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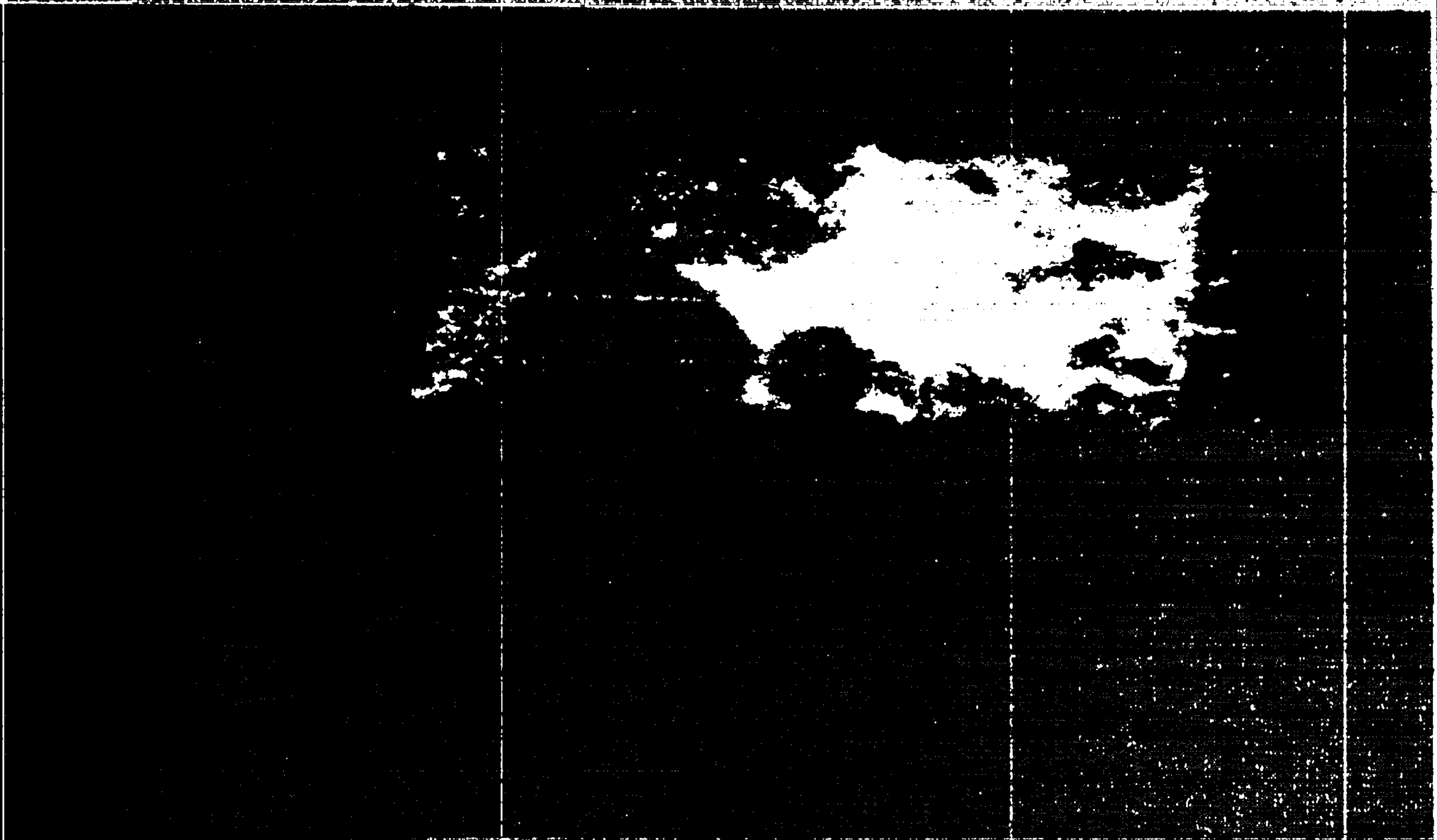

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Predictions of Energy Requirements

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SUPPLEMENTARY DOCUMENTATION FOR AN ENVIRONMENTAL IMPACT STATEMENT REGARDING THE PANTEX PLANT:

PREDICTIONS OF ENERGY REQUIREMENTS

by

N. M. Schnurr

ABSTRACT

This report documents work performed in support of the preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's Pantex Plant near Amarillo, Texas. Energy requirements for each of the alternatives addressed in the EIS are discussed in this report. The present consumption of natural gas and electricity at the Pantex Plant is analyzed, and methods of reducing energy use are investigated. Predictions of energy requirements for all alternatives are developed.

I. INTRODUCTION

This report documents work performed in support of the preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy's Pantex Plant near Amarillo, Texas. That EIS addresses continuing nuclear weapons operations at Pantex and the construction of additional facilities to house those operations. The EIS was prepared in accordance with current regulations under the National Environmental Policy Act. Regulations of the Council on Environmental Quality (40 CFR 1500) require agencies to prepare concise EISs with less than 300 pages for complex projects. This report was prepared by Los Alamos National Laboratory to document details of work performed and supplementary information considered during preparation of the Draft EIS.

This report addresses the annual energy consumption for each alternative discussed in the EIS as listed in Table I. The present consumption of energy at the Pantex Plant is analyzed, and methods of reducing energy use are investigated. Predictions of energy requirements for all alternatives are developed.

TABLE I

LIST OF ALTERNATIVES FOR THE PANTEX PLANT
ENVIRONMENTAL IMPACT STATEMENT

	Pantex Alternatives
P-1	New construction
P-2	Total Plant upgrade
P-3	Total Plant replacement
P-4	Existing facilities only, "No Action"
P-5	Mitigation measures
	Iowa Army Ammunition Plant Alternatives
B-1	Partial relocation
B-2	All new Plant
	Hanford Alternative
H-1	All new Plant
	Termination Alternative
T-1	Close Pantex

II. ANALYSIS

The procedure used to predict the total annual energy consumption was divided into the following steps.

1. Energy use at the Pantex Plant was analyzed to determine the amount consumed for various purposes. The heating, ventilating, and air conditioning (HVAC) requirements were of particular interest.

2. Energy conservation measures were analyzed to determine potential savings at the Pantex Plant.

3. Estimates of HVAC energy requirements for new facilities at Pantex were obtained.

4. The effect of weather on HVAC energy usage was analyzed to predict energy consumption for the old buildings at the Iowa Army Ammunition Plant (IAAP) and for new construction at the IAAP and Hanford.

5. Results of steps 1 through 4 were used with architectural data to compute the predicted total energy consumption for each alternative.

Details of each step are discussed in the remainder of this section.

A. Energy Use at the Pantex Plant

The Pantex Plant consists of more than 250 separate buildings having a total floor space of approximately 140 000 m^2. The energy consumed at the Pantex Plant is primarily in the form of electricity and natural gas. Gasoline is used for operation of the facility vehicles, and some fuel oil is reserved for standby operations of emergency generators and boilers. Gasoline represents less than 3% of the total energy consumption within the Plant boundaries, however, and consumption of fuel oil is negligible (USDOE 1976). Replacement of existing vehicles with more fuel-efficient models and more compact Plant designs of alternatives involving all new construction are expected to result in significantly lower gasoline consumption for all alternatives. This study, therefore, concentrates only on natural gas and electricity.

Consumption of natural gas and electricity for the past 10 years is listed in Table II. The total size of the Plant measured in square meters of

TABLE II

ENERGY USE AT THE PANTEX PLANT

Year	Electricity (GWh)	Natural Gas (10^6 m^3)*	Floor Space (10^3 m^2)
1972	40.1	22.7	118.7
1973	36.7	20.1	121.7
1974	34.4	18.0	127.3
1975	36.3	18.2	131.4
1976	35.3	17.2	131.6
1977	36.7	15.0	135.6
1978	39.0	16.5	137.2
1979	39.7	14.4	139.0
1980	39.9	12.6	148.5
1981	39.8	10.5	148.5

*Average heating value of natural gas = 37.48 MJ/m^3.

floor space is also given. Total electrical consumption has remained nearly constant, while the Plant has increased in size by 25%. The electrical energy savings resulted from replacement of lamps with more efficient ones and raising the thermostat settings for cooling. Consumption of natural gas has decreased by more than 50%. These savings were primarily achieved by eliminating heating of ramps, lowering thermostat settings in winter, lowering steam pressure, shutting off sections of steam line when not in use, and making improvements in the condensate return system.

An exact breakdown by end use for current energy consumption at the Pantex Plant cannot be obtained because of insufficient monitoring. A study was carried out, however, for 1973 energy consumption (USDOE 1976). The results of that study are given in Table III. We assume the same fractional breakdown can be applied with reasonable accuracy to current energy usage.

It is desirable to determine heating and cooling loads and the amounts of energy used for heating and cooling. These values can be inferred from the data of Table III and information in Beck 1981. That report includes a list of HVAC equipment for all Pantex Plant facilities. A study of the existing heating and cooling equipment indicates that heating is done by steam generated from natural gas for buildings having 93% of the total floor space, by electrically driven heat pumps for 5% of the total floor space, and

TABLE III

PANTEX PLANT ENERGY USE BREAKDOWN, 1973

	Fraction
Electricity	
Air conditioning and heating	0.62
Building lighting	0.25
Ramp lighting	0.03
Security lighting	0.03
Manufacturing operations	0.07
	1.00
Natural gas	
Steam - Heating and cooling	0.88
- Process use*	0.10
Pumping water	0.02
	1.00

*This quantity is estimated based on a survey of process equipment capacities.

electric boilers for the remaining 2%. Cooling is by electrically driven vapor-compression systems for 98.5% of the total floor space and by absorption refrigeration using steam generated by natural gas for the remaining 1.5%. The efficiency of energy delivery for the steam plant, including heat losses in the steam lines, is approximately 75%. Coefficients of performance are assumed to be 2.5 for heat pumps, 2.0 for vapor-compression refrigeration, and 0.7 for absorption refrigeration systems.

The current consumption of natural gas for heating and cooling is $(0.88)(10.5 \times 10^6) = 9.24 \times 10^6$ m^3. The corresponding energy is 96.1 GWh. Then

$$(0.93/0.75)\ Q_H + (0.015)/(0.75)(0.7)\ Q_C = 96.1\ , \qquad (1)$$

where Q_H and Q_C are the total heating and cooling loads, respectively. The first term in Eq. (1) represents steam heating and the second is absorption cooling. The consumption of electricity for heating and cooling is

$$(0.05/2.5)\ Q_H + (0.02)\ Q_H + (0.985/2.0)\ Q_C = 24.7\ . \qquad (2)$$

The three terms on the left side of Eq. (2) represent heat pumps, electric boilers, and vapor-compression coolers, respectively. The consumption of electricity (24.7 GWh) for HVAC use is 62% of total 1981 consumption.

Simultaneous solution of Eqs. (1) and (2) gives a total annual heating load of 76.5 GWh and cooling load of 43.9 GWh. Annual consumption of natural gas and electricity for heating and cooling is then computed from individual terms of Eqs. (1) and (2). Consumption for lighting, manufacturing, and process use is computed from the data of Tables II and III. These results are normalized with respect to total conditioned floor space (122 400 m^2)* and are summarized in Table IV.

*This figure does not include ramps and buildings that are not heated or cooled.

TABLE IV

BREAKDOWN OF ANNUAL ENERGY USE FOR CURRENT PANTEX PLANT FACILITIES

	Electricity ($kWh/m^2 \cdot yr$)	Natural Gas ($kWh/m^2 \cdot yr$)
Space heating	25	775
Cooling and dehumidifying	176	10
Process, lighting, and miscellaneous	124	107
Total	325	892

B. Energy Conservation at the Pantex Plant

Most existing buildings at the Pantex Plant were constructed during an era when energy was relatively inexpensive. As a result, those structures are very energy inefficient. Several measures could be taken to reduce the heating and cooling loads. The three that would result in the largest energy savings are decreasing infiltration rates, adding insulation, and installing an Automated Energy Management System (AEMS).

An inspection of several facilities at Pantex and discussions with Mason and Hanger-Silas Mason personnel indicate that infiltration losses are large. Actual measurement of infiltration is very costly, however, and the number of buildings is large so that quantitative data are not available. No estimate of potential energy savings of infiltration losses is made in this report. It does appear that such savings could be substantial.

Most Pantex facilities used for production or fabrication have thick concrete walls and ceilings with no insulation. Experience has shown that insulation for ceilings is usually more cost effective than wall insulation, particularly in cases where earth berms are placed against walls. The energy saving that could be realized by the addition of R-30 insulation in the ceilings is computed as follows.

Assume concrete roofs having a thickness of 0.30 m.* The unit conductance including film resistance at the inside and outside surfaces is 1.76 $W/m^2{\cdot}K$ (ASHRAE 1981) and the ceiling area is 122 400 m^2. The heat loss through the ceiling for a typical winter having 2214°C·days is (24)(2214)(1.76)(122 400) = 1.5 GWh. The addition of R-30 insulation would reduce the conductance from 0 to 18 $W/m^2{\cdot}K$ and the heat loss through the ceiling to 1.2 GWh. The heating load would be decreased by 10.6 GWh.

The effect of ceiling insulation on the cooling load is very difficult to calculate accurately because the cooling load is highly dependent on transient effects related to solar radiation and building mass. Large thermal mass, even without insulation, is effective in minimizing the cooling load, and the addition of insulation would not be expected to have as large an effect on the cooling load as on the heating load. The conservative approach taken here is to neglect the savings in cooling energy requirements that would result from the addition of ceiling insulation.

A feasibility study for an AEMS for the Pantex Plant has been made by R. W. Beck and Associates (Beck 1981). They considered a large number of options including space temperature setback, optimized start/stop, supply air temperature reset, duty cycling, monitoring, shutdown, and optimization of

*The computation of energy saving is relatively insensitive to ceiling thickness.

various equipment. Potential energy savings and predicted costs were computed for various combinations of options. The AEMS that they recommend is predicted to decrease natural gas consumption for heating and cooling by 33% and electrical consumption for heating, cooling, and lighting of buildings by 17%.

The effect of ceiling insulation on energy consumption is estimated by computing all terms on the left sides of Eqs. (1) and (2) using $Q_C = 43.9$ GWh and $Q_H = 76.5 - 10.6 = 65.9$ GWh. Each term corresponding to natural gas consumption is then reduced by 33% and the electrical energy terms are reduced by 17% to account for the AEMS. Natural gas usage for processes energy is unchanged, but the electrical energy for lighting is reduced by 17%. All terms are divided by total floor area and the results are given in Table V.

C. Energy Requirements for New Facilities at the Pantex Plant

Only preliminary designs have been completed for all-new facilities. These designs do not include selection of insulation, types of windows, nor HVAC systems, so that direct calculations of heating and cooling loads are precluded. It is assumed, however, that the new construction would follow guidelines similar to the Building Energy Performance Standards (BEPS) developed by the DOE (USDOE 1978).

The BEPS guidelines are given in the form of total energy budgets (HVAC and lighting) for various types of buildings and locations within the United States. Values for Amarillo, Texas, are mostly in the range of 315 to 473 $kWh/m^2 \cdot yr$. We select a value of 394 $kWh/m^2 \cdot yr$ as a reasonable target for the HVAC energy budget for new facilities. Typically, lighting energy represents a small fraction of the energy budget. For the facilities considered here, however, the requirements of withstanding blast damage preclude the use of

TABLE V

BREAKDOWN OF PREDICTED ANNUAL ENERGY USE FOR CURRENT PANTEX PLANT FACILITIES WITH AEMS AND CEILING INSULATION

	Electricity (kWh/m^2)	Natural Gas (kWh/m^2)
Space heating	14	447
Cooling and dehumidifying	147	8
Process, lighting, and miscellaneous	107	107
Total	268	562

daylighting and result in unusually large lighting energy. We do not include lighting in the BEPS budget but treat it as a separate item.

The design energy budget is the sum of weighted values of energy from various sources. The weighting factors proposed by DOE for commercial buildings are 1.0 for natural gas and 3.08 for electricity. We assume the new facilities will use 2.82 times as much HVAC energy from natural gas as from electricity (as do existing buildings with AEMS and ceiling insulation). The HVAC energy usage for new buildings at Pantex based on these assumptions is 67 $kWh/m^2 \cdot yr$ of electrical energy and 188 $kWh/m^2 \cdot yr$ for natural gas.* Process and lighting requirements, per unit of floor area, are assumed to be the same as for the existing plant with energy conservation measures. Results for the case of all new construction at Pantex are summarized in Table VI.

D. Energy Requirements at the IAAP and Hanford Site

Heating and cooling loads depend on the building envelope (wall materials, thickness, insulation, window types, etc.), the HVAC system and its operation, and the local weather. We assume the facilities at the IAAP and Hanford Site are identical to those at the Pantex Plant. Heating and cooling loads are estimated by adjusting the loads for Pantex Plant facilities to account for the effects of weather.

The important weather parameters used in HVAC system design are given in Table VII (ASHRAE 1980, 1981). Heating loads are very nearly proportional to

*We assume that all heating is done with natural gas and all cooling is done by electricity for the all-new construction case.

TABLE VI

BREAKDOWN OF PREDICTED ANNUAL ENERGY USE FOR ALL NEW FACILITIES AT THE PANTEX PLANT

	Electricity (kWh/m^2)	Natural Gas (kWh/m^2)
Space heating	---	188
Cooling and dehumidifying	66	---
Process, lighting, and miscellaneous	107	107
Total	173	295

TABLE VII

DESIGN WEATHER CONDITIONS

	Days (°C)	T_{DB} and Mean* Coincident T_{WB}** (°C)	Enthalpy (kJ/kg)
Amarillo, Texas (Pantex Plant)	2214	35/20	73.5
Burlington, Iowa (IAAP)	3397	33/24	89.5
Hanford, Washington (Hanford Site)	2669	35/19	71.4
Supply condition		13/8	42.2

*T_{DB} = dry bulb temperature.
**T_{WB} = wet bulb temperature.

degree days. The heating loads at the Hanford Site and IAAP are 1.21 and 1.53 times larger than at the Pantex Plant, respectively.

The cooling load dependence on weather is more complex because it depends on dry bulb temperature, relative humidity, and solar insolation. The effect of weather may be estimated by determining the amount of energy that must be removed from outside air at the design dry bulb and mean coincident with bulb temperatures to produce supply air at a typical condition of 13 and 8°C (50% relative humidity).* This procedure accounts for the dehumidification, as well as the cooling, required. The heat removal rates are proportional to enthalpy differences between outside air and the specified design conditions (Table VII). Based on this approach, cooling loads at Hanford Site and IAAP are estimated to be 0.93 and 1.51 times as large as those for similar facilities at the Pantex Plant, respectively.

The first IAAP alternative (B-1 in Table I) uses existing facilities at the IAAP. Those buildings are very similar to buildings at Pantex (MHSM 1972) and are assumed to have the same thermal characteristics. Using predicted energy consumption rates from Table IV, V, and VI and weather factors for cooling and heating developed in this section, it is now possible to estimate HVAC energy requirements for the various types of facilities at all three locations. These are summarized in Table VIII.

*A few cells require lower relative humidity, but an average value of 50% for all facilities is satisfactory.

TABLE VIII

PREDICTED HEATING AND COOLING ENERGY REQUIREMENTS FOR FACILITIES AT THE PANTEX PLANT, IAAP, AND HANFORD SITE

	Natural Gas ($kWh/m^2 \cdot yr$)		Electricity ($kWh/m^2 \cdot yr$)	
	Heating	Cooling	Heating	Cooling
Pantex Plant				
Existing buildings	775	10	25	176
Existing buildings with ceiling insulation and AEMS	447	8	14	147
New buildings	188	--	--	66
Iowa Army Ammunitions Plant				
Existing buildings	1186	15	38	266
Existing buildings with ceiling insulation and AEMS	684	12	21	222
New buildings	288	--	--	100
Hanford Site				
New buildings	227	--	--	62

E. Energy Consumption for Various Alternatives

The floor space for each Pantex Plant EIS alternative is given in Table IX. These data are used with data from Table VII to compute HVAC energy requirements for each alternative. Process, lighting, and miscellaneous energy requirements are taken from Table IV for old buildings and from Table V for old buildings with energy conservation measures (AEMS and ceiling insulation) and for new buildings. Results for all alternatives and options are given in Table X. Note that Pantex Plant option No. 5, mitigation measures, corresponds to the addition of the AEMS and ceiling insulation in conjunction with other alternatives.

III. CONCLUSIONS

Estimates of energy usage for all Pantex Plant EIS alternatives have been computed. The effects of potential energy conservation options including the addition of ceiling insulation and an automated energy management system have been investigated. Energy consumption is given for both electricity and natural gas.

TABLE IX

FLOOR SPACE FOR PANTEX PLANT ENVIRONMENTAL IMPACT STATEMENT ALTERNATIVES*

Option	Location	Old Buildings (m^2)	New Construction (m^2)
P-1	Pantex Plant	123 000	20 500
P-2	Pantex Plant	82 000	126 000
P-3	Pantex Plant	0	208 000
P-4	Pantex Plant	123 000	8 370
B-1	Pantex Plant	123 000	8 370
	IAAP	33 000	560
B-2	IAAP	0	208 000
H-1	Hanford Site	0	208 000
T-1	---	0	0

*This includes only facilities that are heated or cooled.

TABLE X

TOTAL ANNUAL ENERGY CONSUMPTION FOR PANTEX PLANT ENVIRONMENTAL IMPACT STATEMENT ALTERNATIVES

Alternative	Option*	Natural Gas (GWh)	Electricity (GWh)	Total (GWh)
P-1	A	116	44	160
	B	75	37	112
P-2	A	110	48	158
	B	83	44	127
P-3	--	61	36	97
P-4	A	112	41	153
	B	72	34	106
B-1	A	156	56	212
	B	99	46	145
B-2	--	82	43	125
H-1	--	69	35	104
T-1	--	0	0	0

*Option A - Old buildings are unchanged.
Option B - Automated energy management systems and ceiling insulation added to old buildings.

It should be emphasized that these estimates apply only to specific cases based on given assumptions and can be considered valid predictions only to the extent that an option that may be selected is consistent with those assumptions.

Accuracy of these estimates varies depending on the method used and data available. Annual energy consumption estimates for existing structures are based on measured consumption and are believed to be accurate to ±10% for a year having average weather. Estimates for alternatives including old buildings with energy conservation measures are believed to be accurate to ±20%. Estimates for those alternatives having all new construction are based on more questionable assumptions and may be in error by 25 to 50%.

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