COMPUTER TECHNIQUES IN THE CAPACITY DESIGN OF PIPE NETWORKS

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الحاسبات الالكترونية في تصميم شبكات الانابيب

الدكتور صباح الناصري
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خلاصة المقاله

اهتم كثير من المهندسين والباحثين خلال السنوات الاخيرة في استعالات الحاسبات الالكترونية في تحليل شبكات الانابيب ولم ينجز نسبيا الا قليلا من البحوث التي تهتم في جانب تصميم هذه الشبكات.

يتناول هذا البحث طريقة جديدة لتصميم احجام الانابيب للشبكات وحسب الضغوط والكميات من الماء المطلوبة من قبل المستهلكين. ويلخص البحث برنامج الحاسبة الالكترونية الذي تم اعداده لهذا الغرض والذي تميز بامكانية استعاله لاى شبكة من الانابيب مهما كان حجمها او تعقيدها.

ان المعلومات المطلوبة تغذيتها لبرنامج الحاسبة صممت لتكون محدوده وبابسط شكل لضمان استغلال البرنامج من قبل جميع المهندسين العاملين في هذا الحقل.

اما نتائج التصميم التي يمكن الحصول عليها بدقائق محدودة من خلال الحاسبة الالكترونية فلقد اعدت لتكون على شكل جداول واضحة ومبسطة وبنفس الوقت اعطى الخيار في امكانية الحصول على النتائج مؤشرة على مخطط الشبكة التي يتم اتوماتيكيا رسمه بواسطة الحاسبة الالكترونية.

ABSTRACT:

This article summarizes a new method for the capacity design of pipe networks using digital computers.

The method is based on successive iteration technique.

The input data and output results of the computer program are simplified to enable wide uses of the program. A sub-program is attached to the main one to provide an automatic graphical output of the design. hence reducing the engineers efforts in examining and drawing the results. and at the same time minimizing human errors. This sub-program is optional.

The units used with the program can be metric or British. a parameter is introduced to take care of. throughout the analysis. this choice.

INTRODUCTION:

Many engineers and researchers have been involved in the uses of computers on the analysis side of pipe networks(Ref.7-9) while less work has been done on the design side. This may be due to the fact that engineers are generally concerned with the problems of exisiting networks. trying to find out how the system is operating and suggest modifications for improvement.

The increase in the number of new cities required in many developing countries. made it necessary to give more thought to develop fast methods for the design of networks for water supply.

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Various methods and computer programs (Ref. 1. 2. 3. 4.) have been developed for this task: however most of those are rather difficult for many designers to follow and require much time and more experience if they are to be used.

The article summerizes the development of method and computer program for directly sizing pipes in a network when demands and all heads are fixed according to the consumers requirements. The method developed involves successive analysis of the network. The analysis is based on the node balance iteration technique.[Ref5]

The input data for the program is simplified and reduce to the minimum. Emphasis is made to develop a simplified computer output which can be easily examined and interperated by the engineer. The computer program provides the user with a choice of tabulated results or graphical output. In the latter case a complete configuration of the network, together with the final results for the flows,pressures and pipe diameters are drawn.

Review of Previous Work

Karmeli[1] was one of the early researchers on the uses of digital computer in the design of pipe networks. He employed linear programs to design hydraulic networks. Their formulation is only valid in branch networks, i.e. for network without loops.

The treatment of networks with loops by non-linear programing was attempted by Jacoby[2]. The netowrk presented was rather simple.

Waranatada[3] suggested a program to calculate the least cost of a design network, and it was based on jacobys method. He concluded that this procedure would require a good deal of engineering judgement.

Most recent work done in this field is by Rasmusen[6]. He presents a heuristic procedure for optimization of water supply networks. The procedure calculates a least economic cost solution.

Boundary Conditions in Pipe Network Design

Basically there are two main cases, in the terms of boundary conditions, in the design of pipe networks. In the first one the boundary conditions are fixed pressure and draw-off, or supply, at the nodes which are assigned according to the demands: the task is then to compute the size of the pipes required. In the second case the boundary conditions are fixed flow through each pipe with fixed supply, or draw-off at the nodes, the task is then to calculate the pipe sizes required irrespective of the pressure at the nodes.

This article will be concerned with the first case since in practice the engineer is generally interested in satisfying the consumers at each area to get sufficient pressure and supply.

Details of the Design Method Developed

The method developed and programmed is summarized below:-

1— The pressure at the nodes are fixed by the user according to the need.

2— The design velocity of the flow"V" through all pipes is assumed between 3 to 5 fps (0.92-1.5 m/s). This could be altered if needed.

3— The theortical diameters "D" are computed using equation (2) below which is a rearrangement of Hazen-William's formula:-[Ref.5]

$$H = \frac{4.87\,L}{C^{n} \times D^{4.87}}\,Q^{n} \qquad \text{.................(1)}$$

Since $Q = V.\frac{\pi}{4}D$ (for circular section).

$$D = \left| \frac{4.87 . L(\frac{V \times \pi}{C \times 4})^n}{|H|} \right|^{(\frac{1}{4.87 - 2n})} \quad \text{..............(2)}$$

Where L = length of the pipe in feet. H = head loss in feet.

Q = discharge in cfs. C = Hazen Williams cofficient.

n = constant depends on Reynolds number and the kind of pipe.

4— The practicle diameters. i.e. the nearset mafucturers sizes available. are found for the above computed diameters.

5— The network is analysed for the practical diameters and required pressures using the following steps:

(a) The value of residual head "ΔH" is calculated to the first node considered using equation (7)*.

$$\Delta H = \frac{n\Sigma Q}{\Sigma Q / H} + Q_t \text{ ....(7)}$$

(b) The corrected head at the first node is evaluated using the following equation.

$HN = HN_i + H$

Where HN & HN_i are the new and initial head respectively.

(c) Steps (a) & (b) are carried on the next node. and so on. using the latest values of the pressure at the nodes connected to it. to make one complete cycle of network-relaxation.

(d) The above relaxation process is contiunued until a stage is reached so that the residual head and flow at all the nodes is less than the allowables.

(e) The new flow in each pipe is calculated using Hazen-William's formula.

6 The new theoretical pipes diameters are computed for the required pressures and from the flows found in the previous step: hence the corresponding practical diameter are assigned.

7 The newly computed practical diameter is checked with the previously computed one for each pipe. if it is the same for each pipe then the results are printed. and if it is not. then steps from 5 to 7 are repeated.

Derivation of the Correction Formula

Consider the general head loss-flow formula:

$$H = KQ^n \quad \text{.......... (3)}$$

Where H and Q are the initial guesses of head loss and quantity in a pipe respectively. and the improved values are (H + ΔH) and (Q + ΔQ) then:

$$H + \Delta H = K (Q + \Delta Q)^n \quad \text{..... (4a)}$$

* See next section for the derivation

$$H + \Delta H = KQn\,(1 + \frac{\Delta Q}{Q})^n \qquad \text{......(4b)}$$

Expanding by the binomial theorem:

$$H + \Delta H = KQ^n\,(1 + n\frac{\Delta Q}{Q} + \frac{n(n-1)}{21}(\frac{\Delta Q}{Q}\quad) \qquad \text{....(5a)}$$

Assuming that ΔQ is small compared with Q. in other words that the initial assumed values for flows are nearly correct. the third and second terms may be neglected. then.

$$H + \Delta H = KQ^n\,(1 + \frac{n\Delta Q}{Q}) \qquad \text{........(5b)}$$

$$H + \Delta H = KQ^n + n\Delta QK\frac{Q^n}{Q} \qquad \text{.........(5c)}$$

Since $H = KQn$ ....(3)

Then equ. (5c) becomes:

$$H + \Delta H = H + n\Delta Q\frac{H}{Q}$$

$$\Delta H = n\Delta Q\frac{H}{Q}$$

$$H = \frac{n\Delta Q}{Q/H} \qquad \text{...........(5d)}$$

The value of ΔQ for each individual pipe is not known. but only for all pipes connected to a node (junction). so that

$$H = \frac{n\Sigma Q}{\Sigma Q/H} \qquad \text{...........(6)}$$

Equation (6) above is true when there is no draw-off or supply at the node. however if there is draw-off or supply (Qt) at the node then the equation becomes

$$H = \frac{n\Sigma Q}{\Sigma Q/H} + Qt \qquad \text{..........(7)}$$

Description of the Computer Program

The computer program developed consists of three parts. The main part in the analysis and design of the network, which is based on the method explained earlier. The other two parts are sub-programs called at relevant intervals in the main program. The first sub-program is to select the practical size of diameter corresponding to the computed (theoratical) diameter; the practical sizes fixed are the currently known ones by engineers, new sizes can be added if desired. The second sub-program provides the graphical output of the results. The complete text of the main program is given in the next section.

Meaning of Parameters Used in the Coumputer Program

Input parameters:

TITLE	: title of the problem or project.
XN	: value of n in the equation $H = KQ^n$.
NN	: number of the nodes.
NUNIT	: parameter refers to the type of units used
ALH	: allowable (residual) head in each node.
ALQ	: allowable (residual) flow in each node.
N_1(I1)	: no. of node.
H(I1)	: total pressure at the node.
QT(I1)	: quantity of draw-off or supply at the node.
K_4(I1)	: number of pipes incident at the node.
EH(I1)	: elevation of the ground level at the node.
I1	: subscript of the above five parameters and refers to the node number under consideration.
I,J	: subscripts in which I refers to the pipe number. J refers to the node number under consideration.
N_2(I,J)	: the first node number.
N_3(I,J)	: the second node number.
AL(I,J)	: length of the pipe.
D(I,J)	: diameter of the pipe.
C(I,J)	: Hazen-William coefficent for the pipe.

Operation parameters:

R(I,J)	: value of K in general head loss equation $H = KQ^n$.
Q(I,J)	: flow in the pipe.
Z(I,J)	: value of the term $\left\lvert \frac{Q}{nH} \right\rvert$
HH(JJ)	: head loss between node under consideration (first node) and second node.
SUMZ	: summation of parameter Z(I,J) at the node.
SUMQ	: algebraic sum of quantity at the node.
DH(JJ)	: residual head at the node.

SUMQT(JJ)	: algebraic sum of the term (SUMQ+QT(JJ)).
I,J	: as defined in the input parameter section.
JJ	: subscript which refers to the node number under consideration.
NC	: number of relaxation cycles.

Text of the Computer Program

```
          DIMENSION H(30),QT (30) ,K4 (30) ,N2 (7,30) N3(7,30) ,AL (7,30) ,Z (7,30) ,D
          1H(30) ,Q(7,30) ,D (7,30) ,C(7,30) ,R (7,30) ,N1 (30) ,HH1 (30) ,SUMQT (30) ,EH
          (3 20) ,TITLE(20) ,AK (7,30) ,HL (7,30) ,HR(30) ,FD (7,30)
          PI=3.1415
          IC=0
          NC=0
          READ (2,3) (TITLE (I) ,I=1, 20)
3         FORMAT (20A4)
          READ (2,4) XN,NN,NUNIT ,ALH,ALQ,V
4         FORMAT (F10.0,2I5,3F10.0)
          READ (2,2) (N1(11) ,H(11) ,QT (11) ,K4(11) ,EH(11) ,11=1,NN)
2         FORMAT(15,2F10.0,15,F10.0)
          AA=1./XN
          DO 444 J=1,NN
          K3=K4(J)
          IF (K3)6,444,6
6         DO 444 I=1 ,K3
          READ (2,1) N2(I,J) ,N3(I,J) ,AL(I,J) ,C(I,J)
1         FORMAT (2I5,2F10.0)
444       CONTINUE
          WRITE (3,30) (TITLE(I) ,I=1,20)
30        FORMAT (1H1 ,/ / / / / / 10X,20A4)
          WRITE(3,3031)
3031      FORMAT (10X,60 ( ' — ' ),/ /)
          WRITE (3,3030)
3030      FORMAT (30X, ' INPUT DATA ' , / ,28X, 14 (' * ' ). / /)
          WRITE(3,3032) XN,NN,NUNIT,ALH,ALQ,V
3032      FORMAT (10X, ' XN       = ' ,F5.3,/ ,10X, ' NN       = ' ,I5,/,10X, ' NUNIT  ='
          ,I5,/,
          110X, ' ALH       = ' ,F6.4,/,10X, ' ALQ       = ' ,F5.3,/,10X, ' V       = ' ,F5.2,/ /
          / )
          WRITE(3,3036)
3036      FORMAT (19X, ' INITIAL GUESS OF ' ,3X, ' DRAW-OFF ' ,3X, ' NUMBER OF '
          GRO1UNd ' ,/ ,10X, ' NODE ' ,5X, ' TOTAL PRESSURE ' ,5X, ' (SUPPLY) ' ,5X, '
          PIPES ' ,5X, 2 ' LEVEL ' )
          IF(NUNIT-2) 12,21,13
```

```
12      WRITE(3,3033)
3033    FORMAT (23X, ' (FEET) ',10X, ' (CFS) ',17X, ' (FEET) ', /)
        GO TO 14
21      WRITE(3,3035)
3035    FORMAT (23X, ' (FEET) ',10X, ' (GPM) ',17X, ' (FEET) ', /)
        GO TO 14
13      WRITE(3,35)
35      FORMAT(22X, ' (METER) ',BX, ' (CU.M /H) ',15X, ' (METER) ', /)
14      WRITE(3,3034) (N1(11),H(11),QT(11),K4(11),EH(11),11=1,NN)
3034    FORMAT(7X,16,7X,F10.3,4X,15,3X,F10.3)
        WRITE(3,4044)
4044    FORMAT ( / / /12X, ' FIRST NODE ',5X, ' SECOND NODE ',5X, ' LENGTH ' vκ⊂v
        ' C ' )
        IF(NUNIT-2)17,17,18
17      WRITE(3,4455)
4455    FORMAT(42X, ' (FEET) ', /)
        GO TO 19
18      WRITE(3,4405)
4405    FORMAT(43X, ' (METER) ', /)
19      DO 405 J=1,NN
        K3=K4(J)
        IF(K3)7,405,7
7       DO 405 I=1,K3
        WRITE(3,4055) N2(I,J),N3(I,J),AL(I,J),C(I,J)
4055    FORMAT(12X,15,10X,15,F16.2,5X,F6.2)
405     CONTINUE
        IF(NUNIT-2)31,25,26
25      DO 1001 J=1,NN
        JJ=N1(J)
        QT(JJ)=QT(JJ) / 448.8
1001    CONTINUE
        GO TO 31
26      V=V*3.281
        DO 1002 J=1,NN
        JJ=N1(J)
        K3=K4(J)
        H(JJ)=H(JJ)*3.281
        QT(JJ)=QT(JJ)*10.**3 / (3.785*60.*448.8)
        IF(K3)8,1002,8
8       DO 1002 I=1,K3
        AL(I,J)=AL(I,J)*3.281
1002    CONTINUE
31      DO 76 J=1,NN
```

```
      K3=K4(J)
      JJ=N1(J)
      IF(K3)166,76,166
166   DO 76 I=1,K3
      AK(I,J)=4.78*AL(I,J)*( (V*PI/ (C(I,J)*4.) )**XN)
76    CONTINUE
      DO 175 J=1,NN
      JJ=N1(J)
      K3=K4(J)
      HR(JJ)=H(JJ)
      IF(K3)179,175,179
179   DO 175 I=1,K3
      K1=N3(I,J)
      HH(JJ)=H(JJ)-H(K1)
      D(I,J)=(AK(I,J) / ABS(HH(JJ) ) )**(1./ (4.87-2.*XN) )*12.
      DIM=D(I,J) / 12.
      R(I,J)=4.78*AL(I,J) / (C (I,J)**XN*DIM**4.87)
      Q(I,J)=ABS(HH(JJ) / R(I,J) )**AA
      D(I,J)=SQRT(4.*Q(I,J) / (PI*V) )
      DD=D(I,J)
      CALL DIA(DD)
      D(I,J)=DD
      FD(I,J)=D(I,J)
175   CONTINUE
173   DO 180 J=1,NN
      JJ=N1(J)
      K3=K4(J)
      IF(K3)171,180,171
171   DO 180 I=1,K3
      DIM=D(I,J) / 12.
      R(I,J)=4.78*AL(I,J) / (C(I,J)**XN*DIM**4.87)
180   CONTINUE
1777  DO 80 J=1,NN
      K3=K4(J)
      JJ=N1(J)
      IF(K3)10,89,10
89    DH(JJ)=0.0
      SUMQT(JJ)=0.0
      GO TO 80
10    SUMQ=0.0
      SUMZ=0.0
      DO 20 I=1,K3
      K1=N3(I,J)
```

```
            HH(JJ)=H(JJ)-H(K1)
            R1=ABS(HH(JJ) )
            R2=R(I,J)
            Q(I,J)=(R1 /R2)**AA
            IF(HH(JJ) )70,800,800
70          Q(I,J)=-Q(I,J)
            SUMQ=SUMQ+Q(I,J)
            GO TO 37
800         SUMQ=SUMQ+Q(I,J)
37          XX=XN*HH(JJ)
            Z(I,J)=ABS(Q(I,J)  / XX)
            SUMZ=SUMZ+Z(I,J)
20          CONTINUE
            DH(JJ)=-(SUMQ+QT(JJ) )  /SUMZ
            SUMQT(JJ)=SUMQ+QT(JJ)
            H(JJ)=H(JJ)+DH(JJ)
80          CONTINUE
            IF(IC-0)123,123,153
123         DO 4411 J=1,NN
            JJ=N1(J)
            IF(ABS(SUMQT(JJ) )-0.01)4411,4411,1777
4411        CONTINUE
            GO TO 411
153         DO 40 J=1,NN
            K3=K4(J)
            JJ=N1(J)
            IF(ABS(DH(JJ) )-ALh)45,41,41
45          IF(ABS(SUMQT(JJ) )-ALQ)47,41,41
47          IF(K3)3311,40,3311
3311        DO 40 I=1,K3
            IF(ABS(D(I,J)-FD(I,J) )-0.1)40,40,411
40          CONTINUE
            GO TO 181
41          NC=Nc+1
            GO TO 1777
411         NC=0
            IC=IC+1
            DO 5000 J=1,NN
            K3=K4(J)
            JJ=N1(J)
            H(JJ)=HR(JJ)
            IF(K3)5001,5000,5001
5001        DO 5000 I=1,K3
```

```
      FD(I,J) = D(I,J)
      K1 = N3(I,J)
      HHLL = HR(JJ) - HR(K1)
      D(I,J) = (4.87*AL(I,J)*ABS(Q(I,J) )**XN / (C(I,J)**XN*ABS(HHLL) )))**(1./*4.87)
      D(I,J = D(I,J)*12.
      DD = D(I,J)
      CALL DIA(DD)
      D(I,J) = DD
5000  CONTINUE
      GO TO 173
181   WRITE(3,300)
300   FORMAT(1H1,/ / / /10X,42( ' * ' ), / ,18X, ' RESULTS OF THE DESIGN
      ,/,10X,42 1( ' * ' ),/ /)
      WRITE(3,6005) IC,NC
6005  FORMAT (10X, ' NUMBER OF DESIGN CYCLES      = ' ,15,/,10X, ' NUMBER OF
      RELAX 1ATION CYCLES = ' ,15)
      WRITE(3,111)
111   FORMAT(/ / /10X, ' VALUES OF THE RESIDUAL HEAD AND FLOW AT THE
      NODES ' ,1 / ,10X,49( ' - ' ),/)
      WRITE(3,121)
121   FORMAT(10X, ' NODE ' ,10X, ' DH (FT) ' ,8x, ' SUMQT (CFS) " ,4X, ' STATE OF
      NODE 1S ' ,/)
      DO 1000 J = 1,NN
      K3 = K4(J)
      IF(K3)11,1000,11
11    JJ = N1(J)
      IF(ABS(SUMQT(JJ) - ALQ)999,777,777
999   WRITE(3,866)JJ,DH(JJ),SUMQT(JJ)
866   FORMAT(6X,16,5X,E14.6,5X,E14.6,7X, ' BALANCED ' )
      GO TO 1000
777   WRITE(3,555)JJ,DH(JJ),SUMQT(JJ)
555   FORMAT(6X,16,5X,E14.6,5X,E14.6,5X, ' UNBALANCED ' )
1000  CONTINUE
      WRITE(3,302)
302   FORMAT(/ / /25X, ' PRESSURE AT THE NODES ' ,/,25X,21( ' - ' ) )
      WRITE(3,2221)
221   FORMAT( /24X, ' REQUIRED PRESSURS ' ,12X, ' COMPUTED PRESSURES ' ,/,10X,
      ' NO 1DE ' ,9X, ' TOTAL ' ,8X, ' HYDRULIC ' ,8X, ' TOTAL ' ,9X, ' HYDRULIC '
      ,/,21X, ' PRESS 2URE ' ,7X, ' PRESSURE ' ,6X, ' PRESSURE ' ,8X, ' PRESSURE ' )
      IF(NUNIT - 2)42,42,225
42    WRITE(3,22)
22    FORMAT (21X, ' (FEET) ' ,9X, ' (FEET) ' ,9X, ' (FEET) ' ,9X, ' (FEET) ' ,/)
      GO TO 43
```

```
225     WRITE(3.23)
23      FORMAT(19X. ' (METER) ' .8X. ' (METER) ' .8X. ' (METER) ' .8X. ' (METER) ' ./)
43      DO 102 J=1.NN
        JJ=N1(J)
        K3=K4(JJ)
        IF(NUNIT-2)126.126.127
127     H(JJ)=H(JJ) / 3.281
        HR(JJ)=HR(JJ) / 3.281
126     HP=H(JJ)-EH(JJ)
        HPR=HR(JJ)-EH(JJ)
102     WRITE(3.24)JJ.HR(JJ).HPR.H(JJ).HP
24      FORMAT(8X.I5.4F15.3)
        WRITE(3.311)
311     FORMAT( / / /20X. ' FLOW AND HEAD LOSS IN EACH PIPELINE ' . /.20X.35( ' -
        ' ) )
        WRITE(3.28)
28      FORMAT( / 10X. ' FIRST NODE ' .2X. ' SECOND NODE ' .5X. ' K ' .10X. '
        DISCHARGE ' .3 1X. ' HEAD LOSS ' .3X. ' DIAMETER ' )
        IF(NUNIT-2)51.52.53
51      WRITE(3.62)
62      FORMAT(51X. ' (CFS) ' .6X. ' (FEET) ' .6X. ' (INCH) ' . /)
        GO TO 54
52      WRITE(3.29)
29      FORMAT(51X. ' (GPM) ' .6X. ' (FEET) ' .6X. ' (INCH) ' . /)
        GO TO 54
53      WRITE(3.63)
63      FORMAT(49X. ' (CU.M. /H) ' .4X. ' (METER) ' .7X. ' (CM) ' . /)
54      DO 101 J=1.NN
        K3=K4(J)
        JJ=N1(J)
        IF(K3)16.101.16
16      DO 101 I=1.K3
        K1=N3(I.J)
        HL(I.J)=H(JJ)-H(K1)
        IF(NUNIT-2) 99.44.55
44      Q(I.J)=Q(I.J)*448.8
        GO TO 99
55      Q(I.J)=Q(I.J)*3.785*60./10.**3*448.8
        D(I.J)=D(I.J)*2.5
99      IF (N2(I.J)-N3(I.J) )108.108.103
108     JK=N3(I.J)
        IF(K4(JK) )101.103.101
103     WRITE(3.38)N2(I.J).N3(I.J).R(I.J).Q(I.J).HL (I.J).D(I.J)
```

```
38      FORMAT(1 1X.1 5.8X.1 5.4X.E14.6.2F1 1.3.F1 1.2)
        CALL(PLOT)
101     CONTINUE
        CALL EXIT
        END
```

Input Data & Computer Output

The input data for the program are. the constant n (usually for turbulent flow = 1.85). number of nodes. the type of units parameter (Metric or British)*. allowable residual head and flow. the design velocity of flow.Also the input data should include the pressure and draw-off (or supply) at each node. the nodes-connection. the length and Hazen-Williams coefficient for each pipe.

The output results will include the diameter. head loss and discharge in each pipe for the specified requirements.

The rest of this section illustrates the sequence of the input data required and the layout of the computer output for the example network shown below.(fig.1).Node number (1) represents a reservoir with constant supply head of 100 feet. in such cases the number of pipes connected the node should be denoted by '0".

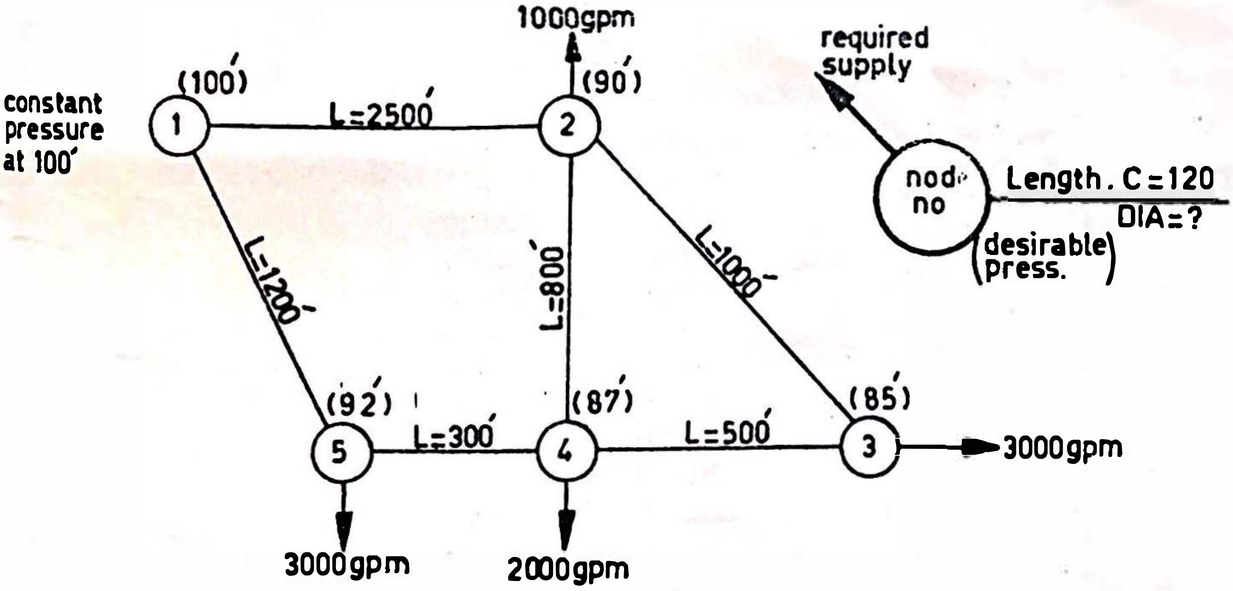

FIG.(1) EXAMPLE NETWORK

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* The program can accept any one of the following sets of units:
(a) L in ft.. d in inches. flow cfs: (ie NUNIT fed = 1)
L in ft.. d in inches. flow gpm: (ie NUNIT fed = 2)
L in M.. d in cm. flow cu.m/hr (ie NUNIT fed = 3)

COMPUTER TECHNIQUES IN THE CAPACITY DESIGN OF PIPE NETWORKS
COMPUTER / LINE PRINTER OUTPUT
EXAMPLE NETWORK
INPUT DATA

THE CONSTANT N =1.850
NO OF NODES =5
TYPE OF UNITE USED.* =2
ALLOWABLE RESIDUAL HEAD =0.1
ALLOWABLE RESIDUAL FLOW =0.001
DESIGN VELOCITY =4.00

NODE	INITIAL GUESS OF TOTAL PRESSURE (FEET)	DRAW-OFF (SUPPLY) (GPM)	NUMBER OF PIPES	GROUND LEVEL (FEET)
1	100.000	0.000	0	0.000
2	90.000	1000.000	3	0.000
3	85.000	3000.000	2	0.000
4	87.000	2000.000	3	0.000
5	92.000	3000.000	2	0.000

FIRST NODE	SECOND NODE	LENGTH (FEET)	C (HAZEN)
2	1	2500.0	120.00
2	3	1000.0	120.00
2	4	800.0	120.00
3	2	1000.0	120.00
3	4	500.0	120.00
4	2	800.00	120.00
4	3	500.00	120.00
4	5	300.00	120.00
5	1	1200.00	120.00
5	1	300.00	120.00

RESULTS OF THE DESIGN

NUMBER OF DESIGN CYCLES =2
NUMBER OF RELAXATION CYCLES =19

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* The type 2 refers flow in gpm., length in ft, diameter in inches, pressure in ft, head loss in ft and velocity in ft /sec.

VALUES OF THE RESIDUAL HEAD AND FLOW AT THE NODES

NODE	RESIDUAL HEAD (FT)	RESIDUAL FLOW (CFS)	STATE OF NODES
2	0.426894E-03	-0.514030E-03	BALANCED
3	0.544899E-03	-0.762939E-03	BALANCED
4	0.435957E-03	-0.928878E-03	BALANCED
5	0.170952E-03	-0.259399E-03	BALANCED

PRESSURE AT THE NODES

NODE	REQUIRED PRESSURES		COMPUTED PRESSURES	
	TOTAL PRESSURE (FEET)	HYDRULIC PRESSURE (FEET)	TOTAL PRESSURE (FEET)	HYDRULIC PRESSURE (FEET)
1	100.000	100.000	100.000	100.000
2	90.000	90.000	90.000	90.000
3	85.000	85.000	85.399	85.399
4	87.000	87.000	87.326	87.326
5	92.000	92.000	92.696	92.696

FLOW AND HEAD LOSS IN EACH PIPELINE

FIRST NODE	SECOND NODE	'K" in $H=KQ^n$	DISCHARGE (GPM)	HEAD LOSS (FEET)	DIAMETER (INCH)
2		0.236221E 00	-3372.773	-9.857	18.00
3		0.680680E 00	-1261.669	-4.742	12.00
4		0.544544E 00	-1091.019	-2.816	12.00
4	3	0.160650E 00	-1718.415	1.926	14.00
5	1	0.678768E-01	5627.816	-7.303	20.00
5	4	0.204204E 00	2527.700	5.370	12.00

Automatic-Graphical Results

In order to simplify further the examination of the desined network by the computer; A sub-program which provides the plotting of the network configuration with the complete results is developed and can be called at if desired.No doubt the use of this sub-program will increase the computer time consumed.this should be balanced against the time required by the engineer to transfer the tabulated results on the network diagram.In many cases this facility proved to be economical besides being the eliminator of human error in transferring the tabulated results on to the network diagram.

Figure (2A) is an example network with specified boundary conditions.The input data was fed for this network and using the computer program described the complete design for the network was obtained automatically as shown in figure (2B).It can be noted that the final pressures at the nodes are slightly different from the specified ones. this is automatically done to make up for obtaining possible sizes of diameters rather than unavailable sizes.

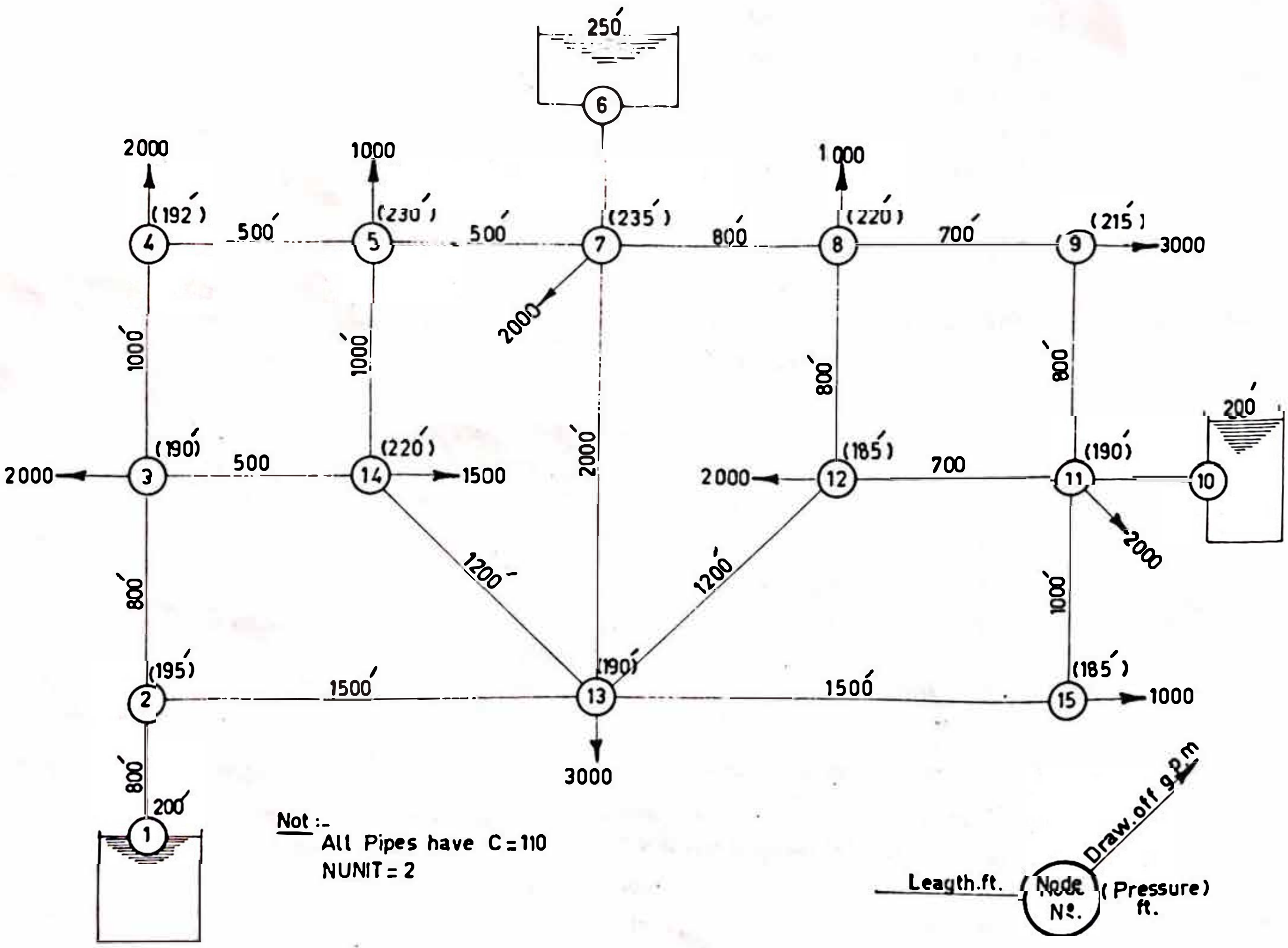

FIG.(2.A) SAMPLE OF DESIGN NETWORK

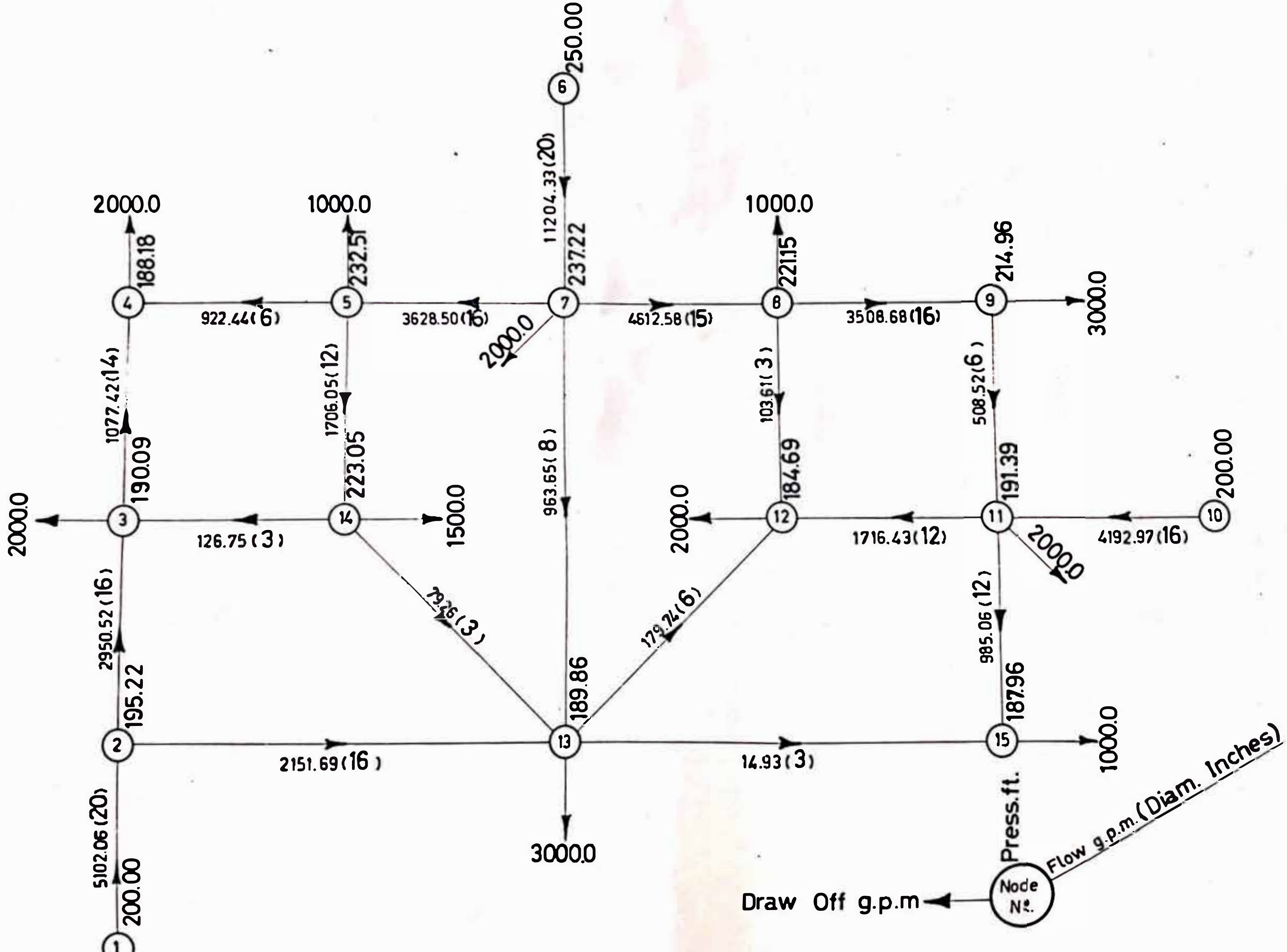

FIG. (2.B)GRAPHICAL OUTPUT OF SAMPLE NETWORK IN FIG(1.A)
Traced From Computer Output

Conculsions:

The growth of many new cities and the easy access to digital computers have imposed the importance of developing methods for the design of pipe networks.

This article demonstrated a simple and versatile method for sizing the pipe netivorks according to consumer demands.The computer program discussed proved its simplicity,both in input data required and output results.The program has been tested for various networks and no difficulties have been encountered.However if new standard pipe sizes are manfactured then slight alteration on the program must be made.The equations used are those for water; if the program is to be used for other fluids, such as gasses, then the basic equation for the head loss against discharge should be altered and a complete new testing for the program is required.

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