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MM&T: MATERIAL HANDLING.(U)
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DEPARTMENT OF THE ARMY
U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BENET WEAPONS LABORATORY, LCWSL
WATERVLIET ARSENAL, WATERVLIET, N.Y. 12189

DRDAR-LCB-SE 1 September 1982

SUBJECT: Final Technical Report

TO: Commander
U.S. Army Armament Command
ATTN: DRSAR-IRM
Rock Island, Illinois 61299

Project No: 6808208

Project Title: MM&T: Material Handling

Project Officer: Robert J. Meinhart

Statement of the Problem: The movement of gun tubes which are large (12" dia.), long (20 feet), and heavy (up to 4 tons), through the shops as well as positioning the pieces in machines for metal removal presents an unusual and difficult material handling problem.

Background & Introduction: The material handling of gun tubes in the bays of manufacturing buildings is done exclusively with large, rail-mounted, overhead cranes. Each crane requires an operator riding in a cab on the crane bridge. Gun tubes are attached to the crane hook by means of a wire rope sling (Fig. 1). Each time a gun tube is moved a person is required on the floor to attach the slings at the pick-up location and detach the slings at the place location. This person working the slings can be a "follower", or helper, whose job it is to assist in the movement of tubes, or this person could be the operator of the machine tool from which or to which the gun tube is being moved. Movement of gun tubes by overhead cranes is effective only within a bay of a manufacturing building. To move a tube between bays in a building it is necessary to place the tube on a gun cart, attach a battery-powered "mule" to the cart, and move the cart between bays (Fig. 2). This operation can happen only in a single section of a bay. Occasionally tube transfers between bays will occur by the bay crane placing a tube in a high bay overlap area. The high bay crane then picks up the tube and drops it in the overlap area of the new bay. The crane in the new bay will then pick up the tube and place it where it is required.

In 1975, the Watervliet Arsenal MM&T project 6717042 "End Item Manufacturing Guide" included a report prepared by RCC Inc. This report indicated that the move time for gun tubes was determined to be 12% of the total time spent in manufacturing a gun tube. It was felt that this percentage of time could be

This project was accomplished as part of the US Army Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques and equipment for use in production of Army materiel.

cut in half by using properly selected material handling systems and equipment. With the "REARM" program occurring this was the ideal time for modernizing the material handling procedures.

Approach to the Problem: Discussions were held with the Chief, Plant Layout Section concerning the overall plan for REARM with regard to gun tube manufacturing. These discussions included relocation of manufacturing lines and proposed changes in the handling of the gun tubes in those lines. At the time of these preliminary discussions there were no commitments made to change the material handling procedures.

A second Watervliet Arsenal material handling related project, 6808060, "MM&T: Improved Manufacturing Processes Related to Final Inspection of Cannon Tubes" was looked at for similar or duplicating efforts. The inspection project is intended to provide a "mechanized" inspection area. It was determined that there is no duplicating effort between the two projects.

Another Watervliet Arsenal material handling type project, 6798104, "MM&T: Improved Breech Block Manufacturing", was also looked at to determine the type of information available on material handling equipment. This block project is investigating "FANSIMS", Flexible Automated Non-Synchronous Industrial Manufacturing Systems, and Flexible Machining. Neither of these systems showed any applicability to tube handling.

Due to time and knowledge constraints, the decision was made to secure the services of an outside concern which would have the expertise to perform an assessment of our current material handling difficulties and make recommendations for easing these difficulties. After attending material handling clinics and talking to experts from various material handling manufacturers and consultants, it was decided to place a sole source contract with SysteCon, Inc., of Norcross, Georgia. The reason for the sole source contract is that SysteCon, unlike other "consultants", is not a representative of any material handling equipment manufacturers. Action to place the contract was initiated in April 1980. The contract was signed in October, 1980. The contractor made visits to Watervliet Arsenal gathering data and information, performing rough tube counts, and timing various production operations from the moment an operator signaled for a crane lift to remove a finished workpiece until a new workpiece was released into the machine. The contractor submitted his report in January, 1981, and the report was accepted in February, 1981. The report is titled "Tube Material Handling Assessment and Recommendation", Watervliet Arsenal, Watervliet, New York, January 5, 1981, DAAA22-81-M-0006. A copy of the report is inclosed as Attachment 1.

Discussion: The manufacture of gun tubes presents unique materials handling problems. The size of the workpiece and the variety of machine tools used to produce a finish machined gun tube cause the major problem with designing a materials handling system. The various machine tools require different loading techniques. One common aspect of these techniques, however, is that machine loading occurs from above the machine tool. To load the machines from the side would require large and cumbersome equipment. This implies a second problem which directs the design and selection of materials handling equipment, the arrangement of the manufacturing facility. Floor space is at a premium. The large number of machine tools required to maintain our production requirements necessitates narrow aisles and limited in-process storage space.

The SysteCon evaluation and subsequent report, produced three alternatives. The first and simplest is to use masted cranes in place of the current cranes and use a central storage area in each manufacturing bay for in-process storage. The second is to use side loading lift trucks and multiple tube fixtures and move the tubes in small batches from operation to operation. However, current cranes would still be required to load the machines. The third alternative is to use the side load trucks in conjunction with an automatic guided vehicle system. Again the current cranes would actually load the machines.

The first two recommendations had been considered earlier in conjunction with the rotary forge integrated production line, MOD 67X7238 "Modern Integrated Production Line for Cannon - Rotary Forge", and MM&T 67X7588 "Rotary Forge Technology". The masted crane and side loading lift trucks were evaluated for handling preforms. However, the cost of the equipment was not budgeted and return on the investment would have been marginal. These options are constantly being reconsidered as solutions to materials handling problems. The third option, the guided vehicle system, has been considered in the general material handling scheme at Watervliet Arsenal but has been found to be unacceptable in the current production philosophy.

The side loading lift trucks and the guided vehicle system would require large amounts of floor space for tube storage. Currently tubes are stacked four or five wide and up to four high using wooden sweeps (Fig. 3). These tube stacks are located in various places in a machining bay. The alternatives suggested by SysteCon would require a storage area for each machine tool and have only single layer storage, two wide on a fixture with space available for a third tube but not being used except when transferring a completed tube to the fixture. This proposal would require more floor space than that which is currently allocated to in-process storage. In addition to the increased storage area, these vehicle-oriented handling systems would require wider aisles than currently allocated, again causing a space problem.

A review of the SysteCon report by the Chief, Plant Layout Section revealed certain "inadequacies" with the report: 1) the sampling performed occurred during a period of relatively low production; 2) rework and defective work report materials were not considered and can produce interference; 3) interference between vehicles and the cranes was not discussed. These inadequacies are most likely due to the low contract cost ($10,000) rather than inexperience of SysteCon. SysteCon's personnel time was charged at the rate of $600 per day. When travel and living expenses are considered, there are not many days in a $10,000 contract. As a result the evaluation and subsequent recommendations made by SysteCon do not have the "depth" or details which would produce a totally adequate report.

Recommendations: As stated previously, the alternatives recommended by SysteCon had received prior consideration as solutions to materials handling problems here at the Arsenal. Therefore the benefits of the recommendations could be considered to be non-existent. However, to have an expert recommend the same equipment as a non-expert, has to boost the confidence level of the non-expert and lend appreciable credibility to his work. The recommendations given by SysteCon will be considered on a continuing basis as solutions to Watervliet's materials handling problems. To utilize these recommendations will require decreasing the amount of floor space dedicated to manufacturing and inspection equipment and increasing the space dedicated to in-process storage and aisles. As more and more machine tools become numerically controlled, performing multiple operations in a single setup in less time, the change from equipment space to storage and aisle space could occur, removing the current space constraints. As that time approaches, the recommendations of SysteCon, or even more sophisticated materials handling equipment, will be implemented into the gun tube production lines.

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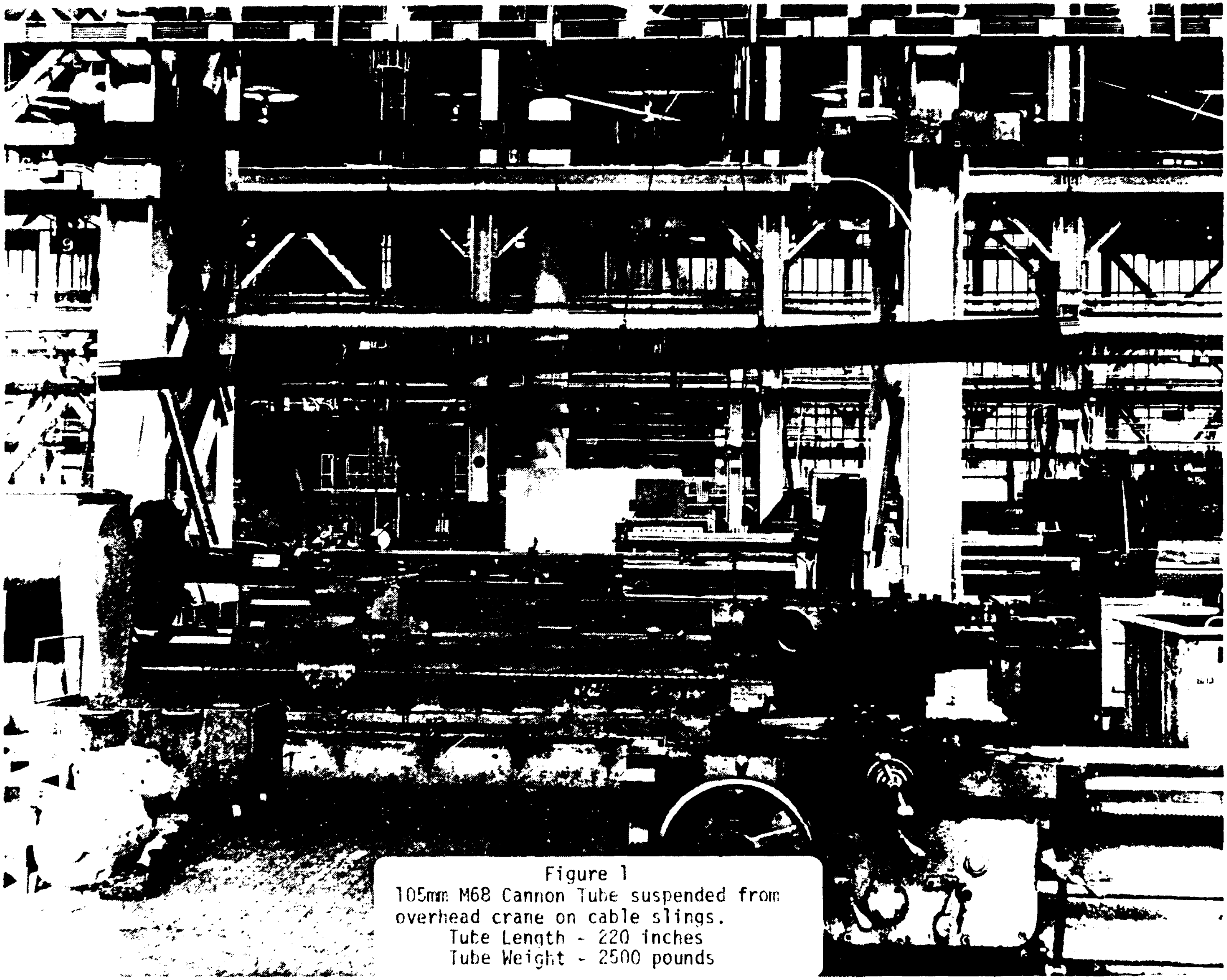


Figure 1
105mm M68 Cannon Tube suspended from overhead crane on cable slings.
Tube Length - 220 inches
Tube Weight - 2500 pounds

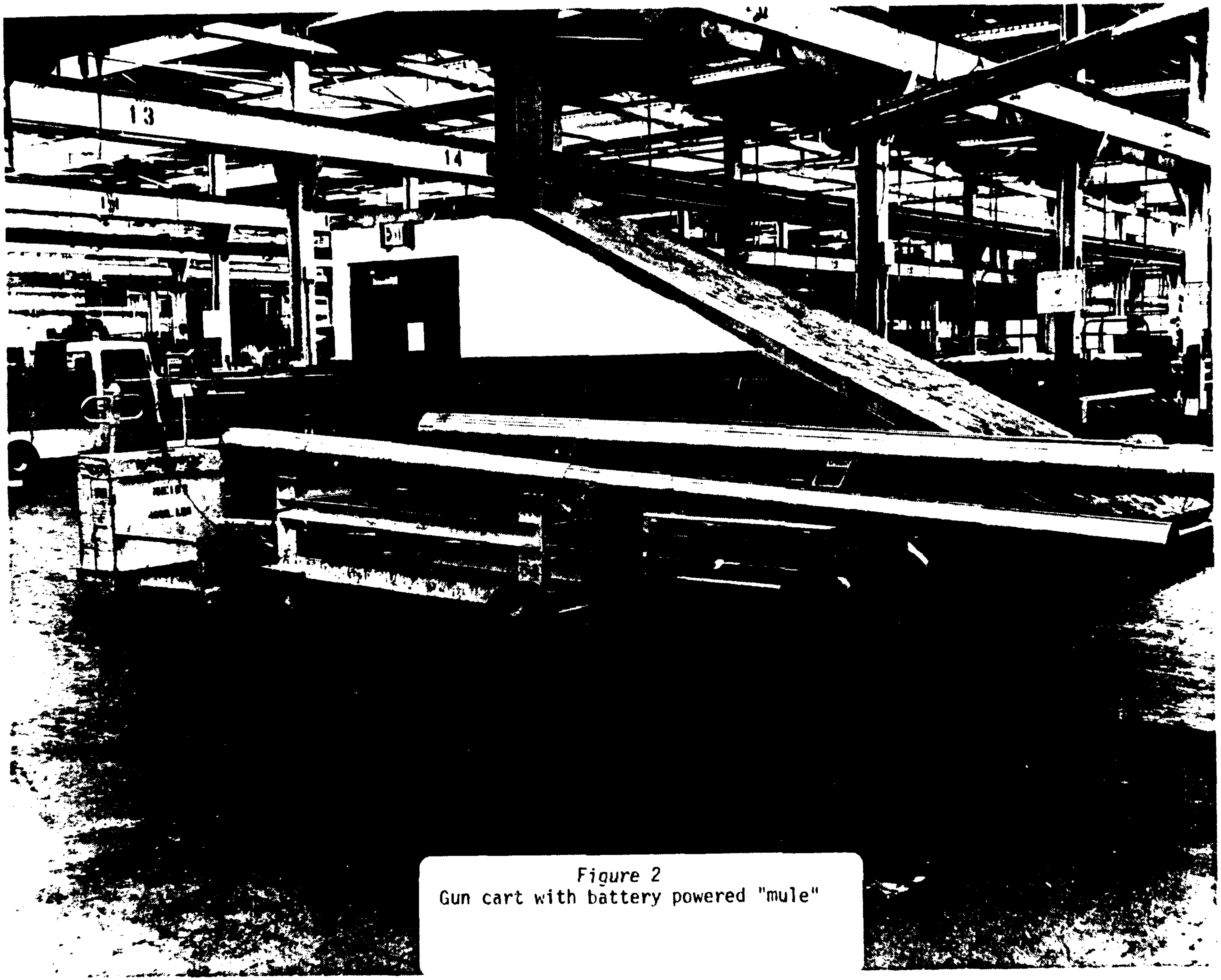


Figure 2
Gun cart with battery powered "mule"

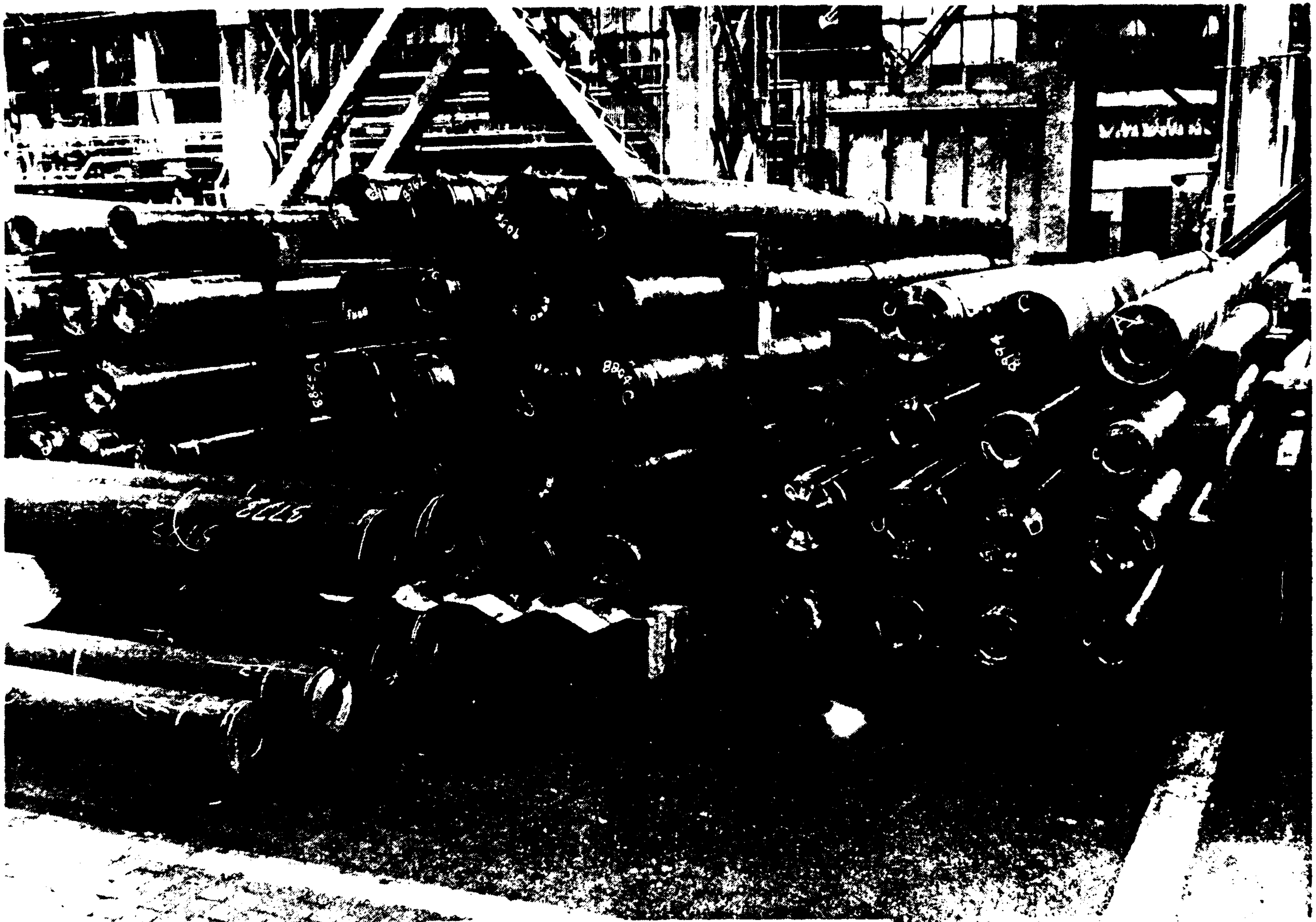


Figure 3
Cannon tubes in various stages of machining awaiting issuance for additional work

TUBE MATERIAL HANDLING
ASSESSMENT AND RECOMMENDATIONS

WATERVLIET ARSENAL
WATERVLIET, NEW YORK
JANUARY 5, 1981
DAAA22-81-M-0006

SYSTECON, INC.
7000 PEACHTREE IND. BLVD.
NORCROSS, GA 30092
404-448-9292

TABLE OF CONTENTS

INTRODUCTION

WATERVLIET ARSENAL IS CURRENTLY UNDERGOING A MAJOR MODERNIZATION AND EXPANSION EFFORT UNDER THE TITLE OF PROJECT REARM. AS A PART OF THE OVERALL PLAN SYSTECON, INC. WAS CONTRACTED TO IDENTIFY AND EVALUATE ALTERNATIVE MATERIAL HANDLING SYSTEMS FOR THE TRANSFER AND POSITIONING OF TUBES DURING THE MANUFACTURING PROCESS.

PREVIOUS STUDIES CONDUCTED BY AND FOR THE ARSENAL, AS WELL AS THIS STUDY, INDICATE THAT THE TRANSFER AND POSITIONING TIME IS EQUAL FROM 10% to 15% OF THE DIRECT LABOR USED TO PRODUCE TUBES. THE CURRENT MATERIAL HANDLING METHODS, FOR THE MOST PART, HAVE REMAINED THE SAME FOR SEVERAL DECADES.

WITH THE AID OF BENET WEAPONS LAB PERSONNEL, SYSTECON HAS BEEN ABLE TO DEVELOP AN UNDERSTANDING OF CURRENT TUBE HANDLING REQUIREMENTS, PROCESS FLOWS, AND THROUGHPUT REQUIREMENTS. USING THIS DATA BASE SEVERAL ALTERNATIVES FOR REDUCING HANDLING COSTS AND INCREASING MANUFACTURING CAPABILITY HAVE BEEN DEVELOPED. THE ALTERNATIVES PRESENTED INCLUDE BOTH LOW AND HIGH TECHNOLOGIES.

BACKGROUND

CURRENTLY TUBE MANUFACTURING, "CHIP" OPERATIONS, CONSISTS OF 2 MAJOR CATEGORIES CLASSIFIED BY THE SIZE OF THE TUBE PRODUCED. MID SIZE TUBES OF 105MM AND 155MM BEGIN THE MANUFACTURING PROCESS IN BUILDING 135 AND ARE TRANSFERRED TO BUILDING 35 WHEN APPROXIMATELY ONE-THIRD COMPLETE. LARGE TUBES OF 8" ARE MANUFACTURED WITHIN BUILDING 110 EXCEPT FOR TWO SEPARATE TRANSFERS TO BUILDING 35 FOR CHROME PLATING AND HEAT TREATING.

THERE ARE THREE TYPES OF MOVEMENTS IN THE MANUFACTURING PROCESS OF TUBES:

- MOVEMENT WITHIN A BAY
- MOVEMENT BETWEEN BAYS
- MOVEMENT BETWEEN BUILDINGS

MOVEMENTS WITHIN A BAY ARE BY USE OF CAB OPERATED OVERHEAD CRANES USING WIRE ROPE SLINGS AS THE HOLDING DEVICE FOR THE TUBE. EACH MOVEMENT OF THE TUBE REQUIRES A PERSON ON THE FLOOR TO ATTACH OR REMOVE THE SLING AT EACH PICK UP OR DEPOSIT POINT. THEREFORE, EACH MOVEMENT REQUIRES TWO PEOPLE, THE CRANE OPERATOR AND A "FOLLOWER", USUALLY A MACHINIST OR INSPECTOR. BECAUSE OF THE IMBALANCE OF OPERATION TIMES A TUBE IS SELDOM MOVED DIRECTLY FROM ONE OPERATION TO ANOTHER, BUT PLACED IN A WORK-IN-PROCESS STORAGE AREA SOMEWHERE BETWEEN THE OPERATIONS. THEREFORE, ONE PROCESSING STEP REQUIRES TWO MOVEMENTS

OF THE TUBE. THE TYPICAL SEQUENCE OF EVENTS FOR A MOVE IS FOR THE MACHINIST TO:

- TURN A RED LIGHT ON TO CALL FOR THE CRANE
- WAIT 5 TO 10 MINUTES FOR THE CRANE TO ARRIVE
- ATTACH THE SLINGS TO THE COMPLETED TUBE IN HIS MACHINE
- FOLLOW THE CRANE WITH TUBE TO THE WORK-IN-PROCESS STORAGE AREA
- REMOVE THE SLING FROM THE TUBE
- FOLLOW THE EMPTY CRANE TO THE WORK-IN-PROCESS STORAGE AREA OF THE NEXT TUBE TO BE PROCESSED
- ATTACH THE SLING TO THE TUBE
- FOLLOW THE CRANE WITH TUBE TO HIS MACHINE
- REMOVE THE SLINGS.

MOVEMENTS BETWEEN THE BAYS ARE BY GUN CARTS PULLED BY BATTERY POWERED MULES. EACH TUBE MOVED BETWEEN BAYS UNDERGOES 3 SEPARATE HANDLINGS INVOLVING A MACHINIST, A CRANE FOLLOWER, AND TWO CRANE OPERATORS. FROM THE MACHINISTS' STANDPOINT THE SEQUENCE OF EVENTS IS THE SAME EXCEPT FOR DEPOSITING THE COMPLETED TUBE ON A GUN CART RATHER THAN IN A STORAGE AREA. THE ADDITIONAL STEPS ARE:

- ATTACH MULE TO GUN CART
- MOVE THE GUN CART BETWEEN BAYS

- WAIT FOR CRANE
- ATTACH SLINGS TO TUBE
- FOLLOW THE CRANE WITH TUBE TO THE WORK-IN-PROCESS STORAGE AREA
- REMOVE SLINGS FROM TUBE
- RETURN TO GUN CART
- REMOVE MULE FROM GUN CART

MOVEMENTS BETWEEN BUILDINGS ARE VERY SIMILAR TO MOVEMENTS BETWEEN BAYS. ALL STEPS ARE THE SAME EXCEPT A FLAT BED RAILROAD CAR IS USED RATHER THAN A GUN CART. ALSO MULTIPLE TUBES AT A TIME ARE MOVED ON THE RAIL CAR AS COMPARED TO ONE TUBE PER TRIP OF A GUN CART.

WITH CURRENT MATERIAL HANDLING METHODS IT IS VERY ADVANTAGEOUS TO KEEP PROCESSING STEPS AS CLOSE TOGETHER AS POSSIBLE AND SPECIFICALLY TO AVOID MOVEMENTS BETWEEN BAYS. WHERE POSSIBLE THE MACHINES ARE LOCATED TO ACCOMPLISH THIS. FROM TIME TO TIME AS PRODUCTS PRODUCED CHANGE OR MANUFACTURING STEPS ARE MODIFIED, THE MACHINES ARE RELOCATED TO ALLOW A MORE OPTIMUM MATERIAL HANDLING FLOW. HOWEVER, THIS TECHNIQUE IS LIMITED BY A NUMBER OF MACHINES WITH UNIQUE REQUIREMENTS, SUCH AS PITS, THAT WOULD BE IMPRACTICAL TO RELOCATE DUE TO BUILDING MODIFICATION COSTS.

IN THE PRODUCTION OF 155MM TUBES THERE ARE 73 STEPS. FIFTY-EIGHT STEPS REQUIRE MOUNTING ON A MACHINE OR PLACEMENT IN A SPECIALLY DESIGNED CABINET OR PIT, 8 STEPS ARE PERFORMED ON WORK HORSES WITH HAND TOOLS, AND 14 STEPS ARE INSPECTIONS. OF THE 73 STEPS,

SIXTY-EIGHT REQUIRE MOVEMENT OF THE TUBE. SIX OF THESE STEPS REQUIRE MOVEMENT BETWEEN BAYS VIA GUN CARTS. THE NUMBER OF STEPS AND MOVES REQUIRED ARE TYPICAL OF MIDSIZE TUBE PRODUCTION. WITH AN AVERAGE SCHEDULED PRODUCTION OF 195 MIDSIZED TUBES PER MONTH OF SEVERAL DIFFERENT TYPE THERE WILL BE APPROXIMATELY 27,690 CRANE MOVEMENTS AND 1,170 GUN CART MOVEMENTS PER MONTH. WITH THE PRESENT MATERIAL HANDLING SYSTEM IT REQUIRES 14 CRANE OPERATORS AND 2 GROUNDSMEN, AS WELL AS THE TIME OF THE MACHINE OPERATOR AND INSPECTORS. PRODUCTION OF LARGE TUBES CONSISTS OF A SIMILAR NUMBER OF STEPS WITH SCHEDULED PRODUCTION AVERAGING 30 TUBES PER MONTH.

BECAUSE OF THE LARGE NUMBER OF PROCESSING STEPS, THE MANUFACTURE OF SEVERAL DIFFERENT TUBES, AND THE SIGNIFICANT VARIANCE IN PROCESSING TIMES BETWEEN STEPS, A LARGE INVENTORY OF WORK-IN-PROCESS TUBES IS REQUIRED. A SURVEY CONDUCTED NOVEMBER 13, 1980 TALLIED 1,065 MIDSIZE TUBES AND 157 LARGE TUBES IN WORK-IN-PROCESS STORAGE. THE CURRENT METHOD OF STORING TUBES IS ON WOOD CRADLES ON THE FLOOR, EACH CRADLE HOLDING 4 TUBES. THESE CRADLES CAN BE STACKED ON TOP OF EACH OTHER TO GAIN STORAGE EFFICIENCIES. CRADLES CONTAINING TUBES OF DIFFERENT TYPES OR AT DIFFERENT PRODUCTION STAGES ARE OFTEN STACKED ON EACH OTHER DUE TO FLOOR SPACE LIMITATIONS. THIS STORAGE METHOD SOMETIMES REQUIRES THE UNDESIRABLE DOUBLE HANDLING BY THE CRANE OPERATOR AND MACHINIST OF TUBES ON TOP OF THE STACK TO RETRIEVE THE DESIRED TUBE.

THE CHARTS AND TABLES ON THE FOLLOWING PAGES PROVIDE ADDITIONAL INFORMATION RELEVANT TO THE CURRENT OPERATIONS.

TUBE MOVEMENT SUMMARY

	MID SIZE TUBE	LARGE SIZE TUBE
PROCESSING STEPS		
USING MACHINES & SPECIAL FACILITIES	51	41
USING HAND TOOLS W/ TUBE ON HORSES	8	12
INSPECTIONS	14	16
TOTAL STEPS	73	69
PROCESSING STEPS NOT REQUIRING MOVEMENT OF TUBE	(5)	(4)
MOVEMENTS WITHIN BAYS	68	65
MOVEMENTS BETWEEN BAYS (NOT INCL. BETWEEN BLDGS)	6	0
MOVEMENTS BETWEEN BLDGS	1	4

SURVEY OF TUBES IN PROCESS

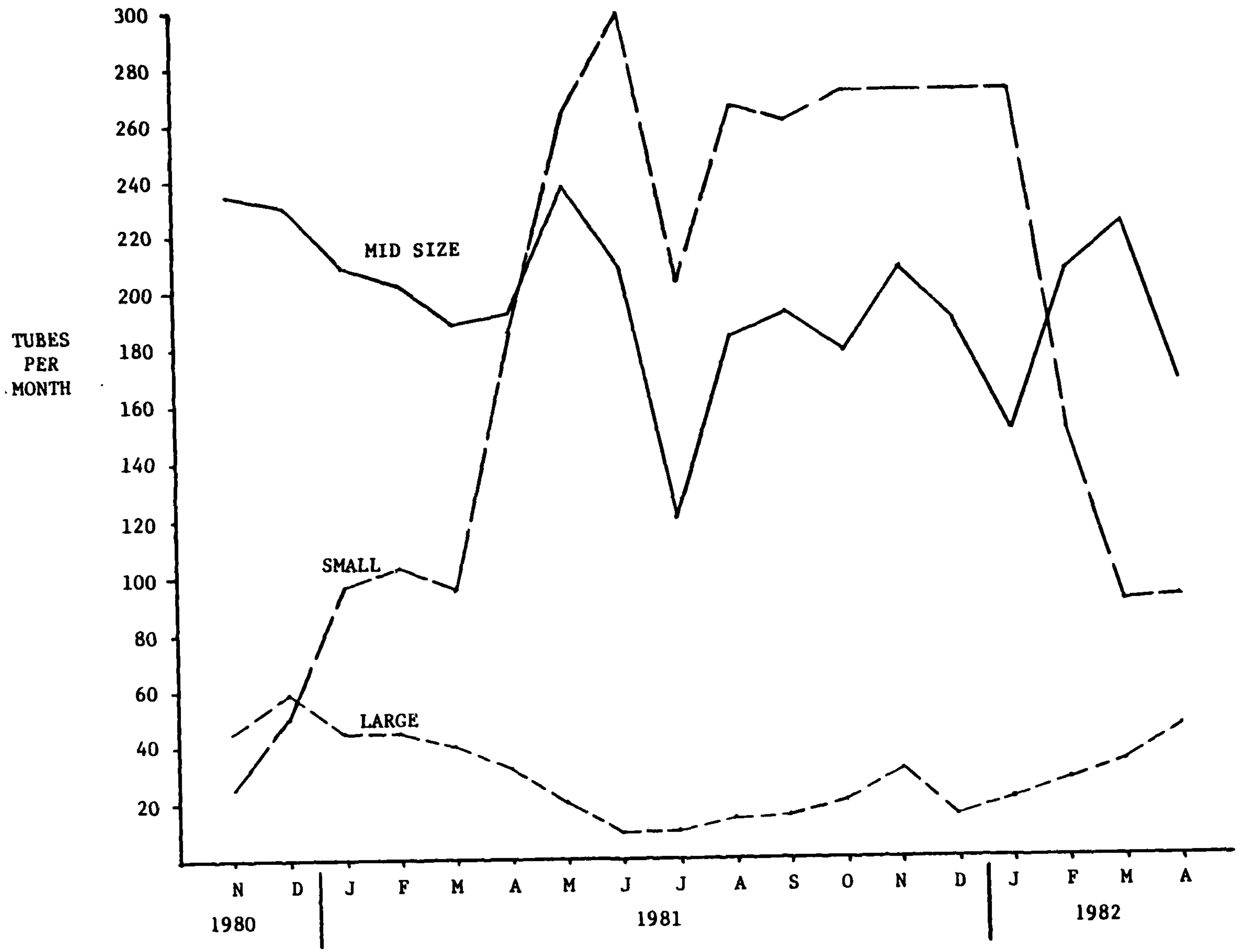
NOVEMBER 13, 1980

	TUBES IN WORK-IN-PROCESS STORAGE	TUBES ON MACHINES OR OTHERWISE ACTIVE	TOTAL
MID SIZE TUBES:			
BUILDING 135			
BAY B	107	12	119
BAY C	114	13	127
BAY D	452	1	453
BAY E	69	0	69
HIGH BAY	21	1	22
TOTAL BUILDING 135	763	27	790
BUILDING 35			
BAY A	13	7	20
BAY B	87	13	100
BAY C	55	10	65
BAY D	106	8	114
BAY E	38	20	58
END BAY	3	0	3
TOTAL BUILDING 35	302	58	360
TOTAL MID SIZE TUBES	1065	85	1150
TOTAL LARGE SIZE TUBES-BLDG 110	157	43	200
ALL TUBES	1222	128	1350

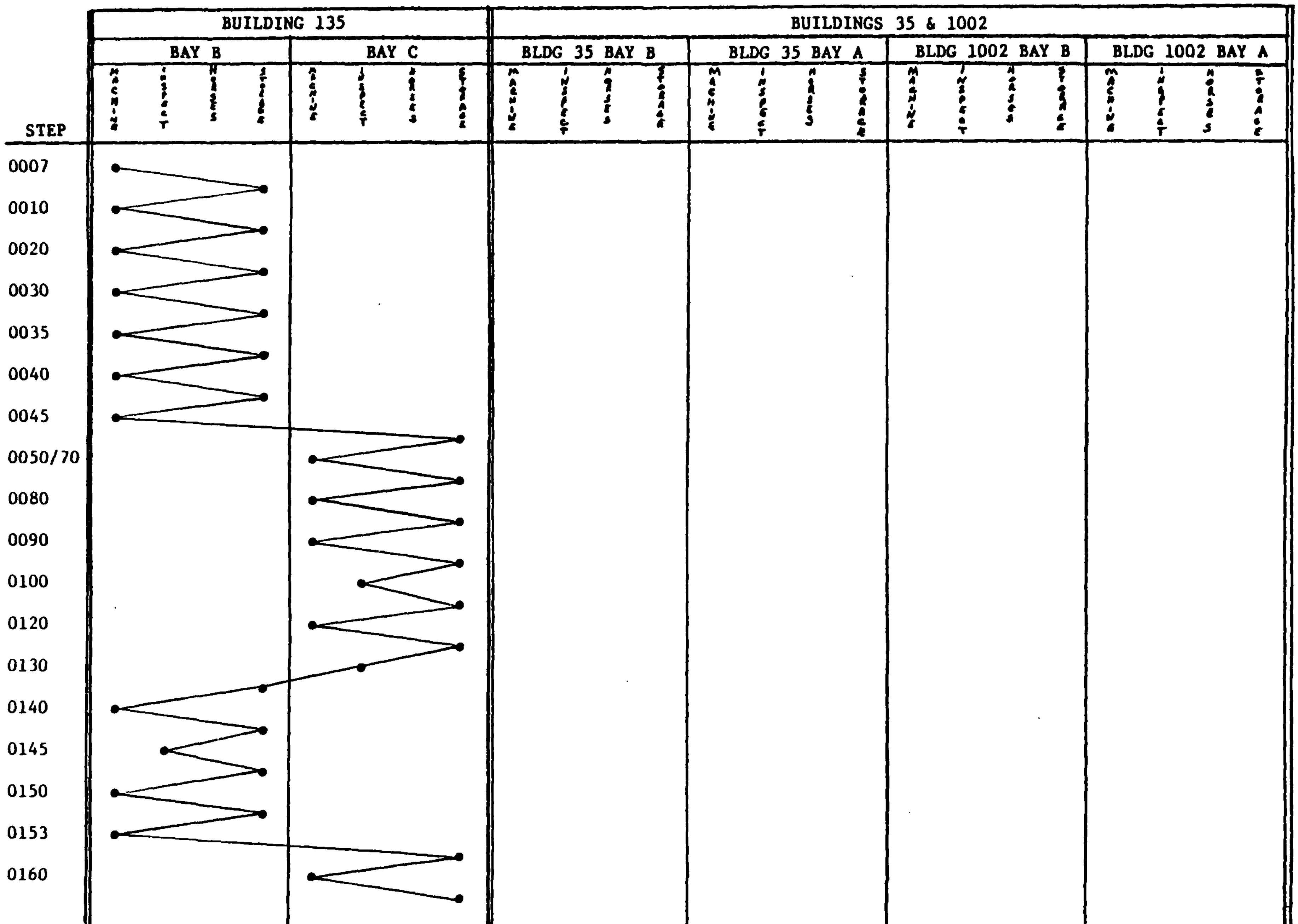
TUBE PRODUCTION SCHEDULE NOVEMBER 1980 TO APRIL 1982

YEAR	MONTH	MID SIZE (BLDGS 135 & 35)	LARGE (BLDG 110)	SMALL (PROTO-TYPE AREA)	TOTAL
1980	NOV	234	45	25	304
	DEC	230	59	50	339
1981	JAN	208	45	96	349
	FEB	202	45	103	350
	MAR	188	40	95	323
	APR	192	32	185	409
	MAY	237	20	263	520
	JUN	208	9	298	515
	JUL	120	10	203	333
	AUG	183	14	265	462
	SEP	192	15	260	467
	OCT	178	20	270	468
	NOV	207	31	270	508
	DEC	188	15	270	473
1982	JAN	150	20	270	440
	FEB	206	27	150	383
	MAR	222	34	90	346
	APR	167	46	91	304
TOTAL		3512	527	3254	7293
MONTHLY AVERAGE		195	29	181	405

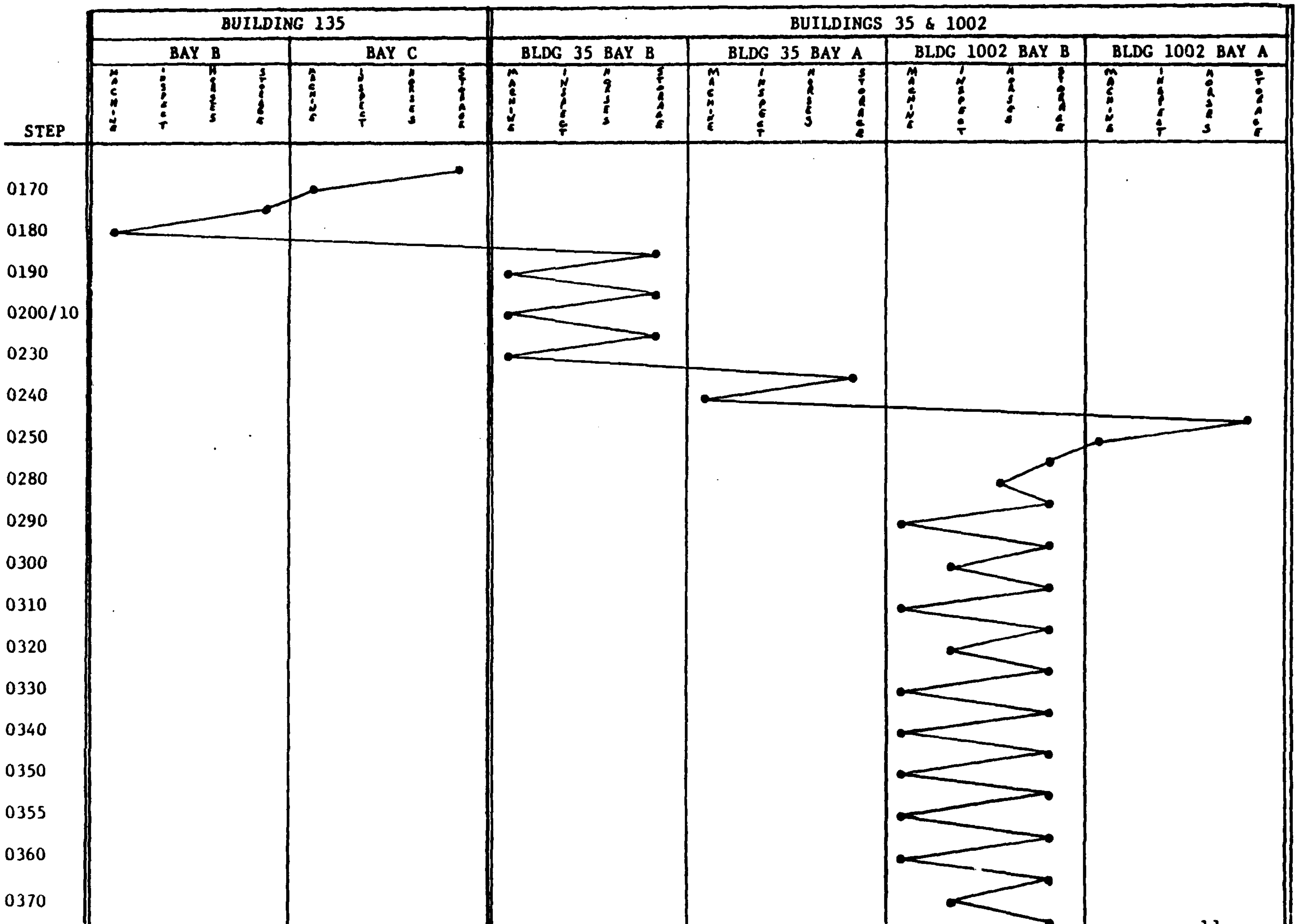
MONTHLY TUBE PRODUCTION



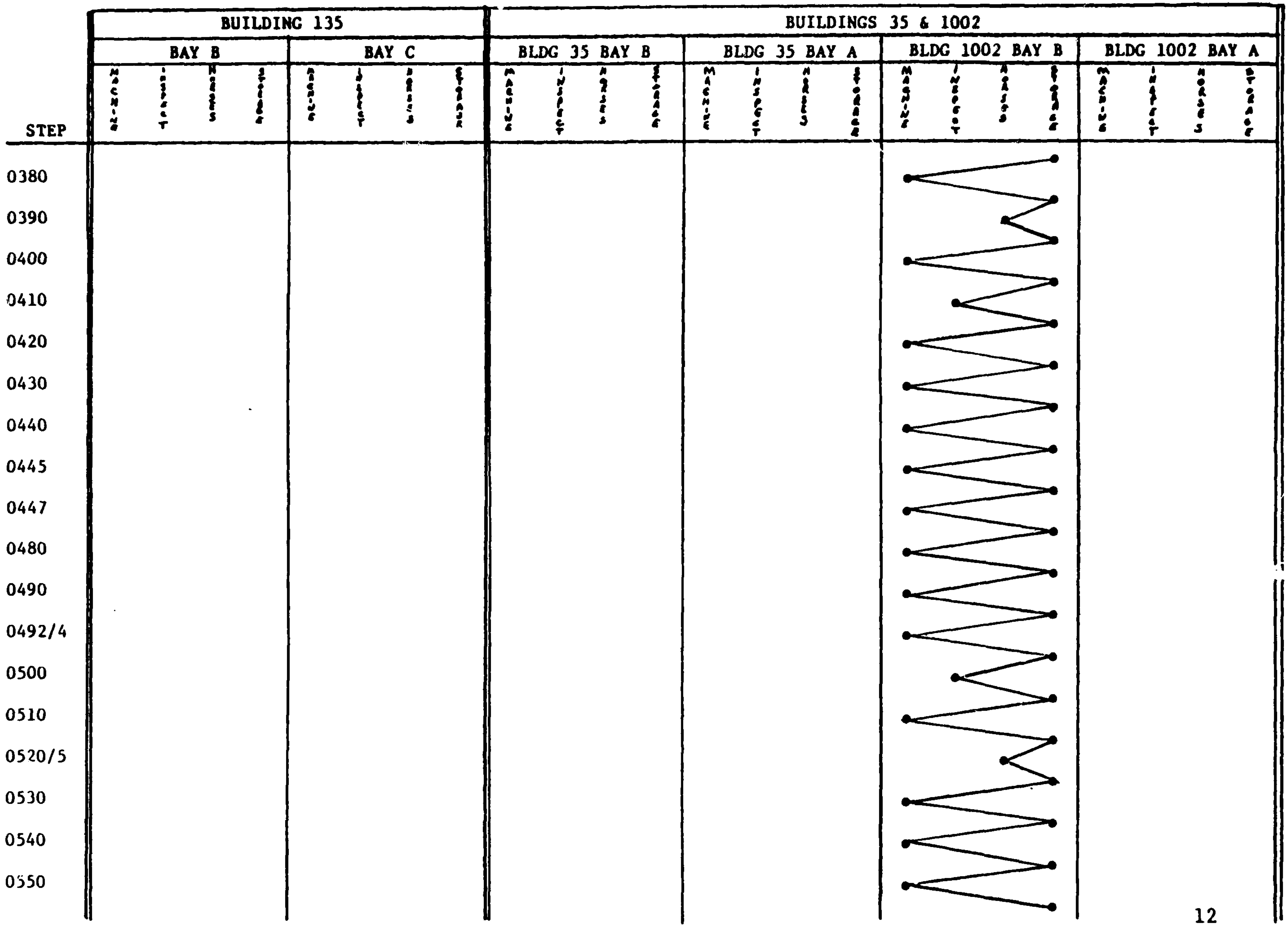
155MM TUBE PRODUCTION FLOW CHART

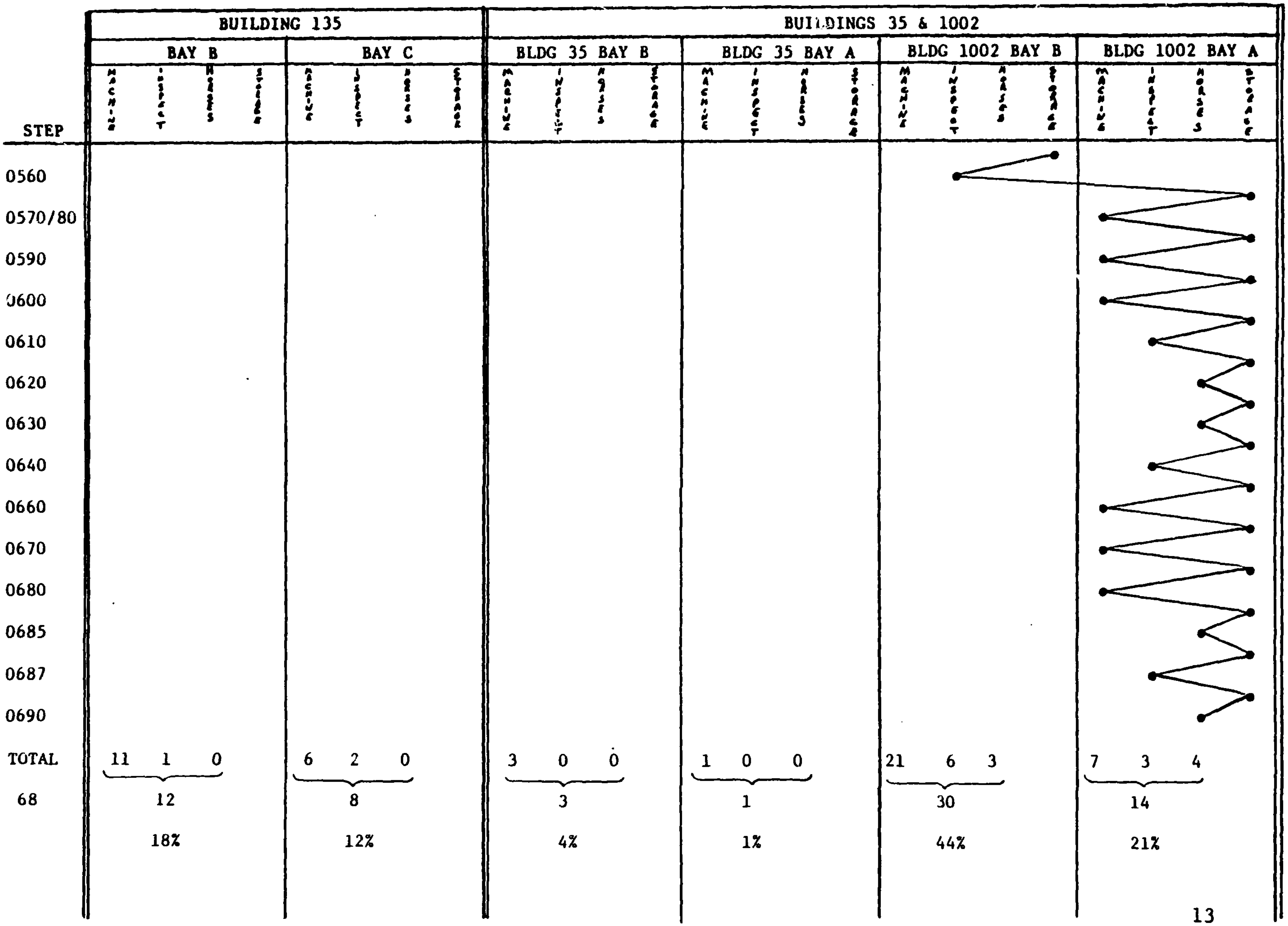


155MM TUBE PRODUCTION FLOW CHART (CONT'D)



155MM TUBE PRODUCTION FLOW CHART (CONT'D)




BUILDING 135
BUILDINGS 35 & 1002
BAY B
BAY C
BLDG 35 BAY B
BLDG 35 BAY A
BLDG 1002 BAY B
BLDG 1002 BAY A
STEP
0560
0570/80
0590
0600
0610
0620
0630
0640
0660
0670
0680
0685
0687
0690
TOTAL
68
11 1 0
12
18%
6 2 0
8
12%
3 0 0
3
4%
1 0 0
1
1%
21 6 3
30
44%
7 3 4
14
21%

155MM CHIP OPERATIONS

STEP #	% IF NEEDED	OPERATION	MACHINE	STD HOURS	ADD'L HOURS
0007		Turn roller spot	Hollow spindle lathe	1.310	
0010		Straighten	Hydralic press	2.500	
0020		Face & chamfer	Lehman hollow spindle lathe	1.630	
0030		Turn	Engine lathe w/ 2 carriages	3.800	
0035		Straighten	Hydraulic press	1.000	
0040		Turn	Engine lathe	3.850	
0045	50	Straighten	Hydraulic press	1.000	
0050		Bore 5.878 Dia.	Guided boring machine	1.720	
0070		Bore 5.935 Dia.	Guided boring machine	1.930	
0080		Bore powder chamber	Lehman 2 end hollow spindle	1.250	
0090		Hone 5.888 Dia.	Barnes horiz. hone	1.000	
0100		Inspect	Wooden horses	--	
0120		Clean, grease, swage	Swage	4.020	
0130		Inspect	Wooden horses	--	
0140		Thermal treat	Elec. furnace	1.110	3.000
0145		Inspect	Wooden horses	--	
0150		Straighten	Hydraulic press	1.490	
0153		Turn	Engine lathe w/ roller nest	1.000	
0160		Bore 6.085 Dia.	Guided boring machine	2.300	
0170		Rough hone	Barnes horiz. hone	1.100	
0180		Saw excess stock	Band saw	.690	
		TRANSFER TO BLDG 35			

155MM CHIP OPERATIONS

STEP #	% IF NEEDED	OPERATION	MACHINE	STD. HOURS	ADD'L HOURS
0190		Bore powder chamber	Lehman hollow spindle	2.770	
0200		Rough grind powder chamber	2440RY Bryant grinder	2.730	
0210		Inspect powder chamber	2440RY Bryant grinder	--	
0230		Turn & spot	Engine lathe	4.630	
0240		Turn	Engine lathe w/ tracing	1.690	
0250		Turn	LeBland NC lathe	4.000	
0280		Bench	Hand tools	.650	
0290		Mill breech thread	Threadmill	3.550	
0300		Inspect		--	
0310		Mill breech key	Horiz. bore mill & drill	2.060	
0320		Inspect		--	
0330		Mill sectors	Milling machine	2.000	
0340		Mill muzzle keyway	Rise & fall milling mach.	.500	
0350		Rough mill slide keyway	Milling M. w/ tracer	2.370	
0355		Chamfer muzzle end	Engine lathe	.500	
0360		Finish hone	Horiz. hone	2.230	
0370		Inspect		--	
0380		Rifle	Rifler	2.930	
0390		Bench	Hand tools	1.030	
0400	20	Re-hone	Hone	.500	
0410		Inspect		--	
0420		Finish muzzle end	Engine lathe	1.180	
0430		Drill 10 evacuator holes	Special mill & drill	2.860	
0440		Drill 3 evacutor holes	Special mill & drill	1.950	

STEP #	% IF NEEDED	OPERATION	MACHINE	STD. HOURS	ADD'L HOURS
0445	10	Burn out broken drills	Tap burn out machine	2.000	
0447		Mill quadrant flat	Mill, tracer controlled	.750	
0480		Bore chamber offset	Gisholt hollow spindle	3.150	
0490		Grind chamber offset	Powder chamber grinder	3.220	
0492		Grind powder chamber	Powder chamber grinder	3.990	
0494		Polish powder chamber	Powder chamber grinder	.750	
0510		Turn breech end bearings	Engine lathe w/ revolve	1.000	
0520		Bench-apply thread ring	Hand tools	2.860	
0525		Bench-clean	Hand tools	.500	
0530		Electro polish chamber	Chrome tanks	1.600	
0540		Chrome plate chamber	Chrome tanks	3.710	7.500
0550		Thermal treat	Gas furnace	1.150	16.000
0560		Inspect		--	
0570		Grind powder chamber	Grinder	2.760	
0580		Inspect	Grinder	--	
0590		Grind slide surface	Grinder	3.560	
0600		Finish mill slide keyway	Mill w/ tracer	2.330	
0610		Magnetic particle inspect		--	
0620		Bench-drill qtr. marks	Hand tools	1.240	
0630		Bench-keyway	Hand tools	2.200	
0640		Inspect		--	

155MM CHIP OPERATIONS

STEP #	% IF NEEDED	OPERATION	MACHINE	STD. HOURS	ADD'L HOURS
0660		Vapor hone	Vapor blast cabinet	1.000	
0670		Apply solid film lube	Solid film cabinet	.960	1.000
0680		Cure solid film lube	Gas furnace	.960	
0685		Bench-grooves	Hand tools	.960	
0687		Inspect		--	
0690		Bench-stamp & lube	Hand tools	1.750	

STATISTICS

CRANE OPERATORS - TUBE OPERATION:

21	DAY SHIFT
10	MIDDLE SHIFT
2	NIGHT SHIFT
33	TOTAL

14 CRANE OPERATORS IN MACHINE BAYS OF BUILDINGS 35 & 135

FOLLOWERS - GROUNDSMEN:

DAY	NIGHT	TOTAL	
1	1	2	BUILDING 135
2	–	2	BUILDING 110
3	1	4	

AVERAGE WAGE:

$12/HOUR

$25,000/YEAR

ALLOWED CRANE WAIT TIME IN STANDARD TIMES:*

5 MIN.	BUILDING 35
10 MIN.	BUILDING 135
10 MIN.	BUILDING 110

TUBE DIMENSIONS:

	LENGTH	STARTING WEIGHT	FINISHED WEIGHT
MID SIZE TUBES			
105MM	220"	2,800 LBS.	1,600 LBS.
155MM	250"	6,600 LBS.	2,500 LBS.
LARGE TUBES			
8"		14,000 LBS.	10,000 LBS.

* CRANE WAIT DELAYS LARGER THAN ALLOWANCE ARE LOGGED IN THE LABOR REPORTING SYSTEM. MANY ARE IN EXCESS OF ONE HOUR.

ALTERNATIVES

MID SIZE TUBES

ALTERNATIVE ONE: MASTED CRANES

CONVERT 10 CRANES TO MASTED CRANES. ESTABLISH A RACKED CENTRAL STORAGE AREA WITHIN EACH BAY. STORE ALL TUBES INACTIVE BETWEEN PROCESSING STEPS IN THE CENTRAL STORAGE AREA OF THE BAY WITH THE NEXT PROCESSING STEP.

ADVANTAGES COMPARED TO CURRENT METHODS:

- MACHINISTS, INSPECTORS, AND FOLLOWERS WOULD NOT BE REQUIRED TO ATTACH/REMOVE SLINGS AND FOLLOW TUBES FROM POINT TO POINT.
- RIGGING TIME WOULD BE SAVED.
- POINT TO POINT MOVEMENT TIME WOULD DECREASE BECAUSE THE CRANE MOVES FASTER THAN THE FOLLOWER WALKS.
- 100% SELECTABILITY OF TUBES, ELIMINATING THE NEED TO MOVE TUBES ON TOP OF THE STACK TO OBTAIN THE DESIRED TUBE BURIED UNDERNEATH.
- INCREASED UTILIZATION OF STORAGE SPACE.
- A STORAGE METHOD COMPATIBLE WITH INVENTORY CONTROL SYSTEMS.

ALTERNATIVE ONE: MASTED CRANES (CONT'D)

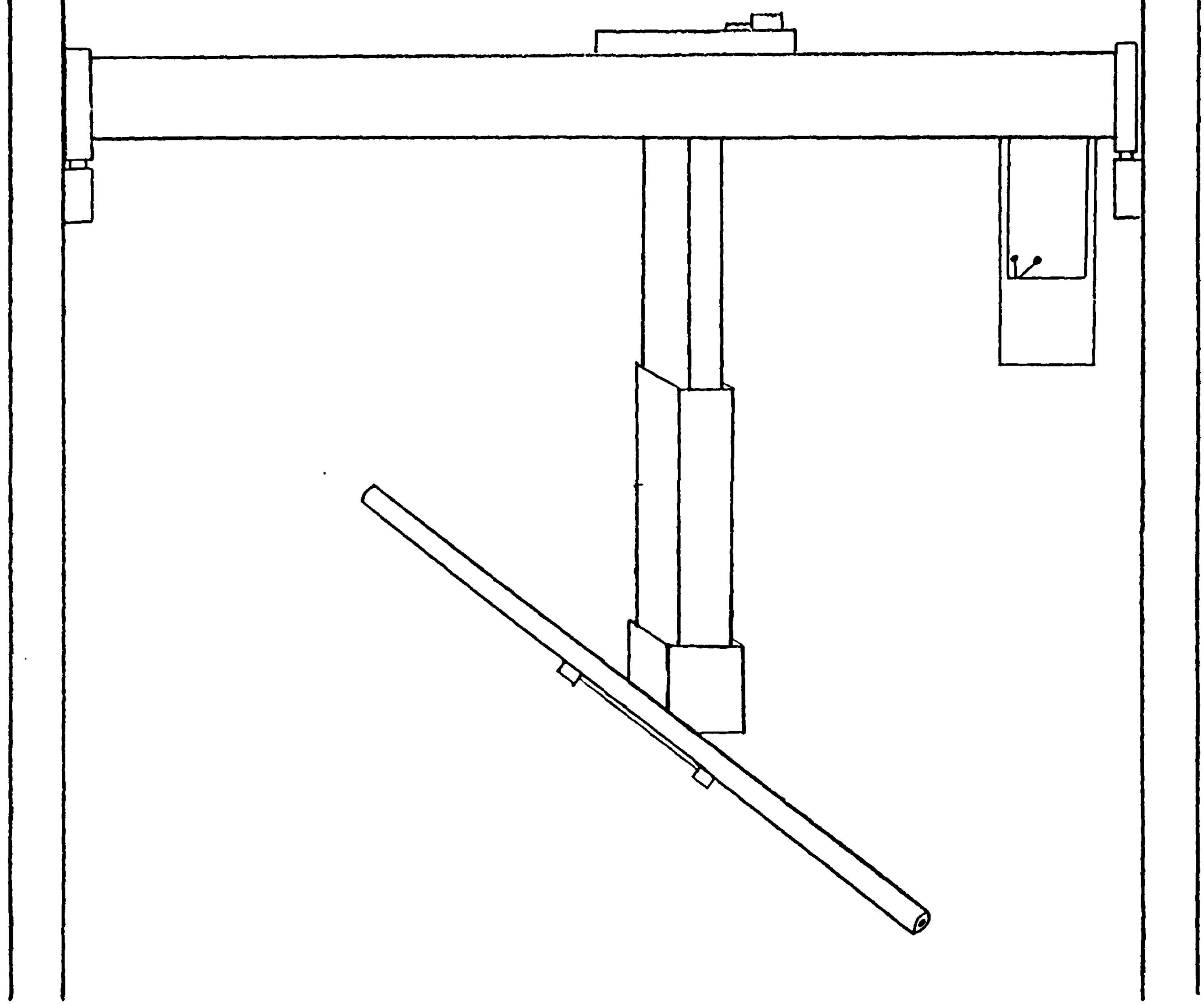
DISADVANTAGES COMPARED TO CURRENT METHODS:

- AVERAGE DISTANCE PER MOVE WOULD INCREASE SLIGHTLY.

PROBLEMS NOT RESOLVED:

- INTER-BAY MOVEMENTS ARE STILL A MULTIPLE STEP OPERATION REQUIRING A FLOOR MOVEMENT.
- TOTAL HANDLING TIME IS DEPENDENT ON LOCATION OF MACHINERY AS IT PERTAINS TO BAY ASSIGNMENT.
- THE OPERATION OF MORE THAN ONE CRANE IN A BAY CAUSES INTERFERENCE DUE TO ONE CRANE BLOCKING THE TRAVEL OF THE OTHER.
- THE CRANE OPERATORS AND MACHINE OPERATORS ARE TIED TO EACH OTHER. NEITHER WORKS WHEN THE OTHER IS WORKING. THEY WAIT ON EACH OTHER.

MASTED OVERHEAD CRANE



ALTERNATIVE ONE: MASTED CRANES

	1981 DOLLARS
EQUIPMENT COSTS	
CONVERSION OF CRANES TO MASTED CRANES 10 @ $200,000	$ 2,000,000
STORAGE RACKS 600 POSITIONS @ $200/POSITION	120,000
TOTAL EQUIPMENT COSTS	$ 2,120,000
ANNUAL SAVINGS (COSTS)	
SAVINGS	
MACHINISTS AND INSPECTORS 195 TUBES/MONTH 68 MOVES/TUBE 3 MINUTES/MOVE, ESTIMATED TIME REDUCTION $25,000/YEAR, WAGE RATE	$ 99,500
CRANE OPERATORS 8 MOVES/HOUR 4 MAN REDUCTION, FROM 14 TO 10 $25,000/YEAR, WAGE RATE	100,000
COSTS	
MAINTENANCE ON NEW EQUIPMENT 3% OF MECHANICAL EQUIPMENT COST FOR PARTS & LABOR	(60,000)
TOTAL ANNUAL SAVINGS	$ 139,500

PAYBACK

15.2 YEARS

ALTERNATIVE TWO: SIDELOAD TRUCKS

USE 5 SIDELOAD TRUCKS FOR INTER AND INTRA BAY TRANSPORTATION OF TUBES. HANDLE TUBES TWO AT A TIME IN A FIXTURE FOR ALL TRANSPORTATION MOVES. ZONE CRANES BY DIVIDING BAYS INTO SEGMENTS. LOAD AND UNLOAD MACHINES BY MACHINIST OPERATING CRANE FROM THE FLOOR. ESTABLISH A RACKED CENTRALIZED STORAGE AREA IN EACH BAY.

THE GENERAL METHODS OF OPERATION CONSIST OF THE SIDELOAD TRUCK DEPOSITING A THREE POSITION FIXTURE WITH AN EMPTY TUBE POSITION AND TWO TUBES TO BE PROCESSED ON THE FLOOR NEAR THE MACHINE TO BE USED FOR THAT PROCESS. THE MACHINIST WHEN FINISHED WITH THE TUBE ON HIS MACHINE WOULD WALK TO AN OVERHEAD CRANE SERVICING HIS MACHINE GROUP, OBTAIN THE FLOOR CONTROLS, MOVE THE CRANE TO HIS MACHINE, ATTACH THE SLINGS TO THE OLD TUBE, DEPOSIT THE OLD TUBE ON THE FIXTURE, REMOVE THE SLINGS, ATTACH THE SLINGS TO THE NEW TUBE, POSITION THE NEW TUBE IN THE MACHINE, REMOVE THE SLINGS, RELEASE THE CRANES FLOOR CONTROLS. THE MACHINIST REPEATS THIS PROCESS FOR THE SECOND TUBE. WHEN THE SECOND TUBE IS MOUNTED ON THE MACHINE THE MACHINISTS TURNS HIS RED SERVICE LIGHT ON. A SIDELOAD TRUCK DRIVER SEEING THE SERVICE LIGHT WOULD DRIVE TO THE FIXTURE CONTAINING TWO OLD TUBES, PICK IT UP, MOVE IT TO THE CENTRAL STORAGE AREA, PLACE IT IN A RACK POSITION, FIND A FIXTURE WITH TWO NEW TUBES, PICK IT UP, AND MOVE IT TO THE MACHINE'S FLOOR STAGING AREA. THE SIDELOAD TRUCK DRIVER HAS THE PROCESSING TIME OF A TUBE AT THIS STEP TO COMPLETE THE REPLACEMENT OF OLD TUBES WITH NEW TUBES. THIS IS USUALLY ONE TO THREE HOURS.

ALTERNATIVE TWO: SIDELOAD TRUCKS (CONT'D)

ADVANTAGES COMPARED TO CURRENT METHODS:

- OVERHEAD CRANE OPERATORS WOULD NOT BE REQUIRED FOR MACHINE BAY OPERATIONS.
- HIGHER UTILIZATION COULD BE MADE OF SIDELOAD VEHICLES VERSUS PRESENT USE OF CRANES. SIDELOAD VEHICLES COULD BE 90% UTILIZED WITHOUT SIGNIFICANT DELAY TIMES. PRESENTLY AT ALMOST ANY LEVEL OF UTILIZATION THERE IS DELAY TIME, AT 65% UTILIZATION THERE IS A DELAY AVERAGING 10 MINUTES PER MOVE, DELAYS AT UTILIZATIONS ABOVE 65% INCREASE RAPIDLY.
- MACHINISTS WOULD NOT WAIT FOR TUBE REPLACEMENT SERVICE.
- SIDELOAD DRIVERS WOULD NOT WAIT FOR MACHINISTS.
- EVERY JOB BECOMES A ONE MAN OPERATION.
- MULTIPLE HANDLINGS OF INTER-BAY MOVEMENTS WOULD BE ELIMINATED.
- MULTIPLE HANDLINGS OF INTER-BUILDING MOVES COULD BE ELIMINATED.
- THE NUMBER OF SIDELOADERS SERVICING AN AISLE ARE NOT FIXED. IMBALANCES OF WORKLOADS BETWEEN BAYS OR BUILDINGS CAN BE ADDRESSED BY REASSIGNING VEHICLES.
- THE LAYOUT OF MACHINERY BECOMES LESS IMPORTANT TO THE HANDLING SYSTEM.
- THE NUMBER OF MOVEMENTS WOULD DECREASE BY 50%.
- 100% SELECTABILITY OF TUBES, ELIMINATING THE NEED TO MOVE TUBES ON TOP OF THE STACK TO OBTAIN THE DESIRED TUBE BURIED UNDERNEATH.
- INCREASED UTILIZATION OF STORAGE SPACE.

ALTERNATIVE TWO: SIDELOAD TRUCKS (CONT'D)

- A STORAGE METHOD COMPATIBLE WITH INVENTORY CONTROL SYSTEMS.
- EQUIPMENT PURCHASED FOR THIS ALTERNATIVE WOULD ADD TO THE TOTAL CAPACITY FOR TUBE HANDLING.

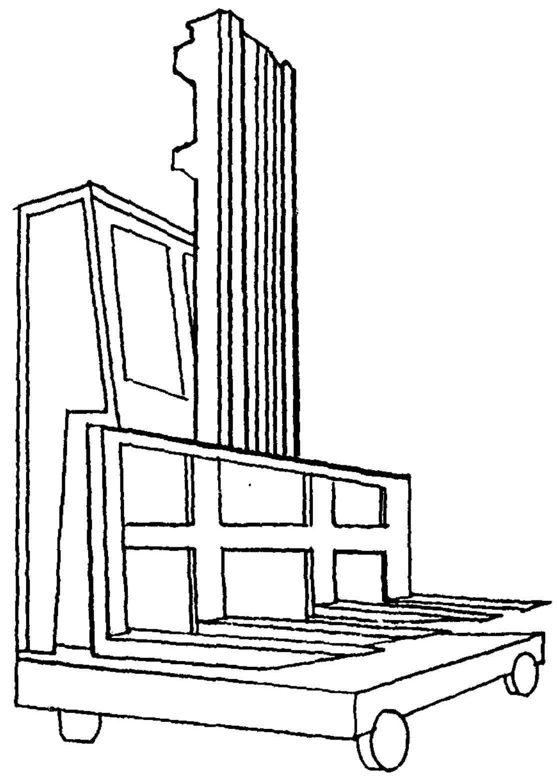
DISADVANTAGES COMPARED TO CURRENT METHOD:

- MACHINISTS WOULD HAVE TO KNOW HOW TO OPERATE CRANES.
- PATHWAYS WOULD HAVE TO BE ESTABLISHED FOR SIDELOAD TRUCKS.
- GROUND TRAFFIC WOULD INCREASE.

PROBLEMS NOT RESOLVED:

- TOTAL HANDLING TIME IS STILL DEPENDENT TO SOME EXTENT ON MACHINERY LOCATION, ALTHOUGH SIGNIFICANTLY REDUCED FROM CURRENT DEPENDENCY.

SIDELOAD TRUCK



ALTERNATIVE TWO: SIDELOAD TRUCKS

	1981 DOLLARS
EQUIPMENT COSTS	
SIDELOAD TRUCKS	
VEHICLES 5 @ $69,000	$ 345,000
BATTERIES 5 @ $5,000	25,000
CHARGERS 5 @ $1,500	7,500
STORAGE RACKS 300 POSITIONS @ $250/POSITION	75,000
TUBE HOLDING FIXTURES 400 @ $600	240,000
TOTAL EQUIPMENT COSTS	$ 692,500
ANNUAL SAVINGS/(COSTS)	
SAVINGS	
MACHINISTS AND INSPECTORS 195 TUBES/MONTH 68 MOVES/TUBE 5 MINUTES/TUBE, ESTIMATED SAVINGS $25,000/YR, WAGE RATE	$ 165,700
CRANE OPERATORS/SIDELOAD TRUCK DRIVERS 8 MOVES/HOUR 2 TUBES/MOVE 9 MAN REDUCTION, 14 CRANE OPERATORS VS. 5 SIDELOAD DRIVERS $25,000/YR. WAGE RATE	225,000

ANNUAL SAVINGS/(COSTS) (CONT'D)	1981 DOLLARS
COSTS	
MAINTENANCE ON NEW EQUIPMENT 3% OF MECHANICAL EQUIPMENT COST FOR PARTS & LABOR	$ (11,300)
TOTAL ANNUAL SAVINGS	$ 379,400

PAYBACK

1.8 YEARS

ALTERNATIVE THREE: AUTOMATIC GUIDED VEHICLE SYSTEM (AGVS) AND SIDELOAD TRUCKS

USE 2 SIDELOAD TRUCKS FOR INTER AND INTRA BAY TRANSPORTATION OF TUBES IN BUILDING 135. INSTALL AN AUTOMATIC GUIDED VEHICLE SYSTEM CONSISTING OF 4 VEHICLES WITH TRAILERS HAVING AUTOMATED LOAD AND UNLOAD DEVICES IN BUILDINGS 35 AND 1002 FOR INTER AND INTRA BAY MOVEMENTS. CONSTRUCT 60 PICKUP AND DEPOSIT STATIONS THROUGHOUT BUILDINGS 35 AND 1002 FOR AUTOMATIC LOADING AND UNLOADING OF TUBES. HANDLE TUBES TWO AT A TIME IN A FIXTURE FOR ALL TRANSPORTATION MOVES. ESTABLISH A RACKED CENTRALIZED STORAGE AREA IN EACH BAY. IN BUILDINGS 35 AND 1002 USE 2 SIDELOAD TRUCKS FOR MOVES BETWEEN THE STORAGE PICKUP AND DEPOSIT STATIONS, AND THE STORAGE RACKS. ZONE CRANES BY DIVIDING BAYS INTO SEGMENTS. LOAD AND UNLOAD MACHINES BY MACHINIST OPERATING CRANE FROM THE FLOOR.

THE CONSIDERATION OF USING AUTOMATIC GUIDED VEHICLES IS EXCLUDED IN BUILDING 135 BECAUSE OF THE DIFFICULTY IN ESTABLISHING A SATISFACTORY GUIDE PATH. THIS IS DUE TO THE LACK OF AVAILABLE SPACE AT THE END OF THE BAYS REQUIRED FOR THE TURNING RADIUS OF THE VEHICLES AND THE METAL PLATES COVERING UTILITY TRENCHES WHICH WOULD MAKE WIRE GUIDANCE IMPRACTICAL.

THIS ALTERNATIVE HAS THE SAME METHODS OF OPERATION AND EQUIPMENT AS THE PREVIOUS ALTERNATIVE IN BUILDING 135. IN BUILDINGS 35 AND 1002 FROM THE MACHINISTS VIEWPOINT THE ONLY DIFFERENCE IS KEYING IN A COMMAND ON A PAD MOUNTED TO THE PICKUP AND DEPOSIT STATION THAT CALLS THE AUTOMATIC VEHICLE RATHER THAN TURNING ON THE RED SERVICE LIGHT. THE SIDELOAD DRIVER IN THE STORAGE AREA OPERATES SIMILARLY WITH SIGNIFICANTLY REDUCED DRIVING DISTANCES AND THE ADDITIONAL OPERATION OF KEYING THE DESTINATION FOR NEW TUBES TO BE DELIVERED.

ALTERNATIVE THREE: AUTOMATIC GUIDED VEHICLE SYSTEM (AGVS) AND SIDELOAD TRUCKS (CONT'D)

THE AUTOMATIC GUIDED VEHICLES MOVE TWO TUBES AT A TIME ON A FIXTURE BETWEEN PICKUP AND DEPOSIT STATIONS AT THE STORAGE AREAS AND THE MACHINE LOCATIONS. THE VEHICLES MOVE WITHOUT A DRIVER. THEY PICKUP AND DEPOSIT THE FIXTURES WITH THE TUBES AUTOMATICALLY TO OR FROM THE P & D STATIONS. THE ONLY HUMAN INTERVENTION REQUIRED IS KEY ENTERING THE DESTINATION OF THE LOAD ON A PAD MOUNTED ON EACH PICKUP AND DEPOSIT STATION. THE KEYING OF THE DESTINATION CALLS THE NEXT AVAILABLE VEHICLE AND INSTRUCTS IT WHERE TO TAKE AND DEPOSIT THE LOAD.

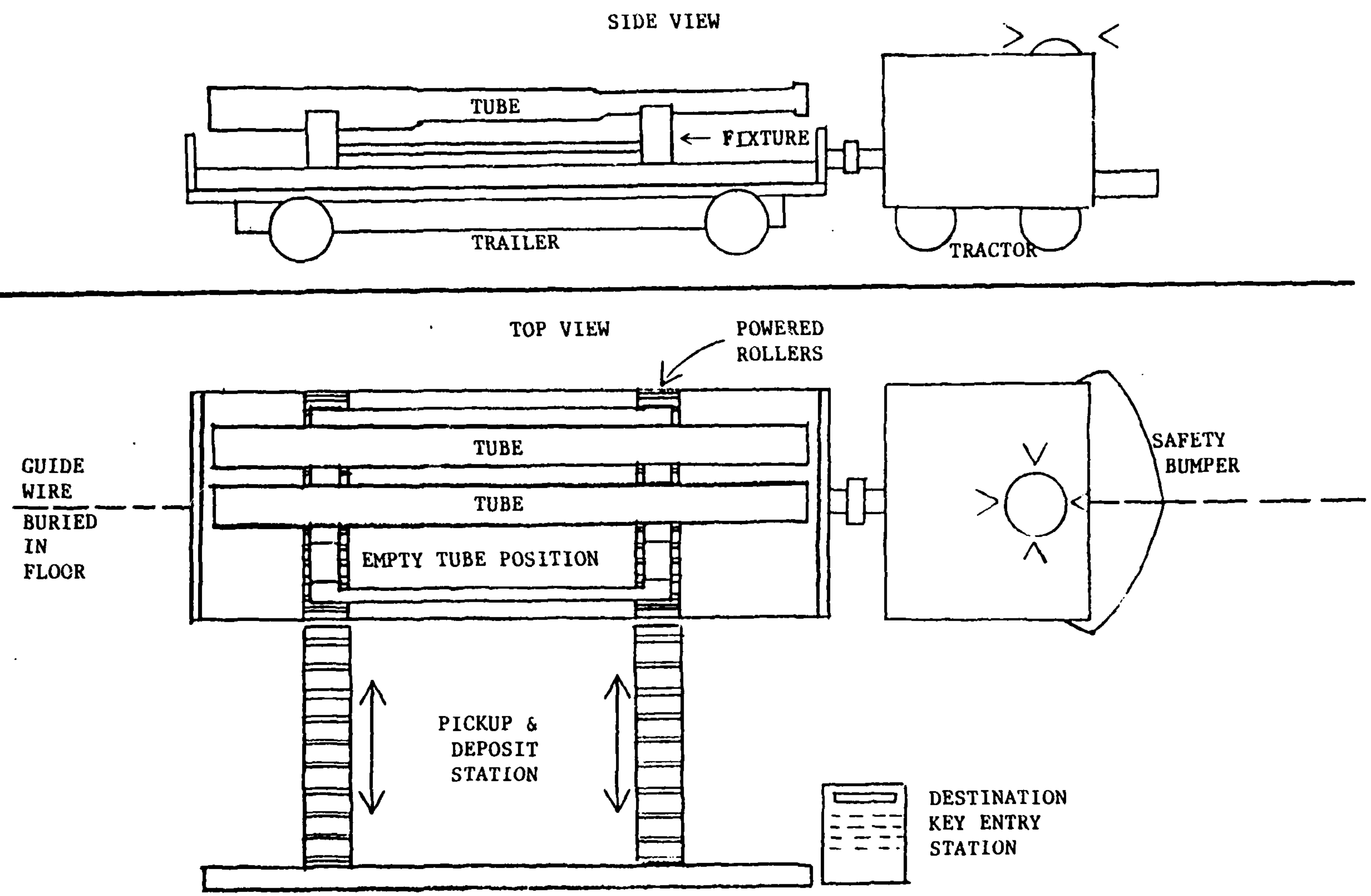
ADVANTAGES OF THE AGV SYSTEM COMPARED TO THE SIDELOAD TRUCK ALTERNATIVE:

- MANPOWER REQUIRED IN TRANSPORTATION OF TUBES IN MINIMIZED.
- MACHINE LAYOUT HAS NO IMPACT ON MATERIAL HANDLING LABOR. (IT COULD REQUIRE ADDITIONAL VEHICLES.)
- IT WOULD ASSURE FIRST CALLED-FIRST SERVED OPERATING METHODS.

DISADVANTAGES OF THE AGV SYSTEM COMPARED TO THE SIDELOAD TRUCK ALTERNATIVE:

- IT IS NOT AS FLEXIBLE.

AUTOMATIC GUIDED VEHICLE SYSTEM
(AGVS)



ALTERNATIVE THREE: AUTOMATIC GUIDED VEHICLE SYSTEM AND SIDELOAD TRUCKS

	1981 DOLLARS
EQUIPMENT COSTS	
AUTOMATIC GUIDED VEHICLE SYSTEM	
TRACTORS 4 @ $19,000	$ 76,000
BATTERIES 4 @ $3,200	12,800
CHARGERS 4 @ $1,500	6,000
TRAILERS 4 @ $5,000	20,000
BATTERIES 4 @ $1,800	7,200
CHARGERS 4 @ $1,500	4,500
WIRE GUIDE PATH 3200' @ $15/FT	48,000
P & D STATIONS 60 @ $500	30,000
SIDELOAD TRUCKS	
VEHICLE 4 @ $69,000	276,000
BATTERIES 4 @ $5,000	20,000
CHARGERS 4 @ $1,500	4,500

RECOMMENDATIONS

THIS STUDY IDENTIFIES TWO ALTERNATIVE SYSTEMS FOR TRANSPORTING TUBES THAT RESULT IN SUBSTANTIAL PRODUCTIVITY IMPROVEMENTS AS COMPARED TO THE PRESENT SYSTEM OF CAB OPERATED OVERHEAD CRANES. THESE ALTERNATIVE SYSTEMS USE SIDELOAD TRUCKS OR AUTOMATIC GUIDED VEHICLES AS THE PRIMARY TUBE TRANSPORTATION DEVICES. THE ESTIMATED EQUIPMENT COSTS AND ANNUAL SAVINGS OF THESE ALTERNATIVES ARE SIMILAR WITH A PAYBACK PERIOD OF 1.8 YEARS FOR SIDELOAD TRUCKS AND 2.0 YEARS FOR AN AUTOMATED GUIDED VEHICLE SYSTEM.

THE ALTERNATIVE TO USE SIDELOAD TRUCKS AS THE MAJOR TUBE TRANSPORTATION DEVICE AND TO ESTABLISH CENTRAL STORAGE AREAS IS RECOMMENDED. THE REASONS FOR RECOMMENDATION ARE:

- BEST COST/BENEFIT RELATIONSHIP OF ALL ALTERNATIVES
- IMPROVED PRODUCTIVITY
- INCREASE OF TUBE HANDLING CAPACITY
- INCREASE OF TUBE STORAGE CAPACITY
- PROVEN EQUIPMENT
- FLEXIBILITY

THE ESTIMATED EQUIPMENT COST TO IMPLEMENT THIS ALTERNATIVE IS $692,500 WITH AN EXPECTED ANNUAL SAVINGS OF $379,400. THE SAVINGS RESULT FROM INCREASED PRODUCTIVITY DUE TO

SIGNIFICANT OPERATIONAL ADVANTAGES THE RECOMMENDED ALTERNATIVE HAS OVER THE CURRENT SYSTEM:

- REDUCES THE INTERDEPENDENCY OF MACHINING OPERATIONS AND TUBE TRANSPORTATION.
- MINIMIZES THE IMPACT MACHINERY LOCATIONS HAVE ON TUBE TRANSPORTATION TIME.
- ALLOWS TWO TUBES TO BE MOVED SIMULTANEOUSLY, CUTTING THE TOTAL NUMBER OF TUBE MOVEMENTS IN HALF.

THE ALTERNATIVE TO INSTALL AN AUTOMATIC GUIDED VEHICLE SYSTEM IS ALSO COST JUSTIFIABLE AND HAS THE SAME OPERATIONAL ADVANTAGES. IT IS A FEASIBLE ALTERNATIVE. HOWEVER, IT IS NOT RECOMMENDED BECAUSE THE SIDELOAD TRUCK ALTERNATIVE ACCOMPLISHES NEARLY THE SAME RESULT IN A LESS COSTLY AND COMPLEX MANNER.

IMPLEMENTATION OF THE RECOMMENDED ALTERNATIVE CAN BE MADE WITH MINIMUM DISRUPTION TO DAILY OPERATIONS. IT DOES NOT REQUIRE ANY MODIFICATIONS TO THE BUILDINGS. IT WILL REQUIRE, TO SOME EXTENT, THE RELOCATION OF MACHINERY TO DEVELOP ADEQUATE TRANSPORTATION AISLES AND STORAGE LOCATIONS.

IT IS POSSIBLE TO IMPLEMENT THE ALTERNATIVE IN STAGES WITH MINIMAL COST PENALTIES. STAGED IMPLEMENTATION COULD YIELD SEVERAL ADVANTAGES. THE COST BENEFITS COULD BE VERIFIED BEFORE A TOTAL EXPENDITURE IS MADE. OPERATIONAL TECHNIQUES COULD BE DEVELOPED AND DEBUGGED ON A SMALL GROUP OF OPERATIONS AVOIDING TRIAL AND ERROR SITUATIONS INVOLVING THE TOTAL FACILITIES.