INDUSTRIAL DATA PROCESSING APPLICATIONS REPORT

Applications	Design of Numerical Control Machines
Type of Industry	Manufacturer of Metal-forming Presses
Name of User	Danly Machine Corp. Chicago, Ill.

Equipment Used	IBM 1130 Computer System CalComp 564 Plotter Digitronics--Tally Tape Read-Punch

Synopsis

Danly Machine Corp. produces metal-forming presses designed to customer specifications. The design of these machines and machine parts has been turned over to the computer. Programs have been written which utilize mathematical models to automate machine design, run verification procedures on these designs and generate a numerical control tape to operate the company's milling machines. Automated engineering design of cams has been developed to a point where about 90 percent of all machine tools can be computer-designed, according to the company.

The Danly Machine Corp. markets internationally throughout the world and has annual sales in excess of $50 million. More than 60 percent of its business is in presses and the rest in die-makers' supplies and die sets. In addition to the main plant in Chicago, there is a Danly plant in Belgium, and the firm has recently acquired the Onsrud Machine Works, Inc., in Niles, Ill., a producer of numerical control and manually-controlled milling machines and woodworking equipment.

Background to EDP

Danly has been involved in engineering computing for about 11 years. The first computer used by the company was an IBM 650 at a local data center for engineering design and analysis. In 1961, an IBM 1401 was installed for accounting use and in 1962 Danly's first engineering computer, an RPC 4000, was installed. Danly ordered the 1130 on announcement and transferred all engineering work to it. The 1401 has been exchanged for a System/360 Model 30, and all non-technical data processing is performed on that system.

The technical segment of Danly's EDP effort is planned and performed by the Technical Services Department. Its function is to promote and develop applications both inside and outside of Danly. The department presently comprises eight people, six of whom are programers, with the remaining two handling system operation.

Products and Services

Danly designs and produces mechanical, hydraulic, and pneumatic presses and die makers' supplies. These are the major products. In the process of designing a press, there can be numerous structures and drive components such as gears, shafts, and bearings which must be designed or analyzed for strength and rigidity. Integral parts of metal forming presses are cams (discs or cylinders of irregular shape). These cams, when placed in motion on a tooling machine, impart a reciprocal shape to the metal part being tooled.

Cams are produced both as integral parts of customers' presses and for Danly's own use to mill parts for a customer machine.

Because two presses are seldom the same, such machines would seem to be poor candidates for automated design and/or design analysis via computer.

A library of programs has been developed to assist in this task. These individual programs represent modules which Danly engineers can select based on the problems confronting them in their specific jobs. Modules range from short, simple programs which analyze one part, to systems which automatically design all components in various subassemblies.

Creating Programs

Programs for Danly have been developed over a period of years. They produce specifications for various parts and for subassemblies of the equipment. All of the programs are written in Fortran with the exception of a few assembler written input/output subroutines. The source programs are compiled, stored on discs, and dumped into digit decks. The working copy of the program that is loaded into the computer at execution is time stored on the disc memory. The source and object decks are kept in card filing cabinets for back-up purposes. However, programs are protected by the IBM MONITOR system and can be deleted only through the MONITOR specifications.

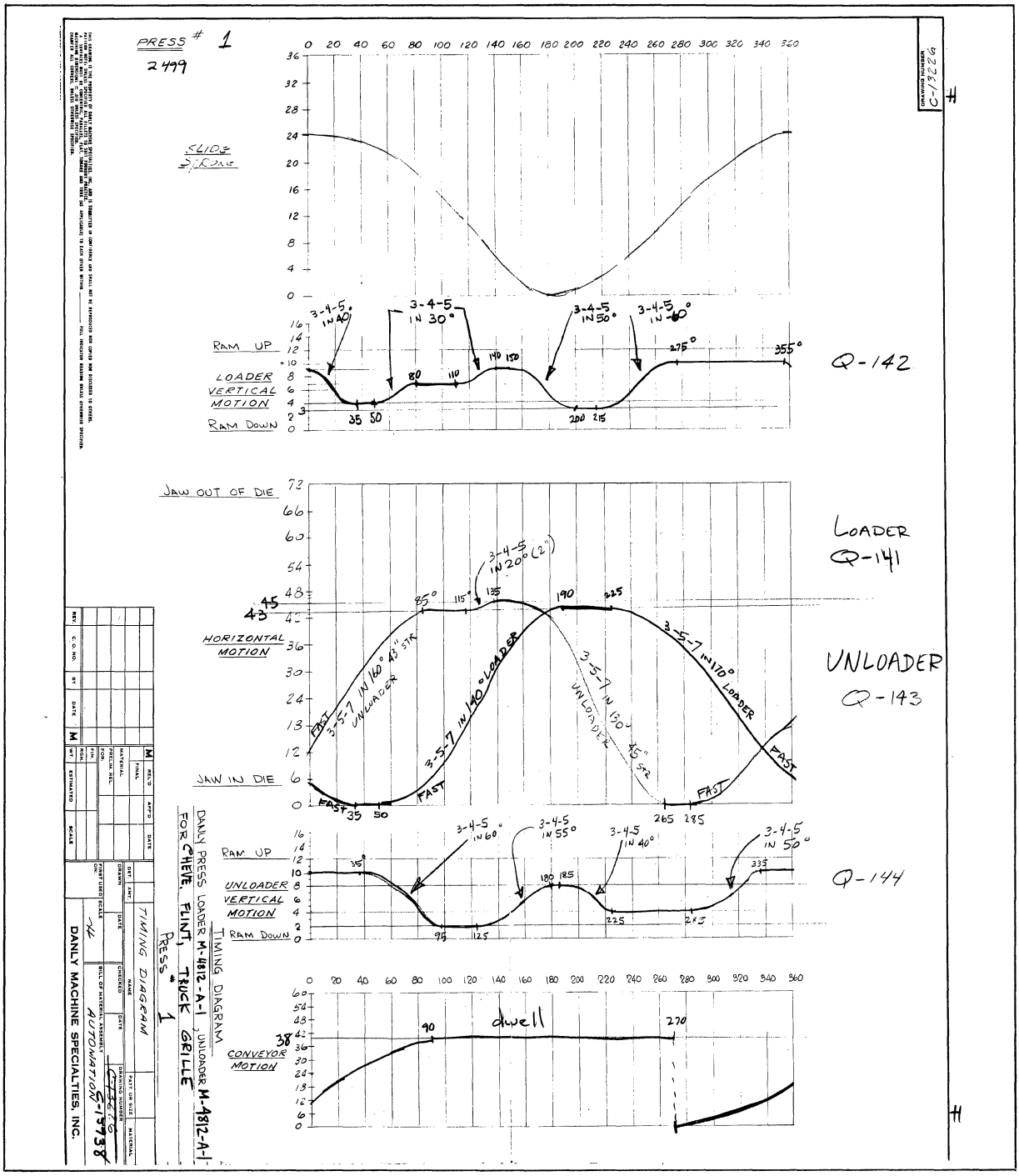
The stock programs stored in the 1130 can handle the design of 95 percent of the mechanical types of machine tool, according to John Hagstrom, manager of Danly's numerical control projects. The existing programs can handle about 90 percent of all motion types required in the caming industry, according to company estimates.

Cam Design

One of the by-products of machine design efforts was the development of a computerized cam design system. With it, Danly designers or customers can specify the motion requirements to be produced by a particular mechanism, and engineers can automatically design the profile, produce a full scale drawing of the cam, and make a motion diagram and a tape for Numerical Control machining of the finished cam. In addition, the N/C tape can be read back by the computer and checked for existence of any errors in punching and data validity.

Order Input

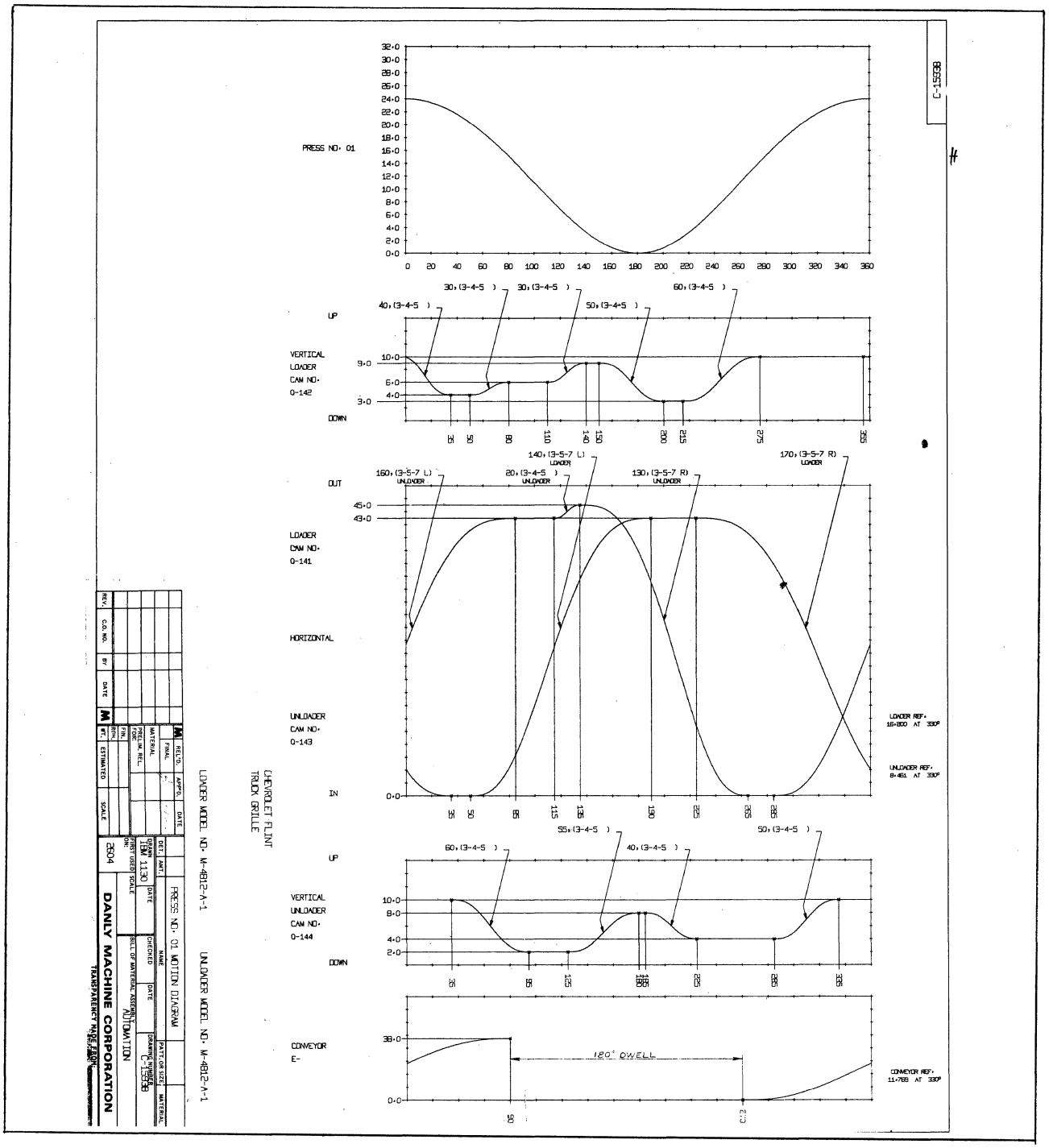
The customer sends his requirements to Danly's engineering department in drawing form. These requirements are essentially the motion characteristics of the output portion of the mechanism to be produced.



CUSTOMER SPECIFICATIONS COME TO DANLY AS SKETCHED MOTION DIAGRAMS.

Characteristics include the structure's basic specifications, the imposed conditions and parameters within which the 1130 must work--the general size and shape limitations. The

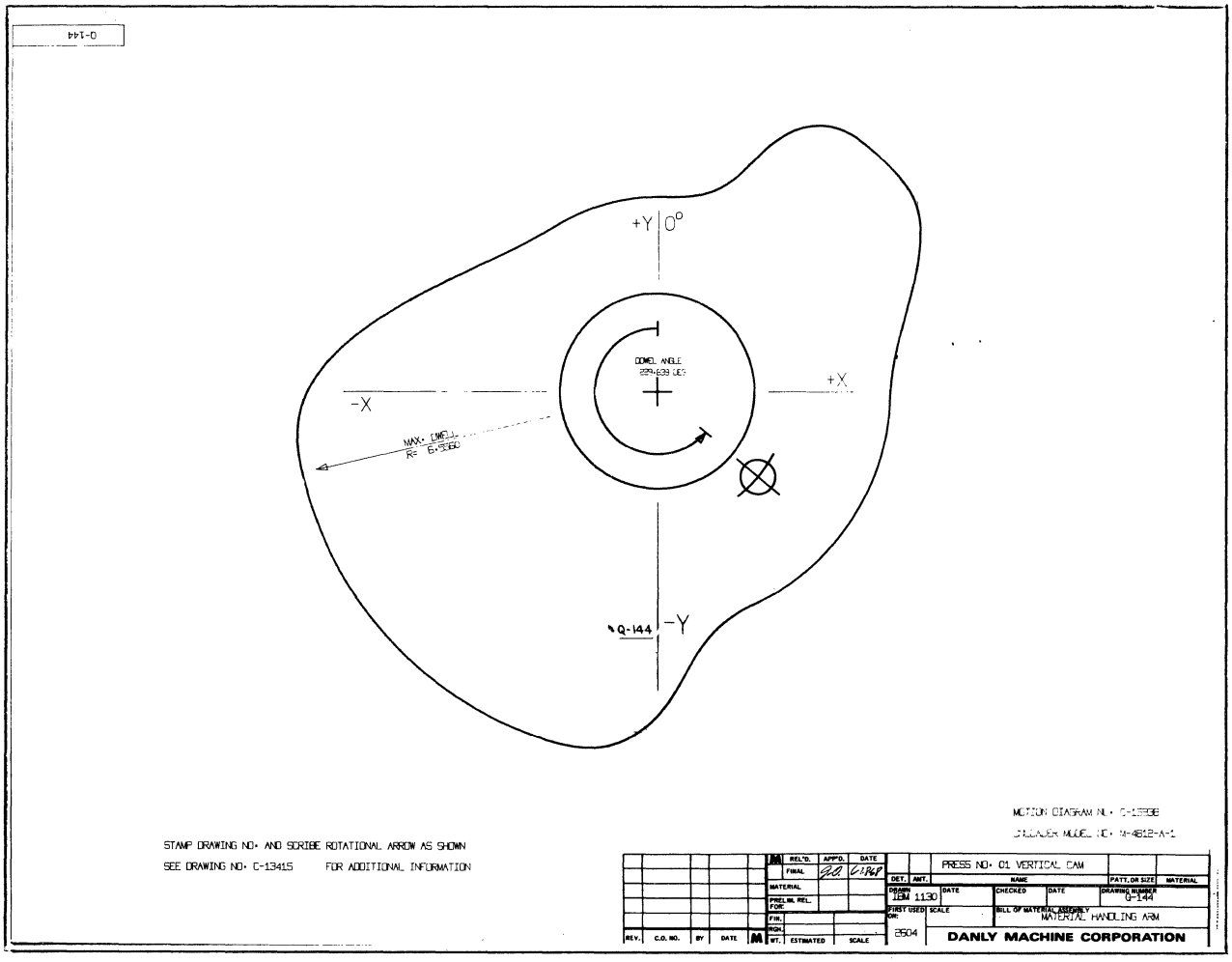
customer's drawings or motion diagrams are checked by the engineering staff for feasibility. The computer operator is given one of these edited drawings; he reads the requirements directly from the motion diagram and punches up cards containing the numerical parameters. Previously this read and punch step was done by engineers, but the computer operator became familiar with the information and now interprets it for card punching himself.



A REFINED MOTION DIAGRAM, RE-DRAWN BY DANLY ENGINEERS FROM CUSTOMER SPECIFICATIONS AFTER A FEASIBILITY CHECK.

Various types of cards are generated by this operation. The model number card contains the descriptive parameters pertaining to the cam mechanism. The job number card and the drawing number card are for cam identification or other part identification. Press cards describe the parameters of the press (the machine used to tool the cam or parts). Identification cards for the cam identify drawings, motions, etc., that are needed to produce the part. An option card describes the refinement of an angular increase such as half a degree. Motion cards describe the beginning and end of the series of coordinates for a particular design sequence of motions. Other punched cards can include identification numbers for motion diagrams, miscellaneous notes cards (which trigger printing of certain standard information on a drawing) and conveyor cards with conveyor and motion identification.

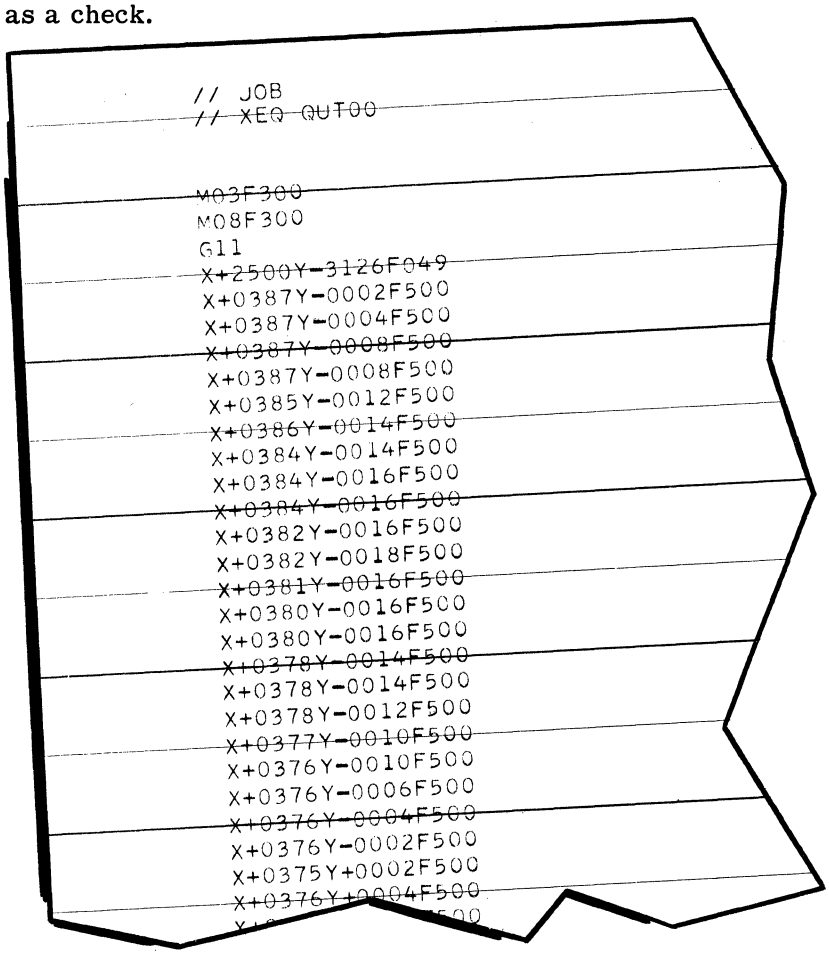
The punched cards are fed into the 1130 and simultaneously generate a drawing on the plotter, and a punched paper tape. Danly's engineers developed the computer interface for the Digitronics tape-reader and the Tally tape-punch. The units are independent of each other but operate strictly on-line to the computer. The plotter parrots back the input diagram (which has previously existed only numerically). The diagrams of the motion characteristics show the engineer if the computer has given him what he asked for. Output of the computer run includes a graphic plot of the motion characteristics (to scale) of the unit to be produced, a full-scale engineering drawing with the profiles of the cam, a cutting template and the numerical control tape containing the machine tool moves needed to manufacture the cam.



THE DIGITAL PLOTTER, USING THE MOTION DIAGRAM PARAMETERS, GENERATES A PUNCHED PAPER TAPE AND A DRAWING OF THE REQUIRED CAM.

Verification

In order to verify the punched paper numerical control tape, a verifier program runs the tape's program in reverse to come up with the original input coordinates--assuming the tape is correct. If original input data is not produced, the tape is probably incorrect. The verification process generates a path plot and a listing of the tape content which also serves as a check.



A LISTING OF PAPER TAPE "CONTENT" FOR REFERENCE PURPOSES IS GENERATED DURING THE VERIFICATION PROGRAM RUN

Benefits of machine-generated numerical control tape are speed and accuracy. Hand-punching a tape is a "typographical process open to typographical errors and may take one man-day to complete," explains Carl Tack, director of technical services. In contrast, cards fed into the 1130 generate the same complete numerical control tape in less than five minutes total time, and using fewer rounded-off numbers.

OTHER APPLICATIONS

Numerical Control

Danly is interested in N/C from three standpoints. First, the firm manufactures N/C milling machines produced by the Onsrud Division. Consequently, it feels impelled to implement some ideas for computer assistance to benefit the customers. Second, tape-controlled machines of various types are used in the Danly shop, and the computer is a necessity in the production of many of the tapes. Third, Danly feels that some of the programs developed are of sufficient general interest to warrant the marketing of these program services to other N/C manufacturers and users.

At the time the 1130 was installed, the company knew that it would be expanding its numerical control activities. Danly has 13 numerical control machines in its plant, including nine point-to-point drilling machines and three contouring lathes. So, the 1130 was equipped with special paper tape handling equipment. The expansion materialized, and in terms of direct cost, the numerical control savings are the most noticeable.

With the computer, input is universal in that it is not related to any specific machine tool. Just one card is necessary to specify (for program triggering purposes) the machine tool to be used. From that card, the computer automatically punches the tape in the proper language and format to control a particular milling machine. A programer does not need to be highly knowledgeable about an entire series of machines. If a selected machine goes down, the program can be quickly re-run for an alternate machine.

Structural Design Analysis

The 1130 accomplishes structural design analysis in about two minutes. Previously, an engineer working with a desk calculator and slide rule would have needed at least 30 minutes to make the same calculations. Press operating linkage design and analysis is a project by which Danly produces a linkage with certain motion characteristics, stroke velocity, and dwell characteristics. Previously, the manual design process required a combination of graphic analysis and desk calculation with the use of log tables. It was slow and not particularly thorough. With Danly's general purpose linkage analysis program (capable of handling numerous linkage trains,) graphic analysis is reduced and hand calculations are eliminated. The computer will analyze the design and list the design characteristics.

While the savings in engineering time is most valuable, the company feels that the effect of the savings on the overall production cycle is even more important. When an engineer is given a press to design at Danly, the press has already been sold and must be delivered on schedule. Also, each press is designed only once in its exact form; the optimum design on the project must be achievable the first time around. There is no opportunity for evolutionary improvement such as exists in a production line operation.

Preparing Estimates for Job Quotations

It is frequently necessary to perform engineering design and analysis calculations not only to provide a firm basis for pricing, but also to confirm the feasibility of meeting various dimensional requirements. By using design and analysis programs, more realistic pricing schedules can be reached through computer estimates of material and components required. Then the preliminary design data can be filed for later use in case the bid becomes an order. About 10 percent of the computer's time is spent on engineering math jobs such as small special programs, generation of gear measurement data tables, books of cost data, etc.

Results and Future Plans

Carl Tack estimates "roughly" that the company would need more than $50,000 annually in added personnel costs in straight numerical applications alone to handle their present program without the 1130. "Obviously, we couldn't get these people (even if we could afford them), so we regard the computer as a 'defense' mechanism in our numerical control operations."

Danly is offering some of its programs for sale. (The cam design services are offered to manufacturers of cam-operated equipment.) And, as the company continues to expand its numerical control services, it plans also to provide software services for customers of Onsrud equipment. The staff has begun using the 1130 for control of the die-set manufacturing process from order point through production and final assembly, including the cutting template, routing and labor cards.

"One point is worth stressing in terms of costs," says Tack. "We can see a tremendous improvement in the quality and reliability of computing hardware and software in terms of what we can do for each dollar. A few years ago, each project we now handle would have cost three to four times as much. Many would simply have been economically impractical for a moderate-sized company like Danly."