A MACHINE-PACED LINE FLOW PROCESS
General Motors Corporation
Chevrolet–Pontiac–Canada Group
Oklahoma City, Oklahoma

The Oklahoma City plant of the Chevrolet–Pontiac–Canada Group (C–P–C), one of the 28 domestic assembly plants operated by General Motors, was situated in the southeast part of Oklahoma City. The plant, built in 1979 on a 436 acre site, was huge, having 3 million square feet of space under roof. The plant employed a total of 5300 people, of which 430 were salaried. The nearly 4900 production workers were employed on two production shifts. (See Figure D1 for a layout of the plant.)

The plant currently assembled two nameplates of the body type A car, the Oldsmobile Cutlass Ciera and the Buick Century, in both sedan and station wagon models. In the past several years, however, as many as five different models (Buick Century, Oldsmobile Cutlass Ciera, Chevrolet Celebrity, and two versions of the Pontiac 6000 [front-wheel drive and all-wheel drive]) had been assembled there.[a] The plant delivered truckloads and rail carloads of these cars to every domestic auto dealer carrying those nameplates. The Oklahoma City plant was one of only two plants to assemble the A car, the other being in Ramos Arizpe, Mexico.

The Oklahoma City plant assembled cars of world-class quality. In the previous two years the plant had been rated as either the third or fourth best plant by J. D. Power, an independent company widely recognized as the arbiter of car quality for North America. In the latest year, the Pontiac 6000 produced in Oklahoma City tallied only 78 defects per 100 cars. This rating was exceeded only by the Lexus and surpassed that of the Toyota Camry and the Infiniti. The Buick Century's rating, 91, and that of the Oldsmobile Cutlass Ciera, 97, were better than that of the Honda Accord and of all other nameplates sold in North America.

[a]Although still selling well, the A car "platform," as it was termed, was aging and for the latest model year, the Chevrolet Celebrity and the Pontiac 6000 had been discontinued.

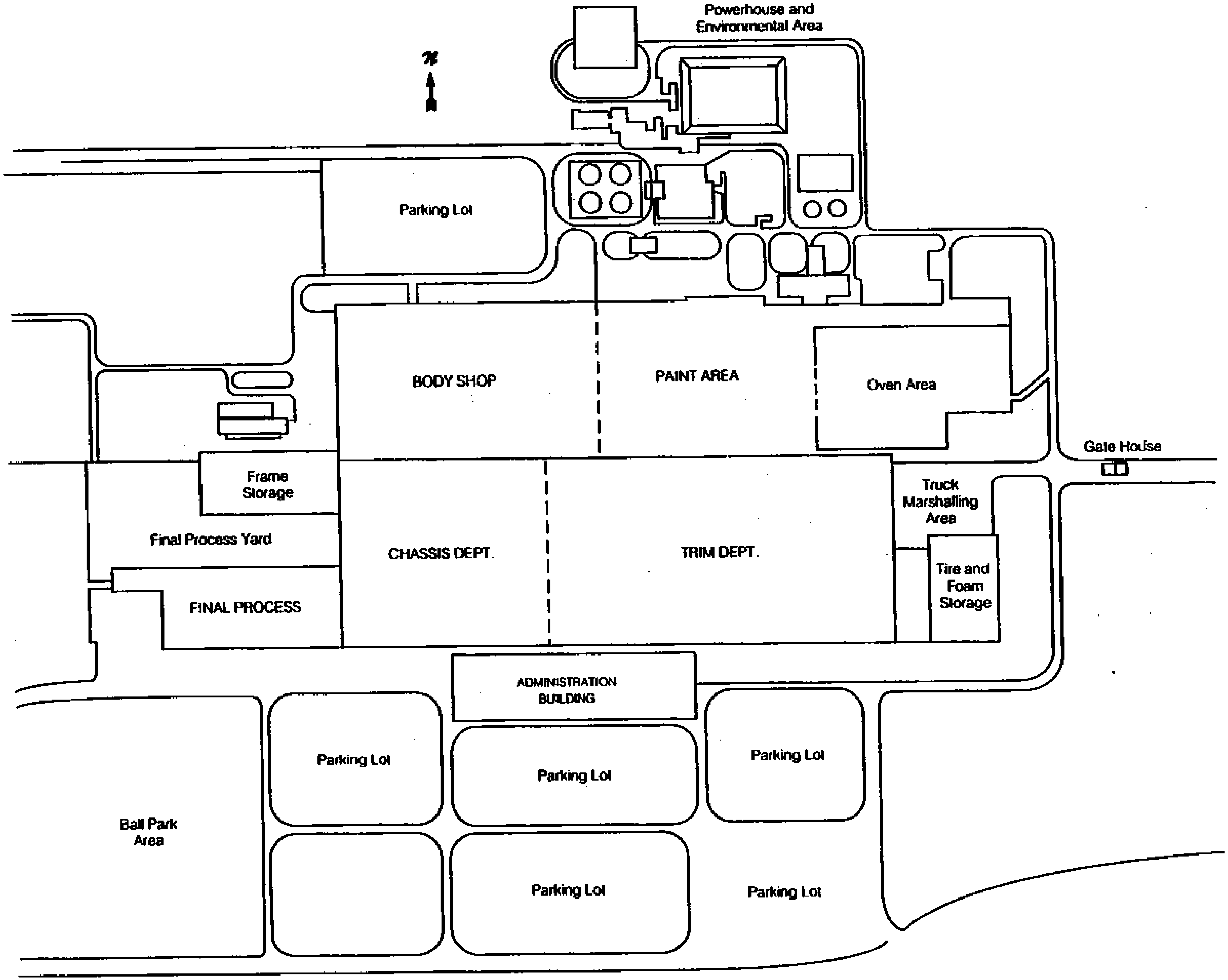

FIGURE D1 Map of the plant site. (*Courtesy of General Motors, Oklahoma City Plant*)

PART ONE

Process Description

How a Car Was Assembled: A Simplified Description

The production process at C–P–C Oklahoma City was a classic, but modern, example of the moving assembly line so closely associated with Henry Ford and the Model T. The essence of the process was to build the car bit-by-bit by having workers perform the same tasks on each car as it moved through their work stations on a conveyor system. The A body car, with its front-wheel drive, could be viewed as the marriage of two large subassemblies: one for the body of the car and one for the engine cradle (the engine, its support structure, the front axles, and the trailing exhaust system and rear-wheel brake lines). The assembly plant was organized to build up the body and the engine cradle separately, to "marry" them, and then to finish the car's assembly and construction. The body and engine cradle lines were both fed by smaller subassembly lines. The plant was laid out with a flow that went clockwise, starting with the body shop, then the paint shop, the trim line (known as General Assembly I), and the chassis line (known as General Assembly II). See Figure D2. A more detailed version of the steps to build a car would require more space and explanation than is merited.

The entire line was composed of about 1800 cars with a single car taking about 28.5 hours to progress through the complete assembly process, a rate of about 1 car per every 50 seconds per work station. A typical work station consisted of 2 workers, 1 on each side of the line, some space in which to do the work, equipment specific to the job, and in many stations, some totes or bins stocked with the parts to be assembled onto the car. A great deal of variety existed from one work station to another. For example, a typical work station in the General Assembly 1 area might have the car moving at ground level, while at other positions in the General Assembly 2 area, the car was raised for work underneath it. An inspection station might have intense lights and raised platforms so that inspectors could easily identify any flaws and mark them for correction. Some work stations in the body shop were completely mechanized, with either robots or fixed automation. About the only consistent feature across work stations throughout the plant was that work averaged about 50 seconds per car.

For some options, such as occurred with station wagons, a worker might have to take somewhat over 50 seconds to do the job. This deviation was termed being overcycled. Naturally, a worker could not be continually overcycled without falling behind the pace of the line. To keep up, overcycled jobs had to be balanced off quickly by undercycled jobs for the workers affected. Given the existence of overcycled jobs, then, the sequencing of cars along the line, to provide a balance of overcycled and undercycled work, was an important endeavor. For example, the larger labor content station wagons were never scheduled back-to-back on the line.

Much of the overcycled work occurred along the General Assembly 1 and General Assembly 2 lines, where many of the multitude of options were added to the cars. Workers were advised what options to include on any car by reading the "broadcast," or "manifest," an instruction

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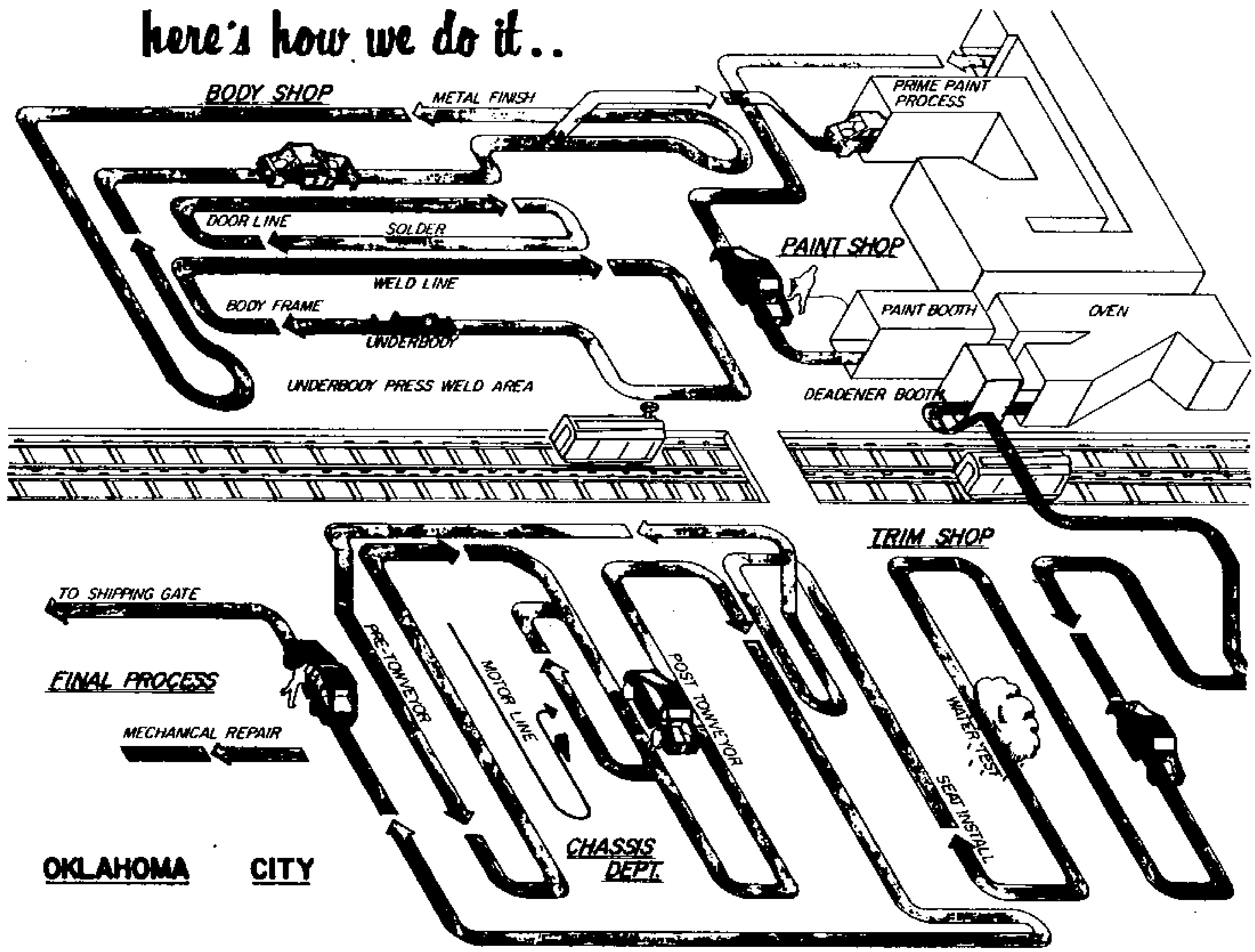
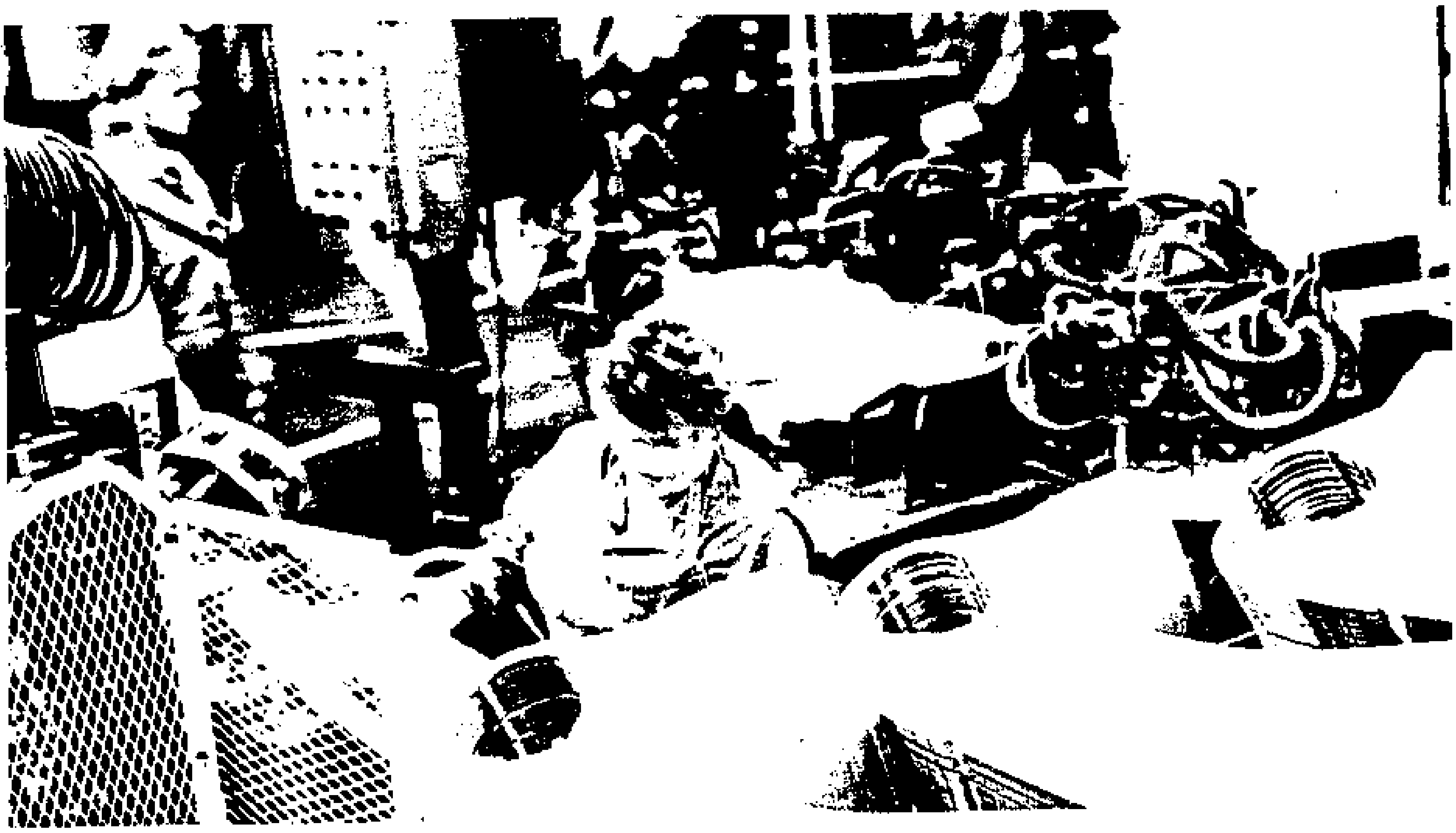
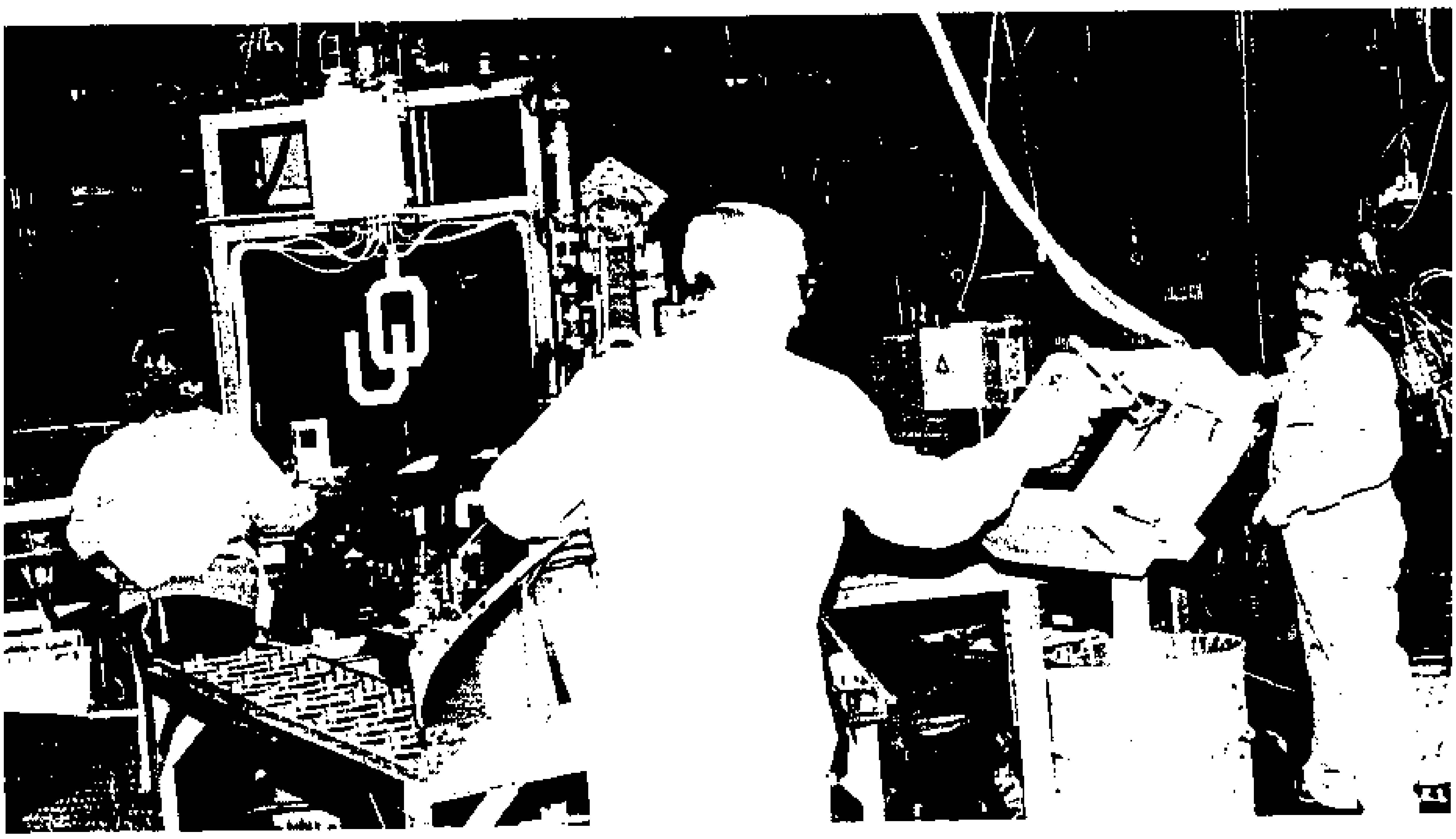


FIGURE D2 How a car is assembled. (*Courtesy of General Motors, Oklahoma City Plant*)



The body shop's wheelhouse subassembly area. (*Courtesy of General Motors, Oklahoma City Plant*)



Calling for replenishment in the body shop's wheelhouse subassembly area.
(*Courtesy of General Motors, Oklahoma City Plant*)

sheet attached to the car, usually on a window. The broadcast was the primary information by which the worker determined what part or component was to be placed on a particular vehicle. In an effort to reduce error, the plant generated some "mini-manifests," which highlighted in large bold print the options that were called for in a particular department. The mini-manifests required more paperwork, but they enhanced quality by simplifying the information flow to workers along the line.

Loading the Plant

Planning Production

Because cars and the parts to make them were both expensive and bulky, considerable thought was given to limiting inventories in the plant. No finished goods inventories were kept. All the cars assembled were trucked or shipped by rail to individual dealers within a short period of time after coming off the production line. Therefore, all of the cars destined for a particular dealer had to be scheduled for completion at roughly the same time to avoid significant delays.

Furthermore, all of the cars were produced to order as to make, model, color, and options. C–P–C Oklahoma City, on its own, was not permitted to ship any dealer a car that the dealer had not ordered. Roughly 5 percent of a dealer's order represented cars that were already sold to particular customers. About 25 percent were orders for fleet sales, and the remainder represented the dealer's speculation about what the dealership would be able to sell. Such production to order, given the wide range of options permitted in a car, placed tremendous demands on the plant's materials function to schedule the proper mix of cars through the line and to secure enough of the proper parts to fill the order.

The scheduling and material procurement functions were characterized by successive tiers of forecast orders and due dates that represented ever more precise refinement. At the broadest level, the corporate office in Detroit determined a rough production schedule for the year. The schedule served as a target for the company's outside suppliers and for its own internal supply groups such as engine plants and transmission plants. As dealer orders came in, the schedule became increasingly firm. The C–P–C central office in Warren, Michigan, scheduled production in the plant in order to meet a customer promise date known as *target build*. When a dealership received confirmation of an order, it also received word of exactly which week each car ordered was scheduled to be built. Meeting this commitment drove the production plan and the materials scheduled from a myriad of suppliers.

This target build program represented a change from the production planning used until the early 1980s and was part of the company's just-in-time production principles, termed "synchronous manufacturing." The plant operated with a firm car-by-car production schedule for 10–15 days in advance; it was known as the "stable schedule process." Any changes to production had to be accomplished beyond the three-week limit set by this stable schedule process. With this schedule, 98 percent of the target build sequence was accomplished when expected. Moreover, that production schedule persisted throughout the entire plant. It was only rarely that a car had to be taken out of the production sequence because problems could not be fixed on line. Thus, a car begun in the body shop maintained its order in the line throughout the paint shop and the General Assembly areas. Some cars, like station wagons, were periodically removed for extra work, but then they were repositioned to the same place in line. This schedule was announced on Mondays, so that every Monday there were 15 days of firm car-by-car schedules.

Although the line was flexible in handling many make/model and option variations, there were certain limitations. A special computer program, known as "auto sequence," helped to take account of them. The restrictions varied. For example, the plant wanted to batch colors as much as possible, but every day, every color was made, although in a specific sequence that went from white, then to light blue, dark blue, medium blue, red, brown, and finally silver, before returning to white. Never, for example, was a red car scheduled next to a white car because of the trouble in purging the paint lines. There were also restrictions caused by the number of side gates in the body shop used to hold side panels. There were 54 gates and only so many of particular models. This meant, for example, that the plant could run no more than 6 Oldsmobiles in a row. In addition, they could run no more than 7 station wagons in every cycle of 54, and these wagons had to be spaced out because of the overcycle condition they provoked in General Assembly 1. Similarly, the auto sequence program spaced out the options of power doors and windows as much as possible.

This system was very much appreciated by the factory's supplier base. The visibility this gave suppliers and the level aspects of the demands placed on them permitted some suppliers to reduce their costs, and this in turn was passed on to the plant in lower prices. The auto sequence program that created the stable schedule was communicated electronically to all of the plants' suppliers on Mondays. This communication was called the production point-of-use. Every Monday, as well, suppliers received a 20-week planning schedule from the Warren Central Office which included the firm 3 weeks that matched the production point-of-use sequence, but also included forecasts for the subsequent 17 weeks. In the future, it was planned for these two documents to be merged into one document that the supplier would receive from the plant.

This change in production planning both removed a good deal of expediting and improved quality at the supplier and at the plant. Although the sequence was known in advance, no material was shipped from the suppliers in sequence. Oklahoma City did its own sequencing simply because it was more economic to do so. All of the plant's part numbers were scheduled in this way.

Purchasing and Raw Materials Inventory and Control

There were 4046 active parts and 493 suppliers that were used by the Oklahoma City plant. These figures represented reductions from the years when all four nameplates were manufactured at the plant and the active parts had totaled 7059. The reduction in the number of suppliers from as many as 783 suppliers to the current 493 was deliberate. The reduction in suppliers often improved both quality and price. For example, the 7 film suppliers previously used by the plant had been collapsed into a single vendor. The C–P–C Central Office in Warren negotiated all of the long-term contracts for the plant. The plant's purchasing people purchased non-production items, paints, sealers, and vehicle fluids, such as fuel, brake fluid, etc.

To avoid excess materials inventory, the delivery of materials was very tightly controlled. The plant had moved to provide reservations for both the truck and rail deliveries. It was essential that suppliers were reliable in these deliveries. For the most part, only between one or three days' worth of production items were kept in inventory at the plant, with one and one-half days being typical. For the relatively expensive items (engines, radiators, alternators), less than one day's production items were inventoried. Such tight control helped greatly, because the most expensive 350 parts accounted for 80 percent of the dollar value of inventory. Even small items like screws were stocked for only two to three days. How many days of inventory were held depended on:

1. *Volume.* The more regular a part's use, the tighter the schedule.
2. *Monetary value.* The higher the value of the part, the tighter the schedule.
3. *Physical size.* The larger the part, the tighter the schedule. And,
4. *Transportation.* The farther away the supplier, the greater the days of inventory held.

Many of the deliveries at the plant involved "milk routes," where a truck or train was filled with deliveries from several vendors and moved on a regular daily basis to the plant from as far away as the Midwest. Oklahoma City unloaded 50 rail cars and 90 truck trailers a day.

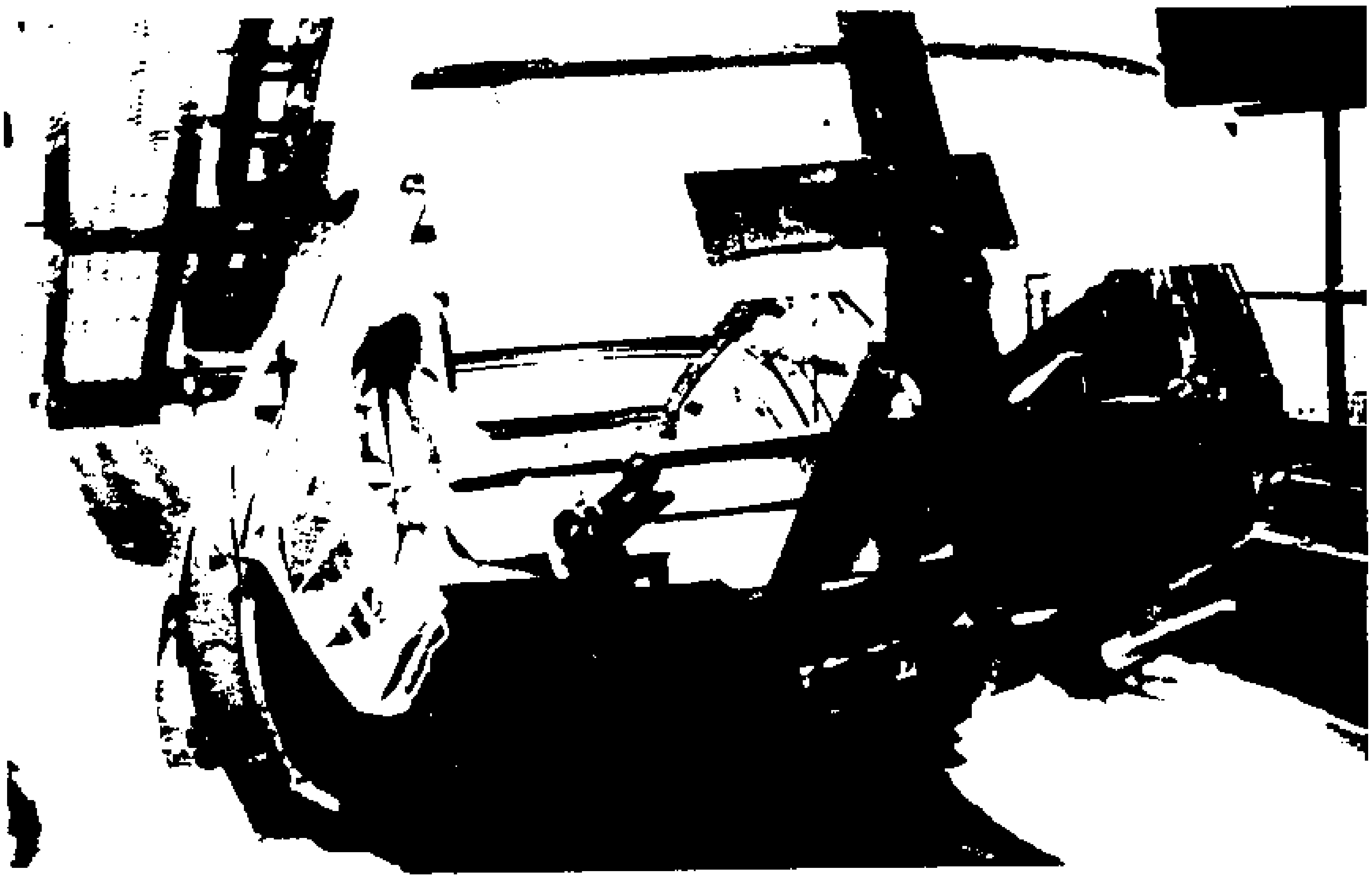
With materials delivery scheduled tightly, it was necessary to monitor the entire supplier network constantly. Failure to have on hand a key part could shut down the plant. Constant vigil was kept on the number and location of all supplies coming to the plant. Every day a list of critical parts that might turn up short or out of stock for the next two days was developed. The plant notified the suppliers to expedite the parts sought. Usually expediting involved securing a part from either the supplier or a sister plant and switching delivery to a faster and generally more expensive form of transportation.

Monitoring materials delivery involved not only the materials department at Oklahoma City (staff to track shipments, unload and handle materials) but also line workers and their supervisors. Even transportation carriers had electronic access to the materials system and knew exactly what the plant's needs were. However, the plant was careful not to incur extra transportation costs just to carry lower inventory levels. Calculations were made that traded off the extra transportation costs against the inventory carrying costs that might be incurred. And, often, more inventory was kept in order to keep the total cost of procurement lower.

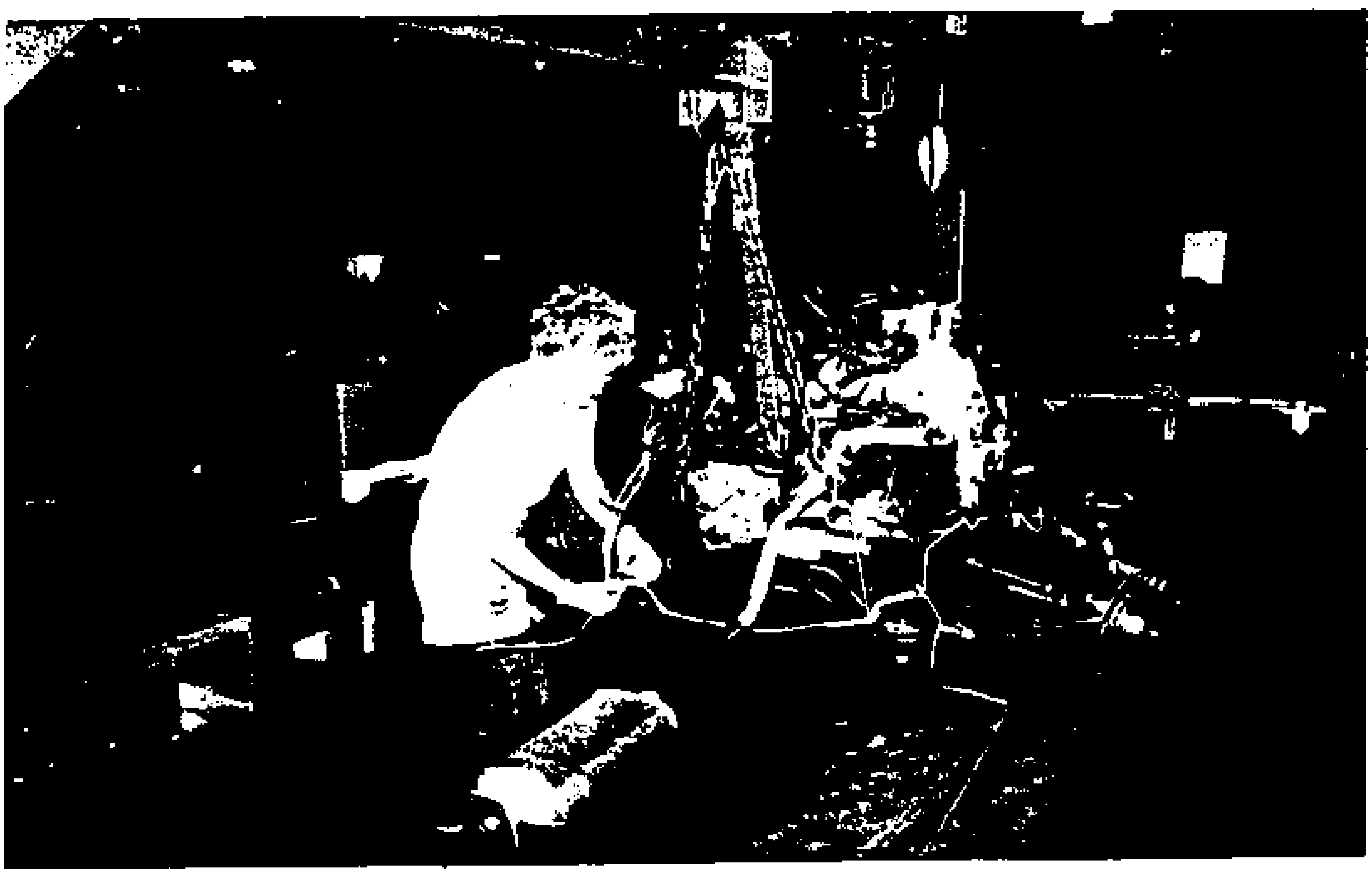
As a result of these improvements in production planning and in "synchronous manufacturing" (discussed in more detail below) inventory turns at the plant had risen consistently over the years. From levels in the mid-1980s of 30 to 40 turns, the plant's inventory turns had risen to a level in excess of 56 turns for 1991, with a peak month level of over 79 annualized turns. What is more, these high turn figures included the fact that the plant owned inventory in transit as well as the inventory that was physically at the plant.

Synchronous Manufacturing

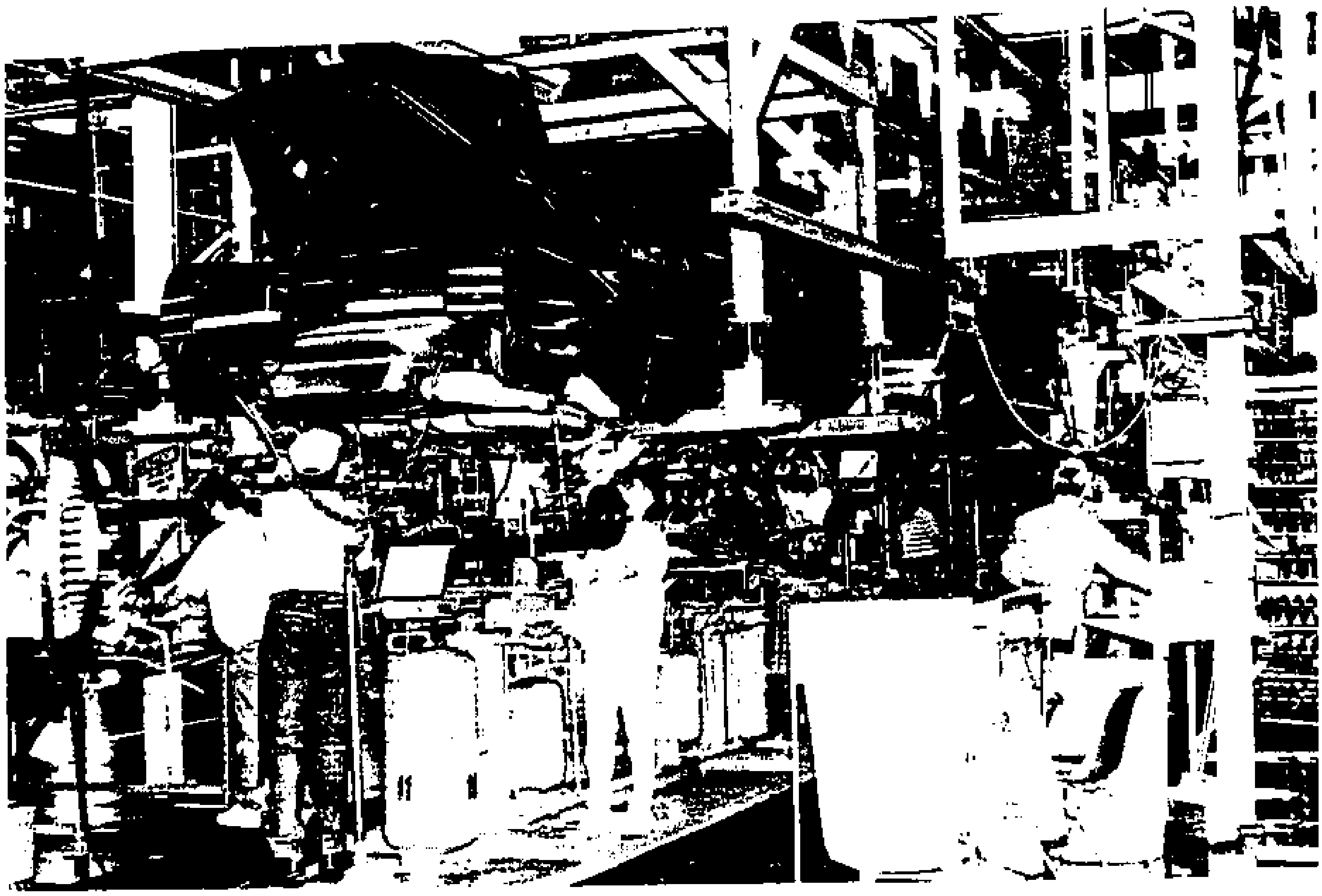
The Oklahoma City plant was well along with a C–P–C division goal to develop synchronous manufacturing in the plant (what many other companies call just-in-time production). Synchronous manufacturing involved a coordinated set of strategies (17 were identified; see Figure D3) that were designed to help identify and eliminate the non-value-added activities in the factory. Thus, there was an effort to rid the plant of unnecessary activities and controls, to eliminate excess inventories, to contract the working space, or work envelope, so that workers could take fewer steps, to simplify the presentation of parts to the worker so that mounting parts on the car was easier, and to help the worker ergonomically so that less stress and strain was placed on hands, wrists, arms, backs,



A car entering the ELPO bath. (*Courtesy of General Motors, Oklahoma City Plant*)



Along the chassis line. (*Courtesy of General Motors, Oklahoma City Plant*)



The marriage of the body and the chassis. (*Courtesy of General Motors, Oklahoma City Plant*)

FIGURE D3 Synchronous Manufacturing

Attachment F

KEY SUCCESS FACTORS	DESCRIPTION
1. Lead time reduction.	Method to identify, measure and eliminate waste.
2. Supplier involvement.	Extension of the process.
3. Reduction of variation.	Method of decreasing deviation from a target.
4. Pull system.	Replenishment based on consumption.
5. Leveling.	Providing stable & smooth flow.
6. Quick set-up.	Rapid preparation and changeover.
7. Total preventive maintenance.	Proactive planned upkeep.
8. Process/operator control.	Prevent problems from being passed on.
9. Problem solving.	Logical thought process to identify and eliminate problems.
10. Standardized systems.	Consistent and repeatable operations.
11. Small lot production.	Minimum material quantity and flow.
12. Capable systems.	Equipment/process within desired range.
13. Facility/equipment layout.	Effective layout of worksites (I.P. "U" shaped cells, etc.).
14. Workplace organization.	Orderly place for everything.
15. Audio visual controls.	Make problems noticeable/status at a glance.
16. Error proofing.	Proactive problem prevention.
17. Flexible systems.	Equipment and process adaptability.

SOURCE: Courtesy of General Motors, Oklahoma City Plant.

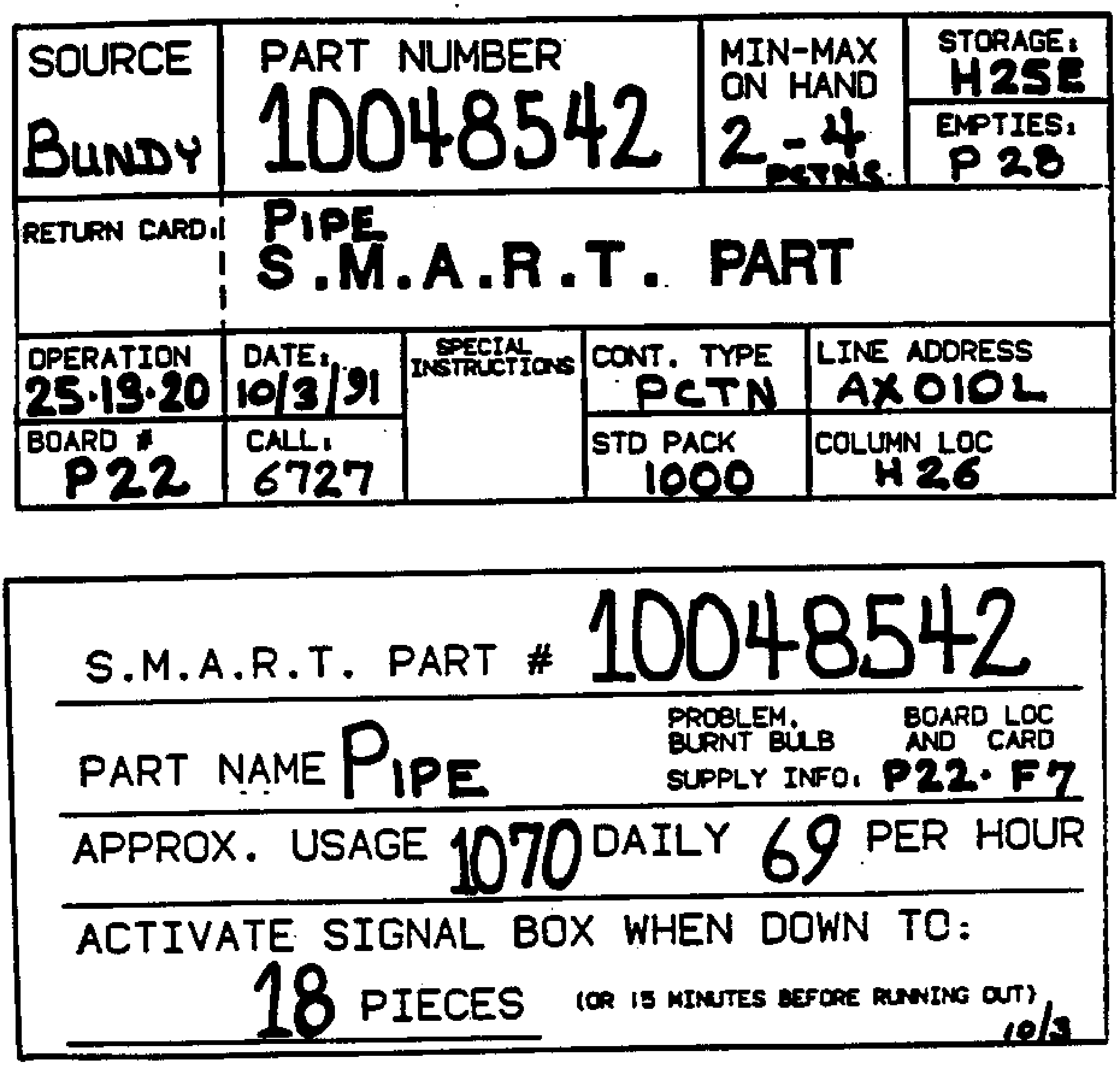
and legs. In line with this approach to manufacturing, the Oklahoma City plant was relatively "low tech" compared to a number of auto assembly plants. It had only between 30 and 40 robots vs. perhaps 150 in a more automated plant. The plant's management pursued a strategy of more incremental automation.

Supporting this movement for synchronous manufacturing was the development of a support network to generate ideas for improvement, to analyze them, and then to implement them. Also supporting synchronous manufacturing was a change in the way materials were ordered and packaged for the line. On the line there were switches that turned on lights on a special panel to indicate to materials handlers that they were needed to fetch small bins and boxes of parts for particular positions on the line. In a standard assembly plant, in contrast, large baskets of many parts would be placed in the vicinity of the line, taking up space and forcing the workers to walk considerable distances to pick the parts needed for a particular car. No special signals would be devised either. Under synchronous manufacturing, parts were placed within easy reach of workers and would be replenished much more frequently by the use of worker-initiated signals. This was called the "pull card" system that was used to "pull" materials through the plant (as opposed to "pushing" materials onto the factory floor in anticipation of their use). Cards were used to identify parts, where they came from, where they were used on the line, how the standard quantities in the totes and bins are used, and when the worker should signal for more (see Figure D4). This system forced the coordination of materials handling to the needs of the line worker, and placed demands on both the process and the supplier network to produce high quality parts so that the line could function well. In addition, all kinds of worker aids and assists had been created for synchronous manufacturing. Special hoists and other ergonomically friendly tools and devices eliminated much of the effort that traditional assembly lines placed on workers.

The areas of the plant that had been converted to synchronous manufacturing were provided with only four hours of parts on the line. These parts were picked from so-called "supermarkets," where larger bins of the parts were kept and where materials handlers replenished the totes and small bins of parts that were found near the line. The supermarkets were laid out in mirror image to the line so that the materials handling fork lifts and cart trains could easily move in to collect the parts that the pull card or "smart light" systems had indicated were needed.[b] Similarly, synchronous manufacturing had also led to the realignment of the line so that subassembly areas were greatly reduced and placed closer to the point of their use along the main assembly line.

The move to synchronous manufacturing affected both supervision and design. The changes in the process gave supervisors "cradle-to-grave" responsibility for distinct segments of the process, say, for example, all of the assembly for a rear door. This increased the identity that supervisors, and their workers, felt for the product and the process. Contributing to this was a plant program (termed "Design for Assembly") to foster redesigns of the car itself so that assembly could be easier and of higher quality. From time to time groups of design engineers came to the plant and spent time learning from the workers how to do the job, actually doing the job on the line, discovering for themselves the problems that production workers had in doing the job, and leaving with numerous ideas for altering the way that the car was designed.

[b]The hand deliverable parts were on the pull card system; the bulk or fork truck deliverable parts were on the "smart light" (Synchronous Manufacturing Andon Retrieval Transport) system.


SOURCE Bundy
PART NUMBER 10048542
MIN-MAX ON HAND 2-4 PCTNS.
STORAGE: H25E
EMPTIES: P 28
RETURN CARD: PIPE
S.M.A.R.T. PART
OPERATION 25·19·20
DATE: 10/3/91
SPECIAL INSTRUCTIONS
CONT. TYPE PCTN
LINE ADDRESS AX010L
BOARD # P22
CALL: 6727
STD PACK 1000
COLUMN LOC H26

S.M.A.R.T. PART # 10048542
PART NAME PIPE
PROBLEM, BURNT BULB SUPPLY INFO:
BOARD LOC AND CARD P22 · F7
APPROX. USAGE 1070 DAILY 69 PER HOUR
ACTIVATE SIGNAL BOX WHEN DOWN TO:
18 PIECES (OR 15 MINUTES BEFORE RUNNING OUT)
10/3

FIGURE D4 A card for the "pull" system. (*Courtesy of General Motors, Oklahoma City Plant*)

Synchronous manufacturing did not lead to any workers losing their jobs. Workers removed from direct labor tasks on the line were reassigned to such tasks as repacking parts in the supermarkets, recycling cardboard and other materials, and doing prototype work on future models.

Synchronous manufacturing had resulted in tremendous gains in productivity, space saved, inventory dollars saved, and quality enhanced.

For example, in the body shop a synchronous manufacturing project reduced the square feet of space from 32,400 to 7593. Work-in-process inventory was reduced from 2076 pieces to 54, and the variable cost declined. Along the instrument panel feeder line, square footage diminished from 30,730 square feet to 11,340, work-in-process declined from 98 pieces to 24, and the number of jobs on the line at any one time dropped from 81 to 44. Similar results were being achieved all over the factory, and new opportunities to apply synchronous manufacturing concepts were being revealed all the time.

Underlying the plant's accomplishments with synchronous manufacturing concepts was a commitment by the plant's top leadership to be the instructors for 13 four-day workshops held at the plant in the previous 16 months. The well-designed workshop format was created by experienced manufacturing personnel utilizing concepts observed at the GM/Toyota (NUMMI) factory in Fremont, California.

Revising and Controlling the Operation

Although the plant did not have much leeway in the purchase of materials or the mix of makes, models, and options it was to assemble, it did have considerable leeway in the design and management of the assembly line itself. Key roles in this effort were played by quality control, the industrial engineering staff, and the plant engineering staff.

Quality Control

The move to synchronous manufacturing put pressure on the plant and its suppliers for quality. The system would only work when everyone had high confidence in what was being sent to the plant. There was no receiving inspection of items; parts went right to the line.

The quality control department coordinated a number of specific functions: inspection, reliability, audit, quality statistics, and customer acceptance criteria, commonly called the "voice of the customer."

It was the plant's aim to try to match key characteristics of the product, as made evident by the customer, to the capabilities of the process. This was known as "matching the voice of the customer to the voice of the process." Outside data were used to provide information on customer desires. Warranty information, data from outside independent surveys and consultants such as Camip and J. D. Power, and surveys done by Buick, and those by the plant itself (called "Sunvisor Surveys") brought the plant in contact with customers. In one year, for example, the plant, on its own, called 10,000 of its car buyers to solicit their opinions and to evaluate their complaints to find out exactly what customers thought was wrong or right with their cars. The plant was beginning to be "obsessed with the customer" and would stop at nothing to remedy a customer problem, even if it meant sending people and replacement parts to dealers anywhere in the country. With this focus on the customer, discrepancies had dropped to less than one per car, which was world-class performance.

While the plant still did some inspection, the number of inspectors had dropped considerably from a level of about 370 in 1986 to about 200 in 1991. Under a concept called "Build-In-Station," people on the line were paid a higher rate to assume responsibility for their own inspection with the intent of integrating inspection into the building of the car. There were inspection stations along the line, as are typically found in auto assembly plants, but these inspections stations were fewer than ever before. Inspectors marked on both the car and the inspection tickets that travelled with the car exactly what corrective work needed to be done farther down the line in certain repair areas.

The quality control department's reliability group was charged with a number of tasks. They were the overseers of driver and passenger safety in the car. They also dealt with incoming quality by working with suppliers. They were also responsible for engineering change orders and for leading any product changes that had been mandated.

The audit group was responsible for grading the production quality every shift. Eighteen cars were investigated every shift, selected at random. Four of those cars were checked for everything. Fourteen others were checked systematically for the most prevalent problems. Once the more prevalent problem areas were studied, and preventive countermeasures arranged for them, then the inspection sampling for those problems was reduced and other problem areas were sampled more intensively. Three cars a month were subjected to a comprehensive evaluation and were measured in every way possible so that "variables," as opposed to "attributes," data[c] were collected on things like noise, fit, finish, and other important criteria for the customer. In addition to these three cars, a competitor's car was also evaluated in the same way.

The daily audit included a special 18-mile road test and a 12-hour cold soak. These processes allowed the auditors to check for cold starts, squeaks, and rattles. The number of defects per car was assessed. In addition, about ten times a year, unannounced and at random, a quality audit team from Detroit would perform their own audit of 20 cars. This procedure served as a check on the plant's daily audit.

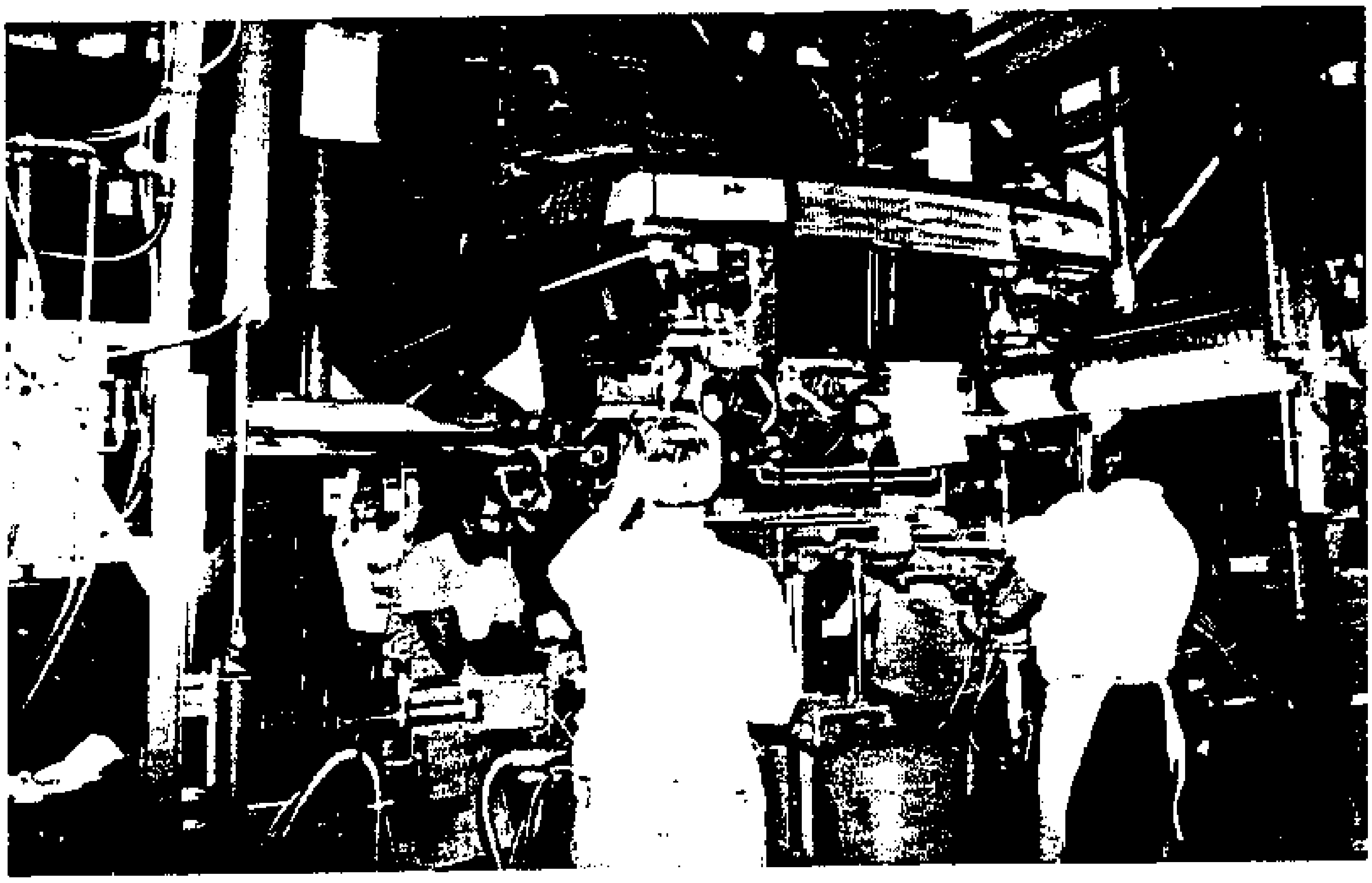
By matching the voice of the customer to the voice of the process, the plant developed some statistical measures that provided the information needed to improve the process. Currently, the plant had between 70 and 80 quality control charts, about the same number of trend charts, and very many more charts of raw data that supplied insight into process improvement. Problems that had shown up repeatedly were assigned to special cross-functional teams that were charged with mapping the process with a process flow diagram and then indicating where production variability might be caused. This systematic investigation, in conjunction with some experimentation, led to effective countermeasures aimed at prevention of these problems.

In addition, any employee could shut down the line if a quality problem cropped up. Such actions were seldom taken, however. The factory had programs whereby both hourly and salaried employees acted on specific problems that had been raised by customers. Employees were also sent to supplier companies to educate suppliers on exactly what the assembly plant's requirements were. Numerous quality aids had been introduced in the process. In some cases these aids were protective devices for the car itself, such as to avoid scratches or other damage, and in others they were worker production aids that decreased effort or fatigue (ergonomics) or increased precision or reliability.

Industrial Engineering

The Industrial Engineering Department was charged with: (1) translating the engineering design of an automobile into a step-by-step procedure for assembling it; (2) laying out the line, work stations along the line, and any production aids such as equipment and fixtures for the work stations; (3) assigning work to each worker on the line and measuring that work so that it was appropriate; (4) establishing the authorized level of work and monitoring that

[c]For this distinction, consult Chapter 4 on quality management.



The point on the line where the engine is lifted up and married with the body.
(*Courtesy of General Motors, Oklahoma City Plant*)

Ergonomic fixtures in the door pad subassembly area just off the main line.
(*Courtesy of General Motors, Oklahoma City Plant*)

Small-part delivery trucks in a "supermarket." (*Courtesy of General Motors, Oklahoma City Plant*)

level; and (5) devising methods improvements or other ways to lower costs and/or increase productivity. The Department spearheaded many of the synchronous manufacturing initiatives at the plant. Ideas for changes typically sprang up from the workforce, supervision, or industrial engineers themselves. Conceptual drawings for any change were done by the Industrial Engineering Department.

As mentioned earlier, the line was designed in such a way that all workers averaged about 50 seconds' work on each car. Given any major model changes, the line would have to be thoroughly redesigned so that workers assigned possibly very different work tasks from what they were used to still had about the same amount of time to work on each car. This is what line rebalance was about. With the adoption of synchronous manufacturing, line rebalance occurred all the time as tasks were changed and jobs (or job links) were altered, non-valued-added tasks removed, and value-added tasks reshuffled so as to put fewer workers directly on the line.

In greater detail, the rebalance of the line followed a number of stages:

1. Given the car's engineering and design, the industrial engineer described what had to be done to assemble the car. This description involved painstaking detail; for example, one could not simply specify, "mount headlight" since the task may take either shorter or longer than the desired cycle time. Mounting

Call board for large parts. Part of synchronous manufacturing.
(Courtesy of General Motors, Oklahoma City Plant)

a headlight would involve a number of separate actions such as walking 5 feet to the supply bins, reaching for a headlight and screws, walking back to the line, positioning headlight in the socket, and using a power screwdriver to screw in two mounting screws.

2. Each of these separate actions (job elements) was assigned a time. These times were primarily determined by reference to standard time data established by General Motors, although sometimes they were determined by a special stopwatch where an engineer would time a worker performing a task. The standard time data typically would derive from numerous stopwatch studies, films of workers, and other sampling studies of specific worker tasks.
3. Once times were assigned to specific elements, the industrial engineer would review them with the relevant supervisor on the production line to determine whether they were reasonable. The changes would then be made.
4. Once an agreement was reached, the task, its elements, element time estimates, and whether the task was performed on all cars or only a few, were placed in computer-readable form. A computer program then calculated the work schedule, trying to bal-

ance work loads among the workers, such as by taking job elements from one worker and placing them with another, or otherwise shifting assignments to distribute the work evenly.

5. Generally, the initial computer schedule left some workers with either too much or too little to do. What was to be avoided was putting workers in an overcycled condition where they would consistently have too much work to perform for the time cycle decided on. If an imbalance in the line were serious and could not be remedied easily, the task was sometimes taken off the main line and performed as a separate activity. This course of action was considered a last resort, however.

   On the basis of the computer-run, tasks and times were adjusted and a subsequent computer run made. This run was studied for reasonableness, and again adjustments were made. Numerous iterations of this adjustment process were generally performed before the line was satisfactorily balanced, at least on paper.

6. The paper balance of the line was then ready for trial on the factory floor. Industrial engineers, supervisors, and workers all became involved in this activity. The danger was that the predicted and actual times would not mesh. If this in fact occurred, the first thought was to help the worker improve the time by changing the layout of the work station, adding fixtures or other equipment, or changing methods. Such action was usually sufficient, but, if need be, another operator could be added or a modest rebalance of the line effected.

Plant Engineering

The Plant Engineering Department directed all the construction, maintenance, repair, recycling, and environmental work of the Oklahoma City site's land, buildings, and equipment (except tooling, which was handled by the assembly engineering group). All the plant's requests for major expenditures and capital appropriations were coordinated by Plant Engineering.

Plant Engineering was constantly on the alert for technological improvement and was involved in all of the plant's initiatives for synchronous manufacturing. The Plant Engineering Department did the detailed engineering on equipment involved in the synchronous manufacturing effort. It did the costing and the approvals for any capital dollars required. And, it was responsible for the installation. Oklahoma City tried to do as much of its own installation as it could, contracting out, as a matter of course, only concrete work and roof work. Installations were meant to be flexible and easily repositioned. There was no bolting of machines to the floor unless safety concerns so dictated.

The Plant Engineering Department was involved in technological advances such as the use of turbo bells for painting and the use of robots for applying adhesives to the windshield or to the door paper. A new dynamic vehicle testing area was the responsibility of Plant Engineering.

The Oklahoma City plant prided itself on being able to make most line and equipment adjustments on the fly, without disrupting production.

THE WORKFORCE AND THE PERSONNEL DEPARTMENT

The plant's non-supervisory factory floor personnel were paid by the hour. All supervisory and clerical people were paid a salary. The plant currently operated two shifts of production with an hour of scheduled overtime each shift, a total of 18 hours of production a day. In addition, the plant operated two Saturdays a month. The first shift began at 7 A.M. and ended at 3:30 P.M., with a half hour break for lunch. The second shift began at 5:00 P.M. and ended at 1:30 A.M. During each half of each shift, the entire line shut down for 23 minutes so that workers could rest. This was termed "mass relief" and replaced the individual-by-individual tag relief that had proceeded it. Mass relief was seen as improving quality.

The hourly employees were represented by the United Auto Workers (UAW) union. Most features of the agreement between GM management and the plants workers were spelled out in a 597-page national agreement covering a wide range of topics, including wage payments, fringe benefits, seniority, grievance procedures, overtime, layoffs, safety production standard procedures, and numerous other topics. There was also a smaller 194-page additional agreement between the local UAW organization and the plant's management. This separate agreement provided detailed information on wages, layoff procedures, health and safety measures, and the like.

Plant relations with the union were generally cordial and constructive, fostered by daily dialogue between the parties. There were no secrets at the plant. Any union member could attend any meeting at the plant except for those relating to human resource issues. A union representative was always present at staff meetings.

Most worker complaints were resolved without recourse to the grievance procedure. Grievances, such as overwork conditions, were generally resolved at the first of four levels of the grievance procedure. Few grievances reached the final arbitration level.

The plant's personnel department was an essential factor in plant management. Not only did the personnel department oversee labor relations with the UAW, but it was also charged with training responsibilities and payroll.

The personnel department had spearheaded the drive for increased competitiveness and worker involvement with a program called the "Voluntary Input Process" (the VIP process). Teams of workers, typically between six and ten, met for half an hour every Wednesday morning to discuss improvements that could be made to the process. About 75 percent to 80 percent of the plant was involved in this effort. For their involvement, workers were paid an additional fifty cents an hour. A VIP operator had a number of responsibilities, including attendance at the weekly meetings, knowing all of the jobs that were done within the unit, agreeing to rotate to retain proficiency in those jobs, helping to maintain the cleanliness and good housekeeping of each unit area, providing training for others, and working to improve the materials scrap processing and efficiency of that area. VIP operators worked to build quality into the car in their areas through the use of statistical process control (SPC) and self-inspection. The VIP process had resulted in an increase in quality and a number of helpful suggestions for the increased efficiency of the plant. It fit well with the drive for synchronous manufacturing. In addition to the VIP operators, the program also had duties for the support people assigned to every unit along the line (see below) and for the group coordinators or supervisors that oversaw the area.

C–P–C Oklahoma City offered the hourly employee a number of possibilities for advancement and work preferences from the simple movement from one shift to another, to transfers between departments and promotions to higher-pay classifications. Hourly employees could also move to management by becoming supervisors.

Supervision

Work on the line was directly overseen by first-line supervisors assisted by three to four group leaders, called support people. Typically, the supervisor was directly responsible for between 30 and 35 workers on a shift. There was one support person for about every seven-to-ten member unit. Supervisors were thoroughly familiar with all aspects of work within their own sections of the line and of what workers could or could not be expected to do, largely because of once having been one of them. At the start of the shift, the supervisor's immediate concern was manning the production line and making sure material and tools were available.

Once workers were at all of the line positions, the supervisor spent much of the remainder of the shift in two activities: promoting and checking quality and troubleshooting any problems on the line, such as equipment malfunctions, pending parts shortages, or defective materials. Very little of the supervisor's time was spent at a desk. For most of the shift, the supervisor walked the line, talking with the line's workers, trying to solve any problems they might have, and promoting quality.

Four or five supervisors in turn reported to a general supervisor, and the general supervisors reported to one of four superintendents, one each at the body shop, the paint shop, General Assembly 1, and General Assembly 2. (See the organizational chart in Figure D5.)

The superintendent's job included many aspects of the first line supervisor's, plus other responsibilities. The superintendent was concerned primarily with quality and safety, but also spent considerable time and effort on cost

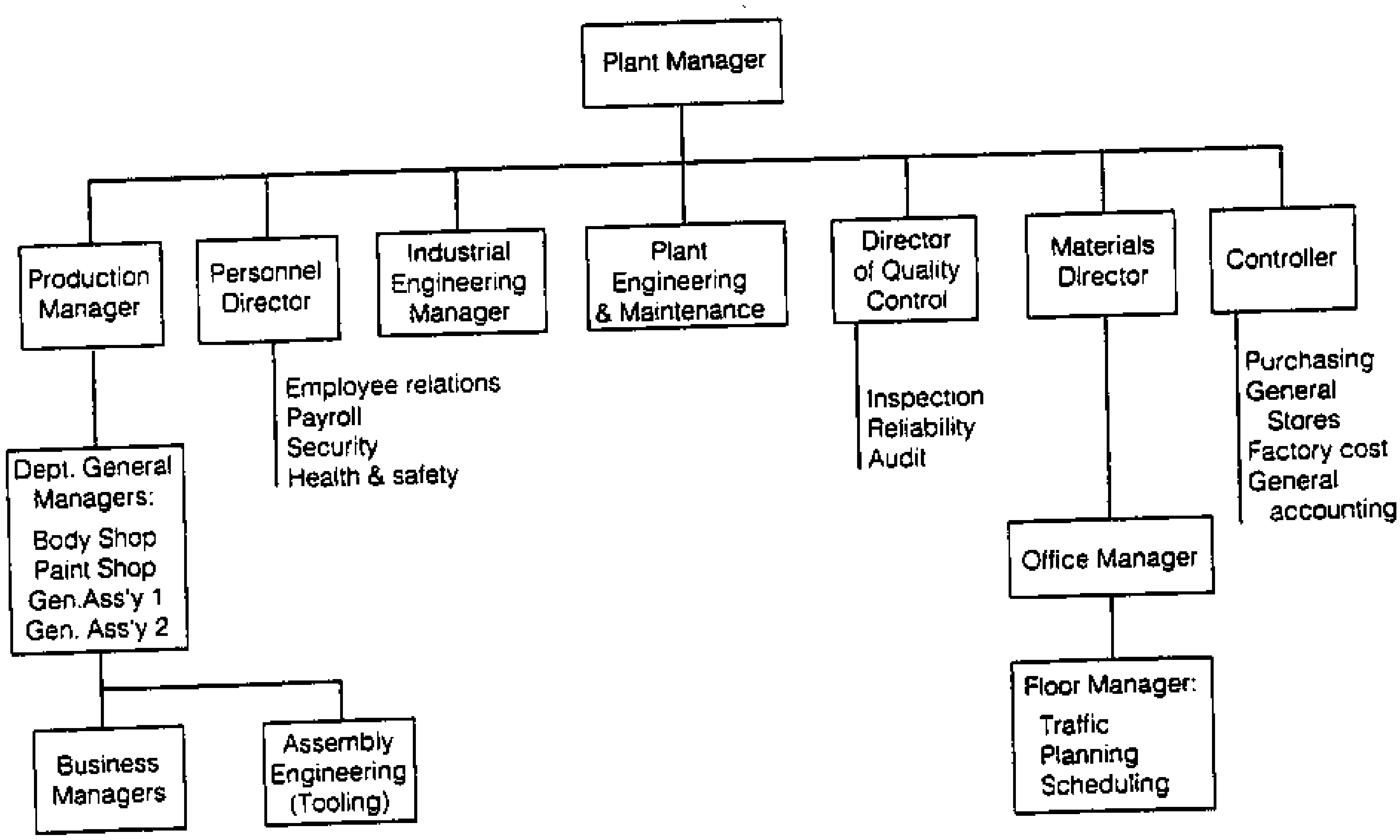


FIGURE D5 Organization chart for the C–P–C Oklahoma City plant.
(*Courtesy of General Motors, Oklahoma City Plant*)

control, human relations, and housekeeping chores. Some of these tasks were routine, such as meeting with union committeemen, checking absenteeism, and conferring with other superintendents. But there were always special plans or meetings and unexpected problems on the line to overcome.