EXECUTIVE SUMMARY

FINAL

ENERGY ENGINEERING ANALYSIS PROGRAM AT RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA

VOLUME I

FOR

DEPARTMENT OF THE ARMY

NORFOLK DISTRICT, CORPS OF ENGINEERS

CONTRACT NO. DACA65-80-C-0016

A&E COMMISSION NO. 1827-A

JULY 1983

Hayes, Seay, Mattern and Mattern

ARCHITECTS • ENGINEERS • PLANNERS

DEPARTMENT OF THE ARMY
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ENERGY ENGINEERING-ANALYSIS PROGRAM
AT RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

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ROANOKE, VIRGINIA

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1. INTRODUCTION

This summary was prepared to document the results of Hayes, Seay, Mattern and Mattern's energy engineering analysis at Radford Army Ammunition Plant. The work, undertaken to expand the plant-wide energy system plan, included 147 buildings on the site. After surveying nineteen typical buildings and interviewing plant personnel, the Architect-Engineer investigated past and present energy consumption at the plant and began to formulate projects for conservation. As a result of this work, eight ECIP projects were recommended for Increments A and B. A number of other projects were investigated under Increments F and G. The projects under Increments A, B, and G will result in a combined savings of 349,880 MBTU per year. The projects under Increment F, including energy modifications made by RAAP in 1981 and 1982, will result in an annual savings of 248,204 MBTU. The analysis also included a steam trap study and recommendations for insulating steam lines, which are presented as appendices to the main report.

2. EXISTING ENERGY CONSUMPTION

In order to determine patterns of energy use at Radford Army Ammunition Plant, records of energy consumption from 1974 to the present were reviewed. Annual consumption for fiscal years 1975 through 1980 is summarized in table 1. In 1980, the year closest to the year of the survey, total energy consumption at the plant was 3,502,649 MBTU.

The pattern in energy use over the years indicates that consumption is directly proportional to product output (rather than to building area, for example). This relationship is evident in the quantities shown in table 1. It can be seen that in 1980 the plant consumed 158,775 BTU for every pound of propellant it produced.

Because of the lack of metering at the plant, it was not possible to allocate energy consumption to specific buildings or areas. Figure 1 shows the proportion of energy consumed by particular functions per pound of propellant produced during fiscal year 1980.

TABLE 1

ENERGY CONSUMPTION AND PRODUCT OUTPUT

Fiscal Year	Consumption, MBtu	Total Cost, Dollars	Product Output, pounds	Btu/ pound	Dollars/ pound
1975	4,981,279	9,500,003	57,980,775	85,913	0.16
1976	3,596,355	6,077,573	28,482,150	126,267	0.21
1977	3,625,795	5,582,265	25,539,240	141,970	0.22
1978	4,217,981	7,218,557	27,492,004	153,426	0.26
1979	3,618,687	7,403,931	20,420,369	177,210	0.36
1980	3,502,649	7,242,271	22,060,417	158,775	0.33
1981	4,133,786	7,786,872	25,723,131	160,703	0.30
1982	4,249,365	8,861,476	26,925,945	157,817	0.33
MEAN (FY 76-FY-80)*			24,798,830	151,530	

*Values for FY 75 were not used in calculating the mean, because they deviated from the general trend.

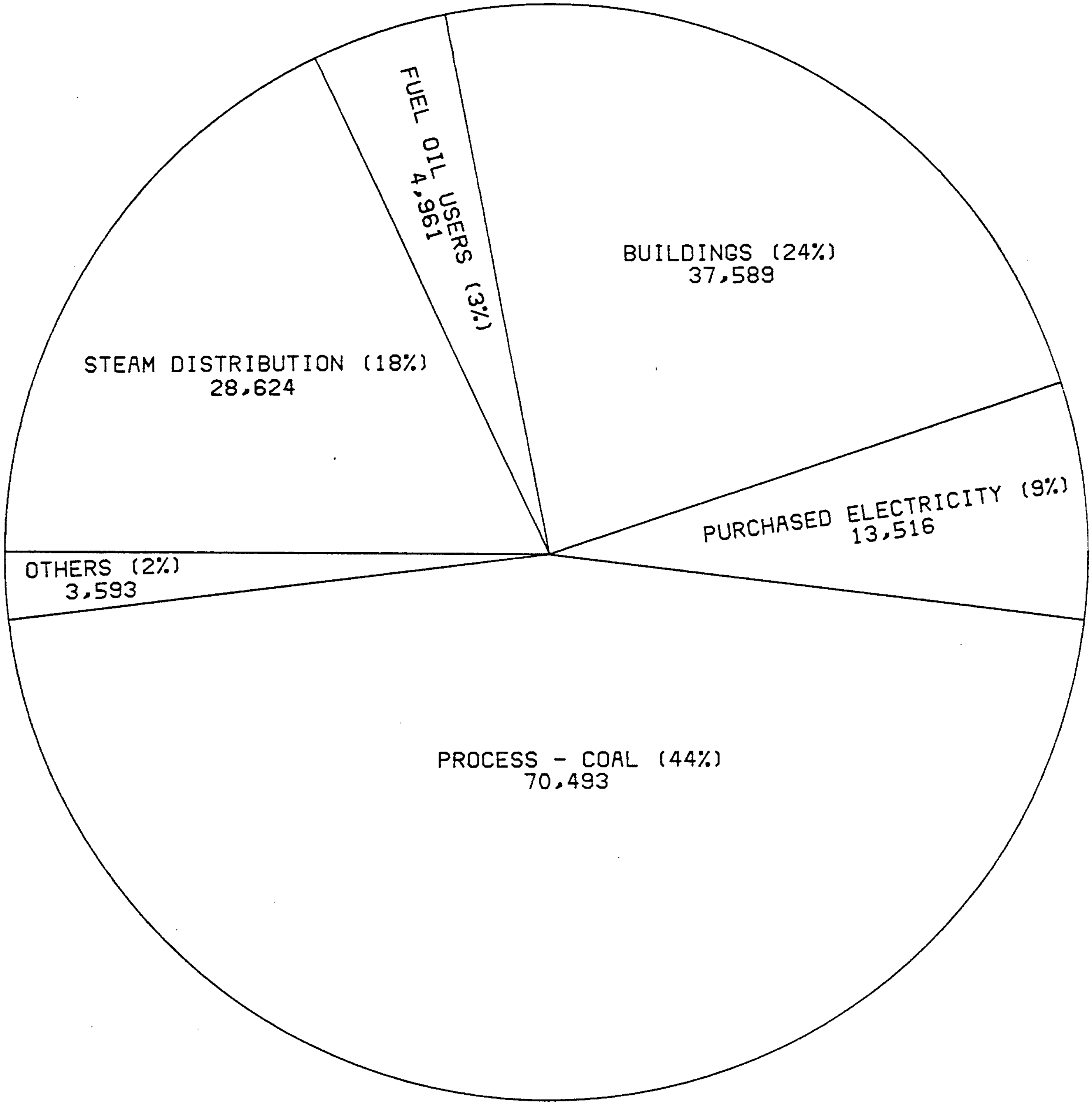

FIGURE 1, PLANT-WIDE CONSUMPTION FY'80
158,777 BTU/LB OF PROPELLANT

3. ENERGY CONSERVATION MEASURES DEVELOPED

3.1 Conservation Measures Investigated

A number of energy conservation measures were investigated as the analysis progressed. Where the opportunity for conservation appeared to be particularly advantageous, ECIPs were developed. The ECIPs under Increments A, B, and G were evaluated on the basis of two economic criteria: the energy-to-cost ratio (E/C) and the benefit-to-cost ratio (B/C). The ECIPs under Increment F were evaluated on the basis of the savings-to-investment ratio (SIR). All of the projects reviewed are listed in tables 2 and 3.

In many cases, obvious energy-saving measures were already being planned or implemented under other programs. In other cases, projects were abandoned because of conflicts with safety regulations or because of excessive costs. Insulating the buildings at RAAP at first appeared to offer substantial energy savings. Most of the buildings, however, are used in the manufacture of propellants, and insulation would add to the hazard of fire and explosions. Only three groups of buildings, therefore, are included in the ECIP that will install insulation. (The change houses and grinder building will be weatherized under a separate project.) Projects for installing air curtains in the combined shops and a bypass system in the small grain evacuating and casting house were also considered. Neither of these projects provided an acceptable E/C ratio. Insulating steam pipes, another promising energy conservation measure, proved to be unacceptable for reasons of safety: new insulation can not be applied directly over the old, because it contains asbestos. A project for improving steam traps in the distribution lines was abandoned when it was learned that a maintenance program for steam traps had been undertaken.

Automatic controls, usually a dependable method of conserving energy, are not readily adaptable to the situation at RAAP, where a multitude of small buildings is distributed over a large area. Automatic lighting controls would not greatly increase energy savings, since manual controls are already used to maximum advantage. Existing motor controls, both automatic and manual, are also adequate. An energy monitoring and control system would be impractical for the buildings surveyed, since they do not have a central HVAC system.

3.2 ECIP Projects Developed

The following ECIP projects for Increments A and B are recommended for implementation:

Individual Bay Heaters for FAD Houses--T-101: This modification will provide individual bay heaters in the FAD houses to conserve energy when the buildings are operated with only one or two bays loaded.

Heat Recovery for Curing Houses--T-103: This project will use exhaust heat from the process to preheat incoming fresh air to the heater house. Individual bay heaters and a heat pipe will be installed in four curing houses.

Heat Pipe for FAD Houses--T-104: The heat pipe will recover energy from the exhaust air to preheat incoming fresh air.

Ambient Sensing Steam Control Valves--T-105: This project will install control valves in the main steam lines that provide space heat for the 147 buildings included in this program.

Return Condensate System Plant-Wide--T-106: A condensate return system consisting of new pumping stations and schedule 80 pipe will be provided to serve nitrocellulose lines A and B, the solvent recovery area, the first rolled powder area, and combined shops.

Steam Tie-Line Linking Power House 400 with Horseshoe Area--T-107: This project will connect the two steam distribution systems so that only the main power plant is used for production during peacetime.

Change House Modifications--T-108: This project will install new fluorescent lighting in conjunction with modifications being performed under an existing project.

Insulating and Weatherproofing Combined Shops, Solventless Press House, and 4th Rolled Powder Line--T-109: These buildings will be insulated, using a closed-cell material for reasons of safety.

3.3 Minor MCA and O&M Projects

A number of energy conservation measures identified by this analysis can be accomplished as maintenance projects under Increment G. These projects are as follows:

Installation of HPS Lighting--T-110G: Installing high-pressure sodium lighting in the combined shops, boiling tub basements, and wringer houses will save considerable energy in these areas.

Replace Plastic Blow-Out Panels with Insulated Panels, Mix House--WO-111G: This project will replace the existing plastic panels with urethane panels.

Installation of Photocells at Fourth Rolled Powder Line--WO-112G: Four photocells will be strategically located to shut off the outside lights.

Insulate Ether Still House--WO-113G: Sprayed-on polyurethane insulation with a silicone coating will be installed in this building.

Replacement and Installation of Gate Valves--T-102G: This project will replace 137 defective gate valves and install five new gate valves, four in the first rolled powder area and one in area A.

Water Dry Tank Covers--WO-114G: This project will provide tank covers specifically designed to save energy and recover ether.

As a result of the field survey, the Architect-Engineer was able to make specific recommendations for energy conservation projects already in progress at Radford AAP. These recommendations, as well as some of the current projects, are discussed in the main report.

3.4 Facilities Engineer Conservation Measures

The following ECIP projects for Increment F are recommended for implementation:

Insulate and Weatherize Buildings--115F: This project proposes to insulate the walls and roof of the grinder house, building 442, with one inch of spray-on polyurethane insulation; to weatherstrip the doors and windows of buildings 2521, 3521, and 3524-A; to install a storm window in building 3524-A; to install a motorized damper in buildings 2521 and 3521; and to fill the holes in the walls of buildings 2521 and 3521.

Nitric Acid Concentrators - Sulfuric Acid Concentrators (NAC-SAC) Insulation--116F: This project proposes to insulate the dehydration towers and denitration towers in the NAC-SAC building with one inch of fiberglass insulation. The towers presently are not insulated.

Deactivate Steam Lines During Summer--117F: Presently, a steam aspirator is used to pull a vacuum which opens the glaze and blender barrels in buildings 1800, 1801, 1825, 1826, 1827, and 1828. This is the only use for steam during the summer on these branches of the distribution system. This project proposes to replace the steam aspirators with pneumatic controls, thereby allowing 6700 feet of steam line to be deactivated during the summer.

Insulate Exterior Pressure-Reducing Stations--118F: This project proposes to insulate fifty exterior pressure-reducing stations with two inches of fiberglass insulation.

Insulate Six Adsorber Tanks--119F: This project proposes to insulate the six adsorber tanks in buildings 2555 and 3555 with one inch of fiberglass insulation.

Replace Steam Jet Pumps--120F: This project proposes to replace the forty-year-old steam jet pumps beside buildings 2510 and 3510 with float-controlled electric sump pumps. The existing pumps are manually controlled and often operate unnecessarily.

Insulate Air Heaters in Blower Houses--121F: This project proposes to insulate the air heaters in the blower houses with one inch of removable fiberglass insulation.

Lighting Modifications--122F: This project proposes to modify the operation of the lighting system in Buildings 2045 and 3045 by means of photocell control.

Heat Recovery from Waste Explosive Incinerator Afterburners--124F: This project proposes to recover heat lost from the uninsulated surface of the waste explosive incinerator afterburners by enclosing the exposed surface with a metal jacket and preheating the combustion air in the two-inch annular space.

Recovery of Low Pressure Steam from Hot Condensate--125F: Currently, hot condensate, at an average temperature of 350 degrees F, is flashed at atmospheric pressure, resulting in a large discharge of steam to the atmosphere. This project will provide a pressurized flash tank operating at 40 psig. The flash steam will be piped into the low-pressure steam main. The condensate from the pressurized flash tank, which will have a temperature of 286 degrees F, will be flashed to atmospheric pressure as before, but the steam waste will be reduced by approximately one-half.

Condensate Return from the NAC-SAC and AOP Areas--126F: At the present time, condensate from the NAC-SAC system, which leaves the heat exchangers at pressures of 125 to 250 psig, is flashed at atmospheric pressure and then dumped to the sewer. Condensate pumps, instrumentation to divert the flow in the event of low pH, and condensate piping are already in place and ready to use. The power plant has refused to accept this condensate in the past because of operational problems; these problems, however, should be corrected even if the condensate is not returned.

TABLE 2: SUMMARY OF ENERGY CONSERVATION OPPORTUNITIES
(IN DESCENDING E/C PRIORITY)

Project No.	Project Description	CWE in 1984 Dollars	E/C Ratio	B/C Ratio	Energy Saved, MBTU/Yr.	Dollars Saved, $/Year	Payback Period, Years	Action
--	Install Gate Valve in 8" Main at TNT Area	14,021	230.0	-	3,224	11,761	1.2	Valve already installed
--	Replace Defective Steam Traps	23,955	70.8	-	1,695	7,437	3.2	Dropped because of existing steam trap maintenance program
T-102-G	Replacement and Installation of Gate Valves	191,537	69.4	4.7	13,295	52,578	3.6	Submitted - Increment G, EC/CC = 4.95
T-105	Ambient Sensing Steam Control Valves	536,089	48.1	1.7	25,808	79,876	6.7	Submitted - Increment A
T-101	Individual Bay Heaters for FAD Houses	102,895	32.6	3.0	3,352	15,284	6.7	Submitted - Increment A
--	Final Wringer Timers	31,454	31.6	-	995	5,134	6.1	Timers already installed
T-108	Change House Modifications	135,200	28.4	4.2	3,838	36,000	3.8	Submitted - Increment A
--	Return Condensate System for TNT Area	323,384	25.5	-	8,240	33,142	9.8	Condensate system already installed
T-104	Heat Pipe for FAD Houses	2,385,729	25.3	1.6	60,349	306,448	7.8	Submitted - Increment A
--	Heat Recovery For Air Dry House	690,755	23.5	.76	16,225	18,146	38.1	Not submitted because B/C $<$ 1
T-106	Return Condensate System Plant-Wide	3,786,679	21.1	1.1	79,716	328,520	11.5	Submitted - Increment B
WO-111G	Replace Plastic Blow-out Panels with Insulated Panels, Mix House	18,254	21.0	1.1	383	1,185	15.4	Submitted - Increment G, EC/CC = 1.17
T-107	Steam Tie-Line Linking Power House 400 with Horseshoe Area	6,883,510	20.3	7.2	139,777	3,098,614	2.2	Submitted - Increment B (Design Completed under WE project)

TABLE 2 (continued)

Project No.	Project Description	CWE in 1984 Dollars	E/C Ratio	B/C Ratio	Energy Saved, MBTU/Yr.	Dollars Saved, $/Year	Payback Period, Years	Action
T-109	Insulating and Weather-proofing Combined Shops, Solventless Press House, and 4th Rolled Powder Line	387,756	18.9	1.1	7,346	23,737	16.3	Submitted - Increment A
T-103	Heat Recovery for Curing Houses	615,143	17.6	1.7	10,849	58,723	10.5	Submitted - Increment A
--	Weatherize Change Houses	279,728	15.8	-	4,410	16,308	17.2	Already in progress under WE program.
WO-113G	Insulate Wall & Roof, Ether Still House	23,300	13.3	.7	309	956	24.4	Submitted - Increment G, EC/CC = 0.74
--	Insulate Wall & Roof Cotton Pulp & Dry House	42,095	12.3	-	518	1,916	21.2	E/C not valid; violates safety regulations
WO-112G	Installation of Photocell at 4th Rolled Powder for Walkway Lighting	8,032	11.5	1.6	92	1,341	6.0	Submitted - Increment G, EC/CC = 0.83
--	Insulate Wall & Roof Press & Cutting House	40,337	10.9	-	441	1,631	24.7	E/C not valid; violates safety regulations.
--	Insulate Wall & Roof, Mix House	35,219	10.7	-	378	1,398	25.2	E/C not valid; violates safety regulations.
WO-114G	Water Dry Tank Covers	230,302	8.6	12.9	1,973	322,810	0.7	Submitted - Increment G, E/C = 0.48
--	Replace Drive Shafts with Individual Mixers at Poacher-Blender Houses	2,481,000	8.6	-	21,487	110,870	22.4	E/C not valid.
T-110G	Installation of HPS Lighting in Combined Shops, Boiling Tub Basement and Wringer Houses	354,493	7.9	1.2	2,793	27,954	12.7	Submitted - Increment G, EC/CC = .91

TABLE 2 (continued)

Project No.	Project Description	CWE in 1984 Dollars	E/C Ratio	B/C Ratio	Energy Saved, MBTU/Yr.	Dollars Saved, $/Year	Payback Period, Years	Action
--	Reinsulating Steam Pipe Plant-Wide	17,142,103	7.4	-	127,658	505,005	33.9	E/C not valid.
--	Insulate Wall & Roof, Can Pack House	19,441	6.1	-	118	436	44.6	E/C not valid; violates safety regulations.
--	Insulate Wall & Roof, Poacher-Blender House	184,689	5.6	-	1,026	3,794	48.7	E/C not valid; violates safety regulations.
--	Insulate Wall & Roof, Final Blend House	15,518	3.8	-	59	218	71.2	E/C not valid; violates safety regulations.
--	Diverter Valve for Small Grain Evacuating & Cast House	58,273	3.2	-	189	1,376	42.3	E/C not valid.
--	Heat Pipe for Dry Houses	903,643	3.0	-	2,674	9,888	91.4	E/C not valid.
--	Ceiling Fans for Boiling Tub, Poacher-Blender & Final Wringer Houses	27,029	2.7	-	76	53	510.0	E/C not valid.
--	Air Curtains for Doors in Combined Shops	34,171	2.6	-	90	331	103.0	E/C not valid.
--	Insulate Wall & Roof Boiling Tub House	110,541	2.2	-	247	913	121.0	E/C not valid; violates safety regulations.
--	Insulate Wall & Roof	65,527	2.2	-	146	540	122.0	E/C not valid; violates safety regulations.

TABLE 3: SUMMARY OF INCREMENT F PROJECTS
(ACCORDING TO DESCENDING SIR PRIORITY)

Project No.	Description	SIR	Manhours	CWE (Jan 83) Dollars	Annual Dollar Savings	Annual Energy Savings (MBTU)
126F	Condensate Return from NAC-SAC and AOP Areas	---	0	0	68,017	34,073
125F	Recovery of Low-Pressure Steam from Hot Condensate	19.3	448	40,430	52,885	28,425
124F	Heat Recovery from Waste Explosive Incinerator Afterburner	7.4	329	18,781	13,796	2,083
122F	Lighting Modifications	7.0	48	2,822	1,930	442
116F	NAC-SAC Insulation	5.1	100	11,684	3,007	2,857
117F	Deactivate Steam Lines during Summer	4.3	67	10,984	3,340	1,786
118F	Insulate Exterior Pressure-Reducing Stations	3.2	646	60,040	13,183	6,785
119F	Insulate Six Adsorber Tanks	1.9	479	25,148	3,495	1,869
115F	Insulate and Weatherize Buildings	1.8	415	21,355	3,609	1,246
120F	Replace Steam Jet Pumps	1.2 (1.7*)	31	5,877	1,065	199
121F	Insulate Air Heaters in Blower House	1.2 (2.3*)	235	37,831	8,889	1,264

TABLE 3: (Continued)

Project No.	Description	SIR	Manhours	CWE (Jan 83) Dollars	Annual Dollar Savings	Annual Energy Savings (MBTU)
127F	Rectification of Acid Vapors from Sulfuric Acid Concentrators	0.28 (1.9*)	2,515	556,100	127,810	4,175
123F**	Heat Recovery from Spent Acid Combustion Chamber	0.12	2,986	155,130	318	946

*Projects 120F, 121F, and 127F have nonenergy savings that exceed twenty-five percent of the total savings. The SIRs shown in parentheses were calculated using the total discounted savings, but disallowing the energy investment credit.

**Not recommended.

4. ENERGY AND COST SAVINGS

4.1 Plant-Wide Consumption After Energy Conservation Projects Are Implemented

The energy savings and cost savings attributable to the recommended ECIP projects are shown in Table 4. Energy modifications implemented since 1981 are also included in this table. It can be seen that these projects will reduce plant-wide energy consumption by 17.08 percent per year over 1980 consumption. Whereas the production of one pound of propellant required 158,775 BTU in 1980, 131,664 BTU will be required after the projects are complete.

Figure 2 shows the proportion of energy that will be consumed by particular users after the projects are in effect. Comparing this graph with figure 1, which gives the same information for 1980, provides one indication of the projects' combined effect on energy consumption patterns at the plant.

The overall energy-to-cost ratio for all the recommended projects in Increments A, B, and G is 22.3. The combined payback period is 3.6 years. The combined savings-to-investment ratio for all the recommended projects in Increment F is 10.0.

4.2 Allocation of Savings from Energy Conservation Projects

The recommended projects evaluated under Increments A, B, F, and G will reduce total energy consumption at Radford AAP by 17 percent. In figure 3, these savings are allocated among the three energy-user categories investigated by this study—buildings, the steam distribution system, and process functions.

For the building projects and the steam distribution projects, the savings will be in the form of electricity and coal used by the power house. The FAD and curing house modifications provided by the process projects will reduce steam consumption and, consequently, coal consumption at the power house.

4.3 Projected Energy Consumption

Figure 4 shows that, while energy consumption varied greatly from year to year, the amount of energy consumed per pound of propellant produced increased steadily from 1975 to 1979. This trend changed in 1980, when energy consumption per pound of propellant decreased by 10.4 percent as a result of in-house conservation measures. The top portion of figure 4 shows projected FY 85 energy consumption per pound of product and the energy consumption goal. It should be noted, however, that energy consumption per pound of product varies considerably, depending on the propellant product mix. The bottom portion of the graph shows the cost of fuel per pound of product. By FY 85, the ratio will be $0.44 per pound, assuming a 10-percent escalation in cost per year. If production for FY 85 were the same as for FY 80, Radford AAP's fuel bill would be $9,640,000, assuming that no conservation projects were enacted. If all the recommended conservation projects were enacted, resulting in an energy consumption of 131,664 BTU per pound, Radford AAP's fuel bill would be $8,000,000.

The goal of Radford AAP, as specified by MACOM in the Army Facilities Energy Plan, is to reduce FY 75 energy consumption by 20 percent. (This analysis used FY 76 as the base year for energy reduction.) This goal, based strictly on energy used in production, would equal a consumption rate of 101,014 BTU per pound of product.

The planning use model in figure 5 illustrates the effect of the energy-saving projects on the inversely proportional relationship between production levels and the amount of energy consumed per pound of product. The model shows that the projects will enhance the effect of increased production on process efficiency. The model also shows that, once production exceeds plus or minus 20 percent of the mean, additional inefficiencies creep into the production process.

TABLE 4

ANNUAL SAVINGS AFTER RECOMMENDED ECIP PROJECTS ARE IMPLEMENTED

Project No.	Description	ENERGY SAVINGS Coal (MBTU)	Electricity (MBTU)	Dollar Savings	Percent of Base-Wide Energy Reduction
BUILDING PROJECTS					
T-105	Ambient Sensing Steam Control Valves	25,808	-	79,876	
T-108	Change House Modifications	-	3,838	36,000	
T-109	Insulating and Weatherproofing Combined Shops, Solventless Press House, and 4th Rolled Powder Line	7,346	-	23,737	
T-110G	Installation of HPS Lighting	-	2,793	27,954	
WO-111G	Replace Plastic Blow-out Panels with Insulated Panels, Mix House	383	-	1,185	
WO-112G	Installation of Photocell at 4th Rolled Powder Line	-	92	1,341	
WO-113G	Insulate Ether Still House	309	-	956	
115F	Insulate and Weatherize Hydraulic Pump Houses, Chemical Grind House, and Grinder Bldg. 442	298	948	3,609	
116F	Insulate NAC-SAC Towers	2,857	-	3,007	
122F	Lighting Modification in Continuous Nitrator	-	442	1,930	
	SUBTOTAL	37,001	8,113	179,595	1.29

Project No.	Description	ENERGY SAVINGS Coal (MBTU)	Electricity (MBTU)	Dollar Savings	Percent of Base-Wide Energy Reduction
STEAM DISTRIBUTION PROJECTS					
T-106	Return Condensate System - Plant-Wide	81,443	-1,727	328,520	
T-107	Steam Tie-Line Linking Power House 400 with Horseshoe Area	140,358	-581	3,098,614	
T-102G	Replacement and Installation of Gate Valves	13,295	-	52,578	
117F	Deactivate Steam Lines During Summer	1,786	-	3,340	
118F	Insulate Exterior Pressure-Reducing Stations	6,785	-	13,183	
120F	Replace Steam Jet Pumps Beside Blocking Press Houses	200	-1	1,065	
125F	Recovery of Low-Pressure Steam from Hot Condensate	28,425	-	52,885	
126F	Condensate Return from NAC-SAC and AOP Areas	34,073	-	68,017	
**	Deactivate Steam Line to 4th Rolled Powder Area	25,000	-	46,750	
**	Implement Steam Trap Maintenance Program	40,950	-	76,576	
**	Repair Steam Leaks in Pressurized Lines	66,250	-	123,888	
SUBTOTAL		438,565	-2,309	3,865,416	12.46

Project No.	Description	ENERGY SAVINGS Coal (MBTU)	Electricity (MBTU)	Dollar Savings	Percent of Base-Wide Energy Reduction
PROCESS PROJECTS					
T-101	Individual Bay Heaters for FAD Houses	3,352	-	15,284	
T-104	Heat Pipe for FAD Houses	63,446	-3,097	306,448	
T-103	Heat Recovery for Curing Houses	11,465	-616	58,723	
WO-114G	Water Dry Tank Covers	1,973	-	322,810	
119F	Insulate Six Adsorber Tanks in Activated Carbon Buildings	1,869	-	3,495	
121F	Insulate Air Heaters in Blower Houses of FADs and Curing Houses	1,264	-	8,889	
124F	Heat Recovery from Waste Explosive Incinerator After-burners	2,083*	-	13,796	
**	Reduce Cycle Time at FAD Operation	11,825	-	22,113	
**	Eliminate Drying of Wood Pulp Prior to Nitration	9,650	-	18,046	
**	Eliminate Drying of Cotton Linters Prior to Nitration	13,500	-	25,245	
SUBTOTAL		118,344 (COAL) 2,083 (#2 FUEL OIL)	-3,713	794,849	3.33
TOTAL		593,910 (COAL) 2,083 (#2 FUEL OIL)	2,091	4,839,860	17.08

*Fuel Oil Savings (MBTU)
**Energy Modifications Since 1981

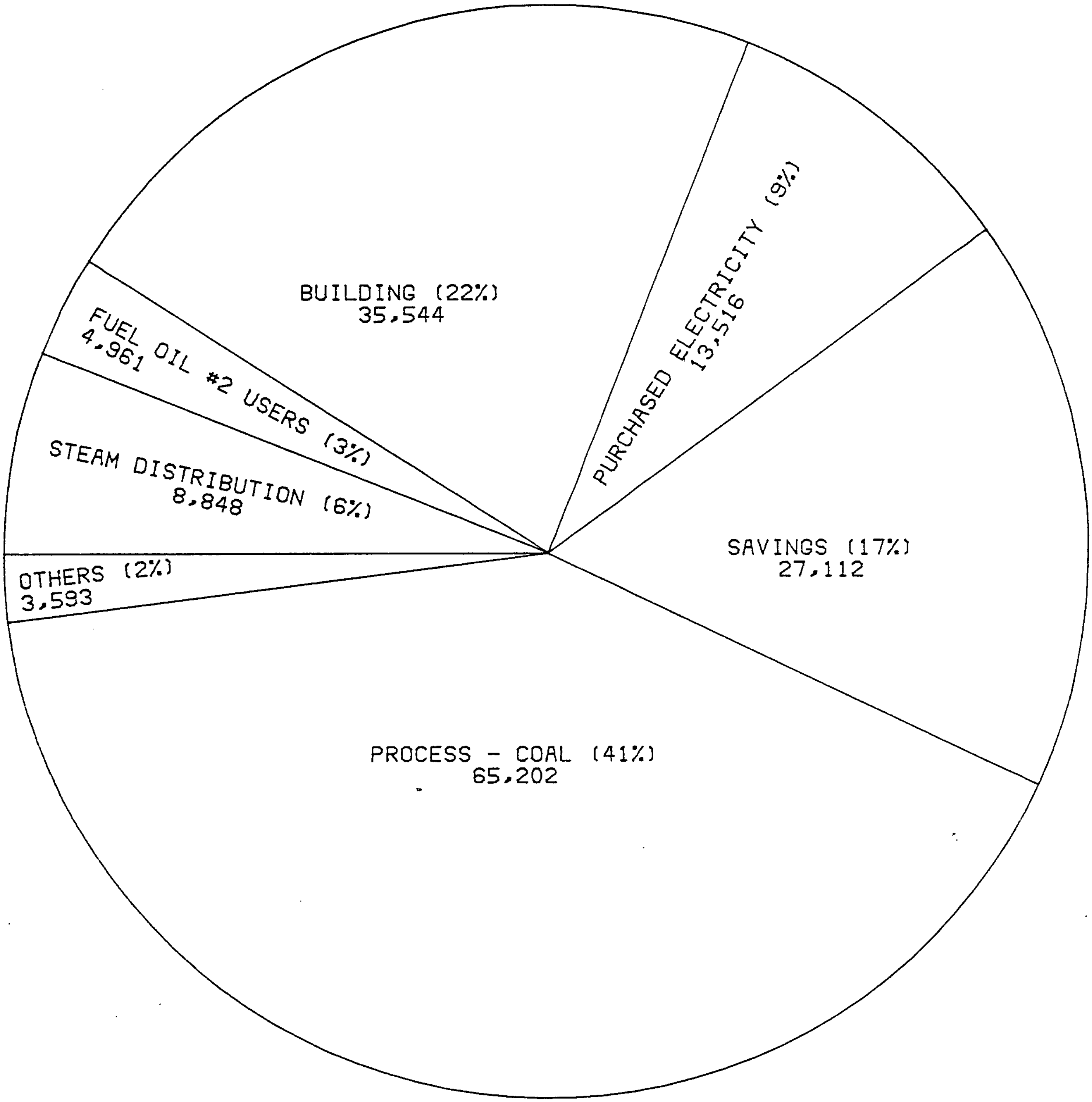

FIGURE 2, PLANT-WIDE CONSUMPTION
AFTER A&E ECIP PROJECTS
131,664 BTU/LB OF PROPELLANT

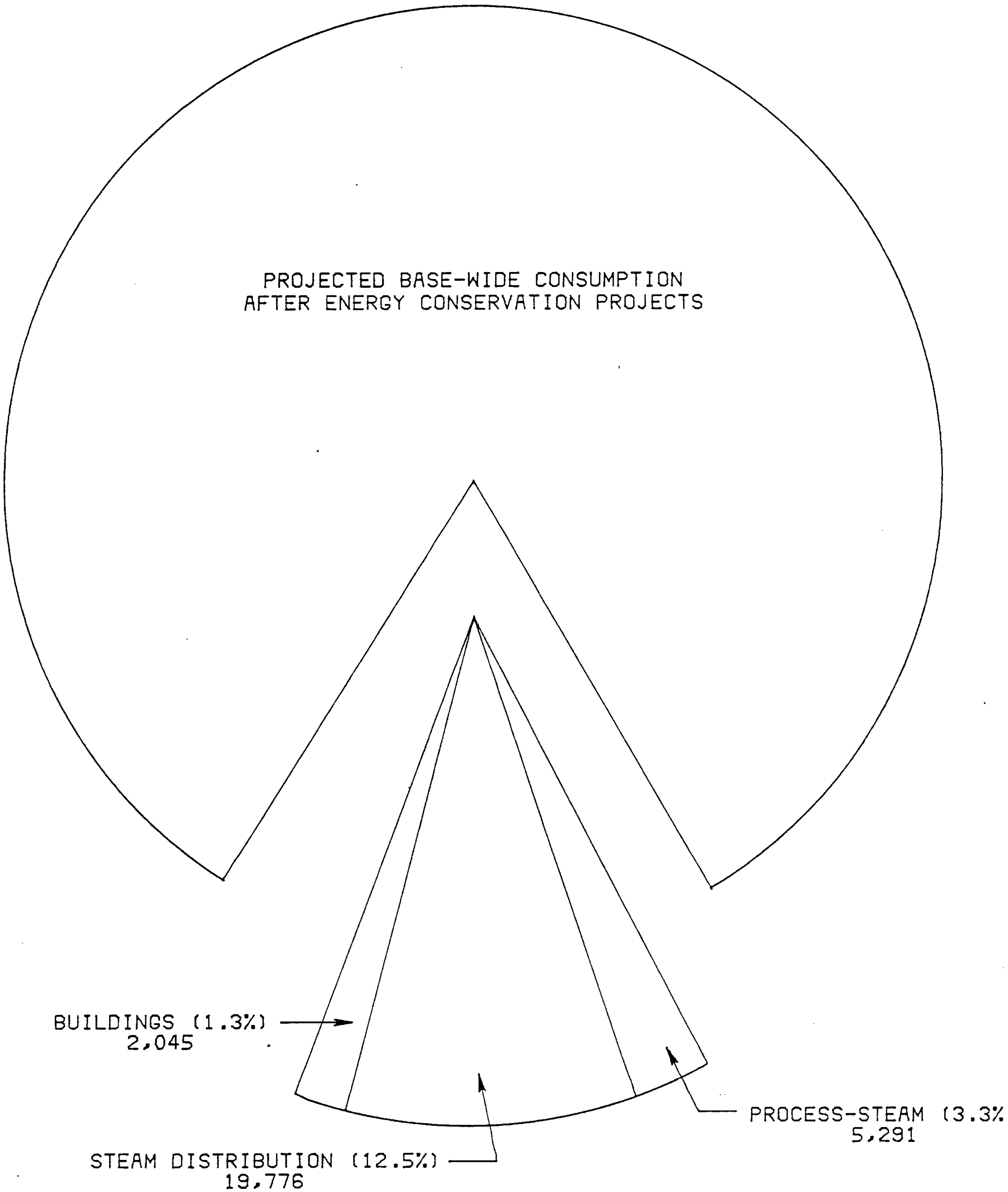

FIGURE 3. ALLOCATION OF ENERGY CONSERVATION SAVINGS 27,112 BTU/LB OF PROPELLANT

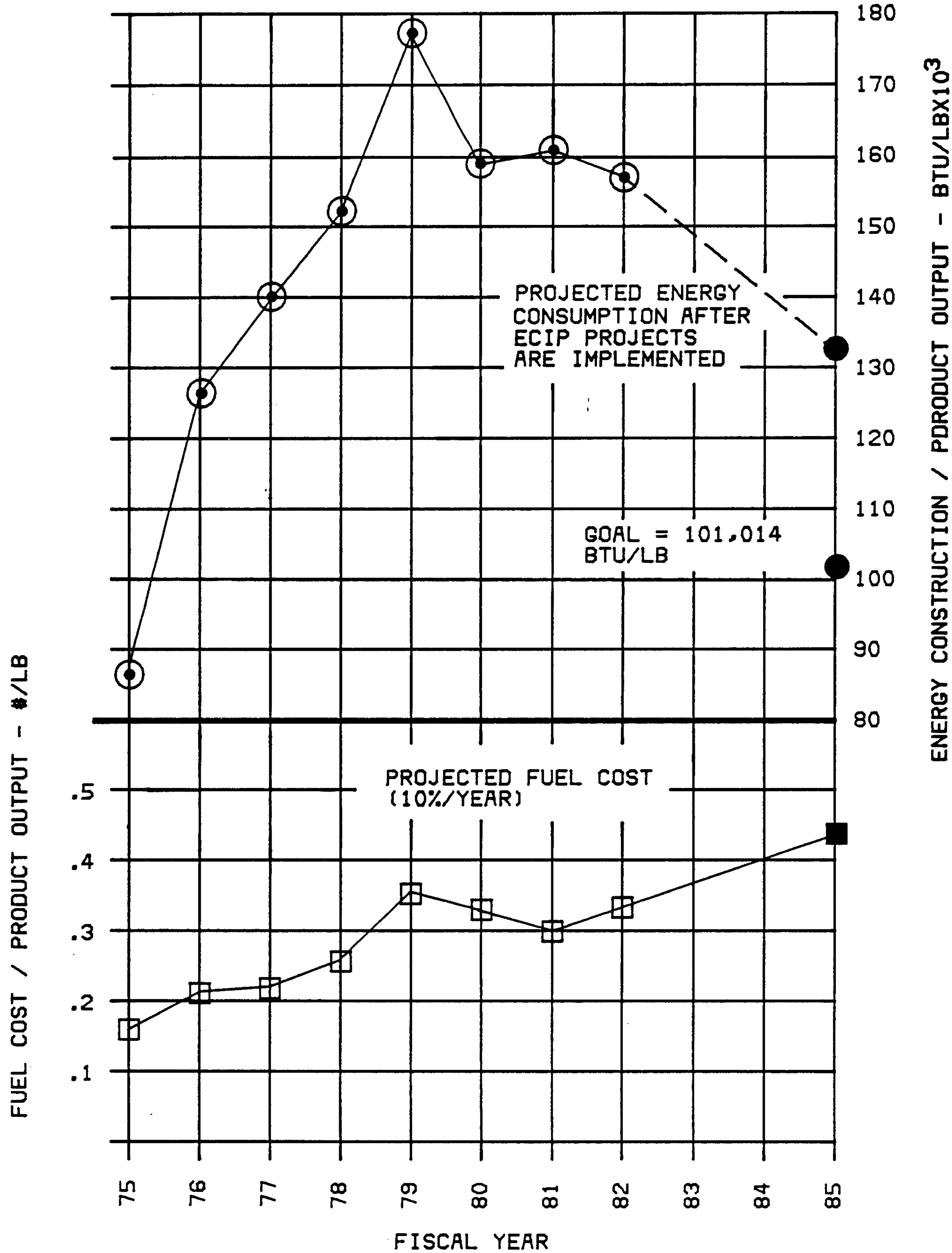

FIGURE 4, FUEL COST AND ENERGY CONSUMPTION PER POUND OF PRODUCT

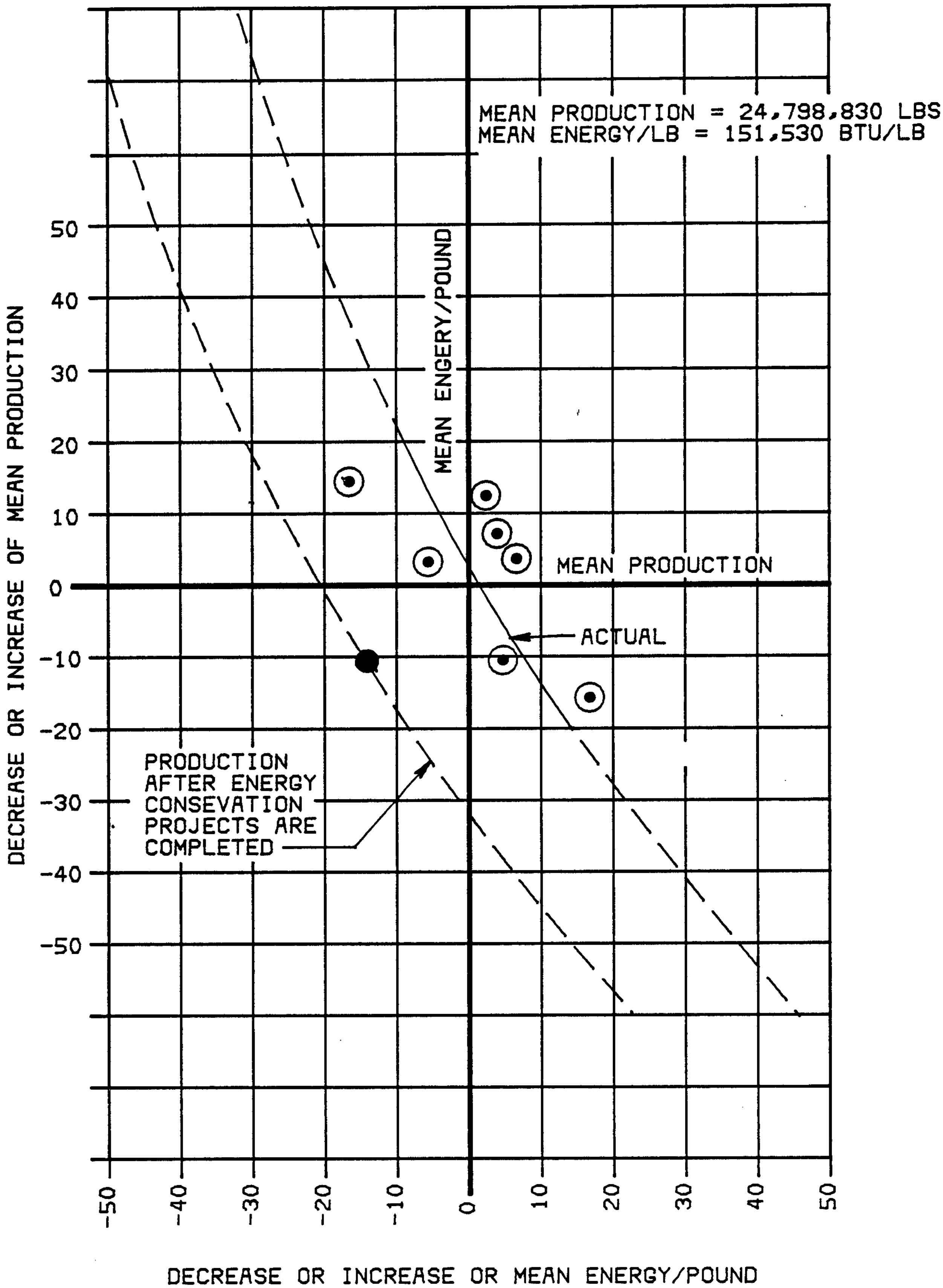

FIGURE 5, PLANNING USE MODEL