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The Employment of and Demand for Women Workers in the Manufacture of Instruments—Aircraft, Optical and Fire-Control, and Surgical and Dental

One of a series of reports on women's present and possible employment in war industries, based on field surveys by Women's Bureau investigators in the fall of 1941. (Issued first in mimeograph.)

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The Employment of and Demand for Women Workers in the Manufacture of Instruments—Aircraft, Optical and Fire-Control, and Surgical and Dental[1]

INTRODUCTORY

The making of aircraft, optical and fire-control, surgical and dental instruments is important in defense production. Manufacturers of these instruments have expanded their plants and organizations; new plants have been opened; and contracts and subcontracts have been awarded to plants whose machinery and organization are of a kind adaptable to small metal and instrument manufacture.

Aircraft instruments for indicating, measuring, recording, or controlling the flight and navigation of an airplane are a vital link in the aircraft industry even though their manufacture is not so spectacular as that of the engines and planes. The same is true of fire-control instruments, which are predominantly optical instruments such as panoramic sights, gunsights, periscopes, telescopes, and binoculars used for controlling the aiming and firing of guns, torpedoes, and bombs. Many of the fire-control instruments are of a secret character built for special naval and military requirements. Surgical and dental instrument demands have increased to supply the medical units of the Army, Navy, and Air Corps, and since Germany, formerly the principal source of surgical instruments, has been cut off the market, impetus has been given to domestic manufacture to supply the needs of foreign and home buyers as well as the new demands of the defense program.

Most instruments are relatively small, light in weight, made up of many intricate parts and assemblies so that direct labor employed is a primary factor in production cost. The light work, the many small parts, and the painstaking requirements of certain operations make instrument manufacture a field especially adaptable to the employment of women.

Scope of survey.

Eastern States have most of the instrument plants, with a few in the Midwest but practically none in the South and West. Seventeen factories in New York, New Jersey, Pennsylvania, Illinois, and Minnesota manufacturing aircraft, fire-control, and surgical and dental instruments, and related electrical parts, were visited to observe the work and the possibilities of employing women. The number of factory operatives ranged from approximately 100 to 6,000; the number of women employed was from 6 to nearly 1,400, with the proportion of women varying from about 3 percent to almost 50 percent of the total.

[1] As of fall months of 1941.

Minimum-wage rates and daily work-hour shifts.

Minimum hourly rates paid to women ranged from 35 to 55 cents, with 40 cents the most frequently reported, while for men the range was 40 to 61 cents, with 55 cents the most common.

All but two plants had more than one shift for the workers, with the numbers employed decreasing materially on the second and third shifts. At the time of survey, eight plants had two shifts and seven had three. Women predominantly were employed on the first shift, and in only three plants were a small proportion of women working on the second.

SUMMARY

In normal times the manufacture of instruments of the types covered was on a relatively small scale, and much of the production of aircraft and fire-control instruments was on a constantly changing and experimental basis. For many years, machining and assembly were done almost entirely by men classed as all-round skilled instrument makers. But with increased production, jobs have been broken down and women employed to a considerable extent. The proportion of women and the jobs on which they are employed, however, differ materially from plant to plant. In some plants women are working satisfactorily on machine and assembly operations, while for the same jobs in other plants women have never been considered. In the sections of this report dealing with each type of instrument—aircraft, fire-control, and surgical and dental—the actual work being done by women is discussed. The summary presented here is merely indicative of the kinds of work being done and the feasibility of extending the employment of women on the various processes.

Summary of Principal Operations and the Employment Opportunities for Women in the Manufacture of Instruments—Aircraft, Optical and Fire-Control, and Surgical and Dental

	Sex of operatives (M—men, W—women)	*Extension of women's employment*
AIRCRAFT INSTRUMENTS		
Assembly and Bench Work:		
Mechanism subassembly	M and W	Proportion could be increased.
Mechanism final assembly	M and W	Do.
Special assemblies—		
Diaphragm	M	Could be used entirely.
Pitot tube	M	Slight probability of using.
Gyro motors	M and W	Proportion could be increased.
Autosyn electric motors	M and W	Do.
Closing of instruments	M and W	Could be used entirely.
Testing and Inspecting:		
Parts inspection	M and W	Proportion could be increased if trained or upgraded from instrument-assembly operations.
Calibrating	M and W	
Electrical tests	M and W	
Cold, vibration, and run tests	M and W	
Final instrument inspection	M	

	Sex of operatives (M—men, W—women)	*Extension of women's employment*
OPTICAL AND FIRE-CONTROL INSTRUMENTS		
Optical Work:		
Blocking	M and W	Only a few women are used on single-spindle blocking and polishing.
Grinding	M	
Polishing	M and W	
Centering	M and W	With training, women could be used or proportion might be increased on all operations.
Cementing, engraving, etching and silvering	M and W	
Cleaning and inspecting	M and W	
Assembly and Bench Work:		
Range and height finders, panoramic sights, periscopes, plotting boards, quadrants, sextants, octants, etc.—		
Minor subassemblies	M and W	Subassemblies made by women are very minor and not much possibility of increasing proportion.
Main assemblies	M	
Binoculars, telescopes, aircraft sights, and small gunsights—		
Mounting, cleaning, and inspecting optical parts	M and W	Proportion could be increased.
Sighting, Adjusting, Collimating, Calibrating, etc	M	With training, women could do in part.
SURGICAL AND DENTAL INSTRUMENTS		
Assembly and Bench Work:		
Forceps, pliers, retractors, etc	M	
Dental stands and chairs—		Slight probability of increasing proportion.
Minor subassemblies	M and W	
Main assemblies	M	
Dental hand pieces and fittings	M and W	Proportion could be increased.
Clinical thermometers	M and W	Women employed extensively.
Special Machining of Dental Burrs and Broaches	M and W	Women employed extensively.
GENERAL OPERATIONS APPLICABLE TO MOST INSTRUMENTS AND SMALL METALS PRODUCTION		
Heavy-Duty Machines:		
Drill presses	M and W	Proportion could be increased.
Punch presses	M and W	Do.
Milling machines	M and W	Do.
Metal polishing and grinding	M	Not suitable for women.
Turret lathes	M	With extensive training women could be used on lighter machines. Otherwise, probability slight.
Engine lathes	M	
Hand screw machines	M	
Automatic screw machines	M	
Gear cutters	M	

	Sex of operatives (M—men, W—women)	*Extension of women's employment*
Secondary or Light Machines:		
Bench, watchmakers' lathes, etc. (turning, buffing, burnishing, burring, lapping, etc.)	M and W	Women employed quite generally and they could do more of light work.
Micro-milling	M and W	
Sensitive drill press	M and W	
Small automatic screw	M	Slight probability without extensive training.
Hand and Machine Burring	M and W	Proportion could be increased.
Machine-Shop Inspection	M	Slight probability of employment.
Painting:		
Spray	M and W	Proportion could be increased.
Touch-up and brush	M and W	Women employed extensively.
Fill-in	M and W	Do.
Radium	W	———
Graduating and Engraving	M and W	Proportion could be increased.
Heat Treating, Plating, and Anodizing	M	Not suitable.
Inspecting, Cleaning, Wrapping for Stock and Shipment	M and W	Proportion could be increased.

Training.

In Great Britain special training courses have been offered to women as well as men in the making and fitting of instruments. Instruction covering both theory and practical application is provided in correct use of tools, gages, calipers, verniers, micrometers, and in blueprint reading, soldering, buffing, drill presses, lathes, gear cutters, milling, precision fitting, and bench assembly. In the United States, in the defense training program in most of the cities visited, general courses in machine-shop practice and assembly were open to relatively few women. Only two plants had courses of study and specific training programs as formal instruction for employees, and in one plant only men had been admitted because the training was given primarily as part of an upgrading plan and the policy was not to consider women as parties to job progression beyond unskilled repetitive work. In all other plants, training was on the job. Many of the beginning jobs in the machine shop, assembly, and inspection sections are closed to women, as these operations are regarded as the beginning step for young boys who progress to more skilled work.

Attitudes with reference to the employment of women.

Three plants that employ women on a variety of operations and in relatively large proportions have the most open-minded attitude toward increasing employment possibilities for women. Though most of the work on instruments is light, and little is beyond the

physical capabilities of women, the prejudice and attitude of many in managerial positions is hedged against women. In the plants with a small proportion of women employed there is often an expression of opinion that men and women cannot be employed on a coworker basis. Ideas are expressed that mixing men and women in the shop may disrupt the morale and discipline; men do not like to have women around, as in some way their work freedom is curbed. In plants where the proportion of women is large, or where women have been employed a long time, no mention is made of disciplinarian problems.

Though most of the plants have never offered any special training to women for job progression and upgrading, have never tried to give women training or responsibility for set-up of machines and have limited their work to unskilled repetitive tasks, the generalization often is made that women have no mechanical ability, interest, or aptitude. In a few plants where women are given the responsibility, some set up their machines. England has many examples of women setting up and operating machines and working on all types of materials.

Even where much of the work is on a quantity basis with specialization in jobs, the all-round skills and flexibility of men are emphasized as imperative. Flexibility in the working hours and the ability of men to hold up against long hours and heavy work frequently are mentioned even when most of the employees work on an 8-hour day shift and very little of the work requires strength. Along these lines is an expression of opinion that to employ women on jobs that might involve any hazards of maiming or disfiguring the worker is an undesirable policy because injuries to women are regarded with greater concern by the community and may result in antagonism toward the management. British experience, however, has shown a decreasing accident rate on certain machine jobs where women have replaced men.

The problem of providing additional service facilities such as toilet, wash, and cloak rooms looms with undue significance to some employers even where new buildings and equipment are being provided in the expansion program and the inclusion of special facilities for women could be planned. Inquiry has been made recently in the East as to the cost of providing toilet and washing facilities for 100 women. One estimate for 5 toilets, 5 lavatories, soap and towel containers, and so forth, partitions, painting, and installation, was $479, or an average of about $5 a woman.

The various anti-woman-employing attitudes expressed by management are premised largely on tradition and fear of innovations in personnel set-up.

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AIRCRAFT INSTRUMENTS

Twenty-five years ago, at the time of the first World War, flying was relatively in a preinstrument stage, the flyers being guided largely by direct observations of landmarks, the feel of the wind, the visible horizon, and the sense of gaining speed and height. Today the instrument panel of the modern airplane is covered with a maze of dials to guide the pilot. Instruments usually are grouped according to their function. The four principal ones follow:[2]

1. The primary flight group includes the air-speed, turn-and-bank, and rate-of-climb indicators.
2. The secondary flight group includes the altimeter, artificial horizon, or gyro-horizon, and directional gyro.
3. The engine instruments include oil and fuel pressure gages, suction gages, tachometers, temperature gages, electrical indicating systems, and so forth.
4. Auxiliary instruments comprise those concerned with the recording of the functioning of auxiliary apparatus, such as landing-gear-position indicators, flap-position indicators, outside-air-temperature indicators, and related electrical systems.

Aircraft instruments are all small and light in weight, most of them weighing less than 2 pounds, and as such their manufacture is chiefly light work, much of which is adapted to the employment of women.

Until the present defense program the manufacture of aircraft instruments had been almost entirely an occupational field for men. The all-round instrument maker was distinguished in that he could machine, assemble, and adjust an entire instrument. Aircraft instruments are now being made in relatively large quantities and the operations have been broken down in the machining, assembly, and adjusting processes. Many of the instrument workers who have come into the industry during the present defense period are young, inexperienced employees; some are, and more might be, women.

Machining of aircraft instruments.

The regular standard machine shops of the aircraft instrument plants hire only a very small proportion of women employees. The women are employed almost exclusively as drill-press operators, except for a few on small punch presses. Many of the punch presses are of the kick-press type, the continuous operation of which is strenuous and not desirable for women. No women are employed on regular lathes, turret lathes, automatic screw machines, milling machines, grinders, gear cutters, and other heavy-duty machines. Young men with no experience or only that secured in defense training classes have been hired in the past year for much of the primary machining on

[2] Patton, Orion Edward, Aircraft Instruments, 1941, pp. 171–172.

milling machines, drill presses, and punch presses, and more of this work might be done by women. The main machine-shop operations on aircraft instruments do not afford employment to nearly so many as the assembly and light machine departments.

Most of the unskilled and repetitive jobs are used as beginning occupations for men who are to be trained as machinists in an upgrading plan. Women have not been considered as potential trainees in a long-time program. In most places, tradition and attitude are against the employment of women. The oiliness of the work, the hazards of cuts, are emphasized; and the prevalent idea that women lack interest in and mechanical aptitude for machine-shop work is most marked. British industries are reporting the employment of women machine-shop workers who set up their own machines to drawings and operate all types of machines for grinding, turning, boring, milling, threading, tapping, reaming, and forming on hydraulic presses. In the plants visited in the United States the most accepted possibilities of increased employment of women from a management point of view seemed to be on drill presses and punch presses, the opportunities on the first being the greater.

Floor inspection in the machine shop was done by men who were skilled mechanics able to give advice as to set-up and machining. Hand and machine burring of machined parts was done largely by men, but a few women were used to a limited extent. Apprentices often are started on this type of work and it might be a beginning job for women in machine-shop operations.

Apart from the main machine shop, there are many secondary or light machining operations frequently related to assembly and often accompanying progressive steps in the building up of an instrument. The machines used on these operations are small sensitive drills, bench lathes, watchmakers' lathes, small automatic screw machines, micro-milling machines, burring, burnishing, buffing, and lapping machines, gear hobbers, and so forth. On these smaller machines more women are employed and their numbers might be increased materially. In several plants men and women are operating the same kinds of machines, but often the men are reported as doing precision work on turning and fitting operations that require changing set-ups and more diverse skills. Much of the work of machining, polishing, lapping, and drilling on the lighter machines is for the small internal mechanism of instruments, such as pinions, rocking shafts, gears, and fittings. The work is held to fine tolerance—often in ten-thousandths of an inch—and gages, microscopes, and micrometers are used in checking the progress and accuracy of the work.

In a high-grade British instrument factory, women set up and operate Mikron capstan lathes and Mikron gear hobbing machines, and check tooth profiles and make necessary adjustments. They work with micrometers and to tolerances of 2 and 3 ten-thousandths of an inch.

Aircraft instrument assembly and bench work.

Most of the pressure-actuated instruments consist of a metal or plastic case, bezel or snap rings, front glass, dial, pointers, and the internal mechanism, which includes a diaphragm assembly, rocking

shaft assembly, hand staff assembly, sector assembly, wheel and hair spring assembly, bearing plate, balance arm, and mechanism frame.

Diaphragms made of paper-thin corrugated metal disks are a part of all instruments where pressure is the activating element. The contraction and expansion due to variations in pressure are relayed to the dial indicator. If the diaphragm is defective, the entire instrument must be disassembled or scrapped; so great care is given to its manufacture and assembly. In three factories where diaphragm instruments are assembled, the work is carried on in a small separate department, and the operatives work interchangeably on several jobs. Blanking and corrugating of the disks are press operations, which require care in handling the metal so that it is not stretched. Next, the disks are seasoned in hot baths of oils, soldered, evacuated, and tested for leaks and sensitivity. Women do soldering, but all other operations are done by men in the aircraft instrument plants. However, in a plant manufacturing pressure instruments but not for aircraft outlets, women are making the diaphragms in their entirety.

Special apparatus such as the Pitot static tube has been developed for controlling the intake of the air actuating the diaphragm. The manufacture of the Pitot tube is done entirely by men and involves chiefly torch soldering, assembly of small tubing, filing, plating, and polishing. Much of the work is varied and heavy, and with the small numbers employed there would be little need or possibility of women's employment.

Most women's jobs on aircraft instruments are on the mechanism subassemblies involving use of hand tools such as pliers, soldering irons, tweezers, files, hand mallets, screw drivers, hand drills, bench fixtures, and machines such as arbor presses for staking and riveting, small polishing, lapping, and buffing machines. With these operations there frequently is accompanying inspection using microscope, jeweler's loupe, and gages.

Women in one of the three largest aircraft instrument factories do practically all the work on the rocking shaft subassembly, hair springs, sector assembly, balance arm, and other mechanism subassemblies, including staking jewels into plates, assembling small bearings, staking counterweights to dial pointers, soldering small parts, putting in pivot screws, and so forth. In the other large aircraft instrument plants women are doing a share of these subassembly operations but the majority of the subassemblers are men. As the force expands in all the plants the proportion of women is to be increased, and an estimate was made that they could do at least 75 percent of the assembly work.

The final assembly of an instrument is akin to watchmaking—installing the subassemblies such as the diaphragm, rocking shaft and sector; aligning and fitting parts to close tolerances; adjusting jewels, checking friction, checking end play, and making other necessary adjustments. This work is the sphere of the all-round instrument maker and so far has recruited experienced men or developed them from subassemblers by an upgrading program.

The final assembly of the mechanism calls for a high degree of skill and responsibility, a thorough knowledge and understanding of the use of the instrument being constructed, and a practical knowledge of the field in which the instrument is being used. Only two

women in the aircraft plants visited were reported as final assemblers and all-round instrument makers capable of all assembly processes. Women might constitute a substantial part of the final assemblers if they had the training, experience, mechanical aptitude, and interest, and if management were open-minded to the possibilities of employing them.

After the mechanism has been assembled, the installation into the housing or case follows, and women are employed extensively on the closing operation. They clean and assemble the dials, pointers, and front glass, put in the gaskets, bezel or snap rings, install the end fittings, and attach the name plate.

Instruments with fewer parts and simpler mechanisms, such as the compass, tend to employ a larger proportion of women in assembly. One firm with a separate department for manufacturing the magnetic compass uses almost 50 percent women on this assembly. Women are on the usual repetitive jobs of subassembly category, soldering, peening, screwing, and adjusting parts and fittings. Final assembly was carried on almost entirely by men.

Testing and inspecting aircraft instruments.

Inspecting and adjusting are concomitant in much of the assembly work. Women as well as men do testing along with assembly. For instance, in the assembly of a magnetic compass (simpler than gyrocompass) both men and women balance spider cards—the revolving graduated scale for weight distribution. Women are checking the magnetization of compass balance bearings on a special projecting and enlarging device. The final setting and adjusting of the compass is considered a most skilled job and is done by men.

Cold tests, vibration tests, and compensating bath tests employ only a few men, who work interchangeably at all operations and most of whom know how to make the necessary adjustments on a variety of types of instruments.

Calibration covers testing, adjusting, balancing, and measuring the performance of instruments according to definite standards. Calculations and computations for adjustments may be necessary and the calibrator of the more intricate instruments needs a working knowledge of mathematics and principles of physics involved. In all but one of the plants visited, the final testing of aircraft instruments was carried on solely by men; in the one exception a woman was calibrating suction gages, which are among the simpler instruments. She had been employed in a watch factory and was said to have exceptional mechanical ability. Many of the men calibrating were reported as having years of experience in instrument making or as holding degrees in mechanical engineering. The opinion was expressed that if there is quantity production of one type of aircraft instrument, women might be trained in 3 to 6 weeks to do calibrating of some types of instruments.

Inspection of incoming parts and those in process employs both men and women, the latter working on the simpler gage and visual checking. Of course women could do more of the inspection. Men usually are employed on metal-hardness testing, checking with verniers, calipers, blueprints, and where mathematical computations are involved.

In a large instrument plant that manufactures navy and commercial barometers, automobile altimeters, and compasses similar to certain of the aircraft instruments, women have been employed extensively for many years. In fact, women assembled aircraft altimeters in this plant in the war of 1914–18. At the present time practically all assembly on commercial barometers, hygrometers, and altimeters for automobiles is done by women. The assembly of many of these instruments involves installing a diaphragm, hairsprings, shafts, pinions, dial indicators, and so forth, all similar to operations on aircraft instruments. Women are calibrating these instruments also, and one woman with years of experience calibrated navy barometers.

Similarly, in a mass production plant that specializes in the manufacture of instruments for the panel boards of automobiles, women are assembling ammeters, oil and pressure gages, speedometers, and other instruments on a line assembly and testing for end play and leaks, making final adjustments, and calibrating. Men are serving as group leaders and set-up men. The tolerances on such instruments are not so close as on aircraft, but the operations are similar and there is no reason for assuming that women could not develop the skill necessary to do similar operations on the more delicately adjusted aircraft instruments.

Gyroscopic aircraft instrument assembly.

Another group of instruments are those based on the gyroscopic principle, that is, a spinning wheel mounted and suspended in such a manner that it is free to rotate about any axis, maintaining a fixed position irrespective of the oscillations of the plane. The instruments important in blind flying and automatic piloting of a plane are the gyroscopic compass, the directional gyro, the turn-and-bank indicator, and the artificial horizon.

Two plants visited are making this type of instrument. In the plant of the largest manufacturer of gyroscopic instruments women comprise less than 10 percent, while the other has a considerably larger proportion. In a British plant, women with high degrees of skill are reported as operators of lathes and milling and grinding machines, as assemblers, balancers, and testers of fine gyroscopic instruments with tolerances and limits as close as 2 ten-thousandths of an inch.[3] In the main plant of this same company in the United States, women assemblers are classed as unskilled repetitive workers. The women are on light bench jobs assembling rotor housings, centering rotors into the gimbal, making minor hand adjustments, cleaning bearings, lapping shafts, pivots, and bearings, and using microscopes for inspecting the parts being lapped. All the actual instrument assembly is done by men and the job of a first-class assembler is described as follows:

> Plans and lays out assembly work from blueprints or samples and develops new ideas for simplifying and improving such work. Has a thorough knowledge of machine-shop mathematics. Assembles all types of subassemblies and main assemblies without the use of jigs and fixtures. Skillful in the use of all types of precision measuring tools and indicating devices. Skillful in soldering, filing, fitting, scraping, reaming, pinning, lapping, drilling, turning, milling, and other bench and machine-tool operations required in precision assembly. Able to meet production standards in quantity and tolerances.

[3] Engineering Bulletin of the Ministry of Labor, August 1941.

In a firm manufacturing turn-and-bank indicators women do a major part of the assembly work, such as mounting the gyro motors (until recently done only by men), oiling shafts and putting bearings in the gyro frames, and installing the inclinometer and pointer or indicator assembly.

Again there is no doubt that, if afforded the same training opportunities as men, women could comprise a much larger proportion of the workers.

Testing and inspecting gyroscopic instruments.

Gyroscopic instruments, like other aircraft instruments, are checked in process of assembly, women doing practically all the testing on the smaller rotors being assembled into the gimbal ring, including testing of spring tension, making run tests to ease parts, and vibration tests to detect the slightest friction in movement. Men do the assembly and inspection on the larger and more complicated rotors. Men also balance the rotors on an automatic balancing machine, a job that women might do. Prior to calibrating the directional gyro and artificial horizon women are visually inspecting and cleaning the cases, dials, dial glasses, and internal mechanism. They also check the drift and make simple adjustments on directional gyros, and calibrate and adjust artificial horizons, both these operations requiring approximately 3 to 5 months' training to attain proficiency in making adjustments to close tolerances. The final testing and calibrating is done by men, many of whom have had training in engineering and are able to make a complete visual and mechanical inspection using varied testing equipment.

Electrical indicating systems.

Engine-control instruments such as tachometers, manifold pressure gages, oil and fuel pressure gages, temperature gages, and electrical thermometers, and auxiliary instruments for designating the position of wing flaps, landing gears, wheels, cowl flaps, frequently are dependent on electrical transmission for their indications. Many are tied up with a self-synchronous motor, called an autosyn or telegon, for remote indication of the instrument reading by electrical wiring, which eliminates tubing and mechanical connections and enables multiple indication on one dial.

The autosyn system of remote indicating might be applied to almost any aircraft instrument. It is a combination of transmitting and indicating elements that may be widely separated. A transmitting motor is mounted near the part of the plane whose performance is to be recorded, and the second motor is located on the instrument board controlling the dial indicators or pointers. These autosyns are small fractional horsepower electric motors, and are significant in the manufacture of aircraft instruments. As in the electrical industry, women are employed on much of the work, which is of a machine-shop and assembly nature. Women are employed extensively on drill presses and punch presses and might be used on other machine operations.

Winding of armatures, field coils, and stators; coil taping and forming; assembling armatures and commutators; soldering and connecting wires, and other electrical jobs are done in part by women, and they could do more of the work because of the small size of

autosyns. In some plants men are doing much of the final assembly of the autosyn motors but women could share in the work.

Testing of electric indicating systems includes tests for grounds and shorts, break-down tests, electrical accuracy tests, and time response and performance tests. All these are tests for which women might be trained in a short time. At present, most testing jobs of this kind are held by men.

Miscellaneous jobs on aircraft instruments.

Most of the panel-board instruments have luminous dials and indicators to give visibility for night flying. Radium painting is being done entirely by women in the five plants manufacturing aircraft instruments. Work benches have individual glass-shielded hoods connected with exhausts; rooms are air-conditioned; uniforms are provided and laundered by the firm; periodic physical examinations are given; hands must be washed before leaving the room and are usually examined by the forelady for any particles of luminous paint; and extra clean-up time is allowed at noon and in the evening. The work is painstaking, fine, requiring finger dexterity, and hazardous if prescribed precautions are not respected.

Touch-up painting is quite generally done by women. Stenciling of dials and fill-in painting are other jobs usually held by women. Spray painting, on the other hand, is almost always considered men's work, though women might do it because of the lightness of the parts.

Graduating and engraving.

Pantographs, special engraving machines, and addressing machines, for engraving and imprinting metal dials and name plates, are operated by both men and women. Women might be used on all such jobs.

Other miscellaneous jobs.

Heat treating, anodizing, and plating require only a very small proportion of the total labor force, and the work is varied, heavy, and not advisable for women as all-round workers. In the larger plants women sometimes wire and rack small parts before and after processing but the number of jobs of this kind is insignificant.

Many of the aircraft instrument cases are made of plastics such as bakelite and all the presses molding these are operated by men. Women undoubtedly could be trained to operate and control temperatures on the new automatic molding machine.

Tool-crib attendants are all men. In the large plants women might be used in keeping records and issuing the lighter tools. Women are used to a limited extent in packing instruments and parts for stock and shipment. More undoubtedly could be employed on such work. Work in the foundry and pattern shops requires skills which would have little value in the general woman labor market and much of it is far too heavy.

OPTICAL AND FIRE-CONTROL INSTRUMENTS

Every heavy gun must be accompanied by auxiliary equipment for controlling its fire, properly aiming the gun and setting the shell fuze. Fire-control instruments predetermine the accuracy and check on the effectiveness of gunfire and aircraft bombing. Fire-control and optical instruments include range and height finders for determining the distance between the gun and the target, periscopes for observing and directing the firing of torpedoes from submarines, gunsights, panoramic telescopes, prism binoculars, aiming circles, azimuth instruments, elevation quadrants, sextants, bubble octants, clinometers, plotting boards, drift sights and drift meters for aircraft, fuze setters, and so forth.

Optical-glass manufacturing.

The largest manufacturer of optical glass for fire-control instruments was visited. Mixing, melting, and the early steps in the manufacture of glass are heavy work and unsuitable for women, but women are used extensively in cleaning and inspecting glass. After the glass is cooled, the melting pot is broken away with a sledge hammer and the glass is inspected in large pieces by men cutting away all obviously defective parts. It is then subjected to close inspection by both men and women for striae, strain, bubbles. Men weigh, mold, and press optical glass. Molding and pressing are skilled tasks, the work is hot and strenuous, and there is slight probability that women might qualify or be acceptable to the management. The burring of rough edges and the indexing of optical glass—the latter more or less a laboratory job—are suitable work for women, but none are employed. All the women are on light, unskilled work, cleaning, weighing, inspecting, and packing into trays, with a larger proportion of women working on ophthalmic glass rather than optical.

Lens grinding and polishing.

Optical lenses and prisms probably are the most important and basic components in optical instruments, and lens grinding and polishing are fundamental jobs. Six of the plants visited are grinding and polishing their own optical elements. Blocking, grinding, and polishing of various degrees or stages, silvering, etching, centering, edge grinding, cementing, and correcting are operations in processing of lenses and prisms. In times of normal production, the precision optical worker is expected to be able, if necessary, to carry out all these operations, but during emergency periods when the expansion in production of optical instruments demands many times the usual output, specialization in jobs has become a necessity and inexperienced workers are being trained.

Very few women have been known to do blocking, grinding, and polishing of optical elements, and there is considerable diversity of

opinion as to women's ability to do this work because of the traditional skill attached to the trade. A few were found doing single-spindle blocking and polishing. When grinding and polishing requires handling of heavy cast-iron blockers, the work is too heavy for women, but with specialization in the manufacture of a variety of optics, women undoubtedly could be trained to do the lighter grinding, using small blockers and single spindles.

Sometimes the initial grinding of roughing and smoothing is by hand, but considerable finger and hand pressure must be exercised and the abrasives and rouge are hard on the hands. The grinder and polisher must acquire a feel for the proper rotary motion and suction of the blockers, or spindles. Some of the grinding and polishing was reported as requiring not more than 6 months to a year to attain skill, depending on the type of work and the precision required.

In the process of polishing, the lens must be checked with a test gage to determine the exactness of the work, and on some of the fire-control optics the tolerances are so fine that only men with many years of experience are considered able to carry on the work. But not all the polishing is of such precision. In an instrument factory in Scotland, women do optical grinding and polishing to extremely fine tolerances.

Women's work on optics at the present time is largely centering, silvering, etching, cleaning, and inspecting. Women do a great deal of cleaning, which is work of most careful and painstaking nature, removing microscopic specks with small vacuums and cleaning solvents and visually inspecting lenses and prisms with the aid of magnifying glasses. In centering, considerable skill is required in mounting the lens for edge grinding so that the exact optical center is obtained. Once the lens is mounted and the center secured, the machine grinding of the edges is an automatic process. Centering is being taught to girls in 3 months or less. A trainee works with an experienced operator.

Women often are employed with men on interchangeable jobs in the etching of glass. The glass is first given a wax coating, and then a pantograph engraving machine cuts the surface of the wax and hydrofluoric acid etches the lines on the lens or prism. Women are doing all this work, though the usual comment was that the most precise work requires men. Silvering, shellacking, and painting of optical elements are among the simpler operations and all are done by women as well as men. The number of women could be extended in a time of emergency.

Compound lenses are constructed by cementing—applying hot balsam with a brush—lenses of different qualities. Light pressure to exclude the bubbles of air between the lenses is applied and the operation requires the utmost delicacy of touch. For this reason women have been considered desirable and acceptable for the job and are used almost entirely.

Since women in the larger plants have proved proficient in centering, cementing, engraving, etching, silvering, and inspecting, a definite feasibility seems to be that if women's occupational opportunities were extended to blocking, grinding, and polishing they could meet the demands of such work. The traditions of the indus-

try in the grinding and polishing of precision optics are hedged with attitudes that such occupations are almost monastically male, but if optical elements become increasingly a bottleneck in the production of fire-control instruments, more inexperienced workers must be trained and a good share of the work might be done by women. Basic requirements are patience and skill to work to precise tolerances in terms of wave lengths, and many industries have accepted as a truism the fact that women excel on work that requires great attention to detail.

Assembly of optical and fire-control instruments.

The larger fire-control instruments are very intricate and are still made on a custom-shop basis. Range and height finders weighing 5 tons or more, having more than a thousand mechanical parts, 150 or more optical elements with numerous multiple prisms, may take more than a year to build. Since only a few men with long optical-work histories are considered sufficiently skilled to assemble such an instrument, women could not be expected to augment this group. On other fire-control and optical instruments, such as panoramic sights, periscopes, plotting boards, quadrants, sextants, and octants, the work is not on a quantity production basis even in an emergency, operatives with versatility in skills are necessary, and women are used only on a few minor subassemblies.

Binoculars are the only fire-control instruments on which women are employed extensively. Women are cleaning, inspecting, mounting, and setting optical parts such as lenses, Porro prisms, and reticles into the case or housing, and staking and making minor adjustments of the position of the parts. Similar work is being done by women on telescopes, aircraft sights, and small gunsights.

Sighting, adjusting for parallax, checking definition and focal length, collimating, calibrating, and other final testing is done by men on all optical instruments, including the simpler binoculars and telescopes. Men often have progressed to these jobs from machining and assembly and have a general knowledge of the optical and mechanical systems, and their applications for fire-control purposes, which is a background possessed by few women. On some of the instruments such as binoculars and small telescopes, made in large quantities, women should be afforded the opportunity to be upgraded from assembly operations to some of the testing work.

After all the adjustments and tests have been made on binoculars, women are doing the work of their final closing, disassembling eyepieces and objective lens, cleaning with vacuum lines, fine brushes, cleaning solvents, replacing the cleaned parts, greasing threads, waterproofing screws, seams, and so forth.

Machining of optical and fire-control instruments.

In addition to the optical work there is a great deal of machining and assembling of metal parts. A large proportion of the men in the machine shops are skilled mechanics able to set up all basic machines, follow intricate blueprints, and work to very fine tolerances. As in the aircraft-instrument machine shops, women are most frequently employed as operators of drill presses and occasionally on milling machines, light punch presses, and bench-lathe applications such as burr-

ing, lapping, and diamond turning for finishing surfaces. The proportion of women employed in the machining of instruments is small, and machine set-ups are all made by men except in two instances where women milling-machine operators make their own set-ups. All other machines are operated by men. The present possibilities of extending women's employment seem slight, except for a larger proportion of the drilling, milling, bench-lathe, and punch-press operations and some of the work on smaller hand screw machines and special applications of automatic lathes where long runs are common.

Miscellaneous jobs.

Painting, plating, heat treating, graduating, and engraving of metal parts, and other miscellaneous jobs, are similar to those on aircraft instruments that have been noted in that section of the report.

SURGICAL AND DENTAL INSTRUMENTS AND EQUIPMENT

The elimination of German competition and the defense orders for surgical and dental instruments have given this industry a defense boom. Prior to the war of 1914–18 about 85 percent of all surgical instruments used in the United States were manufactured in Europe, and though the industry got a footing in this country during the 1917–21 period, the United States markets were recaptured by Germany for a decade or more. In the last few years the industry has experienced another war and a great domestic demand, and it is gradually building up to meeting 100 percent of the domestic needs. In addition, exports to Europe, Canada, Latin America, and Asia are increasing each year. Since the industry has come into prominence within the last few years, few skilled, experienced instrument makers are available, and the industry has had to take young men and train them as instrument makers. The Women's Bureau was interested in discovering to what extent and on what occupations women might be trained for work on surgical and dental instruments and equipment.

In terms of total number of wage earners, the surgical and dental industries are small. The industry centers in New York, Pennsylvania, and Ohio, with marked concentration in the first and second. Almost three-fourths of the workers in dental equipment and dental supplies in the country are reported in New York and Pennsylvania, and the largest surgical-instrument manufactures are in New York State.

Five firms in New York State making surgical instruments, dental equipment and instruments, and clinical thermometers were visited. In 2 plants employing 661, of whom 20 were women, only surgical instruments and supplies were made. In the 2 dental equipment and dental goods plants, and one thermometer factory, employing 3,147 workers (759 of them women), there was considerable diversification of products and not all would fall in the field of surgical and dental instruments.

Surgical instruments.

In the 2 firms manufacturing surgical instruments, such as hemostatic and other forceps, retractors, surgical scissors, knives, saws, scalpels, syringes, and so forth, the women are employed on only a few jobs, cleaning, inspecting, and wrapping the articles for stock and shipment. Altogether there were only 20 women reported in the 2 firms, or about 3 percent of the productive workers.

Surgical instruments are made of tool and stainless steels, which present special problems of processing. Forging, annealing, stripping stainless steel, plating tungsten steel, and heat treating are relatively insignificant in the numbers employed, and due to the heaviness and the conditions of work are not considered jobs to be advised for

women. After the forgings have been trimmed, milling surfaces and cutting serrations are the most common machining operations, aside from grinding and polishing. Most of the men set up their own machines and must be able to perform a variety of progressive operations on several types of instruments. A few women might be employed on these operations.

Rough grinding, polishing, and buffing comprise a major part of the work, with a series of operations using successively finer abrasives until the final polishing—known as coloring—is done on rag wheels. In general, these operations are decidedly heavy and dirty. On the coarser carborundum wheels, there are flying particles in spite of exhausts, odors of hot metal, and on all grinding and polishing a firm grasp and hand pressure must be exerted on the instrument against the wheel. Generally the work would hardly seem desirable to many women, for in addition to the strain there is a constant spattering of buffing paste, rouge, fine dust covering hands, face, and clothing. The one job that seems feasible for women is the final color buffing to give a high polish to the metal, but this too is usually a strenuous job and does not employ any appreciable number.

Almost one-half of the employees are on miscellaneous operations of a bench-work nature such as hand filing, fitting, adjusting, soldering, or brazing, and like machining this work is not essentially repetitive and the employee must be versatile, using all sorts of tools and light machines. Bench lathes are used in burring and adjusting and most of the drilling is combined with assembly. Burring and filing are not light jobs, as the steels used are hard and considerable pressure must be applied to the file. Fitting, setting, and assembly requires an estimated minimum of a year's experience to get close adjustments and proper play. Most of the inspection is coupled with the processing. Some of the final assembly jobs are riveting and screwing parts together, inserting springs, breaking-in joints, and oiling. Visual inspection and testing the grip of instruments are done by both men and women.

Though the heaviness of the work, the hardness of the metal, and the variety of the operations were stressed by management as a bar to the employment of women, there are some light jobs that women might do in machining, fitting, soldering, and handling the lighter instruments, if the emergency program demands increased employment of women. In spite of this, the manufacture of surgical instruments would never afford any marked opportunity for employment of women, as even now, when foreign competition has been drastically curtailed, the industry is limited in size.

Thermometers.

In one firm manufacturing clinical thermometers women are now employed on all the major processes. Women are gaging diameter of tubes, cutting tubes to prescribed lengths, blowing and gaging end bulbs, trimming and sealing the ends, pointing, graduating and engraving, fill-in painting, inspecting, and packing. Pointing is marking the thermometer to indicate prescribed temperature points in a controlled bath. Graduating and engraving of scales, serial numbers, company name are done by both men and women on single and gang pantographs. Waxing preparatory to engraving and all

the fill-in painting of scales are done by women. Women are used almost entirely, so there is little if any opportunity for further extension.

Sphygmomanometers also are largely a product of women's work. Women do all the assembly, the cutting and sewing of the sleeve, the pointing of the dial, machining and calibrating operations on the instrument mechanism—work similar to that on aircraft instruments.

Dental instruments and equipment.

Two-thirds of the wage earners in the dental manufacturing industry are in New York and Pennsylvania, and two of the largest firms in the country were visited. Products of the two firms include dental instruments such as burrs, broaches, drills, hand pieces and tools for hand pieces, abrasive points, forceps, pliers, explorers, chisels and cutting instruments; equipment such as chairs, stands with accessory fittings, sterilizers, dental gas apparatus, X-ray equipment, dental lights, and so forth; and consumable materials and supplies such as dental gold, alloys for amalgams and fillings, cement, teeth, orthodontic appliances, waxes, and so on; and in addition nondental products such as aircraft compasses, small electric motors, coils, and accessory parts for aircraft, flexible shafting, and special custom work on small plastic and metal parts.

The manufacture of consumable materials and supplies is more allied to the laboratory processing and the packaging of a pharmaceutical plant than to a metal plant making instruments. Women are used as packers, labelers, and sorters, and the skills and training required are quite different from those of a metal plant. The mixing and processing is done by a small number of men and involves lifting raw materials and tending a number of machines.

Machining of instruments and equipment.

In the standard heavy-duty-machine shop, all machines except a few drill presses are operated by men. Women might do more of the drilling, and also part of the work on punch presses, hand screw machines, and milling.

Dental instruments of the forcep, plier, and chisel type have the same sequence of machining operations as surgical instruments such as retractors, hemostats, and so forth. Grinding, polishing, and buffing, the predominant machine operations, and the miscellaneous bench work for fitting and adjusting are like the operations on surgical instruments, and the same findings hold for the employment of women.

Women do all kinds of light machining on hand pieces, burrs, broaches, and fittings, which are quantity production goods. They are turning, drilling, reaming, milling, lapping, and burring. Men are doing some of the same operations, but though quantity and quality of workmanship on certain processes were reported as about the same for the two sexes, the men are said to be all-round operators with experience and skills that allow them to be shifted to any operation.

Dental burrs and broaches are made in about 150 styles, and are almost entirely manufactured by women, who are straightening, cutting, and inscribing the trade-mark on wire used as raw stock.

Semiautomatic and special automatic machines are used for forming the end of the burr. On some operations girls are tending a battery of machines loading and checking the precision of the operations with a microscope. Broaches are ground and tapered on fine carborundum wheels and barbs are cut on a special bench machine. The operations are checked under a microscope.

On hand pieces and small accessories women are doing small subassembly, using bench tools and appliances. Practically all jobs of this nature could be done by women. Inspection of hand pieces and parts, visual and gage, is done by women.

Assembly of the chairs and dental stands is almost entirely done by men. A small number of women do some minor testing, subassembly of fitting wires and tubes, and touch-up painting. In the gradual assembly of chairs and stands, the entire framework and installation of fittings frequently is carried on by one man, the work being intermittently light and heavy. Men do final inspection, testing, and manipulation of the chairs and stands. If the volume of this type of production were greater, women might fit into the assembly work, but at present all-round experienced men are preferred.

Minor jobs in the numbers of women employed include inspecting burrs and broaches on comparators, wrapping and packing for stock and shipment. Women also wrap some of the smaller parts for chairs and stands. Another minor job held by women is the tending of braiding machines, making cords to be used as pulley drives on some dental equipment. Small electric motors are made in both the dental-equipment plants, and women are employed on their usual jobs of coil winding, building up small commutators, cutting, preparing, assembling, soldering wire and terminals, and so forth. The final electrical assemblies are made by men.

No women are employed in heat treating, plating, painting (except minor touch-up painting), foundry, tool making and tool room, or operating plastic molding machines, and the job possibilities for women in these divisions are slight.

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