A PRODUCTION HYDRAULIC CORRUGATING MACHINE

for use by

THE FULTON SYLPHON COMPANY

by

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A Short Outline of the Work Enclosed

Purpose

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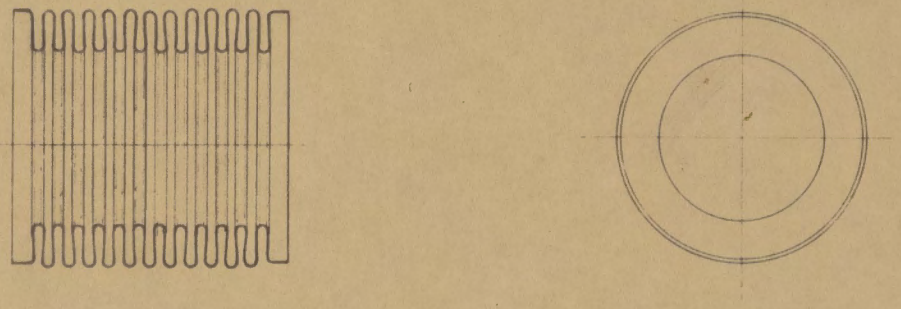
Purpose.--This thesis tells of the redesigning of an experimental hydraulic corrugating machine for production use as actually performed in the production drafting room of The Fulton Sylphon Co. by the writer. The methods of arriving at the final machine are given. The special features and new parts designed by the writer are described. Future possible additions and improvements are mentioned.

All drawings, photostats, and photographs in this thesis are referred to as Figure 1, Figure 2, etc. All parts or places are referred to on the drawings, photostats or photographs as letters, as Y, Z etc. Thus in the description, 7E means figure 7 and the part designated by the letter E. Parts may be referred to on several drawings as 6, 7, 8 and 9F, which means part F on Figures 6, 7, 8, and 9. Each part that is designated by a letter will have that letter on all drawings.

Introduction.--The heart of nearly all of the products made and sold by The Fulton Sylphon Co. is the flexible metallic "sylphon bellows", a sectional view of which is shown by Figure 1. The Fulton Sylphon Co. has made over seven hundred various devices each requiring a sylphon bellows of some kind. Each different device is given an instrument number. Of course, some sizes of sylphon bellows can be used in more than one instrument, but it can be seen that there is a large variety of sizes needed.



SECTION VIEW OF SYLPHON BELLOWS

FIGURE 1

L.G.P.

As each new order generally requires a sylphon bellows of different dimensions or thickness, new tools are needed for each new order. The time required for making these new tools and then making the sylphon bellows was thought to be unnecessarily long. During the life of the sylphon bellows patent, the process for making it was not greatly improved. By holding a monoply of the trade, so to speak, there was no great inducement to improve the method of manufacture. In the last few years many of the various patents on the processes of manufacture have also expired and other companies are now producing flexible metallic bellows. Under the influence of competition, the sales value of the sylphon bellows dropped. Hence there was a period of readjustment in the company in which it was imperative that the cost of production be lowered. Since the sylphon bellows is the heart of the industry, any reduction in the cost of its manufacture is important to the existance of the company.

The Old Method Of Making Sylphon Bellows.--The old method of corrugating or rolling the sylphon bellows has been discarded and a new method has been recently developed. In referring to the "Old method" it is to be understood that this applies to the sylphon bellows of 2 inches in diameter and under. The Fulton Sylphon Company still makes the rolled sylphon bellows up to 8 7/8 inches in diameter from seamless drawn, and brazed, brass tubes. The great majority of sylphon bellows made are 2 inches in diameter or under. The smallest

yet made in production quantities is 9/16 of an inch in diameter.

By referring to Figure 2, we see the evolution of a rolled sylphon bellows. The round brass disc, A, is punched from sheet brass, B, by means of a round sharp-edged cylinder, C, called a punch. This punch is forced through a round sharp edged hole in a piece of steel, D, called a die, with only .001 or .002 of an inch clearance between punch and die on the diameter. This blank, A, is then placed on another die and forced through by another punch. This punch has a spherical end and the die has a radius on the top edge equal to six times the thickness of the blank. The punch and die have a total clearance of twice the thickness of the blank. Thus the blank is formed into a cup, E. The radius on the punch and die and the clearance between them allow the metal to "flow" around the punch. The cup is then placed on another die and forced through by another punch. The clearance between this punch and die is less than twice the thickness of the material. Consequently the cup is squeezed or "drawn" through the die into a tube, F, which is smaller in diameter, has thinner walls and is longer than the cup, E. The drawing operations are in line with standard practice of cupping and drawing brass tubes and shells, and are repeated until the tube is thin enough. Tube, F, is then trimmed of its rough edges and the bottom cut off forming the thin-walled tube, G, which is ready for stamping.

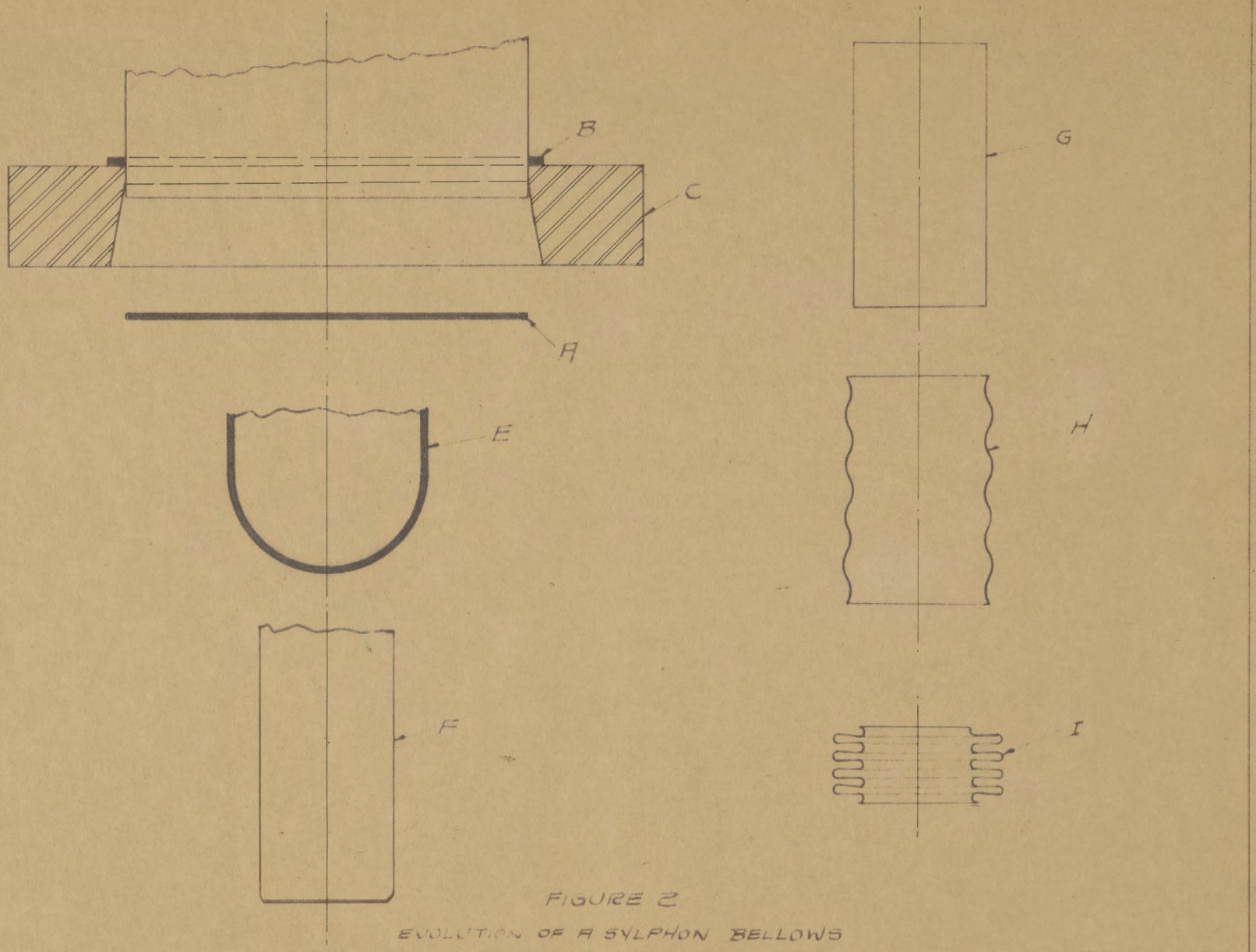


FIGURE 2

EVOLUTION OF A SYLPHON BELLOWS

L.G.F.

The tube, G, is placed on a patented internal expanding punch which produces the tube H. This operation is called a stamping operation. Each corrugation is stamped separately--the punch traveling from top to bottom. The stamped tube, H, is then taken to the corrugating department and the corrugations rolled deeper until a sylphon bellows is produced as in I. The ends are trimmed according to the kind of bellows head required.

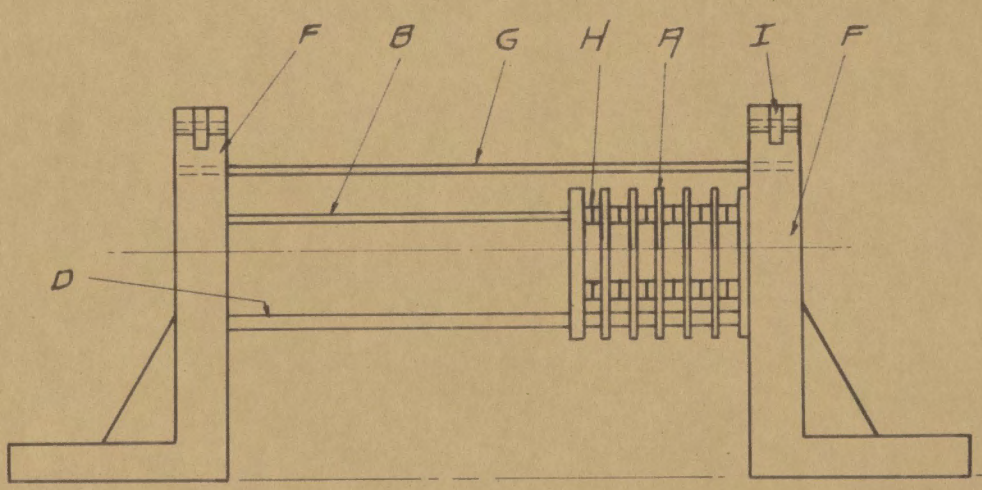
This process consumes much time because each tube has to be stamped from eight to twenty-four times depending on the nature of the sylphon bellows required. There are from five to eight rolling operations. Starting with the stamped tube, H, each set of rolls makes the corrugations a little deeper and closer together. The drawn tubes, G, are hard brass due to the cold drawing effect. It is a well known fact that cold rolling or cold drawing raises the yield point of some metals, including brass, but makes the metal less ductile. The tubes, G, are annealed in an electric furnace to reduce the internal stresses set up by cold drawing and to make the metal more ductile. Unannealed tubes have a tendency to burst when being stamped. The tubes after being stamped are again annealed to increase the ductility of the metal. Some sylphon bellows can then be run through seven or eight rolling operations without being annealed again. Others have to be annealed again after about half of the rolling operations have been finished.

Thus we see the length of time required to make a sylphon bellows from the blank to the finished product is a long one. The new method of corrugating a sylphon bellows takes the tube, F, and makes the bellows, I, in one operation, which saves considerable time and reduces the cost of manufacture.

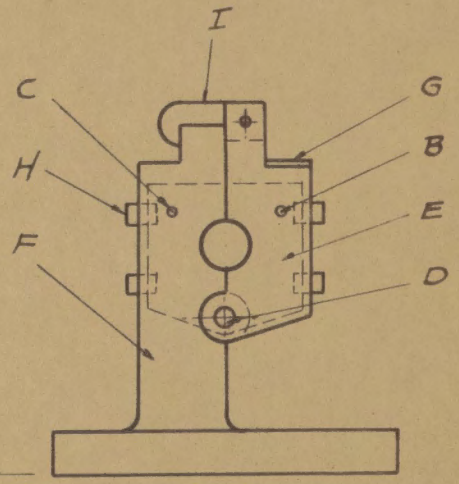
The Theory of the New Method.--The theory by which the machine was developped is interesting. It was thought that, by taking a straight thin walled tube and holding it in a suitable manner, in counterbored plates, sealing the open end and introducing internal pressure, and forcing the plates together along the axis of the tube, the internal pressure would force the corrugations out as the tube and plates were forced together. That is, the internal pressure would act as the sand does that is placed in pipes and tubes for producing smooth bends. By compressing the tube along its axis with internal water pressure smooth corrugations would result from the counterbored spaces in the plates. An important feature of the theory is the spacing of the plates accurately and holding them in their respective positions until the internal pressure swells the tube between the plates enough so that in forcing the plates together they will not lose their spacing.

The Experimental Machine.--Accordingly an experimental hydraulic machine was built and tried out. Figure 3 is a

sketch of the cradle made in halves and hinged at the bottom. The bore in the plates fits the tube exactly. The counterbore is large enough to receive the fold or corrugation of the sylphon bellows after it has been formed. The plates travel horizontally on three rods, B, C and D. The large rod, D, was placed through the hinges of the plates. One rod was placed through each half to locate and hold the plates. Two large thick end plates, E, were made and hinged to two uprights, F, from the bed of the cradle. These end plates were hinged around the same rod, D, as the plates were. The rod, B, that is through the front half of the plates, is held tight in the end plates, E. The plates, A, were made a close slip fit on the rods, B, C, and D. The other rod, C, through the back half of the plates, is held in the two uprights, F, of the cradle bed castings. Thus upon assembling we have half of the plates located by the two uprights, F, and the other half free to swing open around the hinge rod D. The two end plates, E, were tied together by an iron bar, G. Springs, H, were mounted between each two plates so that the plates would separate and be somewhere near the correct spacing required. Different strengths of springs were used for different spacings. An arrangement was worked out whereby spacers were brought between the plates. These spacers (not shown in sketch, see Figure 8J) remain between the plates until the pressure has expanded the tube enough so that the plates, when being forced together, will not slip on the tube.



BACK VIEW



LEFT END VIEW

SKETCH OF CRADLE

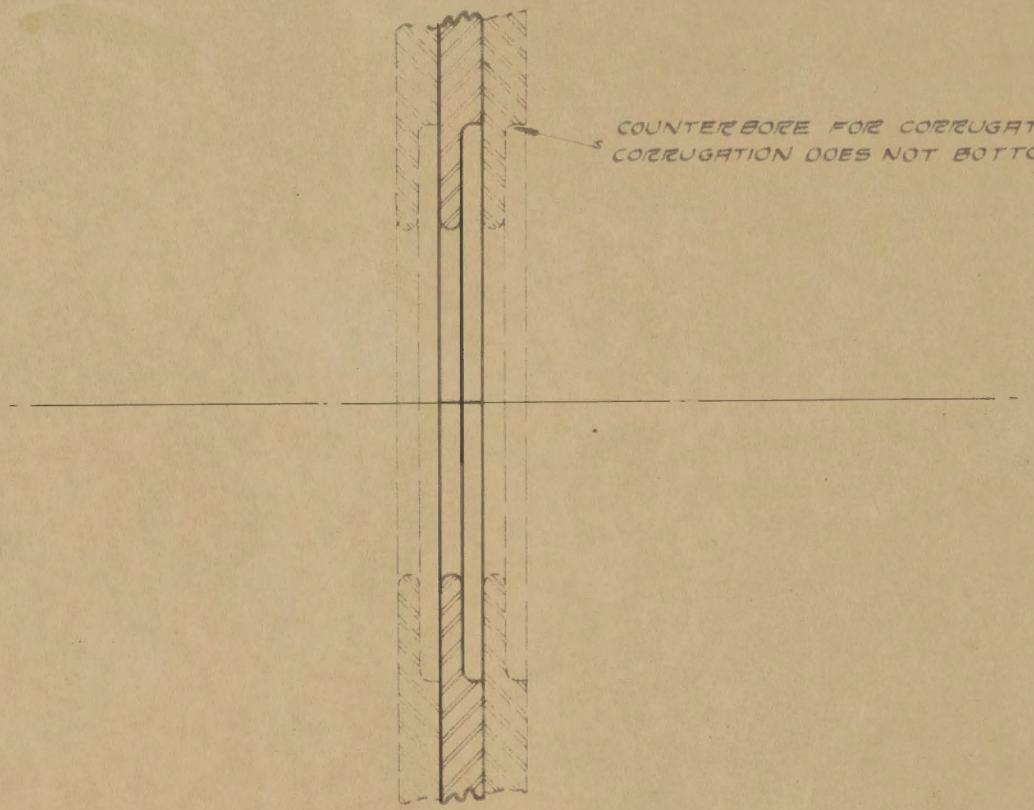
FIGURE 3

L.G.P

Thus each original length of the tube between plates is unchanged. As the plates, A, are forced together, the original spacings are reduced in axial length in proportion to the stroke of the hydraulic cylinder that compresses the tubes, and the internal pressure expands the tubes out in corrugations. The corrugations do not touch the largest diameter of the counterbore. See Figure 4 for a horizontal section view of the plates. They are shown closed. There are places milled in the plates to receive the springs, H, when the plates are flush.

On the machine the operator has several operations to perform. Assuming the cradle is open the operator places the tube in the plates, 3A, closes the front half of the cradle and latches the cradle, closes the latches on the plates, opens a four-way hydraulic valve which operates the cylinder that holds the sealing collet that seals the end of the tube and the cylinder that boosts the pressure and the cylinder that closes the plates, throws the handle that withdraws the spacers and unlocks the hydraulic ram, returns the lever of the four-way valve to its original place which withdraws the hydraulic cylinder plungers, opens the plate latches, opens the cradle latches and cradle, and withdraws the complete bellows. All of this takes place much more rapidly than the time it takes to tell about it.

The cradle latches, 3I, are fastened to the handle (not shown). Each plate has a separate latch (see 7S) to keep the plate halves in the same plane and also to keep the halves



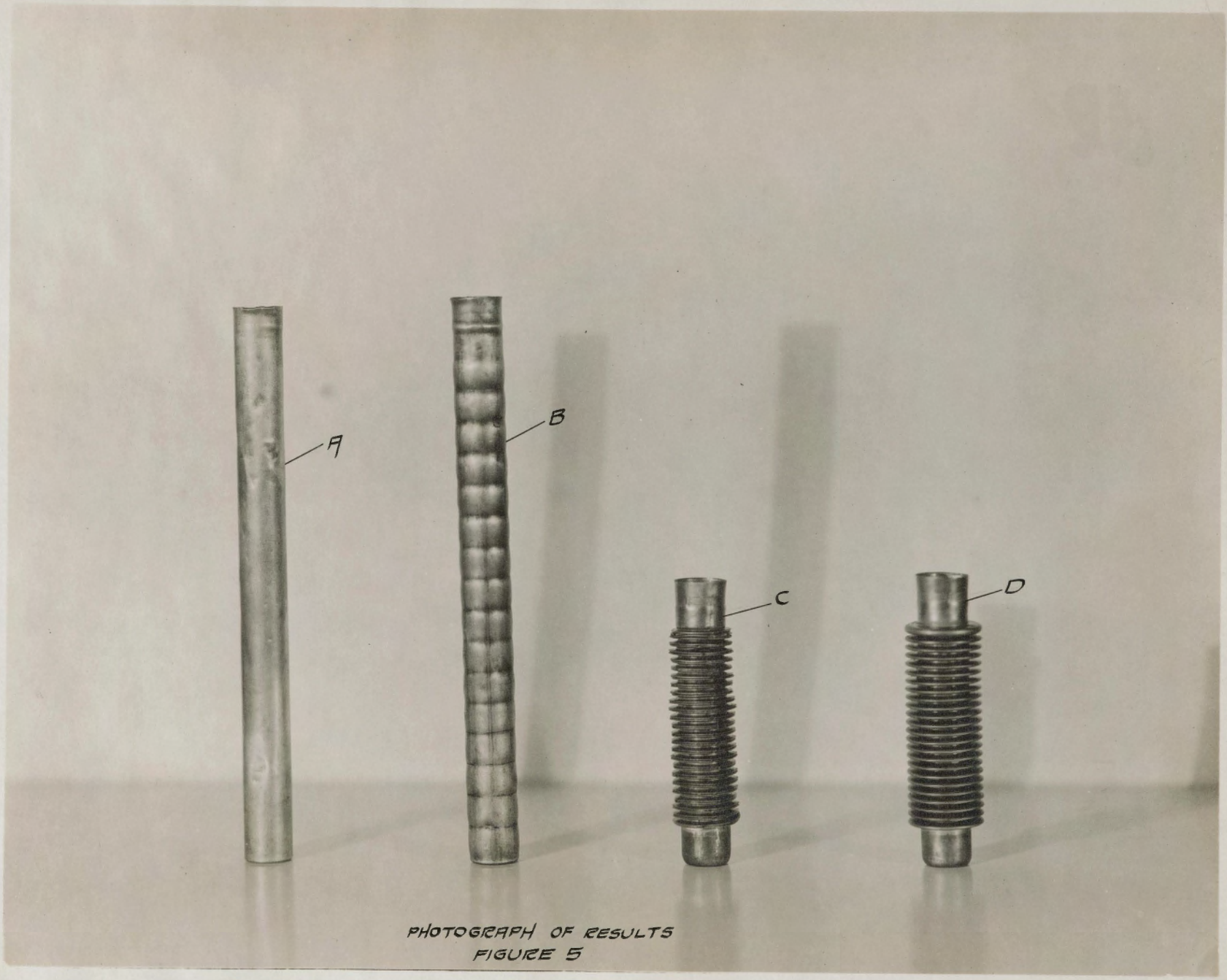
HORIZONTAL SECTION OF PLATES - CLOSED

FIGURE 4

L.G.P.

together. The four-way valve permits water to flow into or out of the three double-acting cylinders. One cylinder travels in and holds a sealing collet. The collet is a four spring jaw clamp type and seals around the end of the tube. As the collet travels forward the taper on the outside of the jaws closes them as they travel into a tapered hole. The booster cylinder boosts the pressure from the 150 pounds per square inch in the reservoir tank and cylinders up to about 3500 pounds per square inch. The pressure is regulated to that which is needed. The cylinder that works the ram has a ram lock on it. When the four-way valve is thrown, the ram travels in until it is brought to rest by the ram lock as the end touches the plates. The ram is brought to rest until the booster cylinder boosts the pressure and swells the tube enough to keep the plates spaced without the need of the spacers. Then the handle is thrown that removes the spacers from between the plates and unlocks the ram. The ram then forces the plates together and corrugates the tube making a sylphon bellows.

Figure 5 is a photograph of the actual results obtained on this machine. The tube, A, is the same as the tube 2F. It is a tube with a bottom in it. The tube, B, is one that has been placed in the machine and the pressure added internally, but not corrugated. It shows clearly how the pressure swells out the tube between the plates. The depressions or shaded portions are the same size as the original tube and



PHOTOGRAPH OF RESULTS
FIGURE 5

are the places around which the plates clamped. After a tube has been so swelled, the spacers can be removed. Upon forcing the plates together, the original spacing remains and makes one corrugation. Figure 5C shows the result of not enough internal pressure. The corrugations were not forced out and the tube was crumpled up. None of the corrugations were even slightly formed. The pressure required has to be found experimentally. The bellows, D, is one that was perfectly formed after the pressure had been determined.

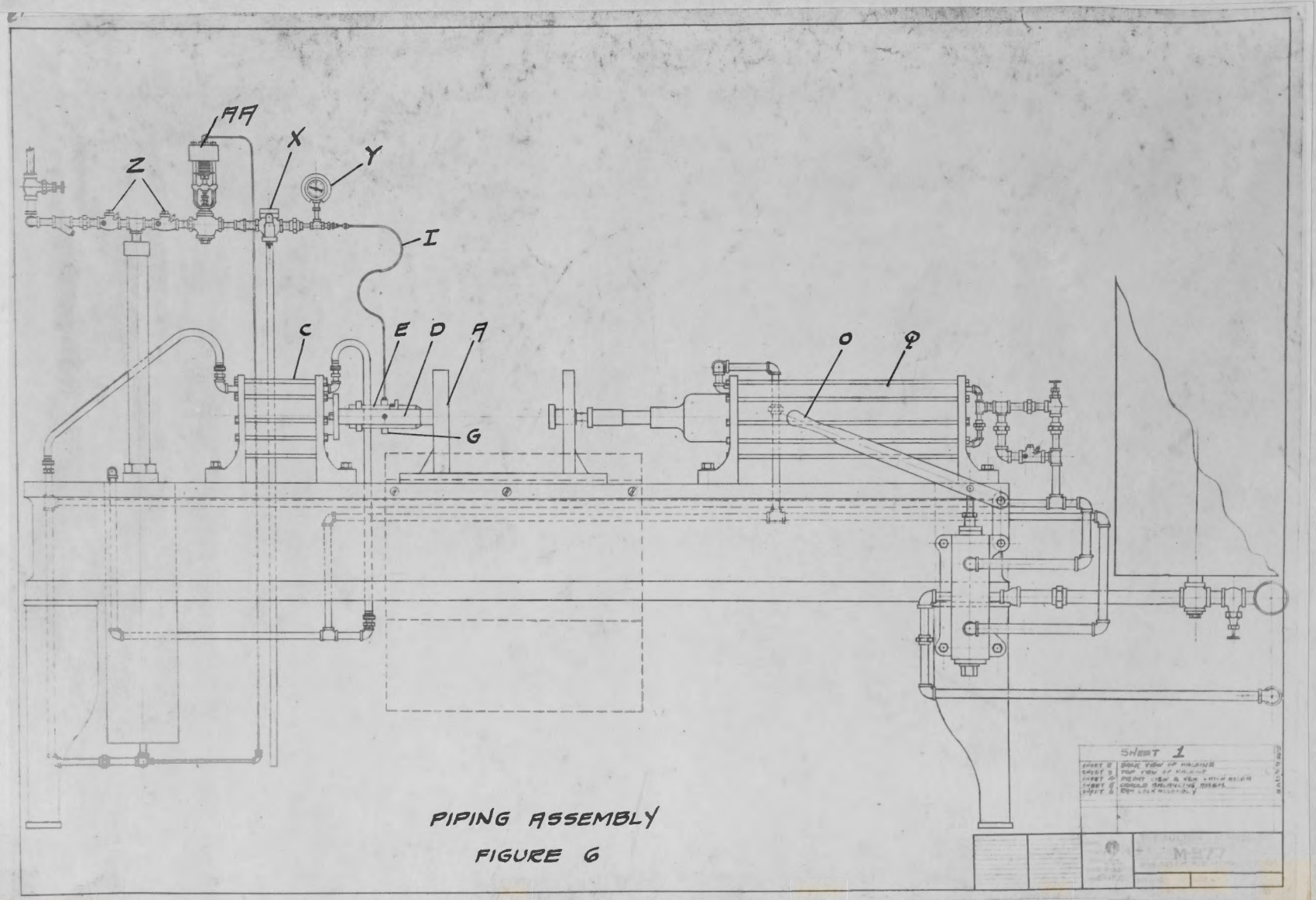
The results obtained have proved that the theory of the machine is all right. Flexible metallic bellows can be made in one operation from a straight tube.

The Beginning of the Work.--The experimental machine having proved satisfactory, the company decided to build three machines that would do for production use. There was a discussion as to whether some of the operations could be eliminated. It happened that the assistant chief draftsman gave the writer the job, probably because the writer had had some work on the experimental machine and understood the operation of it. The writer started on the assembly drawing first. In building up the assembly first, the details were all made by the time the assembly was finished. That is as each detail was drawn in the assembly, a sketch was made of it. If there was already a drawing of a similar part, a blue-print was made and marked with a colored pencil so the

part would fit the new machine. Upon completion of the drawings of the front, back and top views of the machine, each detail was already worked out and a sketch or marked blue-print was available. The writer then had two draftsmen make the detail drawings. Each was checked with each detail by dimension by the writer. Upon the completion of the drawings of the castings, blue-prints were made and taken to the foundry and tool room by the writer. As this is written (5-2-32), the tool room has received the castings from the foundry and is machining them. All of the detail drawings have not yet been sent to the tool room. The tool room is expected to begin on the details in about two weeks.

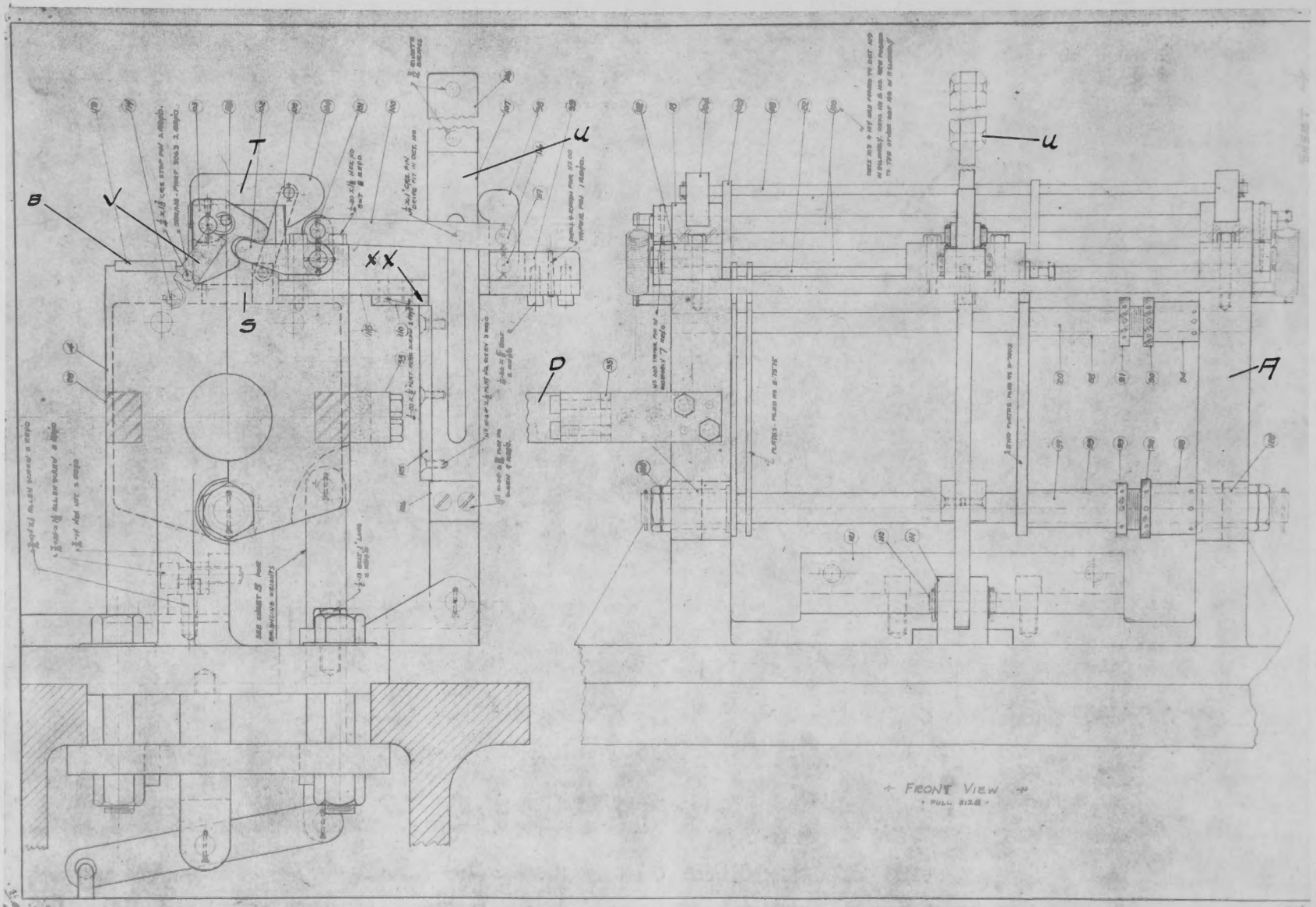
Figure 6 is the piping diagram of the new machine. Figure 7 is a front view of the cradle and the new latching mechanism designed by the writer. Figure 8 is a top view and Figure 9 is a back view of the machine.

Problems Confronted and Methods of Overcoming Them.--One problem confronted ~~with~~ upon the experimental machine was bracing the cradle. The force of the sealing collet cylinder, 6, 8, and 9C was taken by the left upright (Figure 3F) and transmitted to the base. The upright was seen to give a little in actual operation, so the uprights were changed to be cast in one piece with a large base and the strengthening webs made longer (see cradle Figure 6, and 7A). A steel



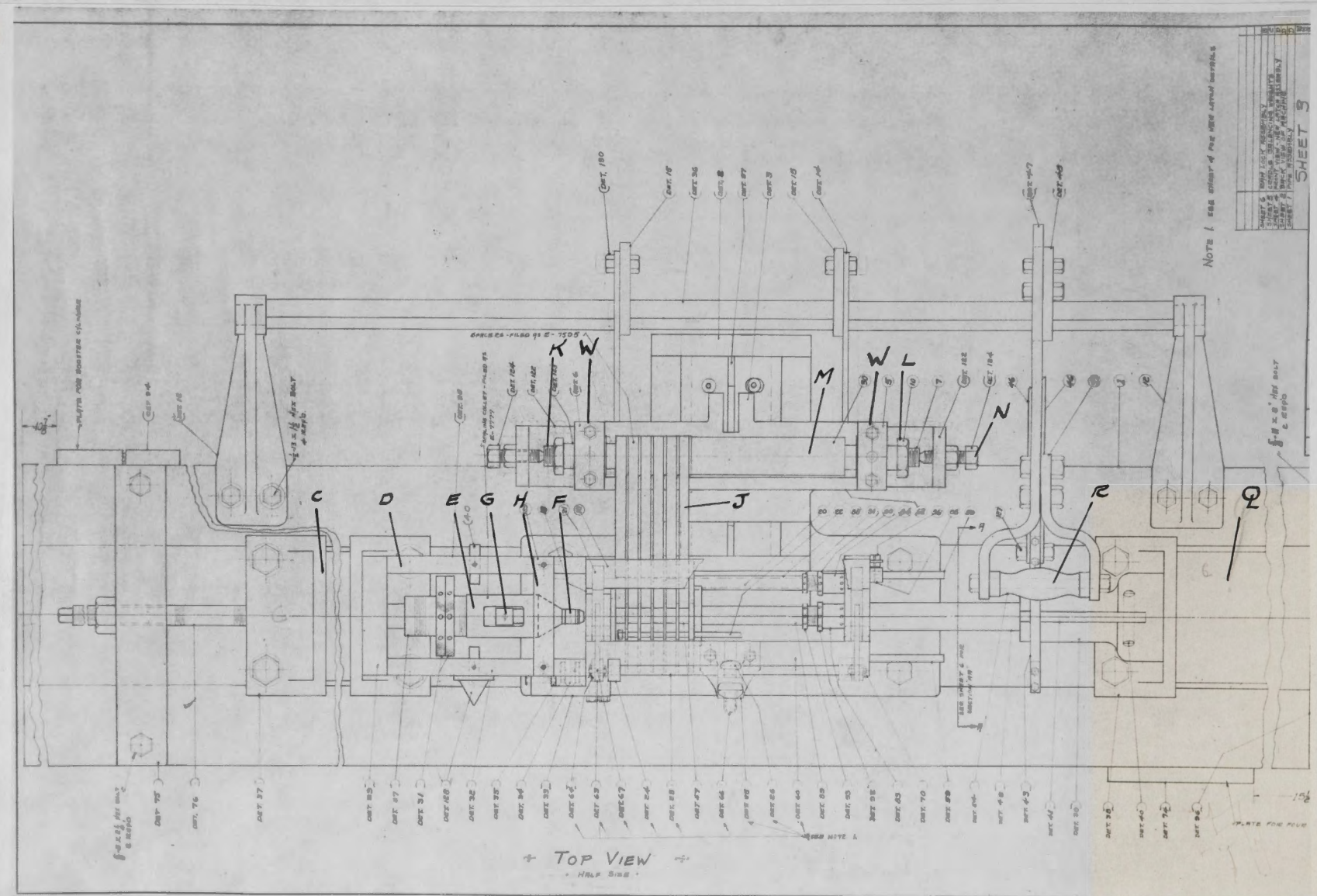
PIPING ASSEMBLY

FIGURE 6



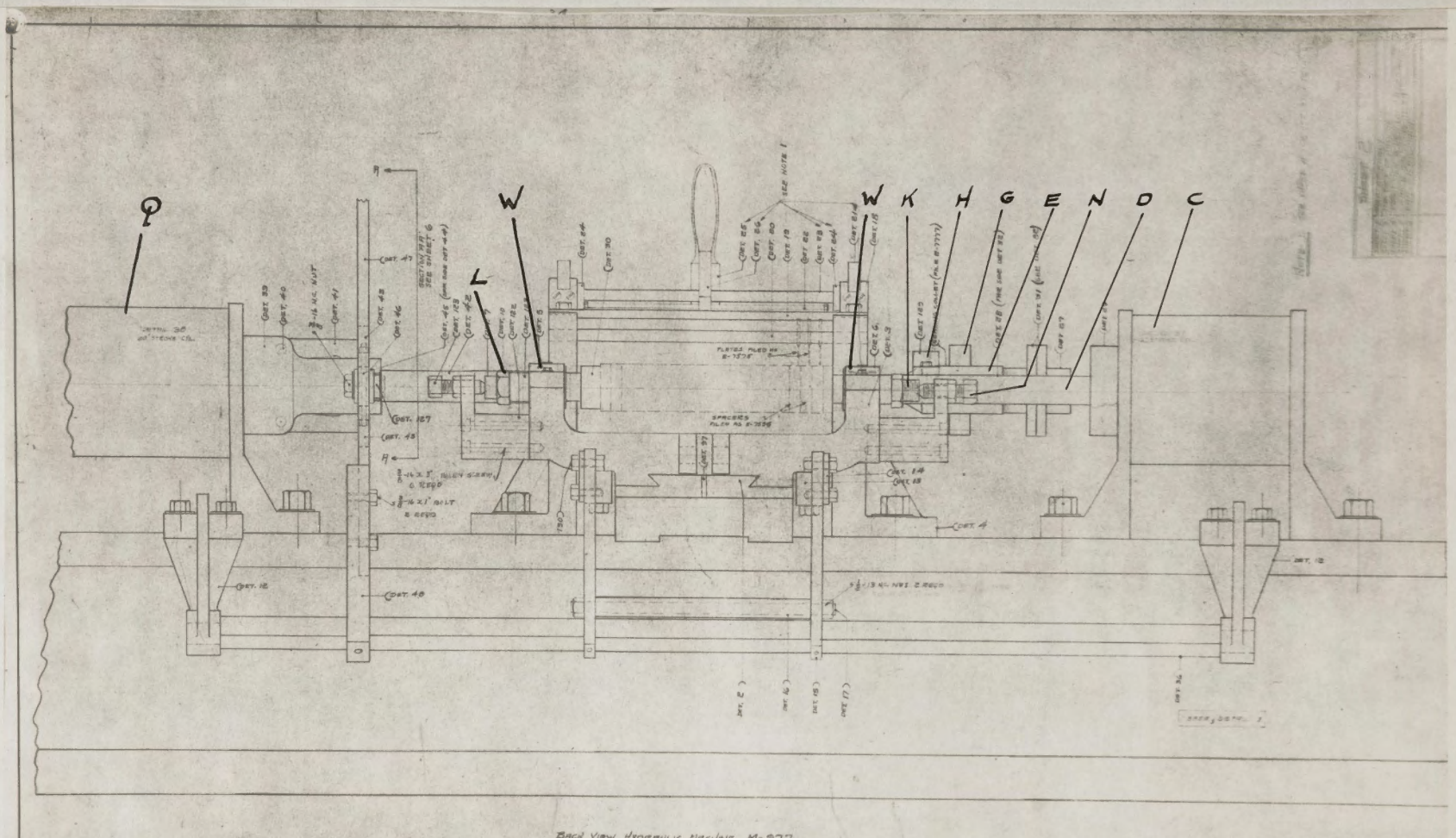
FRONT VIEW AND NEW LATCH ASSEMBLY

FIGURE 7.



SHEET 3
NOTE 1 SEE SHEET 4 FOR NEW LATCH DETAILS
C
D
E
G
H
F
J
K
W
M
W
L
N
R
Q
TOP VIEW
HALF SIZE
PLATE FOR FOUR

FIGURE 8



BACK VIEW HYDRAULIC MACHINE M-977
HALF SIZE

FIGURE 9

bar, 7B, was placed across the top of the two uprights. Also the left upright projection is tied to the hydraulic cylinder frame, 6C, by steel bars, 6, 7, 8 and 9D. By having the uprights, 3F, cast in one piece, 6A, the webs longer, the left end of the upright casting tied to the hydraulic frame, and a large base, the force from the hydraulic cylinder transmitted through the sealing collet will be transmitted to the bed of the machine without perceptible bending or giving.

Another problem that is important is the sealing collet. The four jaw sealing collet used on the first machine leaked some because of the metal to metal contact. However this was incidental. The cost of making a four jaw spring collet for every different diameter tube was thought to be too great. The collet shown on this machine was worked out by the writer from an outline sketch by the assistant chief draftsman. This new collet, 6, 8, and 9E, seals inside of the tube by expanding a rubber ring, 8F, against the inside of the tube walls. The cylinder, 8 and 9C, moves the collet up until the rubber is inside of the end of the tube. An adjustable stop, 8 and 9H, catches the plunger, 6, 8, and 9G, which expands the rubber, 8F, lessening its axial dimension and increasing the diameter. For different diameter tubes, a new rubber and retaining washer are all the extra parts required. The rubber and washer are made .005 of an inch smaller than the inside diameter of the tube. The retaining

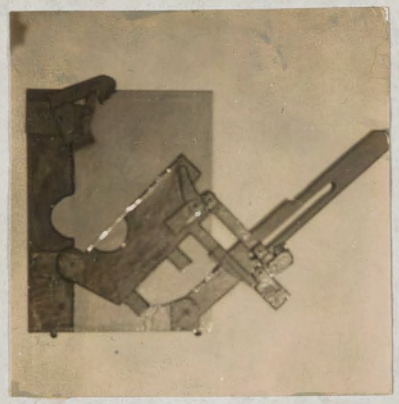
nut is tapered so it will enter the tube readily. The cost of making these extra parts is a small fraction of that of a four jaw spring collet. Also this collet will seal watertight. One such collet has been made and tried out on the old machine lately and works perfectly. The pressure enters the bellows through the collet by means of tube 6I.

The problem of the time required in a new set up was acute. This took from one hour to a whole day. The spacers gave considerable trouble because of dirt, grease, or other foreign matter getting between them in assembling. The spacers are finished, ground and lapped and two consecutive set ups did not always give the same spacing. Accordingly an arrangement was made by which the spacers, 8J, are clamped together on the spacer rod, 8 and 9K, by nuts, 8 and 9L, and adequate fillers, 8M. Formerly the nuts had to be removed before the spacers could be taken off or replaced. Now the whole rod can be quickly removed with the spacers intact by loosening the adjusting screws, 8 and 9N, and removing the bearing caps, 8 and 9W. The whole set up can be laid away for later use. The spacing is not destroyed by this method. The time of setting up the machine for a production run will be reduced.

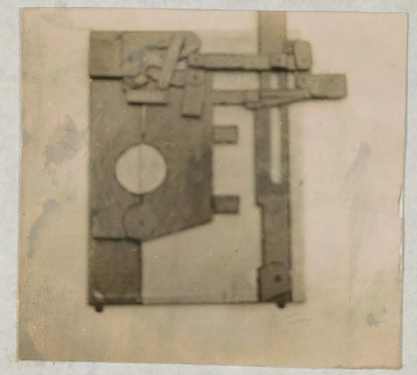
One operation was eliminated by tying the plate latches, 7S, to the cradle latches, 7T. As the operator pulls the cradle handle, 7U, towards him, the cradle latches, 7T, are lifted along with the plate latches, 7S, before the handle unlocks the cradle hinge on the handle at point XX on Fig-

ure 7. The handle moves only ¼ of an inch to unlock the cradle completely, and then continues to open the front half of it. The cradle latches and moving cams were designed completely by the author. A unique method of testing them was tried. The cams, handle, cradle and latches were cut out of paper and pasted on 1/8 of an inch thick cardboard, and the moving parts pinned in their places. Figure 10 shows two photographs of the cardboard model showing the cradle open at A and closed at B. The cardboard model works very well. The writer also laid out the cams and their movements in the extreme positions in double scale for checking purposes. The spring, 7V, holds the latches closed until opened more than halfway by the handle, 7U. The spring is then on the opposite side of dead center and holds the latches and cams open until forcibly closed by the upward movement of the lever, 7U. The problem of opening the cradle latches and the plate latches at the same time with a ¼ of an inch movement of the handle called for considerable ingenuity.

The front half of the cradle will be quite heavy to lift, especially after the operator has raised it about one hundred times an hour for several hours. Accordingly the cradle was balanced by a system of levers and a counterweight as can be seen on Figure 7. The weight is not shown but depends on the tightness of the hinge points. It can be determined once and for all after the machine has been



A



B

Photographs of the Cardboard Model

Figure 10.

built. In a production run on the old machine a certain bellows was made at the rate of one hundred per hour. By eliminating one operation and balancing the front half of the cradle, the number that can be made in one hour will be increased. The time for corrugating a bellows hydraulically is less than that of one rolling operation.

Figure 6 shows the front of the machine and the piping arrangement. Q is the hydraulic cylinder that moves the ram which closes the plates. C is the sealing collet cylinder. P is the booster cylinder that increases the pressure. It moves a plunger in the large tube that is attached on top. Y is the pressure gage. At X is the pressure regulating valve. At AA is the valve that closes off the system from the booster to the sealing collet so that water does not escape. The valve, AA, is opened only when the pressure is turned on the hydraulic cylinders. Two check valves, Z, keep the water from flowing in the wrong direction.

Probable New Features to be Added.--The operator will have to take one step to the right and throw the four way valve lever, 60, down and later step back and throw it up. When the machine is built and is working properly a double-acting air cylinder may be placed on the right side to work the four way valve. The air cylinder would be operated by a small air valve placed near the center of the machine. The air cylinder would make the operations of the machine an easier job. Another hydraulic cylinder may be placed

on the back of the machine to move the spacer carriage in and out instead of moving it by the handle, 8R. Lugs were cast on the spacer carriage with this in mind. A pressure regulating valve could be used to give the cylinder enough pressure to move the spacer carriage in and out, but not enough to bend or break anything in case of an accident.

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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