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TITLE: COMPARISON OF DOE-2 COMPUTER PROGRAM SIMULATIONS TO METERED DATA FOR SEVEN COMMERCIAL BUILDINGS.

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MASTER

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COMPARISON OF DOE-2 COMPUTER PROGRAM
SIMULATIONS TO METERED DATA FOR SEVEN
COMMERCIAL BUILDINGS

by

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ABSTRACT

As part of the DOE-2 Verification Project being conducted by the Los Alamos Scientific Laboratory, seven existing commercial buildings were simulated using the DOE-2 computer program. These buildings included a restaurant, single-floor office building, retail store, hospital, multifloor office building, school, and solar-heated and -cooled building.

This comparison test required each building to be simulated by a separate contractor or national laboratory. Predictions of the DOE-2 computer program were then compared to the utility company monthly metered data. Results of these comparisons for gas/fuel oil use, electric energy use, and total energy use are reported.

INTRODUCTION

The DOE-2 (formerly DOE-1) Verification Project began in 1978 with the preparation of a verification program plan[1] by the Los Alamos Scientific Laboratory (LASL). This plan outlined the tasks to be completed and identified relevant work being conducted outside the LASL project. The methodology adopted for implementing this project was then presented.[2]

Work on Phase I of the DOE-2 Verification Project, which involves comparisons of one-year reference-run simulation results with measured monthly energy consumption data, is nearly complete. An overview of the Phase I work has been presented[3] and a comprehensive interim report[4] detailing all of the LASL DOE-2 verification work to date, as well as relevant outside projects pertaining to the DOE-2 computer program, will be published in the near future. Only the Phase I reference-run comparisons are reported in the present paper.

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APPROACH

Complete verification or validation of a computer program as large, sophisticated, and detailed as DOE-2 is a most difficult task. Even if the program is regarded as verified at some acceptable level, questions may still arise concerning the validity of results obtained by users who are not familiar with the limitations of the program. Therefore, it is necessary to define first what is meant by the term "verification" as it applies to the DOE-2 program, and then to determine how the results of this project can best be applied by the user. Verification, in this case, is defined as the substantiation of energy-use predictions obtained using the DOE-2 program by establishing the level of accuracy of the program within quantified limits.

The DOE-2 program is an interactive set of simulations of real systems. These real systems comprise a building structure; heating, ventilating, and air-conditioning (HVAC) systems and plant equipment; and the building's site and microenvironment. In modeling these real systems, assumptions (approximations) must be made (for example, ignoring negligible second-order effects). To obtain a completely correct model would require infinite detail, and would thus be impossible. Therefore, the verification of the real-system simulations of DOE-2 centers on determining the range of applicability (limitations) of the model and the level of accuracy within this range.

Thus, the primary purpose of verifying DOE-2 is to give users confidence that DOE-2 can accurately predict the energy consumption and thermal behavior of new building designs, design alternatives, or retrofit alternatives. User confidence that DOE-2 can accurately predict the performance of building designs is especially important in the implementation of the Building Energy Performance Standards.[5] While a comparison of empirical versus simulated data is necessary to develop user confidence in the validity of the program, the comparison should be made on the basis of the measured data of most significance to the building designer/analyst in the context of building energy performance. Furthermore, the comparison should be made with the limitations of the program taken into account. The approach used here involves comparisons of simulated versus utility measured data, on a monthly and annual basis, data that reflect the actual energy consumption of the building as seen by the building owner or operator. Also, these comparisons reflect the fact that the simulated results are affected by the judgement of the user in translating the building construction and operating data into

DOE-2 input. Because the user in this reference-run exercise has the most accurate and complete building information that is feasible to be obtained, this judgement has been left entirely up to the reference-run contractor. This implies that the simulated results are uncertain to the extent of the accuracy of the judgement made in translating the building data into DOE-2 input. This uncertainty must be considered in analyzing the comparisons.

PARTICIPANT SELECTION

The reference-run part of the DOE-2 Verification Project involved comparisons made to existing building energy consumption data in an uncontrolled environment. This manner of test, although not yielding an accuracy level directly applicable to any building or system except those tested, provides users with a good indication of the program's usefulness and accuracy as a design/analysis tool.

LASL selected seven building types representative of the most often constructed commercial buildings. The following building types were selected.

- Restaurant
- Single-floor office building
- Retail store
- Hospital
- Multifloor office building
- School
- Solar-heated and -cooled building

Contractors were selected for the first five building types by response to a competitive bid Request For Proposal (RFP); simulations of the solar building and the school were done by LASL and Lawrence Berkeley Laboratory (LBL), respectively. Selection was made on the basis of contractor/building pairs. That is, each contractor submitting a proposal was required to propose an existing building that fit one of the building categories. Selection was based on the technical capabilities of the contractor, the appropriateness of the candidate building and its metered data, and the proposed cost of the effort.

At a minimum, monthly utility metered data were required, but preference was given for available energy consumption data taken at more frequent time intervals or for submetered data. Because of budget limitations, proposals incorporating owner- or operator-measured data were not selected. All contractors selected presented utility-metered data.

SELECTED BUILDINGS

The following buildings were chosen for the comparisons.

Restaurant

A large family restaurant in Downers Grove, Illinois, was selected. The building has a gross floor area of approximately 1,970 m^2 (21,200 ft^2) and consists of complete cooking and food-storage facilities, a main dining room, a private dining room, cocktail lounge, and management offices. The building envelope is hollow-core concrete block with vermiculite-fill insulation. All windows are double-glazed and nonoperable. Occupancy varies from a low of 400 to a maximum of 1400 people per day. The restaurant is open for business from 11:00 a.m. to 11:30 p.m. Sunday through Thursday, from 11:00 a.m. on Friday to 12:30 a.m. on Saturday, and from 11:00 a.m. on Saturday to 1:30 a.m. on Sunday. Lighting is a combination of fluorescent and incandescent; the majority of the lights are operated 24 hours per day.

The main thermal loads of the building are the process loads consisting primarily of cooking and dishwashing. The highest equipment load, 185 kW (630,500 Btu/h), occurs in the kitchen area during the evening on weekends. Approximately 85 per cent of this thermal load is exhausted. Energy use for hot water reaches a peak of 293 kW (1.0 x 10^6 Btu/h) on weekends.

The building HVAC system consists of two constant-volume, variable-temperature, multizone air systems with radiative (hot water) heating around the building perimeter. Reheat coils are provided in individual zones for humidity control. Sixteen exhaust fans are provided for the kitchen, dining rooms, employee locker rooms, and toilets. The plant equipment includes two gas-fired boilers rated at 660 kW (2.25 x 10^6 Btu/h) each and two reciprocating electric chillers rated at 280 kW (80 tons) each.

Single-Floor Office Building

A single-floor bank office building, located in Santa Cruz, California, was selected. The single-floor structure of approximately 600 m^2 (6,500 ft^2) gross floor area has a very small mechanical room/penthouse. Construction is essentially insulated frame walls, built-up roof, and concrete-slab floor. All windows are 1.3 cm (1/2-in.) solar-gray glass.

Maximum occupancy is approximately 120 people, and the maximum internal equipment load is estimated to be 18.2 kW. Three thermostatically controlled zones are served by a constant volume reheat system, with plant equipment consisting of a 70 kW (240,000 Btu/h) hot water boiler and a 91 kW (26-ton) direct-expansion reciprocating chiller. The office is open for business from 8:00 a.m. to 5:00 p.m., Monday through Friday.

Retail Store

A privately owned retail clothing store located in Albuquerque, New Mexico, was used. The store has an approximate gross floor area of 3,027 m^2 (32,580 ft^2) with an open-air parking lot located beneath a large portion of the structure. The building exterior is precast concrete except for the store front that is face brick with a very small glass area. The interior is an open arrangement with access primarily through two main doors. Occupancy varies from a maximum of approximately 300 people on "regular" days to a maximum of approximately 1300 people on preholiday and sale days. Thermal loads within the building include lighting that is primarily flourescent, with some incandescent lighting used for displays. The store is open for business on Monday, Wednesday, and Friday from 10:00 a.m. to 9:00 p.m.; Tuesday, Thursday, and Saturday from 10:00 a.m. to 5:30 p.m.; and is closed on Sunday.

The main mechanical system servicing the above-ground spaces is a multizone air system with six zone air-handling units. The plant equipment consists of a gas-fired, hot water boiler rated at 850 kW (2.9×10^6 Btu/h), a direct expansion chiller rated at 300 kW (86 tons), and an indoor wet cooling tower. The small underground area is heated by three two-pipe fan coil units and is cooled by two packaged electric chillers rated at 26 (7.5) and 14 kW (4 tons) each.

Hospital

A 46,450 m^2 (500,000 ft^2) central hospital located in Chattanooga, Tennessee, was selected for this test. The structure, built in eight phases starting in 1938, has several wings with one to five floors in each. The large building size required the use of 90 zones for a detailed simulation. Approximately 10 different wall constructions and 5 different roof sections were used. The building has 13 different lighting profiles and 17 different base loads, as well as a high outside air requirement. Operation is on a 24 hour per day schedule.

The HVAC system is as complex as the structure itself. It consists of 4 variable air volume systems, 4 variable air volume with reheat systems, 10 constant volume single-zone systems, and 6 four-pipe fan coil systems.

Multifloor Office Building

A three-story structure, housing the main offices of a large restaurant chain, was selected. The building is located in Dayton, Ohio, and has a gross floor area of approximately 5,980 m^2 (64,400 ft^2). A distinguishing feature is an exterior, sloped, north-facing, silver-tone glass, curtain wall. With the exception of a glassed-in entrance way, the remaining portion of the envelope is composed entirely of gray granite block. The mechanical system consists of two large and one small constant-volume reheat systems servicing approximately 46 zones on the three floors. The plant equipment consists of two oil-fired chillers rated at 492 kW (1.68 x 10^6 Btu/h), two equivalent-capacity electric boilers, two 534-kW (152-ton) centrifugal chillers, and a 440-liter (115-gal) domestic hot water (DHW) heater using three 18-kW electric heaters. A separate computer room, operating 24 hours per day, has two 74-kW (21-ton) room air-conditioners, each of which includes a 5.6-kW (7-1/2-hp) fan, a 14-kW, two-stage electric reheat coil, and a 7-kW electric humidifier. The computer room equipment load is estimated to be 59 kW (200,000 Btu/h). Peak occupancy for the building is 200 people on a work schedule of 8:00 a.m. on Monday through 2:00 p.m. on Saturday. Internal equipment loads (exclusive of the computer room) are estimated to be 20 kW maximum.

School

An elementary school in Kennewick, Washington, that was part of the Lawrence Berkeley Laboratory (LBL) school energy conservation program, was simulated. The three wing, single-story building houses 20 regular class rooms, a library, a multipurpose room, a serving kitchen, and an administration area, and has an approximate gross floor area of 3,690 m^2 (40,000 ft^2). The structure has masonry walls and a steel deck roof with a 50 percent window (glass) area. Lighting is of the incandescent type throughout.

The HVAC system has unit ventilators in three zones heated by a 1600 kW (5.4 x 10^6 Btu/h) gas fired boiler. Occupancy is from 8:00 a.m. to 3:45 p.m., Monday through Friday; the school year starts in early September and ends in mid June.

Solar-Heated and -Cooled Building

The National Security Resources and Study Center (NSRSC) located in Los Alamos, New Mexico, was used for this building type. This solar-heated and -cooled structure encompasses approximately 5,800 m^2 (62,500 ft^2) of gross floor area. Solar energy is collected by a 716 m^2 (7,705 ft^2) array of oil-cooled flat-plate collectors.

The HVAC system is principally a two-zone (perimeter and interior) variable air volume system with separate supply and return fans and cooling coils for each zone. Hot water coils for heating are provided in the perimeter zone only.

The air-handling system features recirculation of inside air. A heat-pipe heat-recovery unit in the perimeter zone system serve two functions: it preheats outside air in the heating mode and also sprays the exhaust air to precool outside air in the cooling mode. All light fixtures are cooled by the return air. The main air supply units each have a cooling coil, an air washer, and a supply fan.

The flat-plate solar collector array forms the roof of the mechanical room that houses a heat exchanger, two storage tanks, and two water chillers (a 300-kW (85-ton) lithium-bromide absorption chiller and a 270-kW (77-ton) Rankine cycle unit), either of which can be used for comparative studies of solar air-conditioning. Space heating, DHW heating, and space cooling are provided by the solar system. Both hot- and chilled-water storage is used. The solar energy system is backed up by auxiliary steam heat exchangers that generate hot water directly for space heating or to power the chillers. DHW is heated in a 380-liter (100-gal) tank connected to the solar hot water tank, and augmented by an electrically heated, 150-liter (40-gal) tank downstream.

REFERENCE RUN COMPARISON TESTS

The selected contractors simulated their respective buildings for a one-year period using the DOE 2.0A computer program.[6] Each contractor conducted the reference-run simulation, using all information available through intimate knowledge of the building's construction and actual operation, either his information or that of the owner/operator. The purpose was to reduce the uncertainty in program input by using, where possible, historical knowledge instead of assumptions.

Comparisons were then made between DOE-2 energy-use predictions at the building boundary and the metered energy-use data (electricity and gas/fuel oil consumption) for the building. Weather data used were obtained from the National Climatic Center (NCC) in Asheville, North Carolina, in magnetic tape format. Data were obtained for the year corresponding to the utility-metered data and the reference-run simulation. The closest recording station (maximum distance was 24 km (15 miles) was selected. Three-hour weather data on the NCC tapes were converted to the 1-hour DOE-2 weather file format by editing: a linear interpolation algorithm that filled in the missing hours was used.

RESULTS

Comparisons of DOE-2 predictions and measured building energy use data for the seven buildings are presented below. Monthly results are first presented graphically and in a summary table, followed by presentation of annual results in a summary table. Because of space limitations, not all of the results are shown here. However, the full results are presented in Ref. 4.

Restaurant

Results for the restaurant are presented in Figs. 1-3 as monthly data for gas, electric energy, and total energy (gas plus electric energy) consumption, respectively. These results, as broken down by fuel, electric energy, and total energy, are representative, although generally better than, results for the other six building types. For the restaurant, the simulated data are quite close to the measured data for all three energy categories for nearly all months of the test year. There appears to be no consistent trend of underprediction or overprediction; the deviations are random. Table 1 shows that the composite standard deviation for all months is at most 10.3 per cent (electric energy) for the restaurant; the standard deviation for total energy is 7.0 per cent and 9.9 per cent for gas/fuel oil use. The largest variation in any single month, 20 per cent, is in electric energy consumption.

Single-Floor Office Building

Figure 4 is a plot of the monthly total energy consumption results (predicted-versus-measured) for the single-floor office building. The under-prediction and overprediction appear to be random, with the largest variations occurring in the third and fourth months. As shown in Table 1, the standard deviation for electric energy use (27.8 per cent) is greater than that for gas/fuel oil use (18.6 per cent). A standard deviation of 15 per cent for total energy consumption is also shown.

Retail Store

Monthly total energy consumption results for the retail store are plotted in Fig. 5. The underprediction of the metered data for the majority of months results from a consistent underprediction of both gas and electric energy consumption during the last half of the test year. No reason for this occurrence has been determined. The largest composite standard deviation (35.0 per cent for gas consumption, Table 1) for any of the seven buildings occurred for the retail store. Table 1 also shows that the comparison results for electric energy (8.7 per cent standard deviation) were considerably better than that for gas, resulting in a 24.0 per cent monthly standard deviation for total energy.

Note that a spike in the metered data on Fig. 5 occurs in month 4 that appears out of character with the metered data for the other months. This results from a spike in the metered gas consumption data for that month. Studies of the weather data and the building operation for that period give no indication of the cause of this abnormality: the remainder of the curve appears completely normal. The most probable cause for this occurrence is a billing error that was not corrected in the following period; however, this has not been confirmed. No other explanation has been determined.

Hospital

Figure 6 shows the monthly total energy consumption results for the hospital. Note that both gas and fuel oil were used during the last three months of the year. Bulk delivery of the fuel oil on a nonmonthly schedule precluded accurate measured monthly consumption data for the last three months shown in Fig. 6. The underprediction of the metered data for 9 of the 12 months results from an underprediction of the gas/fuel oil consumption for the same 9 months and an underprediction of the electric energy consumption for all 12 months. The hospital is the only one of the seven buildings, except the solar building, for which either fuel or electric energy consumption is consistently underpredicted throughout the test year. As shown in Table 1, the standard deviation for electric energy (17.4 per cent) is greater than that for gas/fuel oil (12.5 per cent), resulting in a total energy standard deviation of 11.9 per cent.

Multifloor Office Building

Because of random bulk oil deliveries, no monthly oil consumption data are available for the multifloor office building. Therefore, no monthly plots are shown for fuel or total energy consumption. Monthly electric energy consumption results are presented in Fig. 7 where good agreement between predicted and metered data is indicated. The underprediction and overprediction appear to be random. Table 1 shows that the standard deviation in electric energy consumption is 9.8 per cent.

School

Figure 8 shows the monthly total energy consumption results for the school. As is indicated in Table 1, considerable deviations between monthly simulated and metered data occurred in the gas/fuel oil (33.3 per cent standard deviation) and electric energy (29.6 per cent standard deviation) categories. The monthly data exhibited random underprediction and overprediction by DOE-2 in both categories. Therefore, because of compensating deviations, the total energy consumption comparison (Fig. 8) has a standard deviation of 22.1 per cent.

Solar-Heated and -Cooled Building

Plots of monthly comparisons of solar energy delivered to load, auxiliary heating energy (steam) used to supplement the solar system, electric energy, and total energy consumption for the solar building appear in Ref. 4, but are not shown here. Monthly deviations for auxiliary heating energy randomly consist of underpredictions and overpredictions by DOE-2. However, the deviations for electric energy consumption result from consistent underprediction of measured data by DOE-2 for all months of the test year. Because electric energy use is a dominant portion of total energy use, the measured total energy data are underpredicted by DOE-2 for all but one month in the year. The maximum monthly variation is 20 per cent and the standard deviation for total energy use is 13.8 per cent (Table 1).

Because evaporative cooling in the solar building could not be modeled by DOE-2.0A, a LASL-modified version of the program was used in this exercise. Likewise, the active solar system simulator used was a test version that was not officially in DOE-2.0A. Consequently, there are significant uncertainties in the results reported here for the solar building. Nevertheless, the composite standard deviations shown in Table 1 for the solar building are quite similar to the summary results for the other six buildings.

ANNUAL RESULTS

Table 2 is a summation of the annual results obtained by comparing DOE-2 simulations to metered utility data for the seven buildings. The maximum difference for gas/fuel oil consumption was 19 per cent for the retail store and the minimum was 1 per cent for the restaurant. The variation in prediction discrepancies for electric energy consumption was less, with minimums of 1 per cent for the multifloor office building and the school and a maximum of 15 per cent for the solar building. Four of the seven buildings had prediction discrepancies of 6 per cent or less. The prediction of total annual energy consumption (energy budget) varied the least, with a minimum of 1 per cent for the restaurant and a maximum of 12 per cent for the retail store and the solar building.

A statistical analysis of the annual results for the set of seven buildings shows (Table 2) that the standard deviation between simulated and metered data for gas/fuel oil, electric energy, and total energy consumption is 11.0, 9.2, and 7.9 per cent, respectively.

There is a tendency for DOE-2 to underpredict both annual gas/fuel oil and electric energy consumption; however, the trend does not hold for all the buildings considered. The energy budgets are underpredicted for all but one of the buildings.

SUMMARY DISCUSSION OF RESULTS

When the monthly standard deviations between predicted and measured data for gas/fuel oil and for electric energy are compared to the monthly standard deviations for total energy (Table 1), the latter are often considerably smaller than the former. This results from compensating deviations. That is, the gas consumption may be overpredicted in a given month, while the electric energy consumption is underpredicted. This can result in a quite small deviation in total energy consumption.

The absolute difference between predicted and measured data for individual months ranged from 14 to 45 per cent for gas/fuel oil, where the 45 per cent difference was a single-month occurrence for the retail store. Absolute differences for individual months ranged from 13 to 37 per cent for electricity. The 37 per cent difference was a single-month occurrence for the school. Comparable differences for monthly total energy use were in the range of 15 to 33 per cent. Despite the occurrence of rather large differences for a few individual months, statistical analysis of all monthly results (Figs. 1-6 and Table 1) show composite standard deviations for the seven buildings of 26.3, 18.7, and 16.7 per cent, respectively. This provides a good measure of the overall accuracy of DOE-2 in predicting monthly energy use.

Comparisons of predicted-versus-measured energy use on a monthly basis (Table 1) show significantly higher deviations than the annual comparisons (Table 2). Probable causes of this phenomenon include the following.

- Underpredictions in some months tend to compensate for overpredictions in other months, resulting in an improved annual comparison.

- Standard schedules for parameters such as occupants, lights, equipment, and DHW are used in the simulations. Effects of the variations in these schedules for the actual test year tend to average out, matching the standard schedules in the long-term annual results, but not in the shorter-term monthly results.

- Short-term differences in weather between the building site and the weather data monitoring station appear in the monthly results, but tend to be averaged out in the annual results.

- Anomalies in the utility data used for the comparisons cause higher monthly differences. For example, a small error in reading a gas meter could result in an overbilling one month and underbilling the next month that is not readily detected. Also, the date of measure (meter reading) and the date of prediction (end of calendar month) generally do not coincide. In these cases, the utility data were interpolated for the end of the month, resulting in small errors in the monthly results. Again, this phenomenon tends to average out in the annual results.

CONCLUSIONS

Comparisons of DOE-2 simulations with measured utility data for a set of seven existing commercial buildings of various types in a variety of climate zones indicate the following conclusions.

1. For the set of seven buildings tested, there is a standard deviation of less than 8 per cent and a maximum difference of 12 per cent between predicted and measured data for annual total energy use (energy budgets).

2. For the set of seven buildings tested, the difference between predicted and measured data for annual gas/fuel oil and electric energy use results in a standard deviation of 11.0 per cent and 9.2 per cent, respectively. The range of differences is 1-19 per cent and 1-15 per cent, respectively.

3. The composite standard deviation for the set of seven buildings on a monthly basis is 16.7 per cent for total energy use, 26.3 per cent for gas/fuel oil use, and 18.7 per cent for electric energy use. The range of differences is 2-24 per cent, 10-35 per cent, and 9-30 per cent, respectively.

4. The annual and monthly standard deviations reported in conclusions 1-3 above represent the expected accuracy of DOE-2 in predicting energy use results under favorable conditions where the user has historical knowledge of the construction and operation of the building.

REFERENCES

1. Stephen C. Diamond, Bruce D. Hunn, and Thomas E. McDonald, "DOE-1 Verification Program Plan," Los Alamos Scientific Laboratory report LA-7552-MS (November 1978).

2. Stephen C. Diamond, Bruce D. Hunn, and Thomas E. McDonald, "Verification Methodology for the DOE-1 Building Energy Analysis Computer Program," Proceedings of the Systems Simulation and Economic Analysis Conference, San Diego, California, June 27-29, 1978.

3. Stephen C. Diamond and Bruce D. Hunn, "The DOE-2 Verification Project: Phase I Results," Proceedings of the Second Annual Systems Simulation and Economic Analysis Conference, San Diego, California, January 23-25, 1980.

4. Stephen C. Diamond and Bruce D. Hunn, "The DOE-2 Verification Project Phase I Interim Report," Los Alamos Scientific Laboratory report LA-8295-MS, in preparation.

5. "The Standard Evaluation Technique, Technical Support Document for Notice of Proposed Rulemaking on Energy Performance Standards for New Buildings," Office of Conservation and Solar Energy, US Department of Energy report DOE/CS-0120 (November 1979).

6. "DOE-2 Reference Manual," Group WX-4, Program Support, Los Alamos Scientific Laboratory report LA-7689-M (Lawrence Berkeley Laboratory report LBL-8706) (February 15, 1979).

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Galehouse and Associates, Dayton, Ohio.

TABLE 1

SUMMARY OF REFERENCE-RUN RESULTS (MONTHLY)
DOE-2 PREDICTIONS VERSUS MEASURED DATA

	Gas/Fuel Oil Standard Deviation* of all Months (%)	Electricity Standard Deviation of all Months (%)	Total Energy Standard Deviation of all Months (%)
Restaurant	9.9	10.3	7.0
Single-Floor Office	18.5	27.8	15.0
Retail Store	35.0	8.7	24.0
Hospital	12.5	17.4	11.9
Multifloor Office	**	9.8	**
School	33.3	29.6	22.1
NSRSC (Solar)	34.8	15.1	13.8
Total for Set of Seven Buildings	26.3	18.7	16.7

* Standard deviation = $\sqrt{\frac{1}{n}\sum_{n=1}^{12}\left(\frac{\text{Predicted - Measured}}{\text{Measured}}\right)^2}$.

** Monthly data not available.

TABLE 2

SUMMARY OF REFERENCE-RUN RESULTS (ANNUAL)
DOE-2 PREDICTIONS VERSUS MEASURED DATA

	Gas/Fuel Oil (%)	Electricity (%)	Total Energy (%)	Predicted Energy Budget MJ/m^2.yr	(Btu/ft^2.yr)	Measured Energy Budget MJ/m^2.yr	(Btu/ft^2.yr)
Restaurant	-1	-2	<-1	7959	(701,300)	8037	(708,200)
Single-Floor Office	+4	+12	+8	1585	(139,700)	1467	(129,300)
Retail Store	-19	-4	-12	1710	(150,600)	1949	(171,700)
Hospital	-4	-14	-7	4813	(424,100)	5171	(455,700)
Multifloor Office	-14	<-1	-4	1328	(117,000)	1376	(121,300)
School	+5	<-1	+4	1075	(94,700)	1033	(91,000)
NSCSC (Solar)	+15	-15	-12	492	(43,400)	562	(49,500)
Standard Deviation (%) for Set of Seven Buildings	11.0	9.2	7.9				

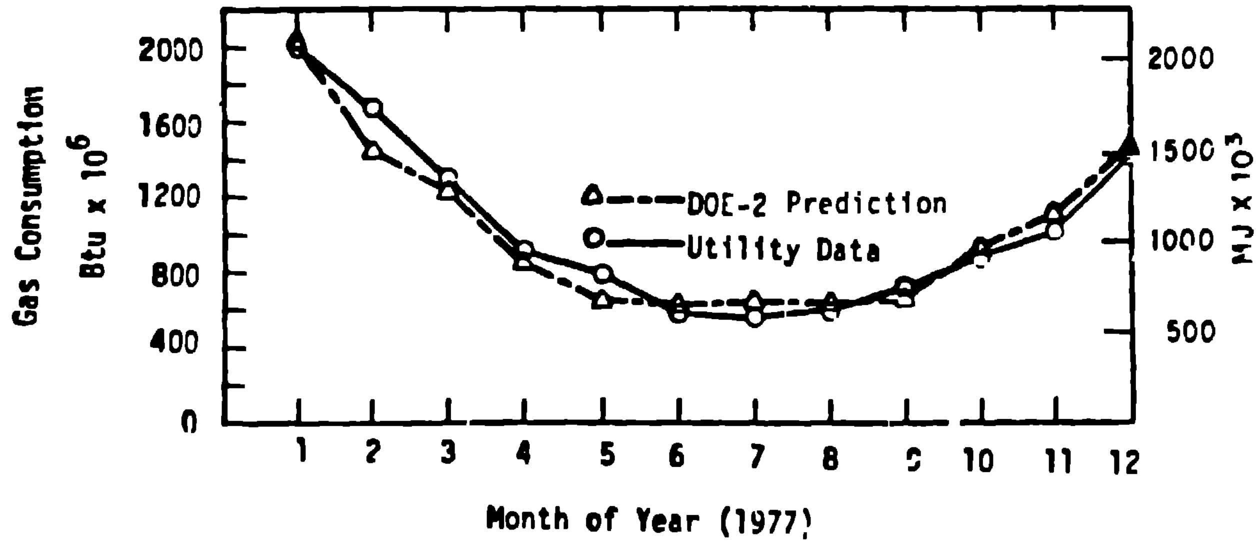

Fig. 1. Reference run - DOE-2 prediction versus gas utility data for restaurant.

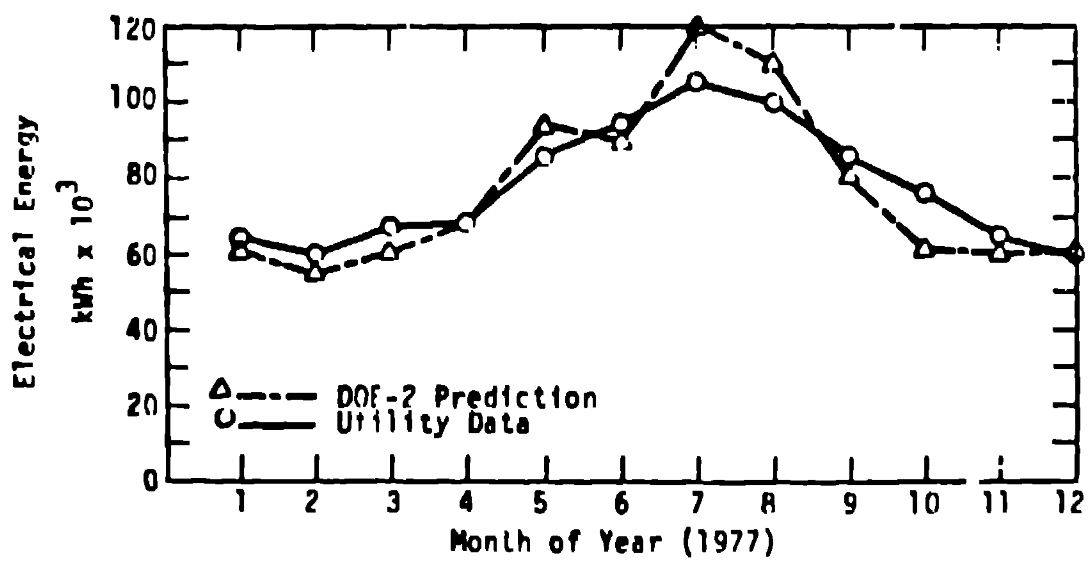

Fig. 2. Reference run - DOE-2 prediction versus electric utility data for restaurant.

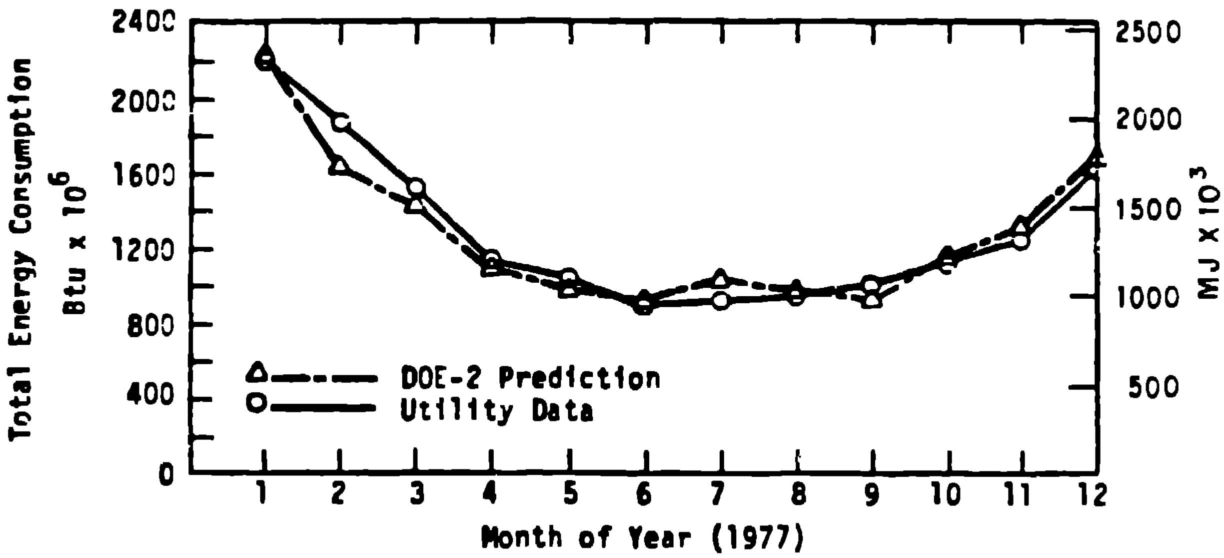

Fig. 3 . Reference run - DOE-2 prediction versus total energy utility data for restaurant.

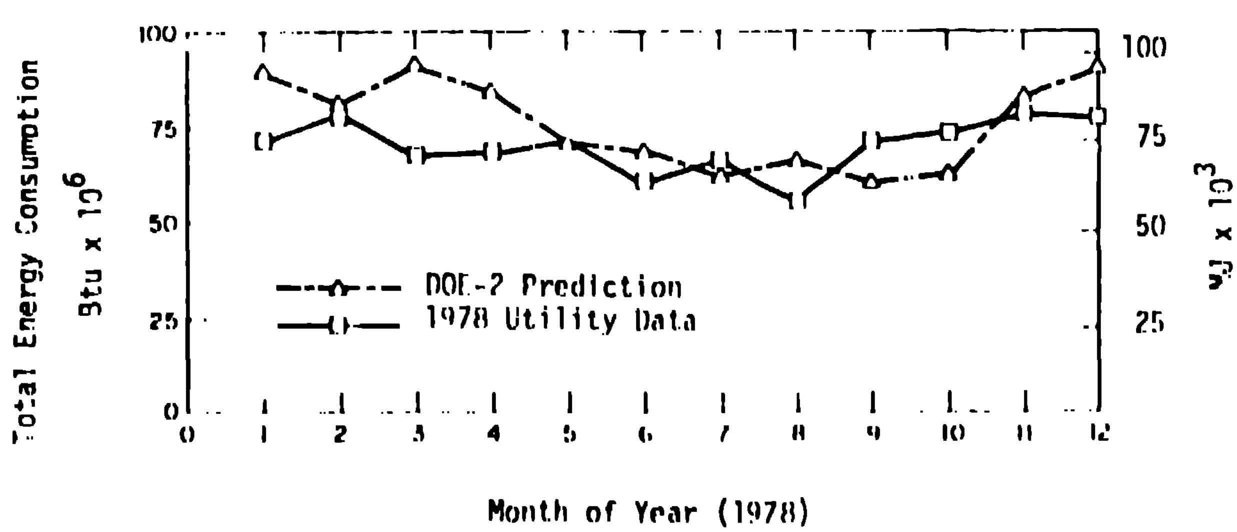

Fig. 4. Reference run - DOE-2 prediction versus total energy utility data for single-floor office building.

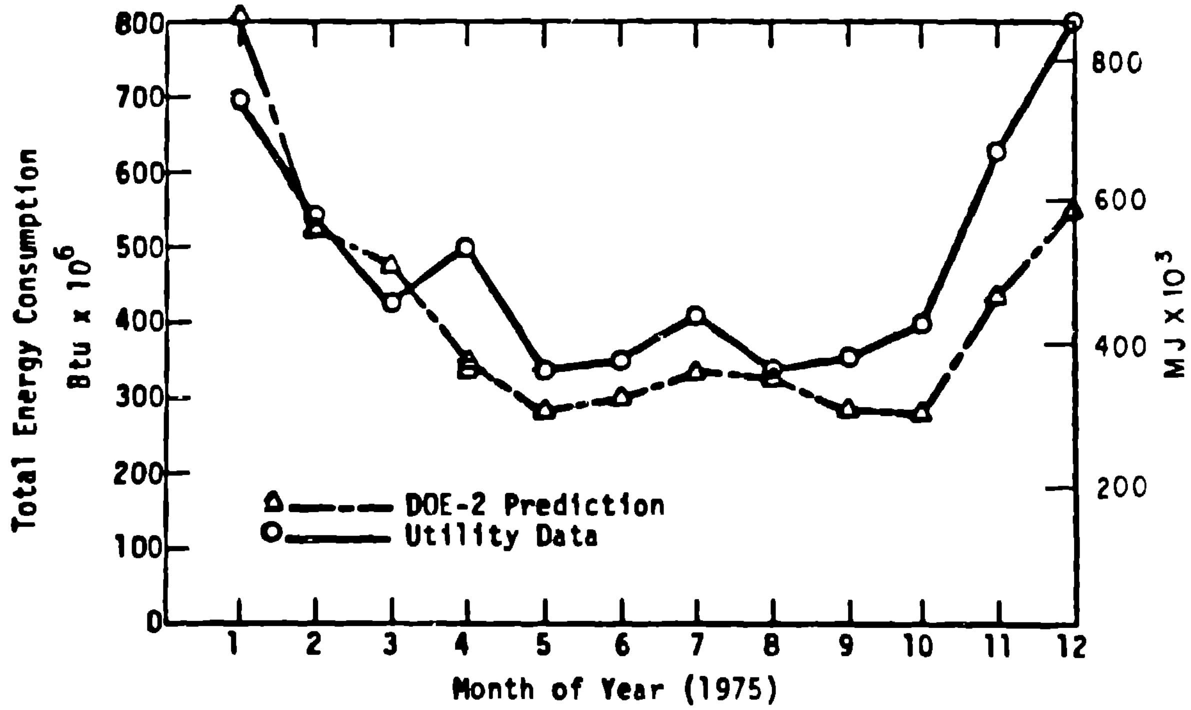

Fig. 5 . Reference run - DOE-2 prediction versus total energy utility data for retail store.

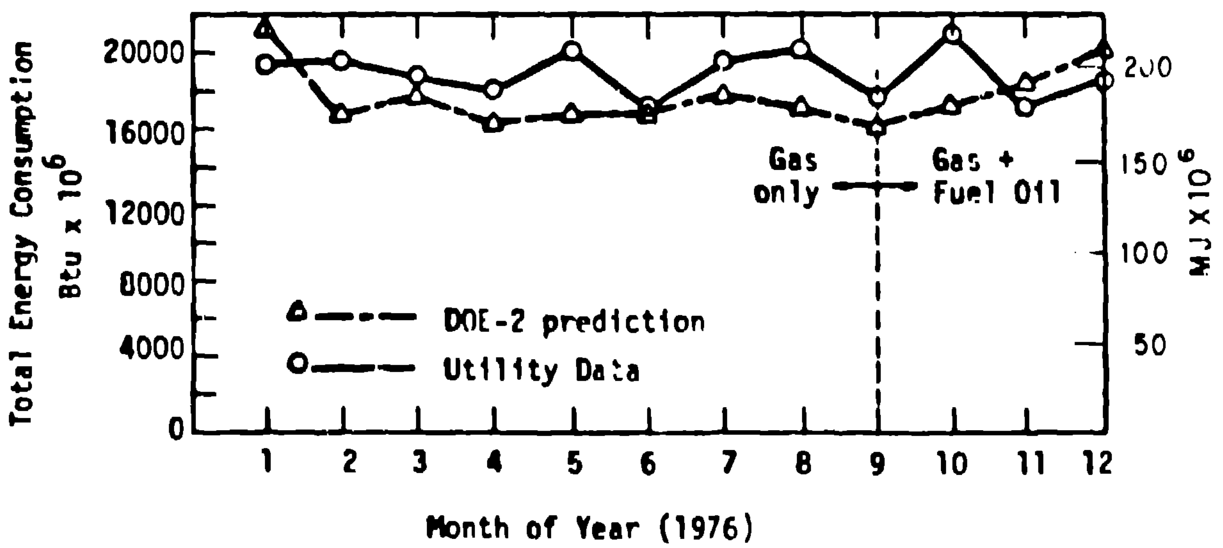

Fig. 6 . Reference run - DOE-2 prediction versus total energy utility data for hospital.

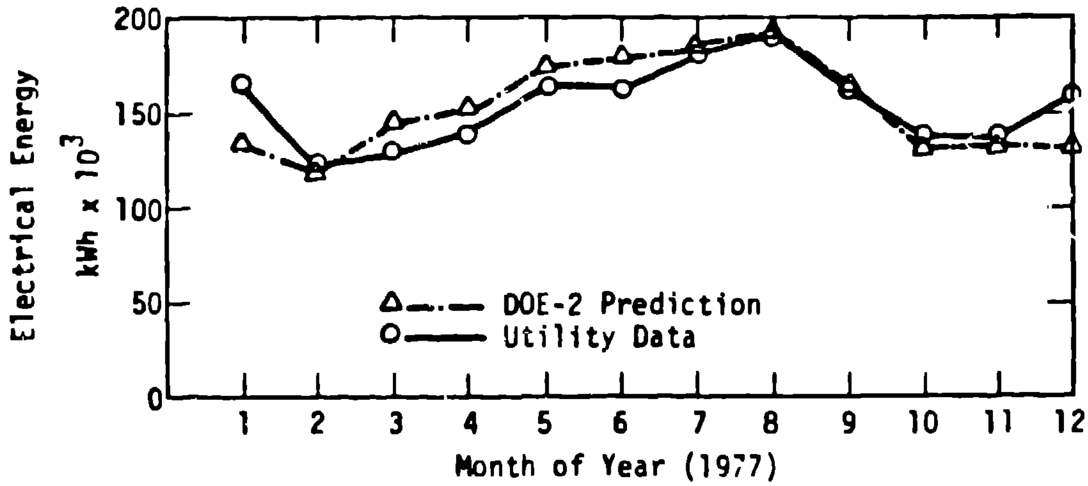

Fig. 7. Reference run - DOE-2 prediction versus electric utility data for multifloor office building.

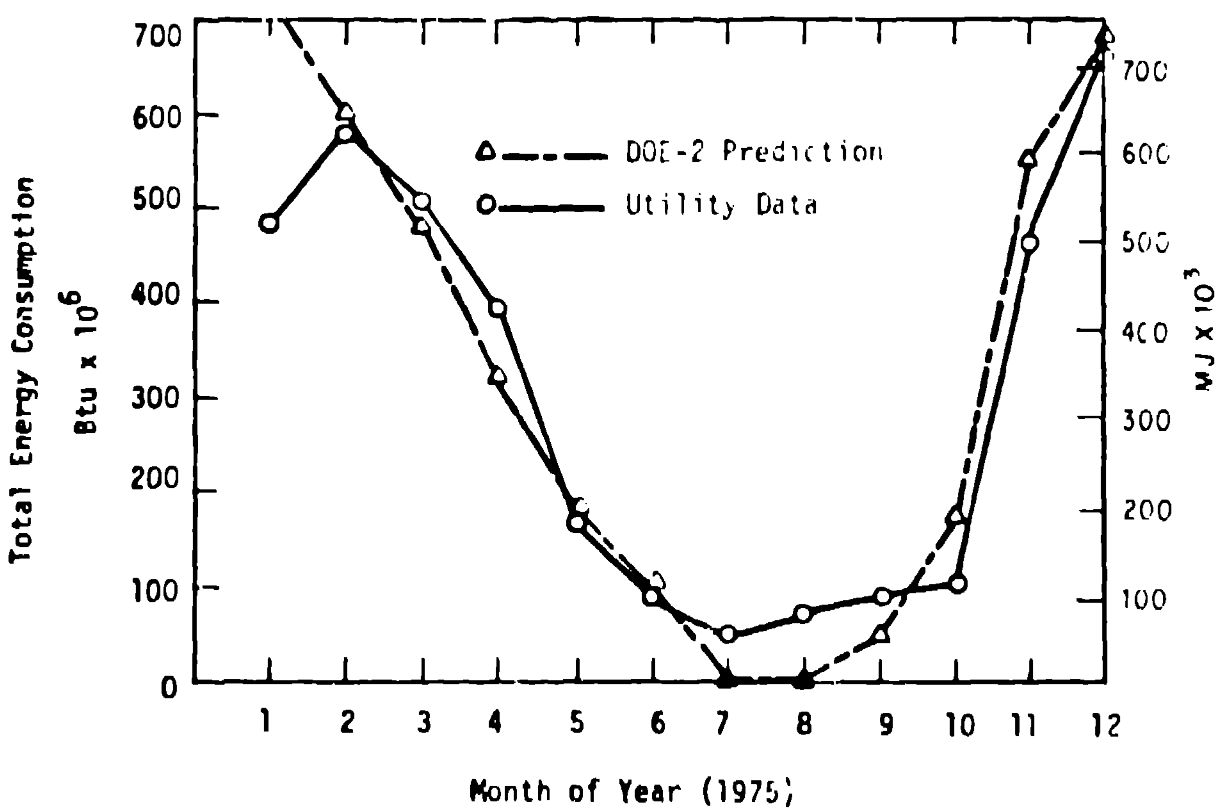

Fig. 8. Reference run - DOE-2 prediction versus total energy utility data f - school.