



TECHNIQUES OF CONDUIT AND PIPE BENDING ON-THE-JOB

GREENLEE
Northend Rental
& Construction Supply

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Produced by Greenlee Tool Division, Rockford, Illinois, U.S.A.

The art of pipe bending, although still dependent upon the skills of the individual, requires a workable formula that can be simply taught and applied. It is the purpose of this booklet to supply this time-saving simplification to the pipe bending industry without sacrificing the precision and quality that is needed.

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EASIEST WAY TO MAKE LARGE SWEEP RADIUS BENDS and CONCENTRIC BENDS WITH HYDRAULIC BENDERS

EQUIPMENT NEEDED

- 1 — Hydraulic Ram with frame and parts to fit pipe to be bent.
- 1 — Hand or Power Operated High Pressure Hydraulic Pump.
- 1 — Pipe Bending Degree Indicator to permit bending to exact degrees.

A great deal of pipe bending is done with what is known as segment type bending shoes, where it is not possible to complete the bend in one shot. In some cases, 90° bending shoes are also used for making a bend larger than the radius of the shoe.

Illustrations No. 1 and No. 2 show equipment for making large sweep and concentric bends. One illustration is marked indicating the proper name of each part so you will be familiar with the current trade names of these items as you read the following copy.

To bend pipe, you first have to determine the following:

1. Size of pipe to be bent.

2. Radius of bend.
3. Total number degrees in bend.
4. After you have done this, you have to figure the developed length which is the amount of the pipe that actually has to be bent so as to get the right radius and degrees.
5. To arrive at the developed length for a 90° bend, multiply the radius by 1.57, which is one-half pi, or, developed length equals number degrees x radius x .0175. To save time and eliminate a lot of figuring, you can refer to charts in this folder.
6. When using the indicated equipment, it is important that you locate the center of the bend required, as most benders have the center mark indicated on the bending shoes. Furthermore, it is easier to figure the location of the other bend marks by locating the center of the developed length first.
7. You now determine the number of shots to be made that will make the bend to suit the requirements, preferably an odd number.
8. Then you figure the width of the spaces, and mark the pipe accordingly, having an even number of spaces each side of the center mark.

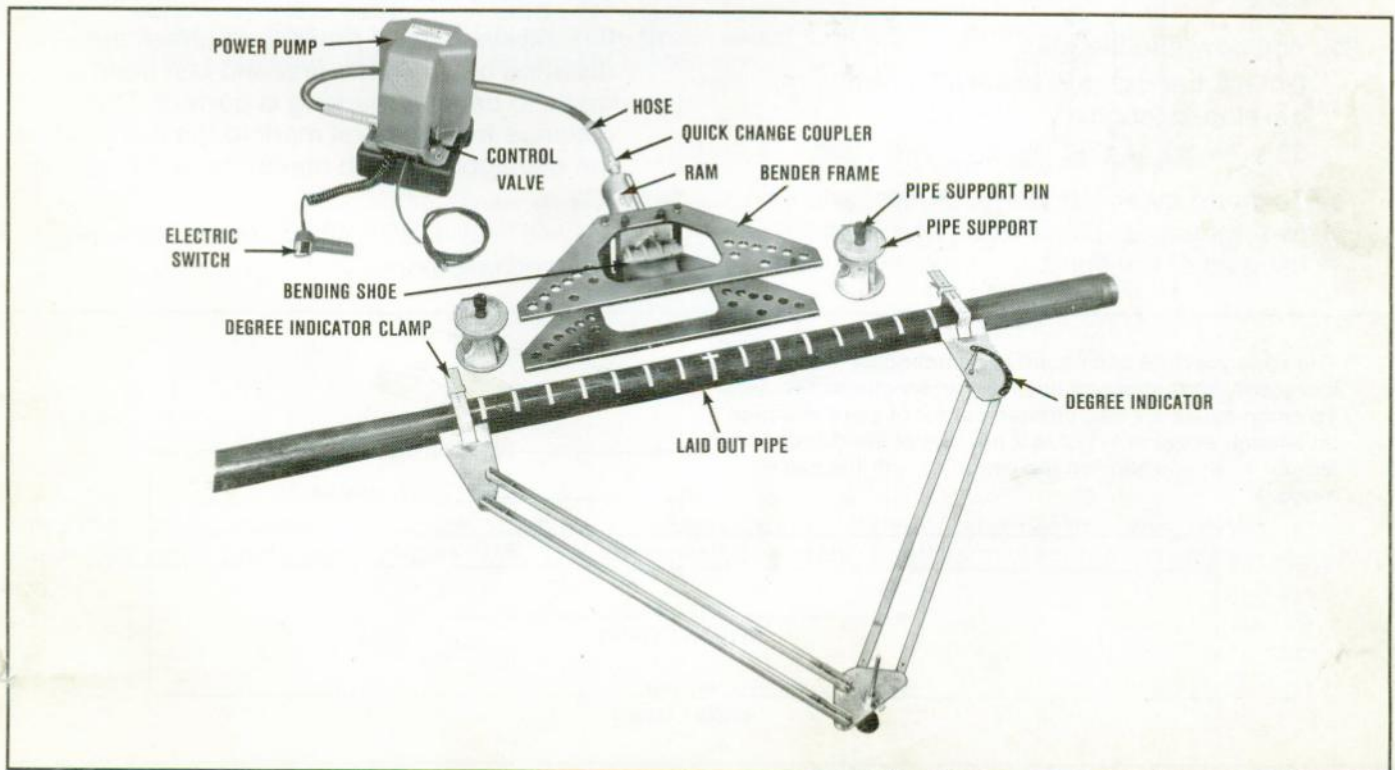
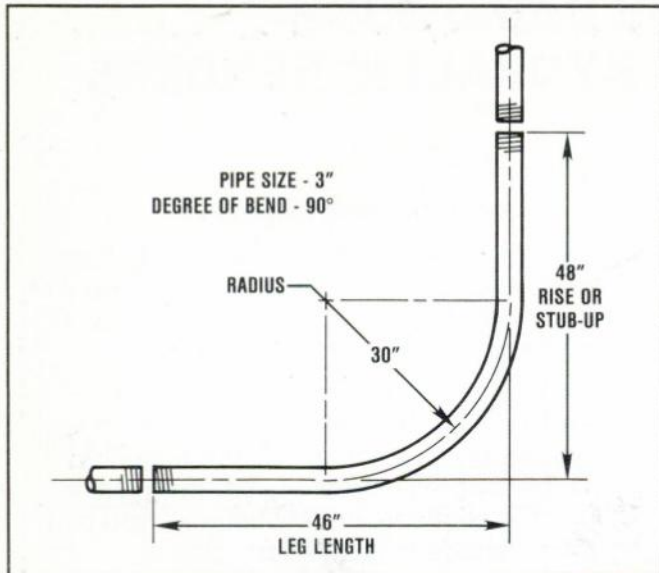


ILLUSTRATION NO. 1 — LARGE SWEEP AND CONCENTRIC PIPE BENDING

LAYOUT OF REQUIRED 90° BEND



SKETCH NO. 1

9. You must know the degrees per bend.
Procedure is as follows:

10. Example:

Calculate the bending data for 90° bend on 3" pipe, 48" riser or stubup with 46" leg length, having 30" radius to center line. See Sketch No. 1.

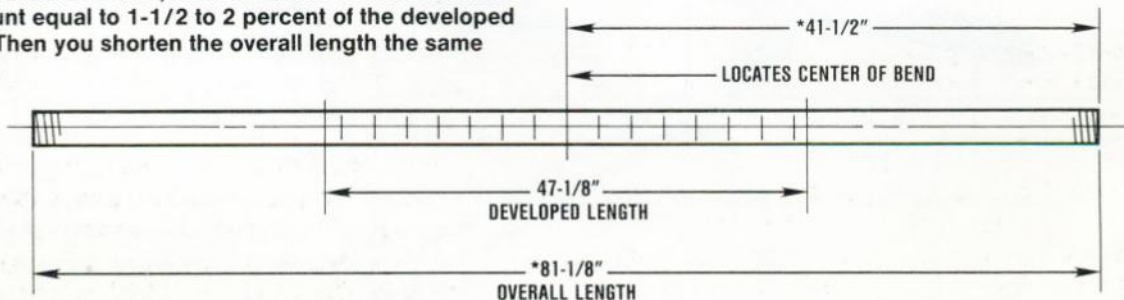
- On 30" radius, the developed length would be $30'' \times 1.57$ or $(.0175 \times \text{degree of bend} \times \text{radius of bend})$ which equals $30 \times 1.57 = 47.10''$, use $47-1/8'' = \text{developed length}$ which is the portion of pipe that has to be bent.
- You now find the gain.
On 90° bends, gain equals $2 \times \text{radius}$ — developed length:
 $30 \times 2 = 60'' - 47-1/8'' = 12-7/8'' \text{ gain.}$
- To figure overall of length of pipe, add the two right angle dimensions and subtract the gain of the bend:

$$48'' + 46'' = 94'' - 12-7/8'' = 81-1/8''$$

overall length of pipe.

- Now locate the center of the required bend. Use the riser or stubup dimension 48". Subtract the radius and add one-half of the developed length.
 $48'' - 30'' = 18'' + 23-1/2'' = 41-1/2''$ from end to center of bend.
- If you want to measure riser from the bottom of the pipe, subtract one-half the O.D. of the pipe ($1-3/4''$) from $41-1/2'' = 39-3/4''$.
- If it is desired to measure from the top of the pipe, add one-half the O.D. of the pipe.
 $41-1/2'' + 1-3/4'' = 43-1/4''$. See Sketch No. 1.
- As a rule, six degree bends or less gives you a good bend on 30" radius. In this case, we will use 6° per bend, making 15 bends. $90^\circ \div 6^\circ = 15 \text{ bends.}$
- Now you have the question as to how far the bends are apart. Divide the developed length by 15.
 $47.125 \div 15 = 3.14''$ or $3-1/8''$.
- Then proceed to make the center mark $41-1/2''$ from one end of the pipe. Next you mark seven marks each side of the center mark, $3-1/8''$ apart, making a total of 15 marks.
- It is always a good practice to check the distance between the first and last bend mark, to be sure marking is correct. The distance from the first mark to the last mark is the developed length minus the width of one space.
 $47-1/8'' - 3-1/8'' = 44''$ distance between first and last mark.

* The springback of each bend is an unknown factor. It increases the radius and in so doing, lengthens the rise. To compensate for this, shorten center of bend distance an amount equal to 1-1/2 to 2 percent of the developed length. Then you shorten the overall length the same amount.



SKETCH NO. 2

BENDING PROCEDURE

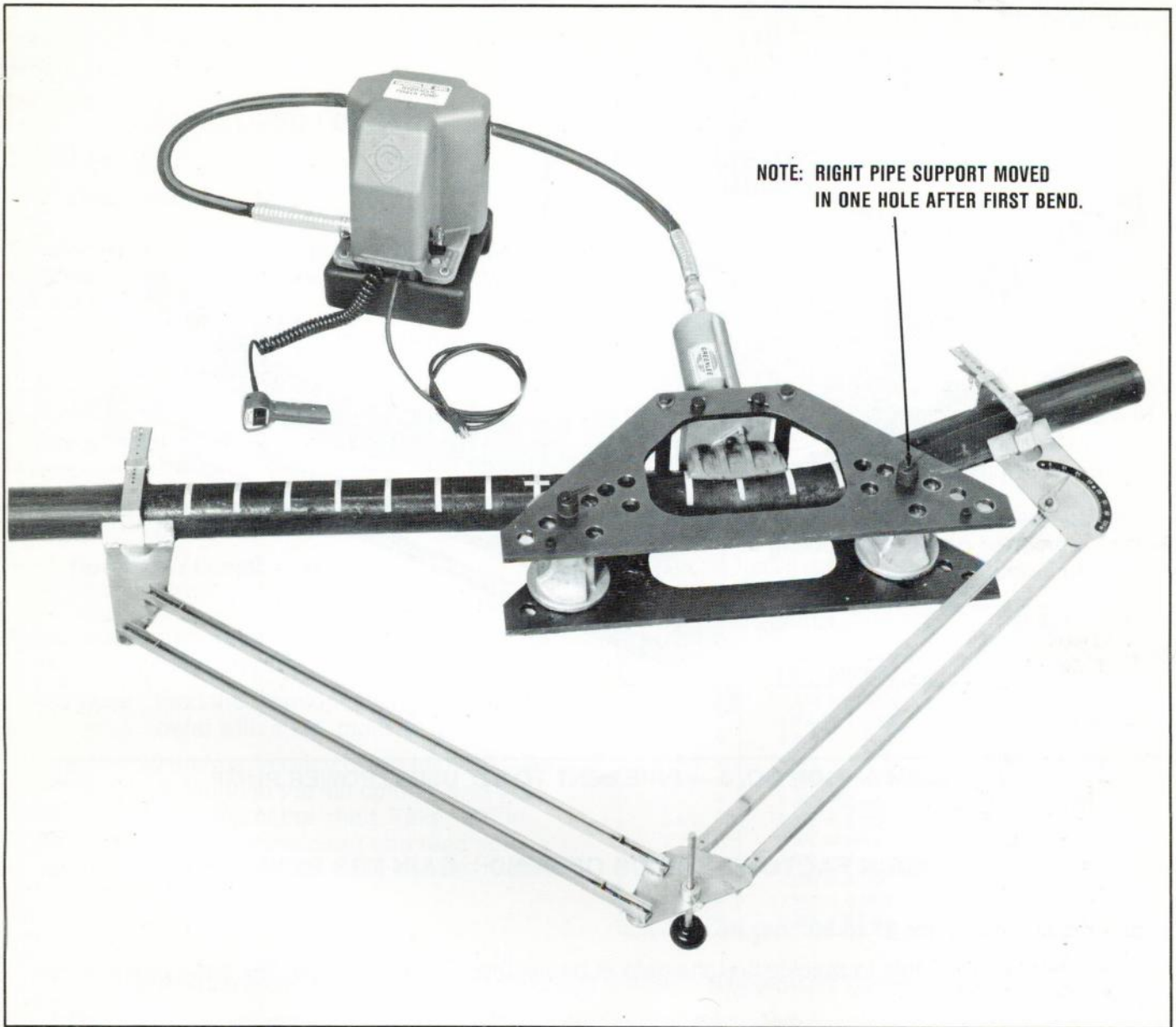


ILLUSTRATION NO. 2 — PIPE BENT TO 18 DEGREES

13. After you have located the pipe in the bender in accordance with Illustration No. 2, you attach the pipe bending degree indicator in the most convenient location, as shown on the print.
14. You locate the pipe supports with the proper face toward the pipe, insert the pipe support pins, lock them in position by turning small lock pin. You are now ready to proceed to making the series of bends.
15. Illustration No. 2 shows you the beginning setup and you bend 6° on the first mark. When you have done this, the indicator will read 6° . Release the pressure, check the springback, if any, and overbend the same amount.

When using a bender with a rigid frame, you now move the pipe support in one hole position towards the ram, that is, on the side that you have bent pipe.

16. Proceed to bend up to 12° on the second mark. Check your springback. When bent pipe gets past the one pipe support, the ram travel on the balance of bends is exactly the same.
17. Follow this procedure until you get to the last mark where you would be bending 90° . Stop exactly at 90° , release the pressure, check the springback and overbend the same amount. You will have a 90° bend without any wows or twists in your pipe.

FINISHED 90° BEND 30" RADIUS

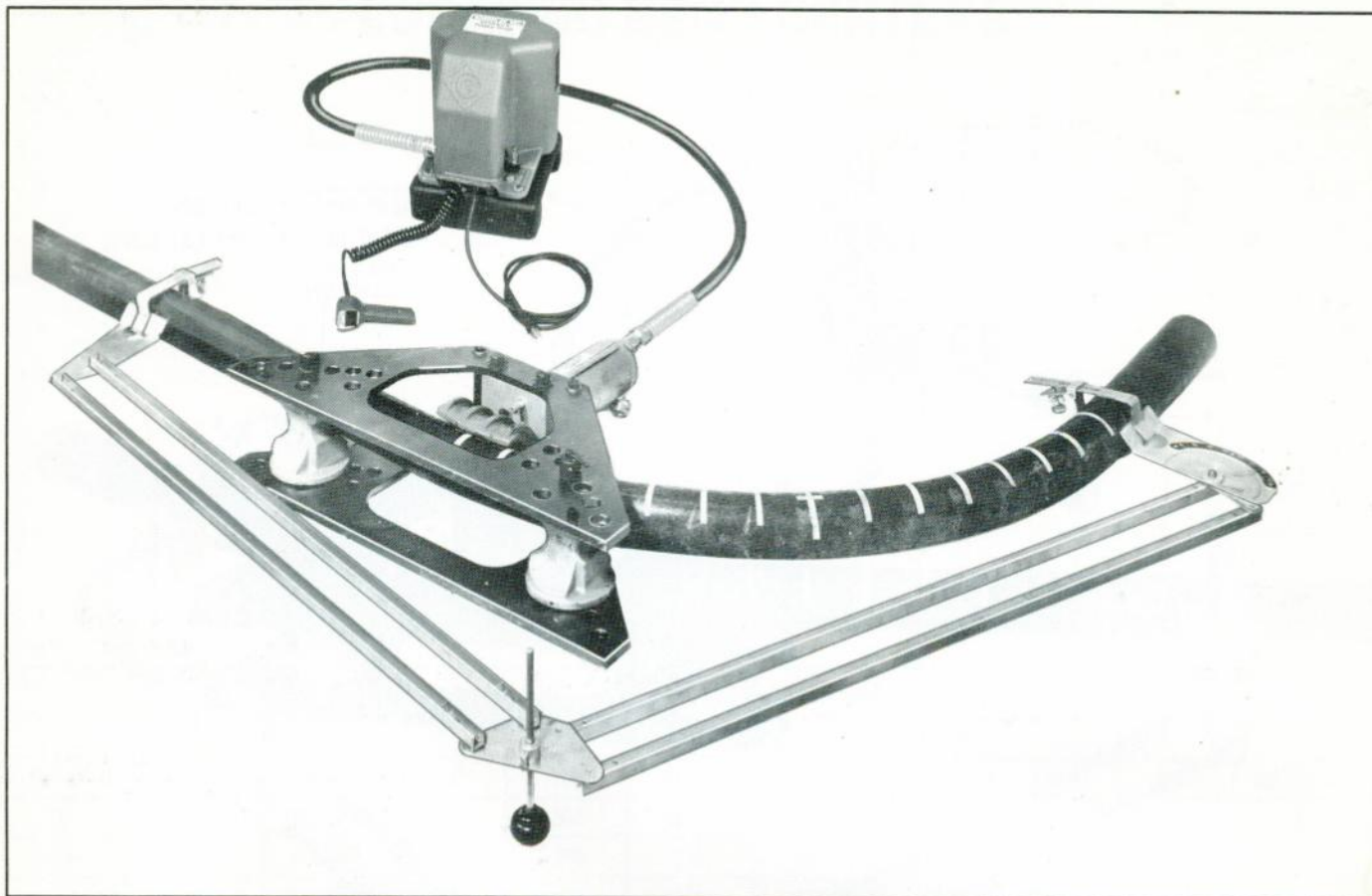


ILLUSTRATION NO. 3 — PIPE BENT TO 90° USING POWER PUMP

$$\text{GAIN FACTOR} \times \text{RADIUS OF BEND} = \text{GAIN PER BEND}$$

Table of gain factors for 0° to 90° bends

It is very helpful to be able to quickly find the gain of bends that vary in degrees. The table below is very useful.

	—	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0003	.0003
10°	.0005	.0006	.0008	.0010	.0013	.0015	.0018	.0022	.0026	.0031
20°	.0036	.0042	.0048	.0055	.0062	.0071	.0079	.0090	.0100	.0111
30°	.0126	.0136	.0150	.0165	.0181	.0197	.0215	.0234	.0254	.0276
40°	.0298	.0322	.0347	.0373	.0400	.0430	.0461	.0493	.0527	.0562
50°	.0600	.0637	.0679	.0721	.0766	.0812	.0860	.0911	.0963	.1018
60°	.1075	.1134	.1196	.1260	.1327	.1397	.1469	.1544	.1622	.1703
70°	.1787	.1874	.1964	.2058	.2156	.2257	.2361	.2470	.2582	.2699
80°	.2819	.1944	.3074	.3208	.3347	.3491	.3640	.3795	.3955	.4121
90°	.4292	—	—	—	—	—	—	—	—	—

EXAMPLE: Find gain on a 45° bend with 15" center line radius.
 Refer to chart. Gain factor is .0430.
 $.0430 \times 15 = .6450$ or $21/32$ " full gain of 45° bend.

FORMULAS

GAIN

"Gain for 90° bends = 2 x radius - developed length."

DEVELOPED LENGTH

Developed length of any degree of bend.

$$\text{Developed Length} = .0175 \times \text{degree of bend} \times \text{radius of bend}$$

Developed length of any degree of bend shown in the chart — multiply the radius of the bend by the constant.

$$\text{Developed Length} = \text{radius} \times \text{constant}$$

DEGREE OF BEND	15°	30°	45°	60°	75°	90°
CONSTANT	.262	.523	.785	1.05	1.31	1.57

Example: Find the developed length on a 90° bend with a 40" radius.

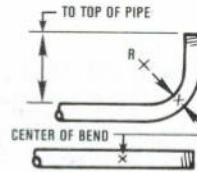
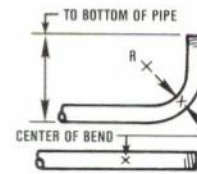
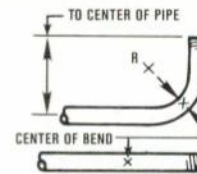
$$\begin{aligned} \text{Developed Length} &= 40 \times 1.57 \\ &= 62.80 \text{ or } 62\text{-}13/16'' \end{aligned}$$

Developed length of 90° bend with any radius up to 100" is listed on chart shown below.

Example: Find the developed length for a 90° bend with a 25" radius.

To find this 25 inches, break it down into "20" and "5". The "20" is found in the left column and the "5" is found at the top of the chart. Take "20" in the left hand column of the chart and read across to column 5 and the answer is 39.25 or 39-1/4"

TO LOCATE CENTER OF 90° BEND



1. Determine leg length to center. Subtract radius of bend. Add 1/2 the developed length.

2. On leg length to bottom of pipe — subtract the radius and 1/2 the O.D. of the pipe and add 1/2 the developed length.

3. Leg length to top of pipe subtract radius and add 1/2 the O.D. and 1/2 the developed length.

It is useful to know the outside diameter of the pipe and also 1/2 the diameter when bending to make a certain length of leg to the top or bottom of the pipe.

OUTSIDE DIAMETER PIPE			ONE-HALF THE OUTSIDE DIAMETER	
SIZE	O.D.	FRACTION	O.D.	FRACTION
1/2" =	.840	= 27/32	.420	= 27/64
3/4" =	1.050	= 1-3/64	.525	= 17/32
1" =	1.315	= 1-5/16	.658	= 21/32
1-1/4" =	1.660	= 1-21/32	.830	= 53/64
1-1/2" =	1.900	= 1-29/32	.950	= 61/64
2" =	2.375	= 2-3/8	1.187	= 1-3/16
2-1/2" =	2.875	= 2-7/8	1.437	= 1-7/16
3" =	3.500	= 3-1/2	1.750	= 1-3/4
3-1/2" =	4.000	= 4	2.000	= 2
4" =	4.500	= 4-1/2	2.250	= 2-1/4
5" =	5.562	= 5-9/16	2.786	= 2-25/32
6" =	6.625	= 6-5/8	3.312	= 3-5/16

FORMULA FOR MAKING 90° BENDS: $R \times 1.57 = \text{Developed Length}$ (See Table)

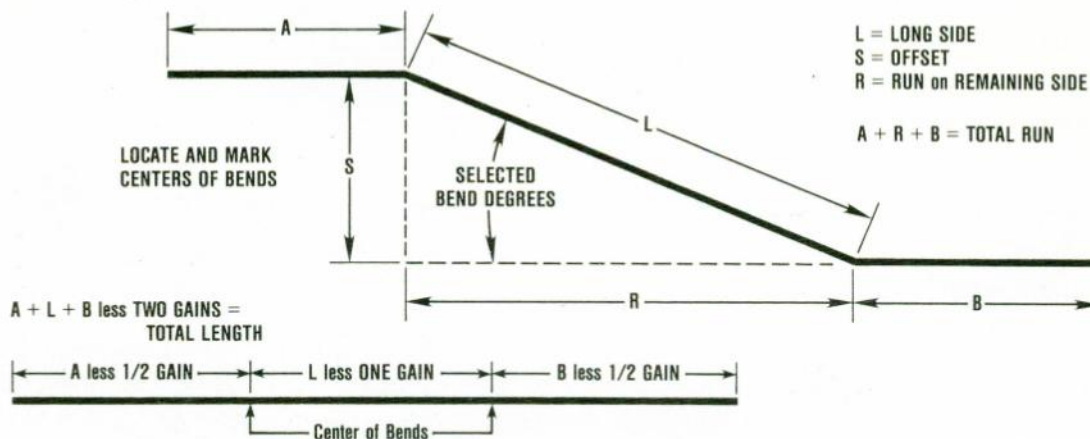
		RADIUS INCREMENTS BY INCHES									
		0	1	2	3	4	5	6	7	8	9
	0	0	1.57	3.14	4.71	6.28	7.85	9.42	10.99	12.56	14.13
	10	15.70	17.27	18.84	20.41	21.98	23.55	25.12	26.69	28.26	29.83
	20	31.40	32.97	34.54	36.11	37.68	39.25	40.82	42.39	43.96	45.53
	30	47.10	48.67	50.24	51.81	53.38	54.95	56.52	58.09	59.66	61.23
	40	62.80	64.37	65.94	67.50	69.03	70.65	72.22	73.79	75.36	76.93
	50	78.50	80.07	81.64	83.21	84.78	86.35	87.92	89.49	91.06	92.63
	60	94.20	95.77	97.34	98.91	100.48	102.05	103.62	105.19	106.76	108.33
	70	109.90	111.47	113.04	114.61	116.18	117.75	119.32	120.89	122.46	124.03
	80	125.60	127.17	128.74	130.31	131.88	133.45	135.02	136.59	138.16	139.73
	90	141.30	142.87	144.44	146.01	147.58	149.15	150.72			

Developed length for following angles use fraction of 90° chart.

FOR	15°	22-1/2°	30°	45°	60°	67-1/2°	75°	90°
TAKE	1/6	1/4	1/3	1/2	2/3	3/4	5/6	See chart

For any other degrees: Developed length = .01744 x radius x degrees.

TABLE FOR CALCULATING OFFSETS AND LOCATING BEND CENTERS



TO FIND UNKNOWN	KNOWN	TIMES CORRESPONDING MULTIPLIER EQUALS								UNKNOWN
		TABLE OF MULTIPLIERS FOR SELECTED DEGREES OF BEND								
		5½°	11¼°	15°	22½°	30°	37½°	45°	60°	
L	S	10.207	5.126	3.864	2.613	2.00	1.643	1.414	1.155	L
S	L	.098	.195	.259	.383	.50	.609	.707	.866	S
R	S	10.158	5.027	3.732	2.414	1.732	1.303	1.00	.577	R
S	R	.098	.199	.268	.414	.577	.767	1.00	1.732	S
L	R	1.005	1.02	1.035	1.082	1.155	1.260	1.414	2.00	L
R	L	.995	2.981	.966	.933	.866	.793	.707	.50	R
GAIN PER BEND	RADIUS OF SHOE	.0002	.0006	.0015	.0051	.0124	.0212	.0430	.1076	GAIN PER BEND

CHART 3

When making offsets it is necessary to make two bends with the same degree of bend. The problem involved is how to figure the distance between the two bends. Refer to chart above. This makes it easy to arrive at the length between the two bends.

First determine offset needed, then the degree of bends to be made. Then multiply offset measurement by figure directly under degree of bend.

The above applies to all sizes of pipe.

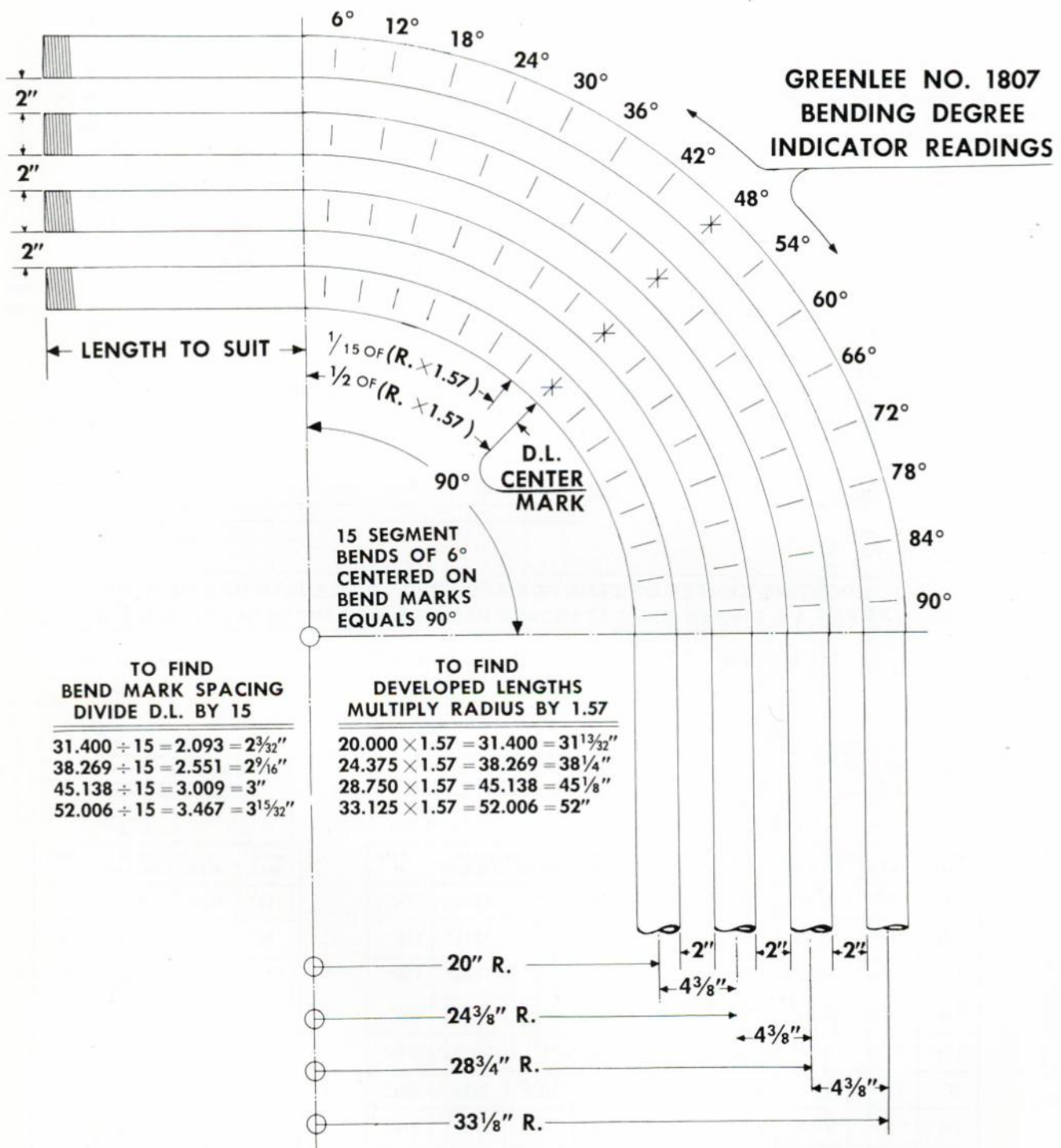
EXAMPLE: 18" offset with two 45° bends. $18" \times 1.414 = 25\frac{1}{2}"$ between bends.

To connect the two ends of an offset to two pieces of pipe already in place, it is necessary to know the overall length of the offset from end to end before bending. $A + L + B - 2$ gains = overall length.

Gain is shoe radius x decimals shown on last line under degree of bends.

EXAMPLE: 3" pipe 45° offset $A 36" + L 25\frac{1}{2}" + B 48" = 109\frac{1}{2}" - 2$ gains $1\frac{9}{32}" = 108\frac{7}{32}"$. Gain is figured 15" radius = $15 \times .0430 = .645$ for one gain. Two gains = $1\frac{9}{32}"$.

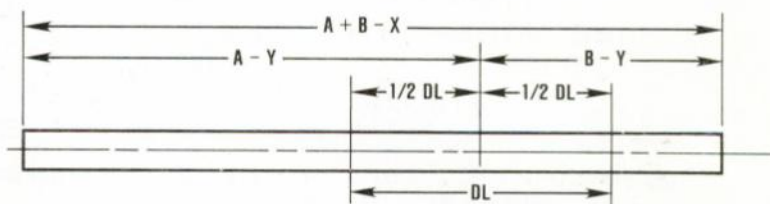
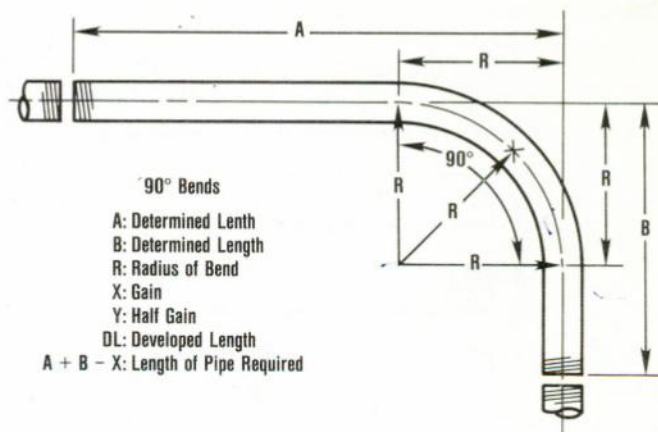
ILLUSTRATING CONCENTRIC BENDING OF 2" CONDUIT—USING GREENLEE EQUIPMENT



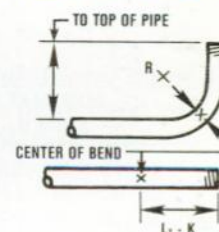
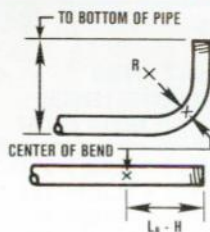
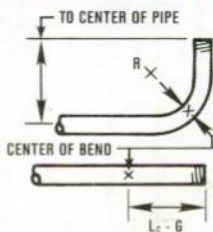
To find the radius increase when pipe sizes vary, add the two outside diameters of the pipe divide answer by 2, then add space between. This gives you the increase in center line radius of the next larger bend.

HOW TO LAY OUT 90° BENDS WHEN USING STANDARD 90° SHOES

PIPE	RADIUS OF BEND R	DEVELOPED LENGTH 90°	GAIN X	HALF GAIN Y
1/2"	4"	6-5/16"	1-11/16"	7/8"
3/4"	4-1/2"	7-1/16"	1-15/16"	15/16"
1"	5-3/4"	9"	2-1/2"	1-1/4"
1-1/4"	7-1/4"	11-3/8"	3-1/8"	1-9/16"
1-1/2"	8-1/4"	13"	3-1/2"	1-3/4"
2"	9-1/2"	14-15/16"	4-1/16"	2"
2-1/2"	12-1/2"	19-5/8"	5-3/8"	2-11/16"
3"	15"	23-9/16"	6-7/16"	3-3/16"
3-1/2"	17-1/2"	27-1/2"	7-1/2"	3-3/4"
4"	20"	31-7/16"	8-9/16"	4-1/4"



LOCATING CENTER OF BEND FOR REQUIRED LEG LENGTH OR RISE HEIGHT AS PER A & B WHEN USING STANDARD RADIUS SHOES SHOWN IN ABOVE CHART



PIPE SIZE	Lc MINIMUM		LESS G
	880-M2 BENDER	883 & 884 BENDERS	
1/2"	10-9/16"	11-7/8"	7/8"
3/4"	10-7/16"	11-15/16"	15/16"
1"	11-3/8"	11-1/4"	1-1/4"
1-1/4"	13-3/16"	16-9/16"	1-9/16"
1-1/2"	15-1/16"	19-3/4"	1-3/4"
2"	17-11/16"	23"	2"
2-1/2"	—	24-11/16"	2-11/16"
3"	—	29-3/16"	3-3/16"
3-1/2"	—	31-3/4"	3-3/4"
4"	—	35-1/4"	4-1/4"

PIPE SIZE	Lb MINIMUM		LESS H
	880-M2 BENDER	883 & 884 BENDERS	
1/2"	11"	12-5/16"	1-5/16"
3/4"	11"	12-1/2"	1-1/2"
1"	13"	14-7/8"	1-7/8"
1-1/4"	15"	17-3/8"	2-3/8"
1-1/2"	17"	20-11/16"	2-11/16"
2"	18-7/8"	24-3/16"	3-3/16"
2-1/2"	—	27-1/8"	4-1/8"
3"	—	30-15/16"	4-15/16"
3-1/2"	—	33-3/4"	5-3/4"
4"	—	37-1/2"	6-1/2"

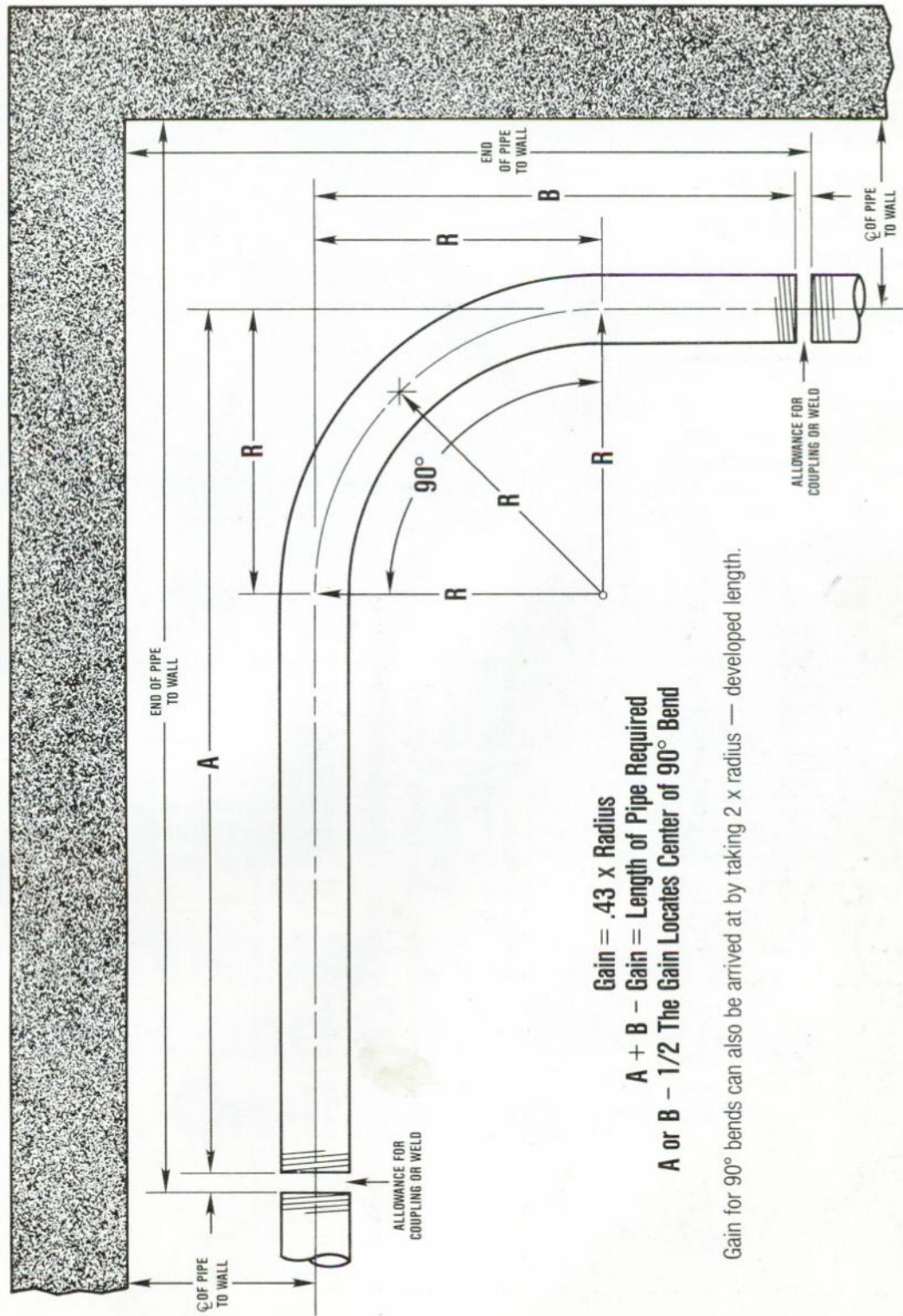
PIPE SIZE	Lt MINIMUM		LESS K
	880-M2 BENDER	883 & 884 BENDERS	
1/2"	10-1/8"	11-7/16"	7/16"
3/4"	9-15/16"	11-7/16"	7/16"
1"	11-3/4"	13-5/8"	5/8"
1-1/4"	13-3/8"	15-3/4"	3/4"
1-1/2"	15-1/8"	18-13/16"	13/16"
2"	16-1/2"	21-13/16"	13/16"
2-1/2"	—	24-1/16"	1-1/4"
3"	—	27-7/16"	1-7/16"
3-1/2"	—	29-3/4"	1-3/4"
4"	—	33"	2"

NOTE: The figures for G, H, and K remain constant for leg lengths above minimum. Add 4-1/2" to minimum Lc, Lb, and Lt when using No. 1807 Bending Degree Indicator.

EXAMPLE: Find the center of bend for a 30" leg measured from the bottom of 2" pipe.

$$\begin{aligned} \text{Center of Bend} &= L_b - H \\ &= 30 - 3-3/16 \text{ (see middle chart)} \\ &= 26-13/16" \end{aligned}$$

HELPFUL CHART **WHEN LAYING OUT A 90° BEND**



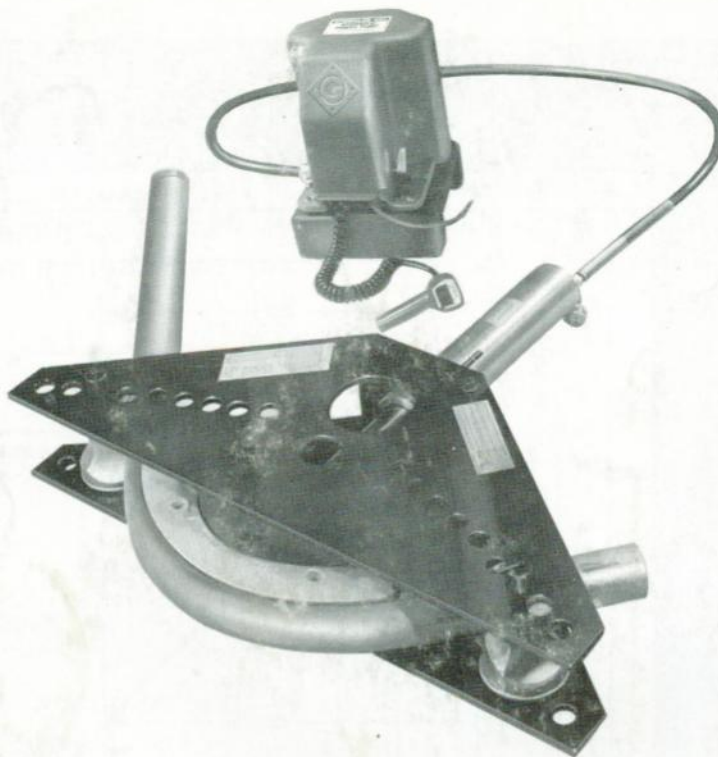
Gain = .43 x Radius

$A + B - \text{Gain} = \text{Length of Pipe Required}$

$A \text{ or } B - 1/2 \text{ The Gain Locates Center of } 90^\circ \text{ Bend}$

Gain for 90° bends can also be arrived at by taking $2 \times \text{radius}$ — developed length.

A TYPICAL LIGHTWEIGHT ONE SHOT 90° BENDER POWER DRIVEN ... RANGE 1/2" THRU 4"



The above illustrates a lightweight one shot 90° bender, capacity 1/2 — 4". It bends any degree from 0 — 90 with one stroke of the ram in one setting.

The pressure control valve as shown has three positions: return, hold and forward. It makes 90°

bends on 4" pipe in about two minutes.

Bending layout charts are shown on page 10. These charts apply on all benders using 90° shoes with radius as listed in the column headed "Radius of Bend" as shown in upper left hand chart.

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