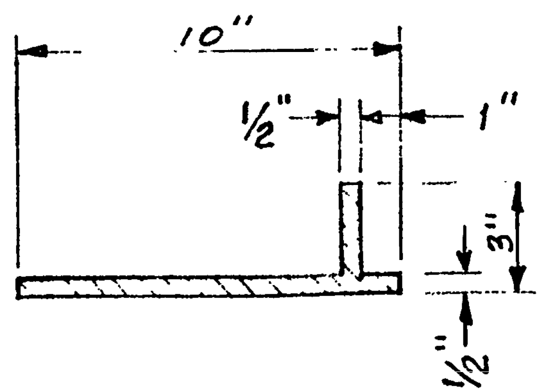
```
JOBD CTUG        .                  21                     000000
BEAM WEB FRM. 49               4023201          1
SHAP BUILT-UP L 10X4               521          7  I    1.
PRTY                        I   10.        I   4.      I       .5    I     .5
PRTY                                          22.95
CNAX                             6.261        7.364
                                 7.246        7.458
                                 8.385        7.549
                                 9.567        7.637
                                10.795        7.737
                                12.153        7.874
                                13.887        8.108
                                15.429        8.378
                                16.542        8.599
                                17.575        8.811
                                18.604        9.011
                                19.770        9.211
                                21.045        9.380
                                22.125        9.471
                                23.048        9.500
                                40.000        9.500
MARK J     A0   P                9.000        7.595
     S     12   P               12.000        7.857
     J     E0   P               18.333        8.959
     D     F19  P               19.500        9.167
     D     F27  P               27.500        9.500
     J     F0   P               28.000        9.500
     S     33   P               33.000        9.500
     J     G0   P               35.833        9.500
     D     MD2  P               39.000        9.500
     J     H0   P               39.281        9.500
ENDS
```

SAMPLE OF INPUT FOR BENDING

FIG. II - 2



SKETCH OF CURVATURE AT THE NEUTRAL AXIS FOR SAMPLE BENDING FRAME



CROSS SECTION OF THE BEAM USED IN THE SAMPLE INPUT

FIG. II - 3

NUMERICAL **CONTROL FRAME BENDING PROGRAM MANUAL INPUT**

JOB NAME CIUG
JOB ID. 21
DATE 09/04/79

PHYSICAL PROPERTIES OF BEAM

BEAM NO. 521
BEAM TYPE
AREA OF CROSS SECTION 0.00
WEIGHT PER FOOT 22.95

WEB DEPTH 10.00
FLANGE WIDTH 4.00
WEB THICKNESS 0.50
FLANGE THKNESS 0.50
AMOUNT OF RECESS 1.00
NASSCO BUILT TYPE

COORDINATES OF CONTOUR IN ESSI FORMAL. NO. OF SEGMENTS = 13

1	6.261	7.364	12.578	-52.343	2
2	8.634	7.568	43.398	-441.294	2
3	10.136	7.681	1.936	105.807	1
4	11.747	7.829	6.306	58.077	1
5	13.760	8.388	7.942	46.684	1
6	15.597	8.410	2.973	74.799	1
7	17.113	8.717	75.405	-280.154	2
8	18.328	8.959	29.360	-49.984	2
9	19.796	9.015	24.413	-21.380	2
10	21.555	9.429	23.392	-12.765	2
11	22.830	9.498	23.053	-4.769	2
12	23.048	9.500	23.048	9.500	0
13	40.000	9.500	0.000	0.000	0

NAME AND COORDINATES OF REF. MARKING POINT
NO. OF POINTS = 10 FWD AND AFT TEMPL. POINTS 0 0

1	J	DO	P	9.000	7.555
2	S	12	P	12.000	7.857
3	J	EO	P	18.333	8.959
4	D	F19	P	19.500	9.167
5	D	F27	P	27.500	9.500
6	J	FO	P	28.000	9.500
7	S	33	P	33.000	9.500
8	J	GO	P	35.833	9.500
9	D	MD2	P	39.000	9.500
10	J	HO	P	39.281	9.500

PRINTOUT OF DATA USED BY THE PROGRAM
(Bending Tape)

FIG. II - 4

DATA FOR EACH WORK LENGTH

NO.	LENGTH	RADIUS	BENDING	TARGET	WEIGHT	AT CYL.
1	2.077	-77.284	33.461	-1.041	1861.246	526.795
2	0.978	-391.278	31.396	-0.530	2903.759	495.838
3	4.000	48.007	30.391	-0.756	940.586	396.159
4	2.353	46.802	26.252	-2.877	1136.222	336.915
5	0.707	67.453	23.758	-3.923	1789.520	311.986
6	2.728	-50.311	22.768	-3.867	848.816	258.178
7	3.268	-22.460	20.229	-2.637	636.780	194.527
8	4.030	5058.271	17.143	-0.033	465.664	126.784
9	4.030	$1000000.0	13.114	-0.033	360.832	70.457
10	4.030	$1000000.0	9.084	-0.033	275.455	26.255
11	4.030	$1000000.0	5.054	-0.033	48.501	0.000

GIRTH LENGTH OF MARKING POSITION

1	2.749
2	5.760
3	12.191
4	13.377
5	21.396
6	21.856
7	26.896
8	29.723
9	32.896
10	33.177

PRINTOUT OF NUMERICAL MODEL FOR THE FRAMEBENDER

(Bending Tape)

FIG. II - 5

```
$...
213Ø14Ø2Ø
L3
TAPE 2183201-4Ø2
REV  NO         1
DATE     Ø9/Ø4/79
JOB
DB JOB       CTUG
WEB FRM. 49
L4
$
TAPE NO. 21-32Ø1-4Ø2-Ø1
BEAM ID  521     BUILT-UP L 1ØX4
BEAM LENGTH REQ. 33-1Ø-12/16
PC. ID. WEB FRM. 49
 1 STABILIZERS REQ.     SPACED BY
  26-1/2
BEAM FLG. DOWN
USE S. CLAMP
$
S145,759
R177
H1
M5
MØ
M1
F1822
M2
F34ØØ
M2
P1181
M4
F614
P48ØØ
W49,Ø
X+6Ø65Y-38
F4836
P48ØØ
W275,26
X+1Ø9Ø1Y-38
F551
M2
F6ØØ
M2
F3685
P48ØØ
W361,7Ø
X+15736Y-38
F4836
P48ØØ
```

PRINTOUT OF PAPER TAPE CONTENTS FOR BENDING

FIG. II - 6

```
JOBD ****          STNG          0
BEAM STOCK S-2079                          1
SHAP BUILT-UP ANGLE          501           7 I   1.
PRTY                     I  10.     I   3.   I  .5     I  .50
PRTY1                       3.75      24.67    35000.     30.
ENDB
```

SAMPLE OF INPUT FOR STRAIGHTENING

FIG. II - 7

NUMERICAL CONTROL FRAME BENDING PROGRAM MANUAL INPUT

```
JOB NAME  ****
JOB ID.      0
DATE       0./00/00
```

PHYSICAL PROPERTIES OF BEAM

```
BEAM NO.   501
BEAM TYPE       7
AREA OF CROSS SECTION    3.75
WEIGHT PER FOOT   24.67

WEB DEPTH          10.00
FLANGE WIDTH        3.00
WEB THICKNESS       0.50
FLANGE THKNESS      0.50
AMOUNT OF RECESS     1.00
NASSCO BUILT TYPE
```

COORDINATES OF CONTOUR IN ESSI FORMAT. NO. OF SEGMENTS = 2

1	0.000	0.000	0.000	0.000	0
2	60.000	0.000	0.000	0.000	0

PRINTOUT OF DATA USED BY THE PROGRAM
(Straightening Tape)

FIG. II - 8

DATA FOR EACH WORK LENGTH

NO.	LENGTH	RADIUS	BENDING	TARGET	WEIGHT AT	CYL.
1	4.000	0.000	61.333	-0.104	3109.597	1617.375
2	4.000	0.000	57.333	-0.104	2767.471	1418.778
3	4.000	0.000	53.333	-0.104	2446.125	1232.914
4	4.000	0.000	49.333	-0.104	2145.563	1059.783
5	4.000	0.000	45.333	-0.104	1865.784	899.385
6	4.000	0.000	41.333	-0.104	1606.789	751.720
7	4.000	0.000	37.333	-0.104	1368.575	616.789
8	4.000	0.000	33.333	-0.104	1151.151	494.590
9	4.000	0.000	29.333	-0.104	954.511	385.126
10	4.000	0.000	25.333	-0.104	778.663	288.396
11	4.000	0.000	21.333	-0.104	623.609	204.403
12	4.000	0.000	17.333	-0.104	489.363	133.148
13	4.000	0.000	13.333	-0.104	375.941	74.643
14	4.000	0.000	9.333	-0.104	283.385	28.945
15	4.000	0.000	5.333	-0.104	51.866	0.000

PRINTOUT OF NUMERICAL MODEL FOR THE FRAMEBENDER
(Straightening Tape)

FIG. II - 9

```
S...
0005015000
L3
TAPE     80501-500
REV NO          1
DATE      09/04/79
JOB
DB JOB          ....
STOCK S-2079
L4
S
TAPE NO. 00-0501-500-01
BEAM ID 501      BUILT-UP ANGLE
BEAM LENGTH REQ. 61-08-00/16
PC. ID. STOCK S-2079
 0 STABILIZERS REQ.
BEAM FLG. DOWN
USE S. CLAMP
S
S137,1061
R104
H0
M5
M0
M0
F5800
P4800
W52,0
X+6400Y-124
F4800
P4800
W283,29
X+11200Y-124
F4800
P4800
W376,75
X+16000Y-124
F4800
P4800
W489,133
X+20800Y-124
F4800
P4800
W624,204
X+25600Y-124
F4800
P4800
W779,288
X+30400Y-124
F4800
P4800
W955,385
X+35200Y-124
F4800
P4800
```

PRINTOUT OF PAPER TAPE CONTENTS FOR STRAIGHTENING

FIG. II - 10

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