Prosjektkomitéen for rensing av avløpsvann

PRA 5.7
Mixing of a jet into a stratified environment

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FOREWORD

This program system is the result of a cooperation between Norsk Institutt for Vannforskning, Oslo (NIVA) and A.S Computas, Oslo. The physical and mathematical fundament has been worked out by NIVA, while A.S Computas has been responsible for the developement of the program system. There has been a high degree of cooperation in the lay-out and testing of the system.

A.S Computas, January 1973

SUMMARY OF DIRECTIVES

HELP	How to use the system.
CIN	Input of constants.
CCOR	Correction of constants.
CSAV	Save constants on file.
COUT	Output of constants.
CGET	Constants from file to core.
JIN	Input of jet data.
JCOR	Correction of jet data.
PIN P	Input of density profile no. P.
PCOR	Correction of current density profile.
POUT P1..PN	Print specified density profiles.
PSAV	Save current density profile.
PGET P	Specified density profile from file to core.
PLIB	Print table of contents of file.
INIT	Initiate file for density profiles.
PDEL P1..PN	Delete from file specified density profiles.
PPAC	Pack density profile file.
CALC P1..PN	Calculate movement of jet.
END	Terminate program

1. Introduction.

The NIVA * JET. MIX is a program complex designed to compute the behaviour of a buoyant jet into a stratified ambient environment. It has the ability to take a various number of data and to save data for later use. The program can also be used to compute a density profile from given temperature and salinity at different depths.

2. Method.

This program analyses the problem of an inclined buoyant jet, mixing by entrainment into a stagnant environment of vertically varying density with stable stratification. The jet may be of two types:

a) Three-dimensional, with circular symmetry.

b) Two-dimensional, that is with practically infinite extension in one horisontal direction normal to jet velocities.

A system of differential equations has been derived based on the theoretical description of turbulant buoyant jet presented by Loh-Nien Fan and Normann H. Brooks, 1969 (1), and by John D. Ditmars 1969 (2).

2.1. Assumptions.

A 1. The fluid is incompressible.

A 2. Density-variations over the flow field are small compared to the reference density.

A 3. The vertical density gradient approximates a constant over the extension of a jet cross-section.

A 4. Density has linear mixing properties.

A 5. The flow is fully turbulent.

A 6. The flow is stationary.

A 7. The radius of curvature of the jet trajectory is much greater than the jet width.

A 8. Similarity over all cross-sections of the jet is assumed for the profiles of velocity, buoyancy and concentration of tracer. Gaussian profiles are good approximations.

A 9. Longitudinal dispersion may be neglected relative to longitudinal convection.

2.2. Definitions.

Fixed space coordinates are (x, y, z), with z in the vertical, downwards direction. The middle velocities of the jet over all cross-sections must lie in the same vertical plane, defined as the x, z - plane.

A jet trajectory (centerline) is defined in the xz - plane, through the centers of the assumed Gaussian profiles. The cross-sections, planes normal to the centerline, are defined by the distance s along the centerline from a chosen reference point. The points in such a cross-section are defined by polar coordinates (r, ∅) for a circular jet, and by the distance n in the xz - plane from the centerline to the point for a two-dimensional jet. The coordinates (s, r, ∅), (s, n, y) then define a point in space. Figures A1, A2 (Appendix 1) shows the coordinates for both situations.

The following quantities are defined :

a. Scalar fields in space:

Jet geometry: Circular	Two dimensional	
$u^*(s,r)$	$u^*(s,n)$	Velocity in s-direction.
$\rho_a^*(s,r,\phi)$	$\rho_a^*(s,n)$	"Undisturbed" density of environment (ambient density)
$\rho^*(s,r,\phi)$	$\rho^*(s,n)$	Jet density
$c^*(s,r,\phi)$	$c^*(s,n)$	Tracer concentration

b. Functions of s:

$u(s)$	centerline velocity in s-direction
$\rho_a(s)$	centerline value of ambient density
$\rho\ (s)$	centerline jet density
$c(s)$	centerline tracer cencentration
$b(s)$	characteristic jet width
$\Theta(s)$	angle between x- axis and jet trajectory

c. Constants.

g: acceleration of gravity

λ^2: turbulent Schmidt number, expressing the difference in dispersion coefficient for momentum and for tracers. Equation A(1) - A(3) implicitly define λ.

α: Entrainment coefficient, expressing the rate of mixing of the jet with the environment. This mixing is due to the jet turbulence, which disperses into the stagnant environment and absorbs it into the jet.

The volume flux Q through a cross-section thereby increases along the jet trajectory, and this increase of Q is given by:

$dQ/ds = 2\pi * \alpha ub$ in the circular case,

and

$dQ/ds = 2\alpha u$ in the two-dimensional case,

where Q = volume flux pr. length in y-direction.

dQ/ds may be understood as the inflow to the jet through the side boundary.

ρ_a = ambient density at the discharge point, used as reference density.

Gaussian profiles are assumed as follows:

For circular jet:

$$u^*(s, r) = u(s)\, e^{-r^2/b^2} \qquad A(1)$$

$$\rho_a^*(s,r,\phi) - \rho^*(s,r,\phi) = \left[\rho_a(s) - \rho(s)\right] e^{-r^2/\lambda^2 b^2} \qquad A(2)$$

$$c^*(s,r) = c(s)\, e^{-r^2/\lambda^2 b^2} \qquad A(3)$$

Nominal jet width: $W = \sqrt{2}\, b$ A(4)

For a two dimensional jet, the identical equations, with r replaced by n, are used.

2.3. Equations.

a) Circular symmetry.

Continuity relations for volume, x-momentum, z-momentum, buoyancy and tracer, together with two obvious geometric relations give the equations:

$$\frac{du}{ds} = -2\alpha \frac{u}{b} + \frac{2g\lambda^2}{\rho_o} \cdot \frac{\sin\Theta(\rho_a - \rho)}{u} \qquad A(5)$$

$$\frac{db}{ds} = 2\alpha - \frac{g\lambda^2}{\rho_o} \frac{b \sin\Theta\ (\rho_a - \rho)}{u^2} \qquad A(6)$$

$$\frac{d(\rho_a - \rho)}{ds} = - \frac{1+\lambda^2}{\lambda^2} \frac{d\rho_a}{dz} \sin\Theta - 2\alpha \frac{\rho_a - \rho}{b} \qquad A(7)$$

$$\frac{d\Theta}{ds} = \frac{2g\lambda^2}{\rho_o} \cdot \frac{\cos\Theta\ (\rho_a - \rho)}{u^2} \qquad A(8)$$

$$\frac{dx}{ds} = \cos\Theta \qquad A(9)$$

$$\frac{dz}{ds} = - \sin\Theta \qquad A(10)$$

$$\frac{d}{ds}(cub^2) = 0 \qquad A(11)$$

Equations A(5) - (10) constitute a system of simultaneous differential equations in the six dependent variables u, b, Θ, $(\rho_a - \rho)$, x, z, as functions of s.

Eq. A(11) integrates into an algebraic equation for the tracer concentration:

$$c = c_o \cdot \frac{u_o . b_o^2}{ub^2} \qquad A(12)$$

or for the centerline dilution $S = {}^{c_o}/c$:

$$S = \frac{ub^2}{u_o b^2} \qquad A(13)$$

Equations A(5)-(13) apply only to the zone of established flow, with gaussian profiles. A zone of flow establisment (zone 1) is therefore incorporated. The jet is assumed discharged from a circular hole of diameter D, and with uniform velocity U, density ρ_d, dilution 1, and at initial angle Θ_o. Deflection is neglected in zone 1, which is taken of length

$$s_1 = 6.2 \cdot D \qquad A(14)$$

and at the end of which a gaussian velocity profile with

$$u_1 = U \qquad A(15)$$

are assumed to be established. Continuity and geometric relations then give:

$$b_1 = D/\sqrt{2} \qquad A(16)$$

$$(\rho_a - \rho)_1 = (\rho_a(s_1) - \rho_d) \cdot \frac{1+\lambda^2}{2\lambda^2} \qquad A(17)$$

$$\Theta_1 = \Theta_o \qquad A(18)$$

$$x_1 = 6.2 \cdot D \cdot \cos\Theta \ (x_o \text{ is set to zero}) \qquad A(19)$$

$$Z_1 = \div 6.2 . D \sin \Theta + Z_o \qquad A(20)$$

$$S_1 = \frac{2\lambda^2}{1+\lambda^2} \qquad A(21)$$

Eq. A(15)-(20) **are used as initial values for the system** A(5)-(10), and A(21) is **used with** A(15), (16) **for correction of** A(13) **into:**

$$S = \frac{4\lambda^2}{1+\lambda^2} \cdot \frac{ub^2}{UD^2} \qquad A(22)$$

b) Two-dimensional jet.

The different geometry leads to the following changes of eg. A(5)-A(22):

$$\frac{du}{ds} = - \frac{2\alpha}{\sqrt{\pi}} \frac{u}{b} + \frac{\sqrt{2}g\lambda}{\rho_o} \cdot \frac{\sin\theta\ (\rho_a - \rho)}{u} \qquad A(5')$$

$$\frac{db}{ds} = \frac{4\alpha}{\sqrt{\pi}} - \frac{\sqrt{2}g\lambda}{\rho_o} \cdot \frac{b\ \sin\theta\ (\rho_a - \rho)}{u^2} \qquad A(6')$$

$$\frac{d(\rho_a - \rho)}{ds} = -\sqrt{\frac{1+\lambda^2}{\lambda^2}}\ \frac{d\rho_a}{dz} \sin\theta - \frac{2\alpha}{\sqrt{\pi}} \cdot \frac{\rho_a - \rho}{b} \qquad A(7')$$

$$\frac{d\theta}{ds} = \frac{\sqrt{2}g\lambda}{\rho_o} \cdot \frac{\cos\theta\ (\rho_o - \rho)}{u^2} \qquad A(8')$$

Eq. A(9) **and** A(10) **unchanged.**

$$\frac{d}{ds}(cub) = 0 \qquad A(11')$$

$$c = c_o \frac{u_o b_o}{u\ b} \qquad A(12')$$

$$S = \frac{ub}{u_o b_o} \qquad A(13')$$

With these initial values eq. A(5) - (10) are used up to the point of neutral density, that is the point where (ρ_a - ρ) passes zero. From here the program shifts to a simple potential energy calculation for the vertical movement, where entrainment and friction are neglected, and gravitation is considered the only active force. Such calculation is also used directly for special initial conditions. The details are given in section 2.6.

The jet is now discharged from an infinite slotof width B, with velocity, density, dilution and initial angle as before, and the endpoint of zone 1 is given by:

$$s_1 = 5.2 \cdot B \qquad A(14')$$

$$b_1 = \sqrt{\frac{2}{\pi}}\, B \qquad A(16')$$

$$(\rho_a - \rho)_1 = (\rho a - \rho_o) \cdot \sqrt{\frac{1+\lambda^2}{2\lambda^2}} \qquad A(17')$$

$$x_1 = 5.2 \cdot B \cos\Theta \qquad A(19')$$

$$z_1 = z_o - 5.2 \cdot B \cdot \sin\Theta \qquad A(20')$$

$$S_1 = \sqrt{\frac{2\lambda^2}{1+\lambda^2}} \qquad A(21')$$

with A(15) and A(18) unchanged.

The correction of A(13') becomes:

$$S = \sqrt{\frac{\pi\lambda^2}{1+\lambda^2}} \cdot \frac{ub}{UB} \qquad A(22')$$

From the point of neutral density, or for special initial conditions, the equations in section 2. 6 are used.

2.4. Numerical values of constants.

Suggested values for the constants α, λ (from lit. ref.[1]) are:

	α	λ
Round, buoyant jet:	0, 082	1, 16
Round, simple momentum jet:	0, 057	1, 16
Two-dimensional, buoyant jet:	0, 16	0, 89

For the last case, eq. A(21') gives $S_1 < 1$ which is obviously unphysical, and follows from the fact that we assume a gaussian distribution of tracer before it is fully established. A similar remark applies to eq. A(17'). This should give a relatively small error in ($\rho_a - \rho$) over a short s-interval after zone 1, increasing calculated values for terminal rizing heights or sinking depths a bit.

2.5. Density calculations.

Ambient and jet density are calculated from salinity and temperature as given in Maintenance Manual, Appendix C2 and C3, and are then assumed to mix linearly.

However, density as a function of temperature is convex upwards, with a positive apex at approximately $T=4^oC$. If molecular diffusion is effective in smoothing temperature profiles resulting from turbulent mixing, density no longer mixes linearly.

For mixing of two freshwater volumes of different temperatures, the actual resulting density will then be higher than the linearly mixed density occuring in the differential equations. (Cfr. mixing of two equal volumes of water with temperatures 0^oC and $8\ ^oC$ respectively).

For waters of different salinities (or other tracer concentrations affecting density) the density is approximately a function of T as before, linearly displaced in the vertical direction by salinity. If the mixing process is considered in two stages, the first stage being mixing of salt and the second mixing of temperature, it becomes clear that we have the same effect as for fresh water.

The result of the error in density will be that the calculated trajectory will rize higher, or sink less, than the actual trajectory, and the results will be on the safe side in terms of upwelling

2.6 Calculation of max/min depth.

When the jet passes the point of neutral density, and goes towards its terminal rizing height or sinking depth, the equations presented will not be valid physically, and mathematically may give convergence trouble because of low velocities.

For the part of the jet path after the point of neutral density we therefore neglect entrainment and friction, and assume the vertical acceleration to be

$$\frac{dv}{dt} = g \cdot \frac{\rho_a - \rho}{\rho} \qquad A(23)$$

with v = velocity in neg. z-direction (upwards).

v_o = u. sinθ as the initial value.

This is transformed into :

$$\frac{dv^2}{dz} = 2g \frac{\rho_a - \rho}{\rho} \qquad A(24)$$

which is solved in steps by the given piecewise linear density profile up to a z value where v = o or the limit in z is reached. Method is given in Maintenance Manual, section 3.6. Equation A(24) is also used directly for special initial conditions :

For $\Theta = 90^o$ if $\rho_a - \rho_d < 0$.

For $\Theta = -90^o$ if $\rho_a - \rho_d > 0$.

For $\Theta = -90^o$ or 90^o, if $\rho_a - \rho_d = 0$ and $\frac{d\rho_a}{dz} > 0$.

The program is therefore hardly of any use for those conditions: for a heavy jet in vertical upwards direction, and for a light jet in vertical downwards direction.

For most normal initial conditions, however, the procedure chosen will give reasonable results, eq. (A(5) - (13) will be used up to the point of neutral density, and eq. A(24) will then give an upper limit for max. depth, or a lower limit for min. depth.

3. Accuracy.

3.1. Choice of step length.

The differential equations A(5) - (13) are automatically solved to a preset accuracy, regulated by the program, and independent of DELTAS. The distance between output points is given by DELTAS.

3.2. Density profile intervals.

The density gradient is taken by program to be linear between given points. It is, therefore, important to use short intervals in areas where the density changes rapidly.

4. User interface.

This program is specially designed to be run from an interactive terminal. The run is divided into different kinds of modi: a)Control mode. b)Zero mode. c)Directive mode. Having got connection with the computer by calling up and typing site identification, the following control statement must be written, assuming running against the Univac 1100 Series operating system :

```
"RUN run-id, account-no, project
      Initiates run
"ASG, option   filename 1., F
"ASG, option   filename 2., F
"USE 7.,       filename 1.
"USE 8.,       filename 2.
```

Assignes files for saving of data. The filenames are chosen by user, but the numbers 7 and 8 are obligatory. The same pair of files must always be used together. For choice of option, see operating systems manual. (UP - 4144).

"XQT NIVA*JET.MIX

This starts program execution and sets run in zero mode.*) That means system is ready to take one of the following directives. Each directive sets run in one of 19 directive modi. On return from a directive mode, run is back in zero mode, except END mode, when run goes back to control mode.

4.1. HELP.

Prints a question and waits for one of the letters I, O, D or F as answer. Prints out information of input, output, directives or file handling, respectively.

4.2. CIN.

Prints a heading and waits for input of five constants:

DELTAS	:	Step length along jet curve in m.
XLIM	:	Max. distance from discharge in m.
GRAV	:	Acceleration of gravity in m/s^2.
ALPHA	:	Entrainment coefficient.
LAMBDA	:	Squareroot of Schmidt number.

4.3. CCOR.

Prints out heading and old values and waits for corrected values of one or more constants. As many constants are corrected as the number of fields in the input line. An asterisk (*) leaves the constant unchanged.

4.4. CSAV.

Saves current constants (if any) on file unit 7 for later use.

*) For use from cards :
"XQT NIVA*JET. MIX/CARD

4.5. COUT.

Prints out current constants (if any) or constants from file.

4.6. CGET.

Reads constants from file 7.

4.7. JIN.

Prints heading and wait for 1 or 2 as answer. 1 means two-dimensional jet, 2 means round.

Then prints new heading and waits for input of
OUTFALL SITE: Any 1-6 characters.
MANIFOLD NO: Integer number, not more than six digits.
Then prints third heading and waits for input of one integer number and five real numbers:

N:	Discharge hole no.
DEPTH(N):	Discharge depth in m.
DIST(N):	Discharge distance from shore in m.
DEFF(N):	Effective diameter of hole in m.
THETA(N):	Elevation angle of discharge in degrees.
U(N):	Initial velocity of jet in m/s.

When one line is inputted, the same line is returned as a control, and it then waits for a new line of the same kind. A maximum of ten lines of this kind may be inputted. The input may be stopped before by writing -1 as the first item of the line.

4.8. JCOR.

Correction of values inputted by JIN. Asterisk (*) means unchanged value. As many values in one line are corrected as the number of items in the correction line. If the whole line is to be unchanged, one asterisk is typed in. Correction is stopped by typing -1 as first item in the line. Old values are always printed out before corrected values are expected.

4.9. PIN P

Input of density profile with number $P(0 \leq N \leq 100)$.
Prints heading and waits for input of:
STATION: Any 1-6 characters.
REG. TIME: Two items, each any 1-6 charcters.
DENSWW: Real number, density of waste water in kg/l.
Prints new heading and waits for input of minimum 2, maximum 40 sets of
DEPTH: Depth in m.
TEMP: Temperature in degrees centigrade, (or density).
SAL: Salinity in 0/00, (or an arbitrary negative number).

These data has to be given in sequence from the uppermost depth (closest to surface) and down. Zero salinity gives fresh water. The corresponding density is computed for each inputted line. Input is stopped by typing DEPTH= -1 or when 40 lines have been inputted.

The density can be given directly by typing in density instead of temperature. This is indicated by giving a negative salinity.

4.10. PCOR.

Same data as PIN, same procedure as JCOR.

4.11. POUT P1 P2 ....PN

Prints out specified density profiles ($N \leq 6$). Prints out all data given by PIN or PCOR. In addition, the corresponding density is printed out. After execution, the last printed density profile, is the current one.

4.12. PSAV.

Saves current density profile on file unit 8. Should always be used after PIN or PCOR if the density profile is to be used later.

4.13. PGET P.

Makes density profile no. P the current one. The earlier current profile is lost if it has not been saved. PGET is automatically called by POUT and CALC.

4.14. PLIB.

Prints out list of saved profiles where:

PROFILE:	Profile number.
STATION:	Name of station.
REGTIME:	Registration time.
NO OF DEPTHS:	Number of depths given in profile.

4.15. INIT.

Initiates new file No. 8.
Must always be used when a new file No. 8 has been introduced. If this directive is used when the file contains data, these data are all lost.

4.16. PDEL P1 P2....PN.

Deletes the specified density profiles from file 8.

4.17. PPAC.

Packs file No. 8. Should be used when density profiles has been deleted or corrected or if a new profile with an earlier used profile No. has been saved. This prevents the file from growing too much.

4.18. CALC P1 P2.....PN.

Does the calculation with the discharge data given by JIN or JCOR, the constants given by CIN or CCOR or earlier CSAV and the density profiles specified.

The normal output gives:
MANIFOLD NO.
OUTFALL SITE
DENSITY PROFILE NO.

DISCHARGE N DEPTH (N) DIST (N) DEFF (N) THETA (N) U (N)	Data given by JIN or JCOR

DENSWW   Given by PIN or PCOR.
And the computed values for each step of length DELTAS:
DEPTH (J): "y-coordinate" of curve
DIST(J):   "x-coordinate" of curve (from discharge)
WIDTH (J): Width of jet at point (x, y) in meters.
DILUT (J): Relative dilution of jet at point (x, y).
AMBDENS: Ambient density at point (x, y).
VEL (J):   Jet velocity at point (x, y) in m/s.
The following special lines may be printed:
y x DEPTH/MIN
y x DEPTH/MAX
y x DEPTH/NEUTRAL
y x XLIMIT REACHED
y DEPTHLIM/MIN REACHED
y DEPTHLIM/MAX REACHED
The meaning is:
DEPTH/MIN or DEPTH/MAX: The tangent of the curve is horizontal, i.e. zero derivative. Note that MIN denotes minimal depth which is a top of the curve, and vice versa.
DEPTH/NEUTRAL: Zero density difference between jet and ambient fluid.
XLIMIT REACHED: Given value of XLIM (one of the constants) has been reached during calculation.
DEPTHLIM/MIN REACHED or DEPTHLIM/MAX REACHED:
Calculation has come outside the defined depth interval of the density profile.

Diagnostics and error messages:
YOU MUST INPUT JET PARAMETERS.

Program is going back to zero mode and input must be done by JIN. Then a new CALC P1 P2.... PN must be written to get back to CALC mode.

DISCHARGE IS OUTSIDE DEFINED DENSITY AREA.

Selfexplanatory. The density profile must be extended or a new discharge depth must be given.

UNSTABLE STRATIFICATION. DENSITY GRADIENT IS SET TO ZERO.

The density is found to decrease going downwards. The density gradient is then set to zero and calculation continued.

NOT CONVERGING.

Calculation goes on without finding anything of interest.

4.19. END.

Terminates program and brings one back to control mode. Must always be the last directive in a run.

4.20. General remarks on input.

All written by user in program mode is input. All input is in free format; that means that the situation on the line is indifferent. Each input item can have from 1 to six characters and must be separated from the others by at least one space. The number of input items is important, except in correction lines where the number of items may be from one to maximum. Writing directives, the first item must be the directive. Six other items may be written.

For directives CALC, PDEL, POUT they must be integer numbers denoting density profiles. For directives PIN and PGET the first item after the directive must be a profile number. The other items are ignored. For all the other directives, only the directive itself is taken into consideration, all the other items are ignored.

Back in control mode, the last statements must be:

```
"FREE.B  7.
"FREE, B  8.
"FIN
```

5. Limitations.

Only one set of constants can be saved. It is, however, possible to have one current and one saved set of constants.

Discharge data for one manifold at one outfall site with a maximum of ten data sets can be run simultaneously.

Up to one hundred density profiles can be saved on one file. Data must be given for minimum 2, maximum 40 different depths.

A maximum of six density profiles can be specified in a CALC, POUT or PDEL directive.

6. Computer information.

a) The program is written in FORTRAN IV. A few special UNIVAC FORTRAN features has been used. One subroutine is written in UNIVAC 1100-series Assembler.

b) Core requirements of program: 18000 words decimal.
Word-length 36 bits.

c) There are two external files:
Unit 7: One logical record of 6 words.
Unit 8: DATRAN file. Max 16 700 words.
Minimum 400 words with no data saved.

d) Source program: Close to 2000 cards.

e) Typical run-time (CPU-time) per density profile per discharge data set: 0.5 to 1.0 sec.

f) The program has been tested on A/S Computas' UNIVAC 1108 both from cards and from teletype. On machine compatibility, see a).

7. Examples.

A typical run is shown in Appendix 2.

8. Literature references.

1. Numerical solutions of turbulent buoyant jet problems, by Fan & Brooks. Report No. KH-R-18, January 69, California Institute of technology

2. Computer program for round buoyant jets into stratified ambient enviroments by John D. Ditmars. Technical Memorandum 69-1, March 1969, California Institute of technology.

3. Mixing of a jet into a stratified ambinet environment, by Bjerkeng and Lesjø. Computas Report No. 73-3, January 1973.

Appendix 1.

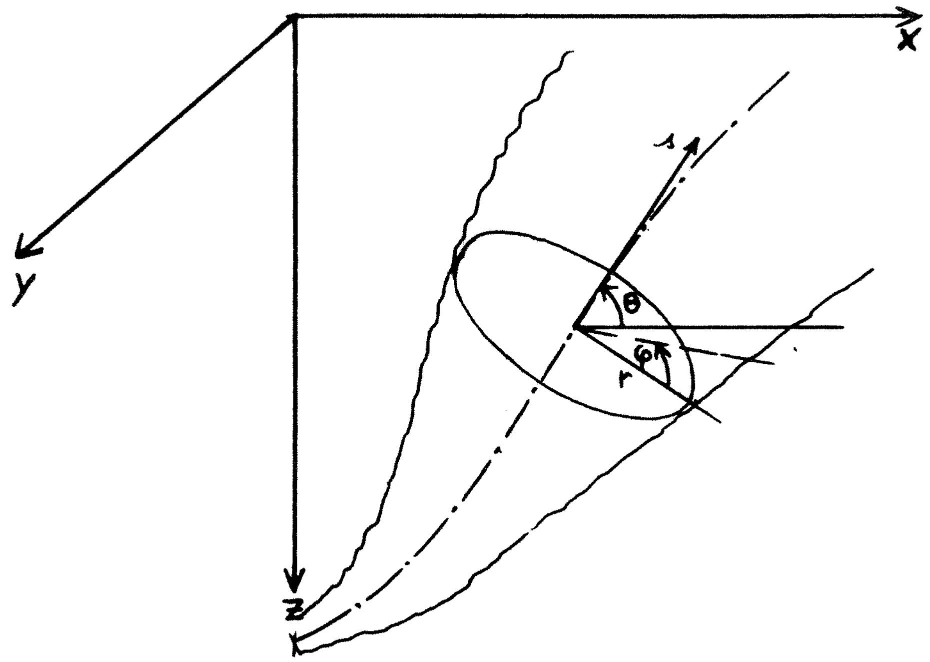

fig. A.1 Circular symmetric jet.

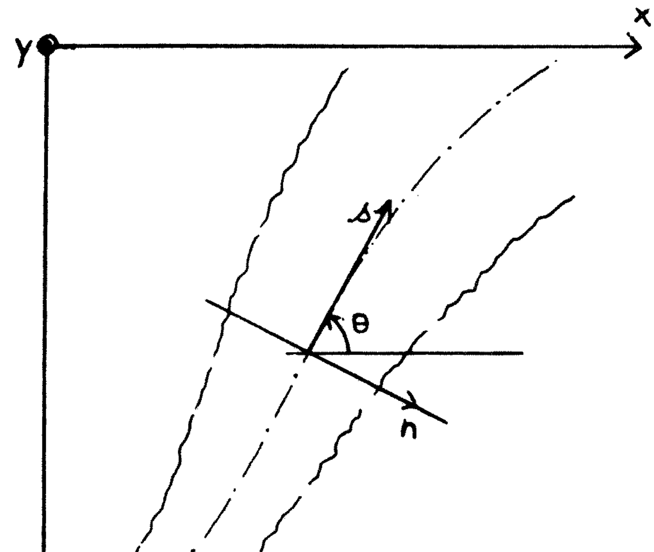

fig. A.2 Two-dimensional jet.

Appendix 2.

NB! All input is underlined.

```
A/S FJERNDATA TIME/SHARING EXEC-8 VERS 2670158*014A
R-BOOT: FEB 02,73 AT 08:31:15 T-BOOT: JAN 30,73 AT 02:45:51
@RUN [redacted]
DATE: 020273          TIME: 131012
@ASG,A NIVA*KONST.
READY
@USE 7.,NIVA*KONST.
READY
@USE 8.,NIVA*PROF.
READY
@ASG,A 8.
READY
@XQT NIVA*JET.MIX


 JET MIXING PROGRAM READY
 GIVE FIRST DIRECTIVE:
INIT
 NEW FILE READY FOR USE.

 GIVE NEW DIRECTIVE:
CIN
 WRITE:
 DELTAS XLIM GRAV ALPHA LAMBDA
5 1000 9.81 0.082 1.16

 GIVE NEW DIRECTIVE:
CSAV

 GIVE NEW DIRECTIVE:
PIN 1
 WRITE STATION, REG.TIME AND DENSWW:
DK1 11/1 71 1.0
 WRITE:
 DEPTH    TEMP    SAL
0 3.3 28.4
1 3.6 28.5
5. 5.3 30.4
10 6.3 30.7
12. 7.1 31.6
14 7.1 31.6
16 8.6 32.6
20 8.8 32.69
25 8.7 32.9
30 8.4 33.02
40 7.9 33.11 *DEL*
40 7.9 33.1
55 7.3 33.11
80 6.9 33.18
-1

 GIVE NEW DIRECTIVE:
PSAV
```

```
 GIVE NEW DIRECTIVE:
PLIB
 PROFILE  STATION        REGTIME  NO. OF DEPTHS
        1       DK1    11/1      71     13
        2       DK1    22/3      71      8
        3       FL1    22/3      71      9
        4       GL1    22/3      71     15
        5       GL1    17/6      71     10
        6       FL1    17/6      71      9
        7       DK1    17/6      71      9

 GIVE NEW DIRECTIVE:
PIN 8
 WRITE STATION, REG.TIME AND DENSWW:
DK1 13/8 1971
 ERROR IN INPUT.
 WRITE STATION, REG.TIME AND DENSWW:
DK1 13/8 71 1
 WRITE:
 DEPTH     TEMP     SAL

**TAPE START**
0 19.6 22.7
1 18.6 23
2 18.6 23
3 18.5 23.2
4 18.5 23.3
5 18.3 23.5
6 18.1 23.4
7 18 23.5
8(98 23.5
9 17.8 23.6
10 17.7 23.7
9: 14.9 25.4
14 13.2 27
16 11.; 28.5
18 9.9 29.5
20 9.2 31.1
25 8 31.5
30 7.6 32.5
35 7.4 32.42
40 7.2 32.81
50 6.9 33.05
60 6.7 33.24
80 6.3 33.36

END OF TAPE
 ERROR IN INPUT.
THE INTERPRETATION OF MEANINGLESS INPUT WAS ATTEMPTED.
THE FOLLOWING RECORD IS ERRONEOUS OR DOES NOT CORRESPOND TO FORMAT SPECI
      FICATIONS:
    9:  14.9  25.4
  I/O  CALLED  AT  SEQUENCE  NUMBER 000163  OF  PIN
THE INTERPRETATION OF MEANINGLESS INPUT WAS ATTEMPTED.
THE FOLLOWING RECORD IS ERRONEOUS OR DOES NOT CORRESPOND TO FORMAT SPECI
      FICATIONS:
    16  11.;  28.5
  I/O  CALLED  AT  SEQUENCE  NUMBER 000163  OF  PIN
```

```
-1

 GIVE NEW DIRECTIVE:
PCOR
 PROFILE      8
 STATION         REGTIME    DENSWW
     DK1   13/8       71    1.00000
*
     DEPTH        TEMP        SAL
       .00        19.60       22.70
*
      1.00        18.60       23.00
*
      2.00        18.60       23.00
*
      3.00        18.50       23.20
*
      4.00        18.50       23.30
*
      5.00        18.30       23.50
*
      6.00        18.10       23.40
*
      7.00        18.00       23.50
*
      9.00        17.80       23.60
*
     10.00        17.70       23.70
-1

 GIVE NEW DIRECTIVE:
JIN
 ROUND OR TWO-DIMENSIONAL JET,WRITE 2 OR 1, RESP.
2
 WRITE OUTFALL SITE AND MANIFOLD NO:
VESTFJ  1
 WRITE:
 N  DEPTH(N) DIST(N) DEFF(N) THETA(N) U(N)
1 40 1000 .2 0 4
-1

 GIVE NEW DIRECTIVE:
CALC 8


  INITIAL JET MIXING (ALL DATA IN M, SEC AND DEG)

 MANIFOLD NO    .  1  OUTFALL SITE NO VESTFJ   DENSITY PROFILE NO    8


 DISCHARGE N  DEPTH(N)   DIST(N)   DEFF(N)  THETA(N).   U(N)   DENSWW
           1     40.00   1000.00      .200        .0    4.00  1.00000

  DEPTH(J)  DIST(J)  WIDTH(J)  DILUT(J)  AMBDENS  VEL(J)
    38.82     6.02       .90      7.96  1.02561     .69
    34.93     9.39      1.45     16.62  1.02536     .55
    30.19    11.51      1.95     27.53  1.02539     .50
    27.71    12.31  DEPTH/NEUTRAL
    17.23 EXTREMAL DEPTH ESTIMATED BY POTENTIAL CALCULATION
    25.29    13.23      3.60     39.64  1.02637     .21
    24.98    13.61  DEPTH/MIN
```

A. 2. 4.

```
  GIVE NEW DIRECTIVE:
 END
  PROGRAM TERMINATED.
  ALL BUFFERS DUMPED ON FILE
@FIN

    RUNID: [redacted]    ACCOUNT: [redacted]          PROJECT: [redacted]          PR
      IORITY : C
    TIME: 00:00:0[redacted]    IN: [redacted]     OUT: 0          PAGES:   [redacted]
    INITIATION  TIME:    11:59:57-FEB 21,1973
    TERMINATION TIME:    12:19:52-FEB 21,1973
REKLAMASJONSFRIST ER 5 DAGER.

                      ****LINE INACTIVE****
```