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A STUDY OF MARKING METHODS FOR USE ON A HIGH-SPEED DIGITAL COORDINATOGRAPH

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I PURPOSE

The purpose of this report is to present the results of a study program conducted by STAT [redacted] to investigate a variety of marking methods that might be adaptable for use on a high speed coordinatograph. It was the specific intent of the study program to determine if any improvement could be made over the marking system STAT currently in use on the [redacted] E-80 High Speed Precision Coordinatograph.

II MARKING REQUIREMENTS

The basic requirements of the E-80 Coordinatograph system are such that the marking device must be capable of the following:

A. A combined line drawing and dotting capability. Lines are to be plotted at speeds up to 16 inches per second in either axis. Line widths and density should be consistent although slight variations which do not jeopardize reproduction are considered acceptable. Lines should start, stop and cross without skipping or spreading. (Charts to be produced require the generation of small symbols, figures, etc. in which the marker makes many short strokes and crosses previous lines.) Dots are to be plotted up to a rate of 350 per minute at a spacing of 1/8 inch. They should be uniform in size, shape and density and should appear 99% of the time.

B. The medium upon which the charts are to be drawn shall be from a 60 inch wide roll supply and shall be capable of producing good diazo copy.

C. The results of the marking system should be fast drying since it is desirable to wind the finished chart onto the takeup roll immediately upon its completion.

D. The system should be capable of operating for significant periods of time (up to 8 hours), reliably, without manual intervention or attention. Using an average writing speed of 12 inches per second and a use factor of 50%, the plotter would be required to draw approximately 175,000 inches of line per 8 hour day.

E. Special environmental conditions in the plotter room such as high humidity or total darkness are not acceptable. Materials and by-products shall not be toxic or unpleasant to handle, inflammable or otherwise dangerous.

III MARKING DEVICES CONSIDERED DURING DEVELOPMENT OF E-80 SYSTEM

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In the original design, [redacted] tested graphite pencils, ball point pens, ribbon percussion devices and capillary pens with ink on ordinary tracing paper. Each of the marking devices presented problems of some magnitude for an application such as the E-80 system. Pencils provided reliable operation, but presented problems of variable density and feeding graphite to the marking surface. Many ball point pens had a tendency to skip and when used without accessories such as wipers to rotate the ball were unreliable in starting and in making successive dots. Ribbon percussion devices were excellent for dotting but essentially unuseable for drawing lines. Capillary pens provided good density and line width control, good starting characteristics (if not left inactive too long), and good line performance at the expense of slow drying and the probability of spills, runs and smears.

Of the marking systems tested it was concluded that capillary pen and ink provided the greatest flexibility in terms of a wide selection of pens, ink and paper to meet the specific needs of any application. The E-80 Coordinatograph system was therefore supplied with a special purpose Electronic Associates, Inc. (EAI) pen and Brush Oscillograph No. RA276002 low viscosity, low surface tension, slow drying ink. The ink supply was contained in a plastic bottle which allowed up to a 4 inch head, which in turn was connected to the capillary pen by a short piece of 0.094" I.D. tubing.

IV PRESENT STATE OF THE ART

A wide variety of marking methods are available for graphic recording. While many are not applicable to the E-80 Coordinatograph, it would seem useful to note them in order that no desirable features of a system by overlooked. In general, marking systems may be divided into three broad categories; (1) those which mark the paper mechanically, (2) those which deposit a liquid such as ink, and (3) those which use heat, electricity or some other form of energy to create a visible change in the medium.

A. Mechanical Systems

Mechanical marking systems rely upon mechanical force or friction to transfer pigment from a source to the paper or to so modify the surface of the paper as to leave a visible trace. The simplest mechanical marking device is a wax or plastic pencil containing graphite or other pigment. Systems using pencils have good marking characteristics, write dry, hence never generate drips and smears, and work well with ordinary paper. Unfortunately they are fragile, hence subject to unpredictable catastrophic failure, and they do not generate lines and dots of uniform width and density.

A more complex mechanical system employs a hard stylus to effect a transfer or modification of pigment from an intermediate ribbon or sheet. The simplest case of this type system uses a full size sheet of carbon paper over the work. The writing stylus merely presses the carbon paper against the work wherever marks are desired. A similar effect is achieved with so-called carbonless carbon paper in which a coating on the work sheet changes color when a treated overlay sheet is pressed against it. In either case the work is not visible until the overlay sheet has been removed. A more complicated use of this principle uses a ribbon of overlay material carried by the marking device. Although such a system is ideal for dotting, a rather complicated rotating ribbon feed system must be provided for drawing lines. While such systems can mark ordinary paper, they use relatively large quantities of the intermediate material which may be expensive and is always inconvenient.

A third class of mechanical system relies upon the mechanical alteration of the surface of the work sheet to create a visible line. Many such systems employ a pigment which is trapped in minute opaque corpuscles in the coating of the sheet and released when the corpuscles are broken by mechanical pressure, or a continuous pigment which is normally covered by an opaque scattering layer of wax or other crystals and exposed when the mechanical pressure of the stylus removes or compresses the wax crystals. These systems offer two serious disadvantages. First, the pigment is uniformly present over the entire sheet initially, hence the material is usually quite opaque to start with. Diazo reproduction tends to be less than satisfactory. Second, the materials are expensive.

Other forms of pressure-sensitive materials use a two reagent system in which one colorless reagent is released into the paper to activate the other and cause a color change as a result of the passage of a pressure stylus. These systems can provide good lines and dots relatively insensitive to tracing speed and they make good diazo copies. On the other hand, they remain sensitive to scratches, folds, etc. and hence deteriorate with usage.

Another technique that is receiving much favorable attention in recent months is scribing; an incising of an opaque surface to produce a negative master from which positive prints can be made. This method is a reversal of the pencil or inking technique where the image is deposited upon the surface. "Scribe coat" films are now available with both a colored undercoat and a white topcoat on a transparent base. The scribed line cuts through both coatings to the transparent base. The cut edge of the colored undercoat contrasts with the white surface coating, making it easy to see where a line has been scribed without the need of a light table. Scribed films offer the advantages of permanence, toughness and dimensional stability and are masters from which a wide variety of excellent prints can be made. However, dotting is not done easily, requiring a rotating or spinning ability for the scribe tool. Also, the scribe coat material is relatively expensive and is not readily available in 60-inch wide roll form as required for the E-80 automatic paper feed system.

B. Liquid Ink Systems

Ink is still the most widely used method of marking. The simplest ink system applicable to the E-80 Coordinatograph is the capillary pen. This system employs a narrow tube to convey liquid ink from a reservoir to a pen which allows ink to flow onto the paper when the pen is in contact with the paper. When the pen is lifted surface tension at the tip prevents the ink from dripping.

Kingmann-White, Inc. successor to J. L. Cannon Mfg. Co., one of the developers of remote reservoir capillary inking systems, recommends that the level of the ink in the reservoir should always be below the level of the pen tip. This arrangement produces a relatively "dry" pen trace. It should be noted, the diameter of the pen tube does not influence the height to which the ink can be lifted when the pen is on the paper, but it does control the height to which the pen may be lifted above the reservoir when the pen is off the chart, without losing its prime. A capillary system provides the advantage of a large reservoir and relatively trouble free operation. Recent attempts by such companies as Kingmann-White and the Esterbrook Pen Company to improve pen tip design hold promise of recording at speeds greater than the ten inches per second once accepted as maximum. A recent new form of capillary pen employs a pigmented wax for its ink. The ink reservoir and pen tip are heated electrically so that the wax is molten. Upon contacting the cooler paper it cools to a solid state rapidly and is thereafter constructively dry. Whatever ink is used in a capillary pen, the viscosity of the ink is another critical parameter. Overly viscous inks will tend to write narrower lines or skip at higher writing speeds while inks of too low a viscosity tend to drip, run out along intersecting and connecting lines, and run back at the ends of lines.

A modified approach is to use a more volatile solvent so that the ink does truly dry on the paper and then to equip the pen with some device to resist clogging when the ink dries in the pen tip. Drafting pens of the Leroy and Rapidograph type are designed with this thought in mind and use a fine wire insert within the tubular pen tip which projects just far enough to give a slight up and down motion as the pen is brought into contact with the writing surface.

Ball point pens provide another possible solution for a suitable marker. They require considerably more force than a capillary system to write successfully, on the order of magnitude of five to fifteen grams or more. They have been used successfully at speeds up to forty or fifty inches per second. The line appears "dry" immediately, runs and drips are impossible since only motion of the ball surface can transfer ink out of the reservoir. On the other hand, since no ink is transferred without ball rotation, the system does not produce dots reliably. One other advantage of the ball point pen is its convenience. Either it works or you throw it away and put in one that does.

Mass production makes it economically feasible to replace them on an arbitrary schedule, thereby reducing danger of running dry in the middle of a plot.

Other pen and ink writing systems such as pressure-inking systems are under development by several companies including Brush Instruments Division of the Clevite Corporation, Esterline Angus Instrument Co., and Beckman Instruments, Inc. Specific details are not available, but in general, pressure pen systems require specialized inks with much higher viscosity, a smooth, hard surfaced paper, plus a higher pen pressure to assist in producing an effective seal between the pen tip and the paper. This requires that the pen tip configuration be such that it is held absolutely square with the writing surface when drawing. When the pen is lifted it is necessary to release the pressure before the tip is removed from the paper or else ink will flow from the pen tip.

C. Other Systems

A most familiar method is, of course, those systems using photographic emulsions which have a capability of producing extremely high quality copy. Very little consideration was given to them in this study because photographic techniques would not comply with the marking requirements defined in Section II of this report.

Electric discharge marking systems depend on an electric potential that burns the coating on a dry sensitized recording paper. The dry recording paper is now available in sheets or rolls and is not affected by light, changes in humidity or temperature. Copy is clear, dry, permanent and usable without further processing or development. Potentials of 70 to 500 volts are used for marking, the actual requirements depending on recording speed, recording current frequency, stylus shape and pressure. The recording surface is of relatively high resistance and the size of the mark is basically a function of voltage.

Some papers are also heat sensitive. For example Communication Papers, Inc. can supply "Timefax NDA" which will allow marking at about three inches per second with a stylus heated to 100°C. Increased marking speeds are possible as the temperature is raised.

In pursuing a study of this type, it seemed desirable to determine what other manufacturers who produce equipment similar to the E-80 system had chosen for markers and to note what success they have had. Personal contact was made with many of them. Table 1 indicates the marker choices of some of these manufacturers.

Table 1. Marker Choices of Some Manufacturers

Manufacturer	Marker Choice
Baldwin-Lima-Hamilton Corp.	Ink or Heat Writing
Beckman Instrument Inc.	Pressurized Ink (2 Models)
Benson-Lehner Corp.	(Trying everything) - Ball Point, Koh-I-Noor, Scribing, Spray-Future
California Computer Products, Inc. (Cal-Comp)	Ball Point Pen and Scribe
Clevite Corp., Brush Instruments Div.	Pressurized Ink 20 mm/sec and Thermal Sensitive Paper
Consolidated Electrodynamics Corp.	Heat Sensitive Paper
Data Equipment Co.	Lines - Pen and Ink Cartridge Characters - Ribbon, Percussion
Esterline-Angus Instrument Co., Inc.	Capillary Pen and Inertial Ink Pump
General Radio Co.	Electrode Stylus - 1 Mark Every 1/3000 sec.
Hewlett Packard Co. Sanborn Div.	Heated Stylus and Heat Sensitive Paper
Honeywell, Inc.	Capillary Pen
Houston Instrument Corp.	Esterbrook Pen Co. Special Capillary Pen
IBM Corp.	Ball Point
Leeds and Northrup Co.	Capillary Pen
Soss Mfg. Co. Amprobe Instruments	Pressure, Electro Sensitive
Texas Instruments, Inc.	Ink or Heat (Best Response with Ink)
Varian Associates	Capillary Pen
Voltron Products	Presses Pointer on Sensitized Paper

After talking with representatives of the manufacturers listed in Table I and in some cases with people who are using the equipment, two facts are worth noting. First, we did not find anyone who was operating a system that combined dotting and line drawing capabilities over a 60" x 60" area at the speeds, and to the accuracy required of the E-80 Coordinatograph. Secondly, while the choices are many and varied, inking is still the most popular form of marking.

Some of the problems encountered by the other manufacturers are illustrated by the following observations made during discussions with them. .... Have trouble with inking, especially at speeds in excess of 2 inches per second. Best results are obtained with a #1 Leroy Pen with Pelikan Ink on Mylar. Are experimenting with special inks .... Best results with Pelikan Ink and #0 Leroy Pen but do not try to operate faster than 4 inches per second .... Have given up using a free flowing ink pen. Scribing is used when good reliable charts are required. For some applications the pen mechanism has been modified to accept Papermate "Piggy Back" ball point refills.

V MATERIALS LIST

In considering the merits of the various marking systems, it must be remembered that the primary goal is to determine if an improvement can be made over the marking system presently in use on the E-80 Coordinatograph. This adds one further considertion to the requirements previously outlined in Section II, namely that the improvements must warrant whatever retro-fitting will be required in order to install the new marker.

From all the possibilities considered, two broad areas were chosen for further investigation; marking with electricity and marking with ink. While most of the effort in the inking tests were directed towards getting the right combination of pen and ink, it is recognized that the choice of a marking medium is an important part of the success of any marking system. The following criteria were considered as an amplification of those already established in Section II (Marking Requirements): (1) once the ink is on the paper it must cease flowing and become dry as rapidly as possible, (2) the paper or film should not experience excessive contraction or expansion due to atmospheric conditions, and (3) although economy is important, quality of work should take precedence over low cost. A good grade of drafting vellum similar to that presently used on the E-80 System was chosen as one possibility. This paper is stable as to atmospheric changes, contraction or expansion not exceeding 1/8 inch in 42 inches in either direction in a 36 hour period. This would be acceptable for many applications, but for superior stability as well as strength and durability it was decided to investigate drafting film. Consequently, a second medium tried was a 0.004 inch drafting film (matte one side) such as Dupont "Cronaflex" or Frederick Post "Polytex". Hereafter the mediums shall be referred to as paper and film respectively. Table 2 indicates the materials used in the tests performed during the study program.

Table 2. Materials List

Product	Manufacturer & Address	Use
No. 1000H Clearprint paper	Clearprint Paper Co. Emeryville, Calif.	Output medium for inking
Cronaflex drafting film (matte one side, 0.004 inch thick)	Dupont Wilmington, Delaware	
Polytex drafting film	Frederick Post Co. Chicago, Illinois	
Front grounding dry electro-sensitive recording paper	Alfax Paper & Engineering Co., Westboro, Mass	Output medium for electric marking
Electrosensitive Recording Papers	Communciation Papers Inc. Scranton, Pennsylvania	
Self Contained Marker #54-1 (0.008 inch I.D. Capillary Pen)	Esterbrook Pen Co. Cherry Hill, New Jersey	Marking device for inking
Capillary Pen #8610 Cartridge Type	Kingmann-White Inc. Placentia, California	
Capillary Pen	Electronic Associates Inc. Long Branch, New Jersey	
Liquid Ink Conversion Kit	California Computer Products Anaheim, California	

Table 2. Materials List - continued

Product	Manufacturer & Address	Use
Ball Point Pens	Kingmann-White Inc.	Marking device for inking
	Fisher Pen Co. Chicago, Illinois	
	The Paper Mate Co. Chicago, Illinois	
	Waterman-Bic Pen Corp. Milford, Connecticut	
	Government Issue Hanover #282	
Drafting Pens (Technical cartridge pen with stylus)	A. W. Faber-Castell-Higgins Newark, New Jersey	
Drafting Pen (Radipograph regular, jewel point end tungsten carbide points in sizes from 0.2 to 0.8 mm line width)	Koh-I-Noor Bloomsbury, New Jersey	
Drafting Pen (Technical pen points in size from 0.2 to 0.8 mm line width)	Staedtler Inc. Montville, New Jersey	
Nylon Nib Pens #7902, 7907 and 7935	Eagle Pencil Co. Danbury, Connecticut	
Solenoid operated pencil and mount (modified by Concord Control to accept ball point pen refill)	Southampton Engineering Co. St. Louis, Missouri	
Special formula	Easy Mark, Inc. Lowell, Mass.	Ink
Ink cartridge #50K-40225	Esterbrook Pen Co. Cherry Hill, New Jersey	
Special Ink #3089-F1	California Computer Products Anaheim, California	
Oscillograph Ink #RA276002	Brush Instrument Div., Clevite Corp. Cleveland, Ohio	
Higgins India Ink (in factory sealed cartridge)	A. W. Faber-Castell-Higgins Newark, New Jersey	
Ink Sample	Kingmann-White	
Black Waterproof Lettering Ink K & E #58-005	Keuffel & Esser Co. New York, N. Y.	
Acetate Ink - Black #3071	Koh-I-Noor, Inc.	

VI MARKING SYSTEMS TESTED

As previously noted two areas appeared to hold the most promise for an improved marking system for the E-80 Coordinatograph. The first area in which tests were made was marking with ink. Here, three types of pens were tried; capillary, ball point and free flowing. Breadboard setups were constructed to simulate the relative motion between the pen and the chart. The drafting paper or film was taped to an aluminum cylinder which was mounted in an adjustable speed metal turning lathe. The various ball point and free flowing ink pens were mounted in a modified Southampton Engineering Co. solenoid operated holder supported on the lathe tool holder. By rotating the cylinder at various speeds, and knowing the circumference of the drum, various "writing speeds" could be obtained between the pen and the paper. To test the capillary pens, a plate carrying a solenoid, springs and pen pivot bearings similar to the one already installed on the E-80 Coordinatograph was built and adapted to be mounted on the lathe tool holder. One problem encountered with the lathe setup was the joint in the paper surface necessitated by wrapping the paper around a drum. This joint interfered with pen performance and prompted the construction of another setup using a 12 inch diameter turntable as the writing surface and mounting the pens in a rigidly supported arm whose radius could be varied. By appropriately choosing an rpm for the turntable and a radius at which the pen was to write, various "writing speeds" could be obtained. In addition to the two pen mounting assemblies described above, a third was built for this breadboard which basically consisted of a Cal-Comp output solenoid and pen mount assembly. In the Cal-Camp device the free flowing ink pen or ball point pen is lifted off the paper when the solenoid is energized and allowed to drop into writing position by gravity when the solenoid is de-energized. This is in contrast to [redacted] previous approach of energizing the solenoid to force the pen down. The new [redacted] mount drops the pen by gravity by removing the pen support when the solenoid is energized and lifts the pen by spring force when the solenoid is re-energized. This eliminated the tendency to drive the pen tip into the writing surface which caused some trouble with the finer free flowing ink pens.

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Finally, since none of the breadboards really present the true problems of controlled high speed starting and stopping in which the pen moves and the output stands still, the three types of pens were tested several times on the actual E-80 Coordinatograph. In order to test the ball point pens a fitting, developed for use with the E-80 solenoid, was mounted on the carriage. This attachment held and guided a ball point refill so that it raised or lowered the proper distance on pen up, pen down commands. It included an L shaped spring metal clip over which the ball of the pen rolled when being lowered to draw or dot, in an attempt to overcome the problem of no ink being transferred to the paper without ball rotation.

The results of these tests are presented in Table 3. A number of the tests were selected for illustration in this report, so that the reader may make a graphic comparison of the test results, and are included at the end of the document.

It is pertinent to note that certain facts which were observed during the tests do not show up in a tabulation such as has been given. The following paragraphs provide a more detailed description of the results of those tests which seemed more significant than others. No attempt is made to list the results in an order of importance, but rather to consider them all so that some meaningful conclusions and recommendations might be reached.

In all cases where the ball point pen was used, it was found necessary to add a spring wiper over which the ball rolled before hitting the paper if successive dots were to be produced.

In tests 16 and 17 in which the ball point refill was dropped by gravity the results were light. As the spring force was increased, the line work improved, indicating that the ball point requires considerable more pressure than the capillary system which requires only a few grams.

In tests 21 and 22 the Kingmann-White capillary pen was mounted on the tool holder such that the pen point was perpendicular to the paper at the top of the cylinder. Results were good when the level of the ink in the reservoir was 1 1/2 inches below the writing surface, but if raised to 3/4 inch above the writing surface, ink dripped out when the pen was raised off the paper. In test 23 the same pen was connected to its reservoir by a length of capillary tubing approximately 100 inches long to observe the effect of a tube long enough to go from a bottle located below the platen of the coordinatograph up onto the gantry and then to the carriage and pen assembly. The length did not appear to cause any trouble, but if the ink level was more than about 1 1/2 inches below the writing surface, some difficulty was noticed in keeping a prime in the system.

In tests 25 through 27 Esterbrook sealed plastic cartridges were used as an ink supply. The cartridges are much superior to present E-80 methods of filling a bottle. However, there is not at present a standard size that fits all our requirements. The 7 cc rectangular cartridge mounted sideways would write enough (approx. 185,000 inches) but sudden motions in line with the vent hole caused a fine spatter on the table. To avoid this would require a new mold for their 60-6 cartridge in which the piercing tube entered from the top. This priming feature works well. The system was left for varying lengths of time ranging from overnight to two weeks and in all cases wrote immediately after compressing the bulb.

Height of pen tip off surface and the force with which the pen rides on the writing surface are important. In the original E-80 design, a flat leaf spring was added to balance the forces exerted on the pen by the solenoid and the return spring. In tests 28 and 29 it was noticed that some of the spatter happened on the upstroke of the pen. This situation was improved in test 30 by shortening the stroke and by installing a small piece of sponge rubber to cushion the contact between the pen housing and spring.

The final group of ink tests were made with various sizes and designs of three different manufacturers pens sold primarily as replacement points for drafting fountain pens. These are hollow steel tubes with a diameter equivalent to the desired line width and equipped with a fine wire riding inside the pen point tube to provide steady non-clogging ink flow. One company, Staedtler Inc., spring loads this wire, which appeared to give more dependable action than depending on gravity for the down motion. One exception was in dotting, where the continual up down motion apparently jammed the spring and caused the wire to stick up in the tube. Most of the pen points have hardened steel tips, although Koh-I-Noor also supplies them with jewel tips and tungsten-carbide tips. Both of these styles were tried.

Tests 32 through 42 used the Cal-Comp ink supplied with the conversion kit. Ink flow was good at low speeds, less than 10 inches per second, but tended to skip at higher speeds. If left overnight without cleaning, the pen tips became clogged and had to be removed and washed before they would write again. Tests 36 through 39 showed this ink dried slowly on film which re-emphasized need to consider all three elements, pen, paper and ink.

Test 42, made on the E-80 Coordinatograph, with a Staedtler 1.0 mm pen on film gave good results at full speed. Variations in line width were discernible when lines are parallel and close together. Dots were good.

Tests 43 through 49 with the free flowing ink pens used the new mounting mechanism as described on page 11.

In test 49 which was made on the E-80 Coordinatograph with the new [redacted] mounting STAT
assembly, the pen took too long to go through the down-up cycle compared with the time the carriage is stopped. Results were dots with tails.

The second area in which tests were made was electric marking. Samples of Alfax front grounding, dry type electrosensitive recording paper were used in a breadboard setup similar to that used for the pen and ink tests. The paper was taped to the aluminum cylinder and the marker or stylus was held in the stationary tool post. It was also necessary to mount a fixed copper wiper to act as a ground connection. A Lambda regulated power supply was used to supply current to a beryllium copper writing electrode. Alfax recommended applying 100 to 150 volts DC to result in 40 to 60 m.a. current. The first tests were made with the drum turning at 113 rps (equivalent to a writing speed of 14.6 inches per second), and with 100 volts applied to the writing electrode. The results were of varying quality, from poor to fairly good.

A second group of tests were made with cut sheets about 6" x 20" held flat on a table by 1 inch wide metal strips around the perimeter of the paper. The voltage was increased to 150 volts. The stylus was moved about by hand at speeds varying from 3 to 20 inches per second. As shown in test 51 the results varied, but were better than those obtained

Table 3. Test Results

Type Pen	Test No.	Manufacturer	Ink	Writing Surface	Line Quality: Greater than 10"/sec.	Line Quality: Less than 10"/sec.	Runs or Smears	Dotting Ability	Spatter	Drying Time	Remarks
Ball Point	1	U.S. Gov't issue	-	Film	Good variation in width	Good variation in width	No	Acceptable with wiper	No	OK	Spring wiper is necessary for dotting with all ball points tried.
Ball Point	2	Kingmann-White	-	Film	Poor	Fair	No	Fair	No	OK	Holder did not give adequate support. Refill is flexible.
Ball Point	3	Hanover #282	-	Film	Fair variation in width	Good variation in width	No	Acceptable with wiper	No	OK	
Ball Point	4	Kingmann-White	-	Paper	-	Fair	No	Did not try	No	OK	Tore paper.
Ball Point	5	BIC	-	Paper	Faint	Faint	No	Fair	No	OK	
Ball Point	6	Kingmann-White	-	Paper	Skipped variation in width	Fair variation in width	No	Fair	No	OK	
Ball Point	7, 10	Papermate (medium)	Red and Black	Paper	Good	Good	No	Acceptable with wiper	No	OK	
Ball Point	8, 11	Papermate (fine)	Red and Black	Paper	Good but Light	Good	No	Fair	No	OK	
Ball Point	9	Kingmann-White	-	Paper	Skipped	Some Skip	No	Fair	No	OK	
Ball Point	12	Papermate (fine)	-	Film	Good but light	Good but light	No	Acceptable with wiper		OK	
Ball Point	13	Papermate (medium)	-	Film	Good	Good	No	Acceptable with wiper		OK	
Ball Point	14	Papermate (fine)	-	Paper	Light	Did not try		Acceptable with wiper	No	OK	

Table 3. Test Results - (cont.)

Type Pen	Test No.	Manufacturer	Ink	Writing Surface	Line Quality: Greater than 10"/sec.	Line Quality: Less than 10"/sec.	Runs or Smears	Dotting Ability	Spatter	Drying Time	Remarks
Ball Point	15	Kingmann-White	-	Paper	Fair variation in width	Did not try	No	Fair	No	OK	
Ball Point	16	Papermate (fine)	-	Film	Some skip	Faint	Residue		No	OK	Spring holding pen on paper not strong enough
Ball Point	17	Kingmann-White	-	Paper	Fair	Faint	Residue	Fair	No	OK	
Capillary	18	EAI	Brush #RA276002	Paper	Fair	Good	No	Good	Yes on dotting	Fair	3" head
Capillary	19	EAI	Brush #RA276002	Paper	Fair	Good	No	Good	Some on dotting	Fair	1" head
Capillary	20	EAI	Brush #RA276002	Paper	Skips	Did not try	No	Good	Some on dotting	Fair	1" head (new pen)
Capillary	21	Kingmann-White	Brush #RA276002	Paper	Did not try	Good	No	Did not try	No	Good	
Capillary	22	Kingmann-White	Brush #RA276002	Film	Did not try	Good	Some	Did not try	No	Slow	
Capillary	23	Kingmann-White	Brush #RA276002	Paper	Did not try	See remarks					Drip when head reached 3/4". 100" tube from source to pen made no appreciable difference.
Capillary	24	Esterbrook	Easy Mark #139	Paper	Did not try	Fair	Yes	Poor	Some under rapid start & stop	Slow	

Table 3. Test Results - (cont.)

Type Pen	Test No.	Manufacturer	Ink	Writing Surface	Line Quality: Greater than 10"/sec.	Line Quality: Less than 10"/sec.	Runs or Smears	Dotting Ability	Spatter	Drying Time	Remarks
Capillary	25	Esterbrook	Esterbrook 50K Fast Dry	Paper	Good	Good	See remarks	Did not try	-	Fair	Ran badly if pen remained in contact with paper without moving.
Capillary	26	Esterbrook	Esterbrook purple	Paper	See remarks	-	-	-	-	-	Pen clogged.
Capillary	27	Esterbrook	Esterbrook purple	Film	See remarks	-	-	-	-	-	Pen clogged.
Capillary	28	EAI	Esterbrook	Film	Fair	Did not try	No	Good	Yes	Slow	Dots spread while drying.
Capillary	29	EAI	Esterbrook	Film	Fair to good	Did not try	Some	Good	Some	Slow	Tried to vary vertical pen travel.
Capillary	30	EAI	Esterbrook	Film	Fair to good		Yes	Good	Some	Slow	
Free flowing ink	31	Higgins	Sealed India ink cartridge	Paper & film	Fair	See remarks	No	Did not try	Some when shaken hard	Fast	Pen clogged.
Free flowing ink	32	Staedtler various sizes	Calcomp #3089 FI	Paper & film	See remarks	-	No	Good	None	Good	Tested by hand on drafting table.
Free flowing ink	33	Staedtler 0.4 mm	Koh-I-Noor Cartridge	Paper	Skip	Acceptable	No	Good	No	Fair	
Free flowing ink	34	Staedtler 0.5 mm	Calcomp #3089 FI	Paper	Good	Good					
Free flowing ink	35	Staedtler 1.0 mm	Calcomp #3089 FI	Paper	Skips	Good	No	Did not try	No	Good	
Free flowing ink	36	Staedtler 1.0 mm	Calcomp #3089 FI	Film	Fair	Good	No	Fair	No	Fair	Line width varied at higher speeds

Table 3. Test Results - (cont.)

Type Pen	Test No.	Manufacturer	Ink	Writing Surface	Line Quality: Greater than 10"/sec.	Line Quality: Less than 10"/sec.	Runs or Smears	Dotting Ability	Spatter	Drying Time	Remarks
Free flowing ink	37	Staedtler 0.2 mm	Calcomp #3089 FI	Film	Fair	Good	No	Good	No	Fair	Pen snagged.
Free flowing ink	38	Staedtler 0.6 mm	Calcomp #3089 FI	Film	Fair	Did not try	No	Fair	No	Fair	Dots spread.
Free flowing ink	39	Koh-I-Noor #62 J-1 (No wire in tube)	Calcomp #3089 FI	Film	Uneven	Did not try	No	Uneven	No	Fair	Results unreliable without wire.
Free flowing ink	40	Staedtler 0.8 mm	Calcomp #3089 FI	Paper	Fair	Did not try	No	Did not try	No	Good	Skips
Free flowing ink	41	Staedtler 1.0 mm	Calcomp #3089 FI	Paper	Variation in width	Good	No	Did not try	No	Good	Skips
Free flowing ink	42	Staedtler 1.0 mm	Calcomp #3089 FI	Film	Good	Did not try	No	Fair. Dots spread	No	Slow	
Free flowing ink	43	Koh-I-Noor #62 J-1	Acetate	Film	Good	Good	No	Good	No	Fast	Ink dries too fast in pen causing clogging.
Free flowing ink	44	Koh-I-Noor #62 J-2	Esterbrook	Film	Good	Good	Some smearing	Good	No	Slow	Dots spread while drying.
Free flowing ink	45	Koh-I-Noor #62 J-2	Leroy (K&E) #58-0005	Film	Good	Good	No	Good	No	Good	
Free flowing ink	46	Koh-I-Noor #62 T-1	Acetate	Film	Good some skips	Good	No	Good	No	Fast	Pen clogged.
Free flowing ink	47	Koh-I-Noor #62 J-2	Acetate	Film	Fair, varied See remarks	Fair, varied See remarks	No	Varied	No	Fast	Ink dries very fast causing clogging & varying line width
Free flowing ink	48	Staedtler #0	60% Calcomp 40% alcohol	Film	Fair	Good	No	Varied	Yes	Good	

Table 3. Test Results - (cont.)

Type Pen	Test No.	Manufacturer	Ink	Writing Surface	Line Quality Greater than 10"/sec.	Line Quality Less than 10"/sec.	Runs or Smears	Dotting Ability	Spatter	Drying Time	Remarks
Free flowing ink	49	Koh-I-Noor #62 J-2	Leroy (K&E) #58-0005	Film	Good	Good	No	Fair See remarks	No	Good	Dots had tails. Pen up - pen down timing not properly adjusted.
Free flowing ink	50	Eagle, nylon tip		Paper	Good Varied with usage	Good Varied with usage	No	Good	No	Good	Wears and broadens with usage.
Electric Pen	51	-	-	Alfax Electro-sensitive Dry Paper	Varies	Varies	-	Good	-	-	Line quality deteriorates as pen is moved away from electrical ground.

on the rotating drum and improved when the ground strap was in a fresh position or applied with pressure. It is believed that the poor results obtained with the rotating cylinder were due to insufficient contact between the ground brush and the paper. Lines or dots were drawn equally well, and the resulting chart made acceptable ozalid copies. There was some arcing and odor and a powdery deposit formed on the writing electrode. The manufacturer recognized the need for an adequate ground strap to maintain satisfactory contact for an acceptable length of time but had no suggestions that were applicable to the E-80 System. The problem here is that the paper is coated and any ground connector attached to the moving head tends to mark the surface. A non-moving ground or clamp, which would also have to operate in harmony with the automatic paper feed, tended to deteriorate with time resulting in non-uniform line work. Another factor which caused some concerns was that the quality of the line decreased as the distance from the marker to the ground strap increased.

Considerable development effort is still being exerted by many companies to improve the techniques required to produce a satisfactory marking system in which "electricity is the ink."

VII CONCLUSIONS

In making a survey of a field so rich in variety of choice as that of marking paper, one of the prime problems is to establish some reasonable means of limiting the study. At the outset of the program the technical goal was defined as a study directed toward significant improvement of the marking system now used on the [redacted] Model E-80 High STAT Speed Coordinatograph. Bearing this in mind certain marker systems were eliminated, with only a cursory consideration, because the E-80 marking requirements made them unsuitable. Examples of marker systems eliminated included any of the systems using carbon paper or similar pressure sensitive methods of marking because of the difficulties in procuring 60 inch wide rolls and of interleaving the carbon paper with the chart paper.

Other methods not considered were damp electrosensitive paper which tends to dry out when the supply roll is left on the machine for several days, and any of the other electrosensitive papers which require an electrode on both sides of the paper. The latter type

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would require that the coordinatograph platen be insulated. A dry, top grounding, electrosensitive paper was tested by the results were not uniform due in some measure to the difficulty in maintaining an adequate ground over such a large area. Considerable effort is being expended by many companies such as Hewlett Packard/Moseley Division, Palo Alto, Calif., Clevite Corp./Brush Instruments Div., Cleveland, Ohio and Alden Electronic and Impulse Recording Equipment Co., Westboro, Mass. to improve the electric discharge technique of marking. Any significant developments in this field could improve the technique to a level which would then make it an excellent candidate for use on a system such as the E-80 Coordinatograph. An electrically heated pen using solid state ink also was eliminated because it exhibited a tendency to spatter under fast reversals and did not appear to dot satisfactorily.

Scribing is a method that produces excellent results on a stable material, although the result is a negative (clear line on opaque background) when compared with the conventional ink or pencil line on clear paper. With the development of double coated scribing materials, which eliminate the need for a light table to read the scribed sheet, and rotating scribe tools to permit dotting, another area is provided which offers good possibilities for a satisfactory marking system for the E-80 Coordinatograph.

All things considered, however, inking still appears to be the method which provides the most opportunity for a significant improvement for the E-80 system. Again, the problem of where to end the study becomes pertinent, since it is obvious that at any point further investigation brings better results. However, after trying many combinations, the following conclusions were reached.

Free flowing ink pens giving a line width of about 0.021 inch and using a black waterproof K & E ink #58-0005 on film gave the best overall results. Line width varied very little even at full speed. Dots were good and dried in less than 10 seconds. These pens did not work as well on regular drafting paper, the rougher surface tending to snag them on occasion. Major disadvantage was the inconvenience of ink drying in the pen which would necessitate removing the pen tip when the unit was not in use and keeping it in a cleaning solution. This could be easily accomplished.

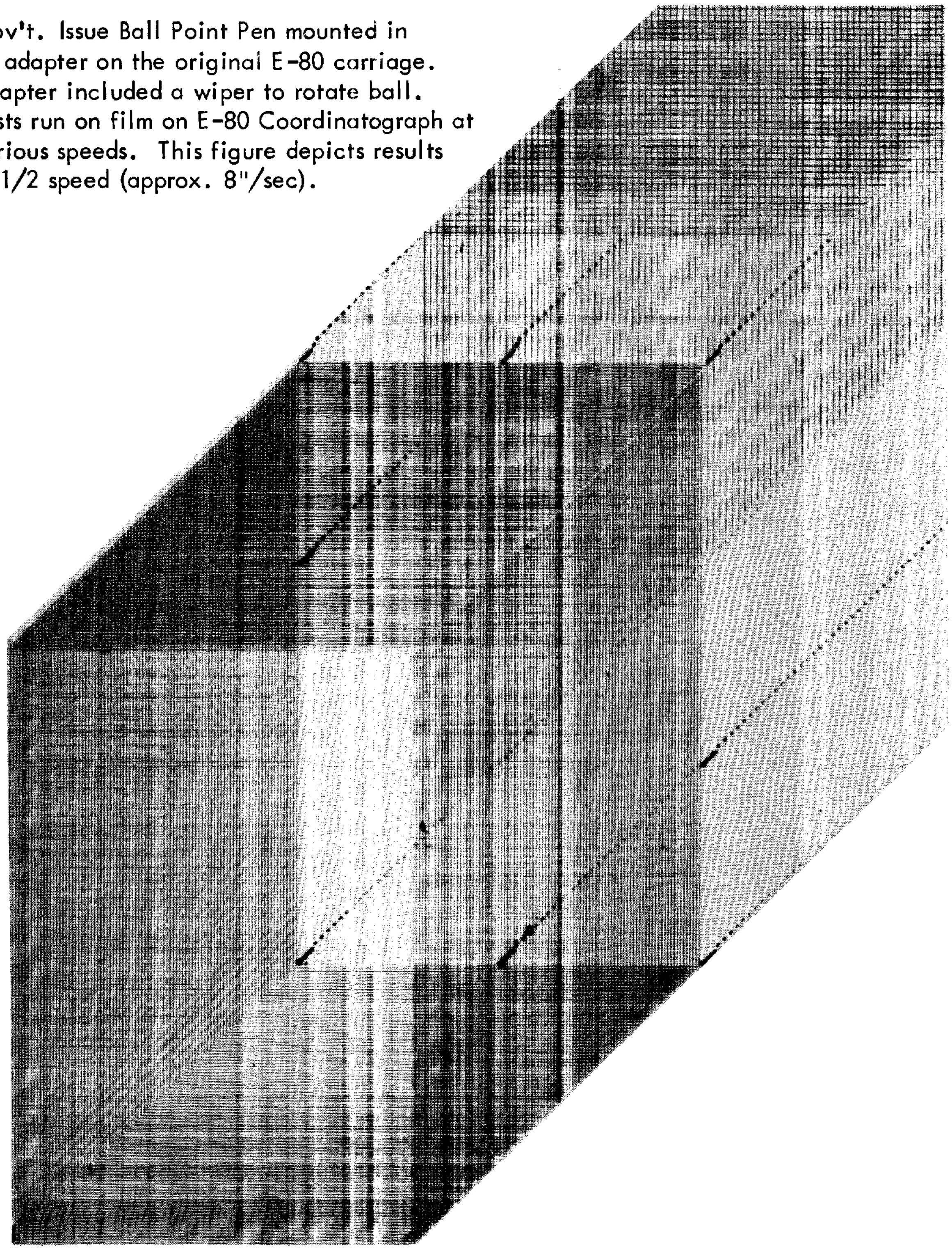
Ball point pens were the next most successful when used with a leaf spring for the ball to roll over just before it struck the paper. The leaf spring is particularly necessary when attempting to produce a series of dots. Dotting was not entirely dependable but an improved mechanical design for the leaf spring would help. Advantages are; economy, ease (no mess) with which the points can be changed, and wide choice of line width and color.

The capillary pen works well when properly adjusted, but the dotting requirements are difficult to meet because of spatter. Improvements such as sealed ink supply cartridges, priming devices, etc. will remove much of the messiness previously encountered on the E-80 installation and modification of the mechanical operation of the pen could help the spatter problem.

VIII RECOMMENDATIONS

It is our recommendation that a universal mount, to accept either the free flowing ink pens described in this report or various ball point pens available, be built and mounted on the E-80 carriage. It appears that good results will be obtained with either of the two pen types. Since improvement in this area is of vital interest to those using the E-80 equipment, such a mount has been built and installed on the equipment with the hope that additional experience gained in operation of the equipment may be useful in complementing the results of this study.

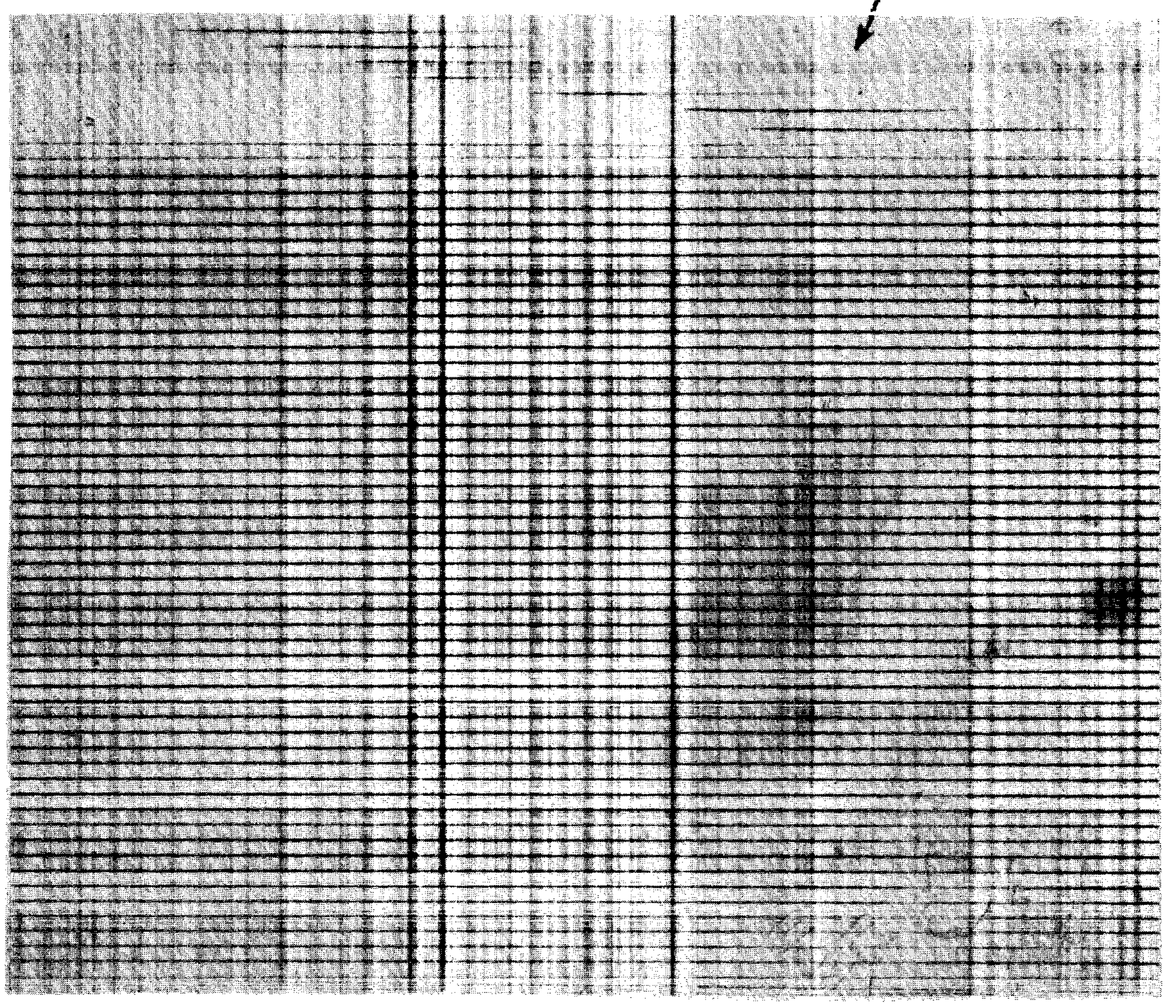
Gov't. Issue Ball Point Pen mounted in an adapter on the original E-80 carriage. Adapter included a wiper to rotate ball. Tests run on film on E-80 Coordinatograph at various speeds. This figure depicts results at 1/2 speed (approx. 8"/sec).



Test No. 1. Government Issue Pen on Film

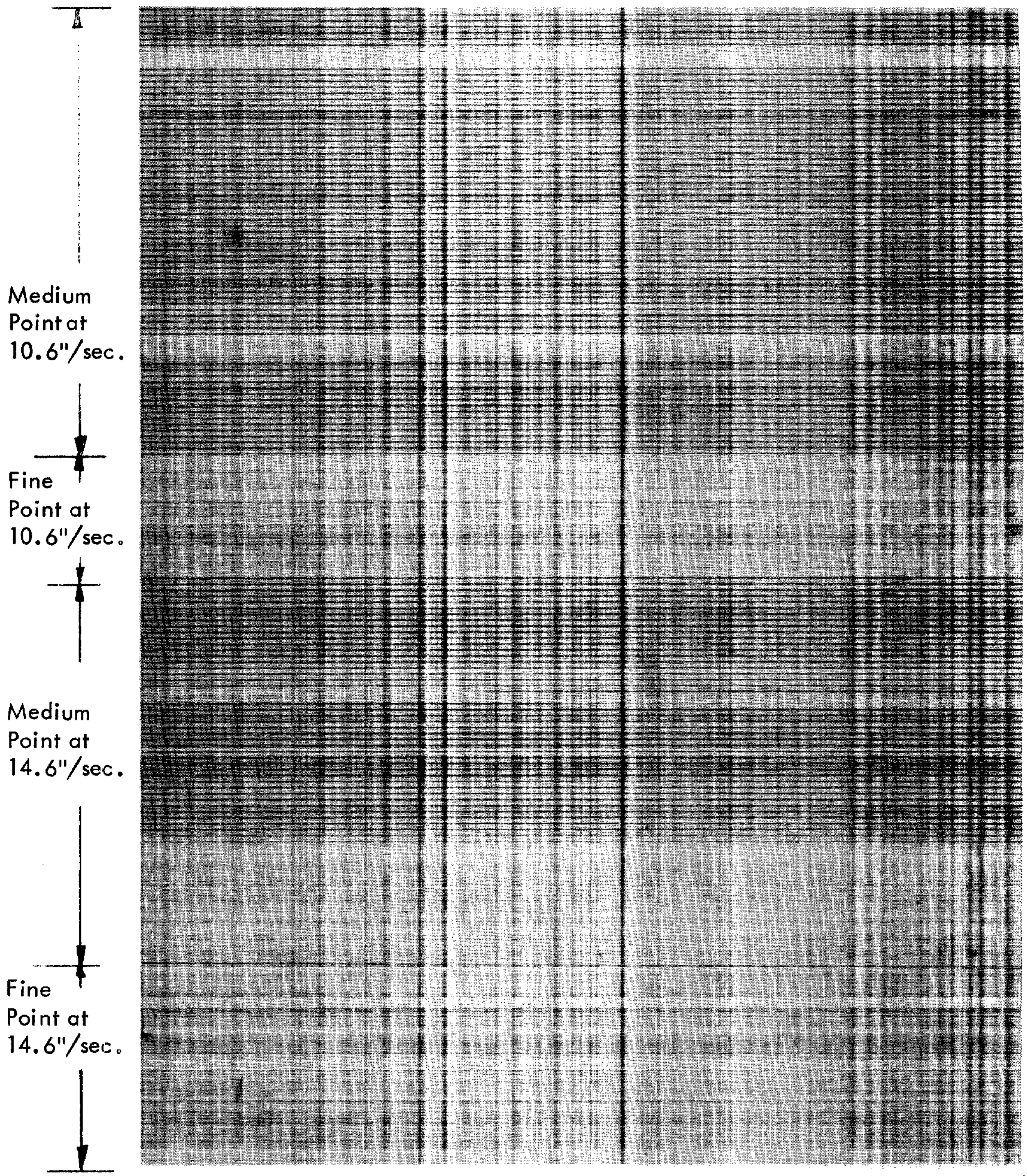
Medium Paper Mate Ball Point Pen (Red or Black)
mounted in [redacted] lathe fixture.
Tests run on paper on rotating cylinder.
Spring wiper needed to make acceptable dots.
Line work shown made with black pen at approx 14.6"/sec.

Initial skips are result of varying pressure between pen and paper.



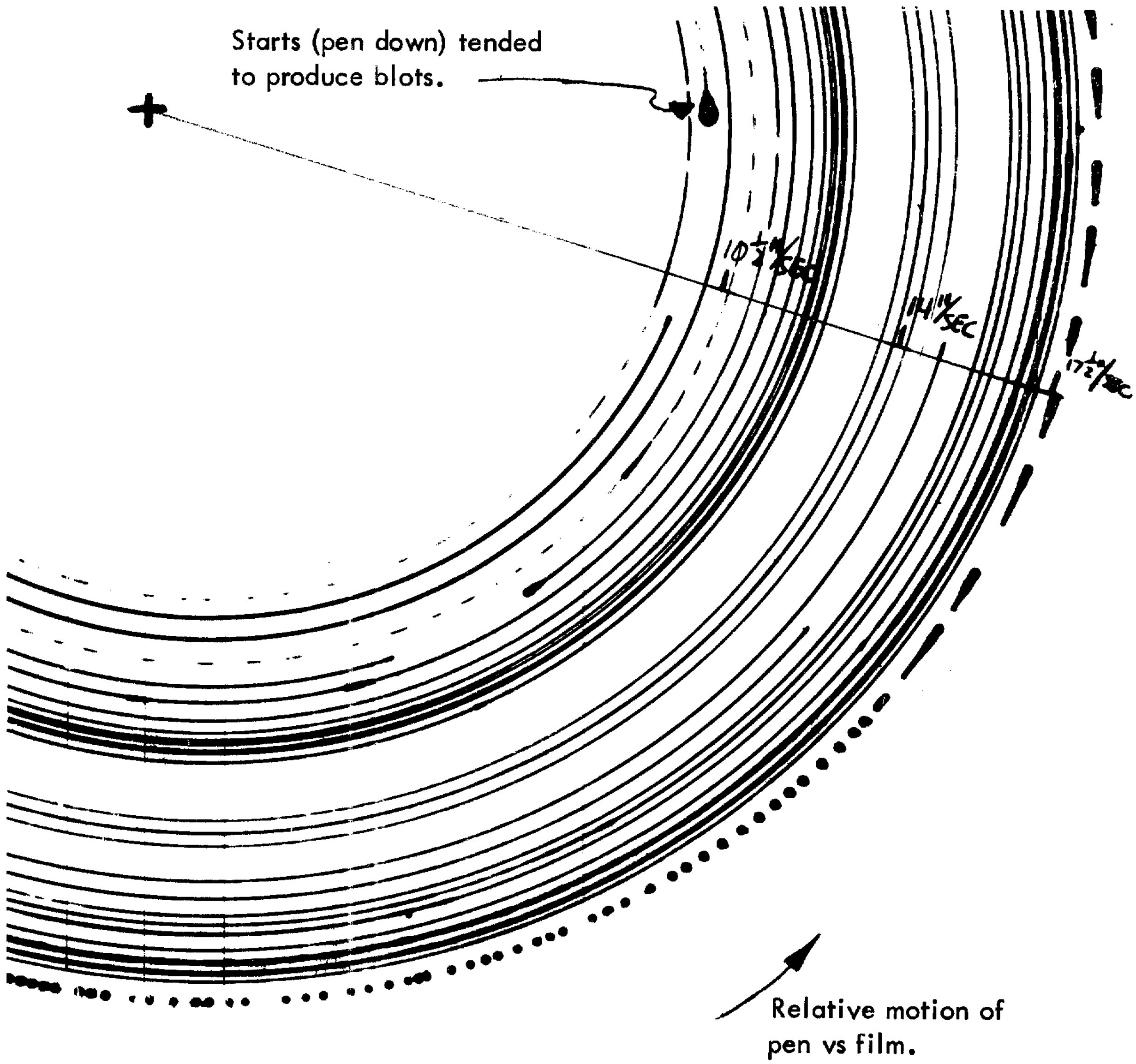
Test Numbers 7 and 10. Paper Mate Pen on Paper

Fine and Medium Paper Mate Pens.
Same setup as Tests 7 and 10 except tests made on film.
Line work shown made with black pen at speeds indicated.



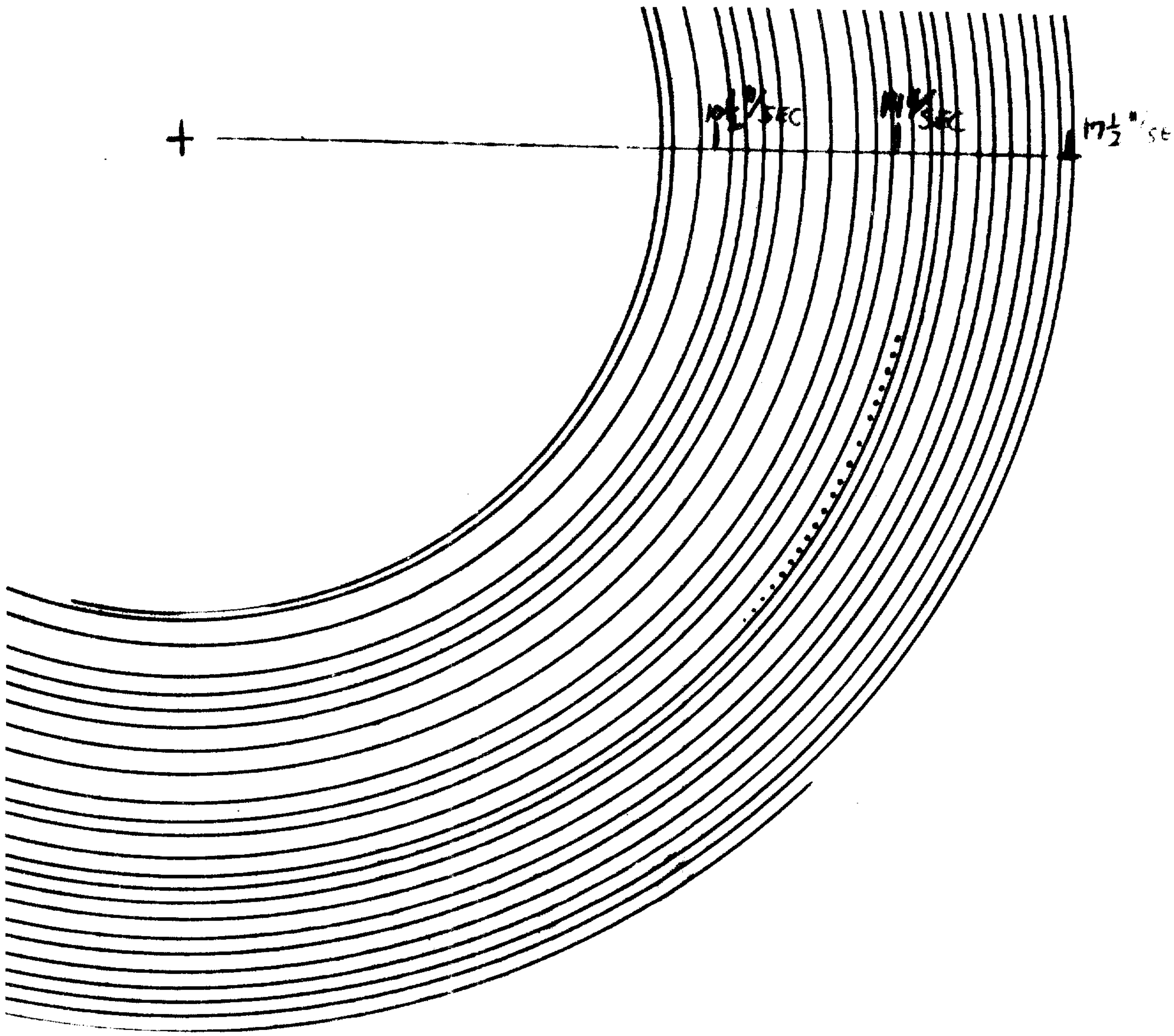
Test Numbers 12 and 13. Paper Mate Pen on Film

Original E.A.I. Pen with Esterbrook Ink on Film.
Slow drying. Note spreading of dots due to long drying time.



Test No. 30. EAI Pen with Esterbrook Ink on Film

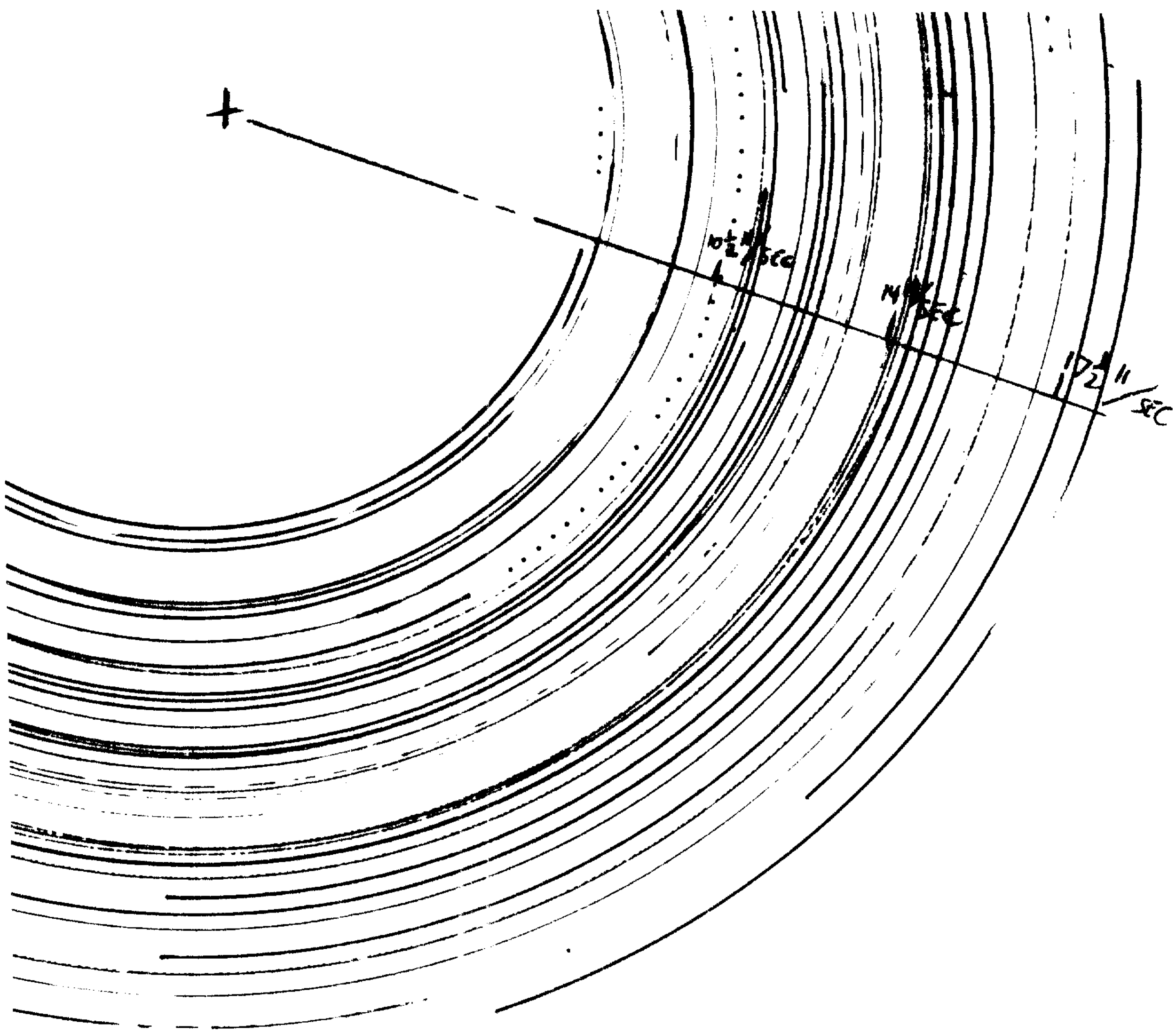
Koh-I-Noor Jewel Tip on Film.
Leroy Ink #58-0005.



Test No. 45. Koh-I-Noor Pen with Esterbrook Ink on Film

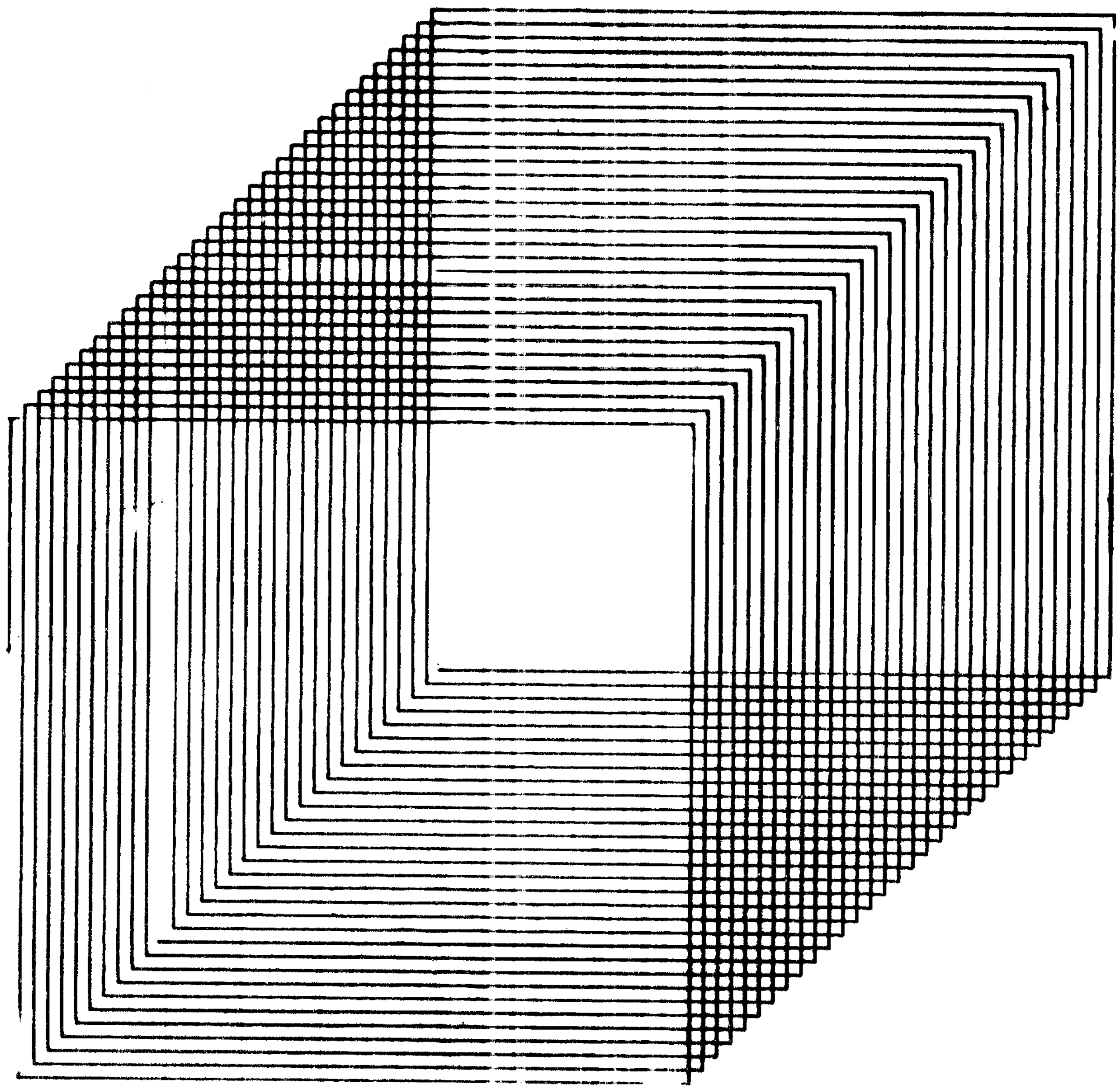
Koh-I-Noor Jewel Tip on Film.
Acetate Ink.

Results are good at first but vary with time due to fast drying ink which tended to clog pen.

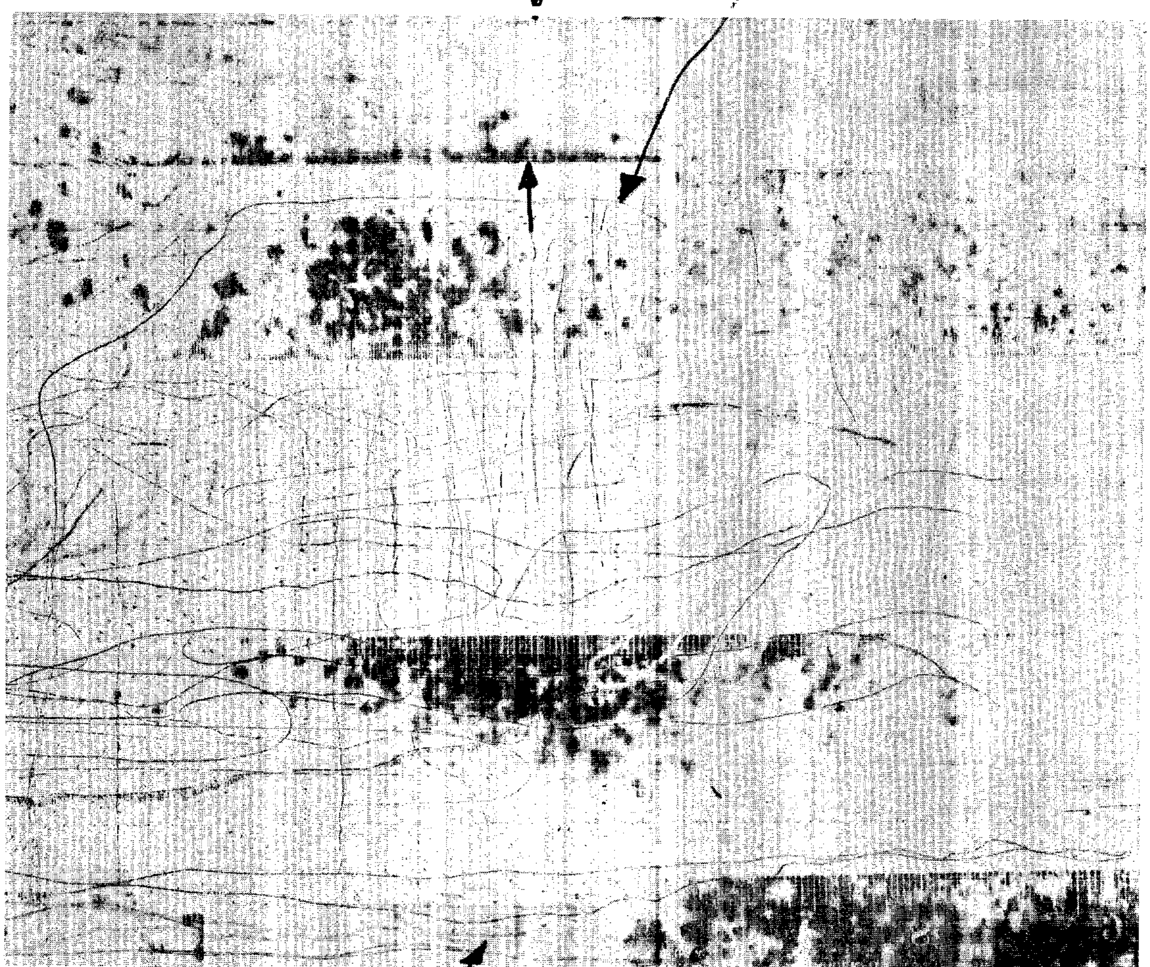


Test No. 47. Koh-I-Noor Pen with Acetate Ink on Film

Koh-I-Noor Jewel Tip on Film.
Leroy Ink #58-0005
STAT
Tests made with new [redacted] mounting plate on
E-80 Coordinatograph.
Results shown here drawn at 3/4 speed (approx. 12"/sec).



Test No. 49. Koh-I-Noor Pen with K & E Ink on Film



Test No. 51. Electric Marking on Electrosensitive Dry Paper

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2. Stabilene Films and Related Equipment - Keuffel & Esser Company
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4. Electrosensitive Recording Paper - Communication Papers Inc.

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