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COMMONWEALTH OF MASSACHUSETTS
ENERGY FACILITIES SITING COUNCIL

Northeast Utilities	)
E.F.S.C. No. 80-17	)

TESTIMONY OF PAUL L. CHERNICK ON BEHALF OF THE ATTORNEY GENERAL

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Q: Mr. Chernick, would you please state your name, position, and office address.

A: My name is Paul Chernick. I am employed by the Attorney General as a Utility Rate Analyst. My office is at One Ashburton Place, 19th floor, Boston, Massachusetts 02108.

Q: Please describe briefly your professional education and experience.

A: I received a S.B. degree from the Massachusetts Institute of Technology in June, 1974 from the Civil Engineering Department, and a S.M. degree from the same school in February, 1978 in Technology and Policy. I have been elected to membership in the civil engineering honorary society Chi Epsilon, to membership in the engineering honorary society Tau Beta Pi, and to associate membership in the research honorary society Sigma Xi. I am the author of <u>Optimal Pricing for Peak Loads and Joint Production: Theory and Applications to Diverse Conditions</u>, Report 77-1, Technology and Policy Program, Massachusetts Institute of Technology. During my graduate education, I was the teaching assistant for courses in systems analysis. I have served as a consultant to the National Consumer Law Center for two projects: teaching part of a short course in rate design and time-of-use rates, and assisting in preparation for an electric time-of-use rate design case.

Q: Have you testified previously as an expert witness?

A: Yes. I have testified jointly with Susan Geller before the Massachusetts Energy Facilities Siting Council and the

Massachusetts Department of Public Utilities in the joint proceeding concerning Boston Edison's forecast, docketed by the E.F.S.C. as 78-12 and by the D.P.U. 19494, Phase I. I have also testified jointly with Susan Geller in Phase II of D.P.U. 19494, concerning the forecasts of nine New England Utilities and NEPOOL , and jointly with Susan Finger in Phase II of D.P.U. 19494, concerning Boston Edison's relationship to NEPOOL. I also testified before the E.F.S.C. in proceeding 78-17, on the 1978 forecast of Northeast Utilities; in EFSC 78-33 on the 1978 forecast and EFSC 79-33 on the 1979 forecast and supply plan of Eastern Utilities Associates; jointly with Susan Geller before the Atomic Safety and Licensing Board in Boston Edison Co., et al., Pilgrim Nuclear Generating Station No. 2, Docket No. 50-471 concerning the "need for power"; in D.P.U. 20055 regarding the 1979 forecasts of EUA and Fitchburg Gas and Electric, the cost of power from the Seabrook nuclear plant, and alternatives to Seabrook purchases; in D.P.U. 20248 on the cost of Seabrook power; in D.P.U. 200 on Massachusetts Electric Company's rate design and conservation initiatives; in D.P.U. 243 on Eastern Edison's rate design; in PUCT 3298, on Gulf States Utilities' Texas retail rate design; in EFSC 79-1 on MMWEC's 1979 supply plan; in D.P.U. 472 on the allocation of the costs of the Residential Conservation Service; and in D.P.U. 535 on rates for small power producers. I have also submitted prefiled joint testimony with Ms. Geller in the Boston Edison time-of-use rate design case, D.P.U. 19845, but we have not yet testified.

Q: Does this testimony comprise a comprehensive review of NU's demand forecast?

A: No. It is my understanding that several portions of the forecast methodology will be substantially different in the 1981 forecast from that in the 1979 and 1980 forecasts. This is particularly true for the migration model, the price forecast, the industrial model, and portions of the commercial model. Hence, I will discuss primarily those sections of the methodology which do not appear to be undergoing any rapid change. I also will discuss certain problems of documentation and modelling approach which may persist despite the anticipated modifications.

Due to the promulgation of the Northeast Utilities Conservation Program for the 1980's and 1990's (NUCPEN), which supercedes NU's 1980 supply plan, I will not discuss the latter.

Q: How does the 1980 NU forecast compare to earlier NU forecasts and to other utility forecasts?

A: The current NU forecast represents a distinct improvement compared to the 1978 forecast, which was the last filing formally reviewed by the EFSC. Much of the improvement was the result of simplification of the economic model. More complex models do not necessarily reflect the real world more accurately than simple models.

Many of the problems of the 1978 forecast persist in the current methodology; considering NU's resources and the time span between the filings, the progress is really rather limited. It is my understanding that the NU forecasting staff has been preoccupied with transferring the model to in-house computational facilities, resulting in deferral of major program changes. The changes in the 1981 methodology (described by Mr. Roncaioli in his letters of February 10, 1981 to Ms. Pastuszek and to me) appear to address some of the problems remaining from the 1978 filing, and may inaugurate an era of accelerated progress in the development of NU's forecasting capability. NU's model is still in many respects the best forecasting model in use by any New England utility. The residential appliance bookkeeping is particularly excellent.

Nonetheless, other portions of the model must be improved considerably, if NU is to remain the regional leader in utility forecasting.

Q: Are there any generic issues of forecasting methodology which are relevant to NU's general approach, but not to the specific portions of the 1980 forecast which are to be retained in future filings?

A: Yes. NU's past approach to the specification process for regression-based modelling equations displays serious deficiencies. While these problems may be corrected in the 1981 filing, the issue is a general one and seems to be related to NU's view of the specification process, rather than to the details of the applications. The difficulties primarily involve the unsystematic, scatter shot approach NU employs, as well as the failure to explain omissions of important variables and variations in specification among similar situations.

NU's general approach to regression seems to be a largely unorganized process of running a large number of equations and selecting one for use in the model, presumably on the basis of the test statistics and the equation's compatibility with the forecaster's preconceptions regarding the signs and magnitudes of the coefficients. This constitutes a basic misuse of statistical methods, and also produces a forecasting model which is difficult to review.

Classical statistical significance tests (e.g., the t and F tests) cannot directly determine whether a regression equation is "correct" in terms of the underlying causality, or even the underlying correlation, of the variables. All the significance test can do is to determine the probability that the observed relationship would have occurred if the variables were actually independent. (Some other specified relationship, rather than independence, can be used for the test.) Saying that a relationship is significant at the 95% level is equivalent to saying "If the variables were unrelated, the chance of observing data showing so strong an apparent relationship is only 5%."

Let us suppose that a forecaster is looking for a relationship which is significant at the 95% level and has the proper sign. If some practical joker has replaced the data with the output from a random number generator, the forecaster still has a 2.5% chance of getting an equation which passes the required tests. The probability of running 28 such regressions without accepting an equation is about 50/50; the probability of running 100 regressions without finding a "significant" one is only 8%. Thus, regardless of the true relationship, or lack thereof, between the variables, running many equations is virtually certain to identify some with acceptable test statistics.

Real forecasting creates conditions rather more complex than the simple example I just used. On the one hand, the data is not random; rather, much of it represents economic conditions which may tend to follow one another, regardless of whether they are causally related. For instance, electric use may correlate well with cheese imports, because both are driven by personal income and other exogenous factors, even though neither variable materially affects the other. Many variables correlate well with time, and hence with one another. On the other hand, the forecaster may apply more criteria than were used in the example. Initial assumptions regarding the values of the coefficients may be used to screen models, as may multiple t tests, correlation coefficients, the Durbin-Watson statistic, and other tests. Hence, it is more difficult to assign a probability to finding accidental patterns in real situations than in the hypothetical example.

Nonetheless, the basis problems remain; running large numbers of regressions weakens the meaning of statistical tests and reduces the degree of assurance that the results are not coincidental.

Q: How does this scattershot technique complicate the review process?

A: Since there may be hundreds of regression runs, it is difficult or impossible to follow the forecaster's decisions regarding which regressions were worth running, which results were appropriate to keep for review, and which specification was preferable for forecasting purposes. If the specification process started with _a priori_ consideration of the potentially relevant variables and of the appropriate functional forms, followed by a systematic winnowing of the contending alternatives, the process should be easier to explain and to understand.

Q: What problems arise as a result of NU's failure to explain variations in specification and the omission of important variables among similar situations?

A: Regardless of how NU happened upon the final specification which it uses for any particular equation, it should at least be able to explain why that specification is superior to the most obvious competitors. Thus, if the specification omits an apparently significant variable, NU should be able to produce the corresponding regression with the variable included, and demonstrate that the selected specification is more appropriate. This problem has arisen in the 1978, 1979, and 1980 industrial models, in which various SIC regressions included a price term, a "conservation effects" term, both, or neither. NU has never been able to explain why these variables appear in some SIC's but not in others. The basis of choice in this case is particularly perplexing in that many of the included variables have coefficients which are not statistically significant, with t statistics as low as 0.35.

The opposite problem also occurs in the 1979/1980 industrial model. The selected specification for SIC 27 includes an oil price variable, again with an insignificant coefficient, even though it is not included for the other SIC's. NU has not really been able to explain why oil price belongs in the equation for SIC 27, but not SIC 28, for example.

This leads us to the other major unexplained aspect of NU's past regression: differences in specifications for similar groups. The 1980 migration model uses some eight different specifications for eighteen cohorts. NU cannot explain why the equation used for men of a certain age is not appropriate for women of the same age; why seven of the eight equations using share-of-manufacturing-employment also have a time variable, but the eighth does not; why five of the six cohorts in the 45 to 59 age range are in log form and the other one is linear; why three of the cohorts use variables which are independent of national conditions; or why insignificant coefficients must be accepted.

All of these equations are apparently dropped from the 1981 forecast, so the origin and suitability of the particular specifications no longer matters. It is important that NU not place itself in the same situation in the 1981 or future filings that it has in past filings. Any forecaster who derives and uses econometric models (or other regression equations) should be able to explain how the selected specification was chosen and why it is superior to at least the most obvious alternatives. The burden of establishing that an equation is the best available is even greater when the test statistics are disappointing.

Q: On what particular portions of the forecast will you be commenting?

A: I will discuss:

1. non-manufacturing employment;
2. electric heating promotion and penetration;
3. appliance efficiency improvements;
4. the commercial model;
5. the treatment of electric price in the industrial model;

6. the price forecast; and

7. the wholesale forecast documentation.

Q: Is the projection method for non-manufacturing employment appropriate?

A: The general logic and structure of this portion of the model seems appropriate. In brief, NU assumes that local employment per capital in each non-manufacturing division follows the trend in that ratio for the nation, as projected by an exogenous forecast. In the absence of other information, this would generally be a reasonable use of unbiased and presumably well-informed independent opinion.

However, other information is available. While national and local employment trends are certainly interrelated, there are reasons to believe that they do not move exactly in tandem. For example, the rapidly growing sunbelt states, coal-mining areas, and oil-exploration areas may well experience more "construction and mining" employment growth in the next decade than NU's service territory will. On the other hand, Connecticut may get a higher percentage of new jobs in "Finance, Insurance, and Real Estate" (FIRE) than the average state.

These a priori speculations are confirmed by NEPOOL data. NEPOOL Model Documentation #8 provides graphs of historical US and state employment in each division per 10000 population. The graphs for Connecticut and the US are attached as Appendix A. Based on recent experience, the constant ratio assumption seems to be fairly accurate for "wholesale and retail trade" and for "transport, communications, and public utilities"; to overstate Connecticut growth for construction, mining, state and local government, and possibly services; and to understate Connecticut growth in FIRE and federal government. Data for 1978-80, statistical analysis, and consideration of some underlying causes for past and future differences in the growth rates should precede the incorporation of those differences in the forecast, but it is likely that at least some of these apparent differentials are real and will continue.

It is not clear whether the overall impact of the refinements described above would significantly affect NU's forecast. However, the effort necessary for the analysis does not seem to be excessive.

Q: Is the basis of NU's penetration projections for electric space heating reasonable?

A: The new market penetrations for electric heating (including heat pumps and backup for wood and solar heat) rise from 20% in 1980 to 45% in 1989 for single-family housing and from 30% in 1980 to 53% in 1989 for multi-family housing. Single-family conversions in the existing market rise from 0.2% in 1980 to 0.48% in 1989. Since all conversions are assumed to be from the non-electric heating market (rather than from other types of electric heating), the actual 1989 conversion rate being projected is about 0.58%.[1/] Both the 1979 and 1980 forecast attribute these increased penetrations, in part, to NU's efforts to promote electric heating. NU's official position is that promotional activities stopped by 1973; see p.43 of the Load Forecasting Methodology (LFM), Mr. Roncaioli's response to Residential question #3 in his letter to me dated 2/10/81, and p.17 of NUCPEN. NU prefers that its program to increase electric heating penetration be referred to as "an effort to clear up misunderstandings" or "consumer education" or pointing out the advantages of electric heating (P.43 LFM). It is clear both from the discussion in LFM and from the materials distributed by NU to date (some of which are attached as Appendix B to this testimony) that NU is in fact advocating electric heating to its customers. The LFM discussion also implies that the penetration rates used in the forecast assume that this advertising campaign will be successful.

1/ In fairness to NU, it should be noted that a woodstove/solar retrofit allowance is included in the calculation of average resistance heating use. If this allowance is properly estimated, some of the conversions from one form of electric heat to another have been accounted for. However, NU does not seem to have allowed for heat pump retrofits in resistance-heated homes. The important point here, though, is that the conversion figures are not what they seem.

NU's reluctance to admit that it is promoting electric space heating is understandable. Electricity is an extremely inefficient means for converting fossil fuels to space heating. The marginal electric supply in New England is essentially always oil, burned at heat rates between 9500 BTU/kwh and 200000 BTU/kwh, or 17% to 36% efficiency. Combined with marginal losses between the generators and secondary customer meters of about 22.5%, residential end-use efficiency for oil-to-electric conversion is about 14% to 29%. The average system marginal heat rate is probably closer to the high-efficiency end of this range, say 11000 or 12000 BTU/kwh, but the correlation of high losses with high heat rates decreases the average delivered efficiency, so 24% average efficiency is probably optimistic.

By way of contrast, Table 1 lists the annual fuel use efficiency reported by DOE for the most efficient furnace and for the sales-weighted average efficiency furnace of each type. The least efficient units listed (average 1978 gas furnaces) are 2.7 times as efficient as electric resistance heating, while the most efficient (the best 1978 oil boiler) is 3.5 times as efficient.

LFM (p.45) indicates that all-electric heat pumps use 33% less electricity than resistance systems; this would raise the average end-use efficiency to about 36%. Direct fossil heating is still 1.8 to 2.4 times as efficient as all-electric heat pumps.

Electric space heating does have some efficiency advantages which are not included in the preceding calculations. Resistance heating can readily be controlled on a room-by-room basis; modern zoning and controls on fossil systems limit the extent of resistance heating's superiority in this regard. All electric heating systems are fueled primarily (perhaps 80-90%) with #6 oil, rather than the more expensive (both in dollars and in production energy inputs) #2 oil.

Type(2)	Average(3)	Best Commercially(4) Available
	%	%
Gas forced air	65	70
Gas boiler	65	75
Oil forced air	75	82(5)
Oil boiler	76	85

Table 1: DOE Data on Furnace Efficiency Levels (1)

(1) 1978 Annual Fuel Utilization Efficiency (AFUE);

(2) indoor location assumed;

(3) sales weighted AFUE, from Federal Register 6/30/80, P.44003; "Level 2 in 1981 corresponds to the SWEF in 1978";

(4) highest AFUE of any basic model commercially available in 1978;

(5) DOE estimate.

Electric heat pumps with fossil backup may use electricity much more efficiently than all-electric heat pumps, but it is not clear whether they will be superior to all-fossil heat pumps. The same is true for heat pumps with a ground water heat source. But in general, until New England is no longer dependent on oil to meet load in most hours (a condition NEPOOL apparently does not expect to occur until 1995, at the earliest), electric space heating will increase the use of oil and gas, as compared to the direct use of those fuels for space heating.

Thus, NU should not be advocating or encouraging the use of electricity for space heating, as it is currently, but instead should be discouraging new space heating installations and encouraging existing customers to replace or supplement resistance systems with heat pumps, (especially fossil or ground water assisted), wood stoves, solar collectors, and increased insulation. This policy reversal could be accomplished by changing rate design and advertising, and through accelerated and broadened application of some of the conservation programs in NUCPEN. At worst, NU should be neutral with regard to electric heating, eliminating subsidies and promotion so that the market effects of rising energy prices can reduce, rather than increase, electric heating penetrations.

I do not believe that the fault in this matter lies with NU's forecasters. After all, if their company is promoting electric heating and expects that effort to be successful, they should include the added load in the forecast. This issue really illustrates that sales forecasts are <u>plans</u> as well as <u>predictions</u>. The gas utilities seem to have accepted this principle long ago; it is also the premise for portions of NEESPLAN and of NUCPEN. While the right hand at NU is planning conservation programs to reduce oil use, the left hand is pushing electric space heat to increase oil use. The latter activity should be stopped and its projected effects should be removed from the forecast.

Q: Please discuss NU's application of appliance efficiency standards.

A: NU seems to have used the standards proposed in DOE's 1979 Preliminary Notices of Proposed Rulemakings (Federal Register 1/2/79, p.49 and 12/13/79, pp.72-77) as the basis of their appliance efficiency assumptions. NU's approach is generally reasonable, except for a few points.

First, NU confuses average efficiencies with minimum efficiencies. The efficiency levels used for NU's baseline estimates (such as 81% for water heaters or 3.8 ft.3/kwh-day for auto defrost refrigerators) are <u>average</u> efficiencies, while DOE proposed standards are <u>minimum</u>

efficiencies. For forecasting purposes, the average values are the significant ones, since only aggregate use is important. Yet NU uses proposed minimum efficiencies as if they were averages.

Clearly, the average value must be greater than the minimum value. Suppose that the principle in the newest proposed DOE standards (Federal Register 6/30/80, pp.439-76) is adopted, so that all appliances sold after a certain date, say 1/1/82, must be at least as efficient as the average 1978 appliance. This can be achieved in several ways. At the least, the non-conforming 1978 appliances (those on the lower half of the distribution) must move to the mean. Some are likely to exceed the minimum; perhaps it is more realistic to assume that the lower half of the distribution simply is transformed into the higher half. Considering that at least some of the initially conforming models are apt to be upgraded to incorporate the additional efficiency improvements which are being added to the non-conforming appliances, the second assumption does not seem overly optimistic.

For a wide range of symmetrical distributions, the mean of the left half of a distribution lies 80% or 90% of a standard deviation from the mean of the distribution. For a normal distribution, the ratio is

$$\sqrt{2 \div \pi} = .798$$

while for a uniform distribution it is

$$\sqrt{3} \div 2 = .866$$

Thus, moving the average non-conforming appliance up to average efficiency improves the average by about .4 times the standard deviation (.8 s.d. for half the population), while moving the average nonconformer up to the efficiency of the average conforming appliance improves the average efficiency by .8 times the standard deviation.
The standard deviations are given in the Federal Register for 6/30/80. In general Alternate Efficiency Level 2 for 1981 is the sales-weighted average efficiency in 1978; while Levels 1 and 3 are, respectively, a standard deviation less or more than average. For example, the standard deviation for top-freezer auto defrost refrigerators is .525 cu. ft./kwh/day. Adding 80% of this deviation to NU's assumed efficiency standard of 6.6 cu. ft./kwh/day increases the efficiency to 7.03, a 6.5% increase.

Similarly, the standard deviation for electric water heaters is 3.2% efficiency points, 3.6% improvement over NU's assumption of 89% efficiency in 1985, and 40% of the 8 percentage point improvement NU projects for the period 1976-1985. The effects of minimum standards cannot be accurately represented by applying the standards as averages.

Second, NU neglects the effects of efficiency improvements in dishwashers and clothes washers on the average electricity use of water heaters. These appliances are major users of hot water; increasing their efficiency should have a substantial impact on the consumption of hot water and hence the energy used in heating that water.

Finally, DOE has proposed new rules for eight of the appliance types NU models (Federal Register 6/30/80). It is not yet clear what the final rules (if there are any) will be, so any firm prediction of any level of national standards is somewhat speculative. However, appliance efficiency levels are subject to utility planning, just as appliance penetrations are. Specifically, NU could seek regulatory authority to prohibit or (more practically) to discourage the installation of inefficient appliances.. For example, initial hookup charges for new construction could vary with the efficiency of such built-in appliances as water heaters, central air conditioners, dishwashers, and ranges. Thus NU could project the efficiency of new appliances with greater confidence, since the Company would be ensuring that at least some of the efficiency improvements take place. The documentation for the DOE standards indicates that most of these improvements are extremely cost-effective.

Q: Please describe the NU commercial forecasting model.

A: NU's commercial model is virtually unchanged since 1978. Hence, the comments in pp. 15-23 of my testimony in EFSC 78-17 are still generally applicable. The model structure itself is dependent on several suspect assumptions:

1. net new employment is proportional to net new floor space;
2. total energy use per employee in a particular year is the same for all buildings; and
3. the fraction of energy use which is electricity depends only on a building's vintage.

The forthcoming elimination of floor space as a distinct entity in the model does not seem to eliminate the first assumption. Incorporation of price effects and retrofits into the 1981 model may weaken the effects of the last two assumptions, but this will not be clear until the 1981 model documentation is available.

The structural problems of the commercial model may be forgivable; no model can be perfect, especially for this diverse and poorly understood sector. However, even if the structure is accepted, the values used in the projection are not well documented or particularly reasonable. Demolition rates are the least important and probably the most reasonable of the projected parameters. The projections of total energy use per employee (Potential Electricity Use or PEU) and of electric penetration (P) are quite problematic.

As I noted in my testimony on the 1978 forecast, the derivation of a positive growth rate in total energy use is quite shaky. It depends on an assumption of constant fossil fuel efficiency, and on erratic and archaic data.

The data on which NU relies is only available up to 1976; large fluctuations and the short time period renders the post-embargo data almost useless. As I demonstrated with regard to the 1978 forecast, the pre-embargo trend depends critically on the time period chosen, varying from an increase of 4.7 kwh/employee/yr. for 1966-71 data to 242.3 kwh/employee/yr. for 1965 to 1973 data. The 1980 forecast used an annual increase of 212.5 kwh/employee/yr for projection while the 1981 forecast apparently uses a 105.4 kwh/employee/yr for annual increase. Whatever the actual pre-embargo growth in energy use may have been, it is inappropriate to assume that the reaction to decreasing energy costs in the 1960's and early 1970's will continue despite the increasing prices of the 1980's.

NU's projection of electric penetration rates suffers from problems similar to those for the PEU projection. There is no way to disaggregate NU's data into energy used in new buildings and energy used in existing buildings, so any estimate of historic penetrations is quite crude. This is particularly true in the post-embargo period, when large amounts of conservation radically changed the energy use in existing buildings. NU's 1980 forecast projected P to rise from .55 in 1980 to .70 in 1982; the 1981 forecast starts P at .60 in 1980, rising to .70. The basis of this projection is the assertion that the historic value of P is .70, and that recent lower values are some sort of aberration (p.59, 1979 Electric Energy Demand). NU has never offered any evidence to support this assertion, other than the analysis in the 1978 filing, which relied on arbitrary allocations of sales to new and existing buildings, on completely unsupported fabrication of parameters, and on absurd concepts (such as negative new floor space with a penetration of negative energy). My 1978 testimony contains a more detailed discussion of these points.

NU's forecasters are to be praised for not citing the 1978 analysis as the basis of their penetration projections; however, this has left the projection without any substantiation. In fact, the pre-embargo penetrations seem to have been much lower than NU assumes. The 1979 Electric Energy Demand volume provides us with the following data in Tables C-3 and C-4:

1. 1973 square footage of 347.9 million.
2. 1965 square footage of 253.6 million.
3. Old floor space being retired at 2.33 million sq. ft. per year in 1979, and declining at about 2%/year. Thus, 22.5 million sq. ft. would have been retired 1965-1973.
4. Hence 1973 commercial space consisted of 231.1 million sq. ft. of pre-1966 space, and 116.8 million sq. ft. of 1966-73 space.
5. Electric saturation in 1965 was 21.2%; in 1973 it was 28.3%.

6. Using NU's assumption that penetration rates are determined only by vintage, we can solve algebraically for the 1966-73 penetration rate that would yield the observed saturation.

The result is 37.6%, which is a far cry from 70%. This value is only as valid as NU's data and assumptions, but it illustrates the point.

Q: Please describe NU's industrial sales forecasting model.

A: The industrial model is econometric in nature; this generally seems to be an appropriate approach. The specifications of the (now obsolete) SIC-specific equations are reasonable, although the poor test statistics and omission of electric price from several equations require explanation, and documentation of the specification process is nonexistent. Nonetheless, the multiplicative functional form and the variables utilized in the equations provide a good basis for future aggregated industrial projections, with two exceptions.

The first major problem is the lack of a lagged price adjustment. Since accomodation to price changes requires some time (up to 10 or 20 years) for addition and replacement of equipment, it is unrealistic to expect an econometric model to accurately incorporate price effects without a phased-in price variable. Virtually every serious attempt to measure electric price elasticity on time-series data has incorporated a lagged adjustment.

For forecasting purposes, the long-term price effects can be modelled separately from the short-run effects, so long as they are adequately incorporated. Estimation of equations on long-term data, without consideration of long-term price effects, may be expected to bias the coefficients.

The second problem lies in the use of the conservation variable which captures some of the price effects in the post-embargo period. While the period during the embargo itself may be anomalous, any conservation observed in 1975 and beyond should be assumed to derive from normal forces, particularly price elasticity, unless some evidence to the contrary is available.

Q: Is NU's price forecast adequately documented?

A: No. NU's 1980 price forecasting methodology consisted of two steps. First, a price forecast was derived by the NU Capacity Planning Department in some unspecified manner with largely unspecified data and assumptions, to determine the fraction of projected costs which would be due to oil. NU's forecasters then multiplied different and inconsistent increases in oil prices by this fraction to estimate overall electric price escalation. If the capacity planners' assumption of constant real oil price had been replaced by the forecasters' projection of rising real oil price, the ratio of oil cost to total cost would have been larger, and the final price projection would have been higher.

Mr. Roncaioli, in his letter to me dated 2/10/81, indicated that the 1981 price forecast was derived in a more straightforward and complete manner. Unfortunately, he also indicated that NU has no intention of documenting the forecast. This position is simply unacceptable.

A forecast which is significantly sensitive to electric price is only as reliable and reviewable as the price forecast which derives it. NU cannot expect that public decisions will be based on NU's word that its price forecast is properly, if secretly, derived. If NU is large enough and sophisticated enough to conduct "an indepth analysis which accounts for all costs of generation" (and I believe it is), then it should be able to explain how those costs were estimated. A small utility (such as Fitchburg) may rely on a purely judgmental price forecast which seems reasonable to the forecaster. Reviewers of such a forecast would know that the price forecast is arbitrary and could readily substitute equally reasonable alternative values. NU asserts that its price forecast is based on an expert analysis, as is appropriate for a company of this size; reviewers must then examine the validity of the assumptions on which that analysis is based.

Some portions of the price forecasting methodology, particularly production costing models, may be so complex that they are difficult to explain in detail, and so standardized and non-controversial that such details are not necessary. Substantial amounts of important documentation should be available, however: descriptions of the models used (such as would be provided in a user's manual, for example), backcasts and calibration checks, and projections of important input values. Among these input values would be

1. fuel costs;
2. baseload unit availability;
3. O & M costs for transmission, distribution, and various generator types;
4. capital costs for new generation, transmission and distribution facilities, and for additions to existing facilities;
5. commercial operation dates for major new facilities and coal conversions;
6. dates of plant retirements;
7. carrying charge components, including capital structure, return on common equity, income and property tax effects, debt and preferred stock issuances and retirements, and overall cost of capital;
8. impact of NEPOOL interchange; and

9. the escalation and inflation rates used in projecting costs and reducing them to constant dollars.

While this may seem to be a large amount of data, it is all required for deriving the price forecast in the first place, and most of it can be quite simply stated. In the absence of this data, the price forecast can only be viewed as the forecaster's unsupported speculation.

Q: Is NU's wholesale forecast adequately documented?

A: No. In fact, NU offers nothing more than a table of sales to various customers. In previous years, some effort was made to at least back out sales from the customer's forecast of output and of generating capability. In 1980 forecast, no documentation or derivation is offered, nor is any planned for the 1981 forecast. Thus, the wholesale forecast is largely unreviewable.

The problem is exacerbated by the inconsistencies between NU's projections of its wholesale customers' purchases and those customers' own statements. MMWEC's filings with the EFSC have always indicated that wholesale purchases are to be phased out. According to the 1979 EFSC filing of MMWEC on behalf of its members, Westfield's wholesale purchases are to end in 1981, and South Hadley's in 1987. Thus, NU's forecast for 1989 includes at least 140 GWH which MMWEC and its members apparently intend to provide. Chicopee is also a member of MMWEC, while Groton, Jewett City, and Norwich are members of the

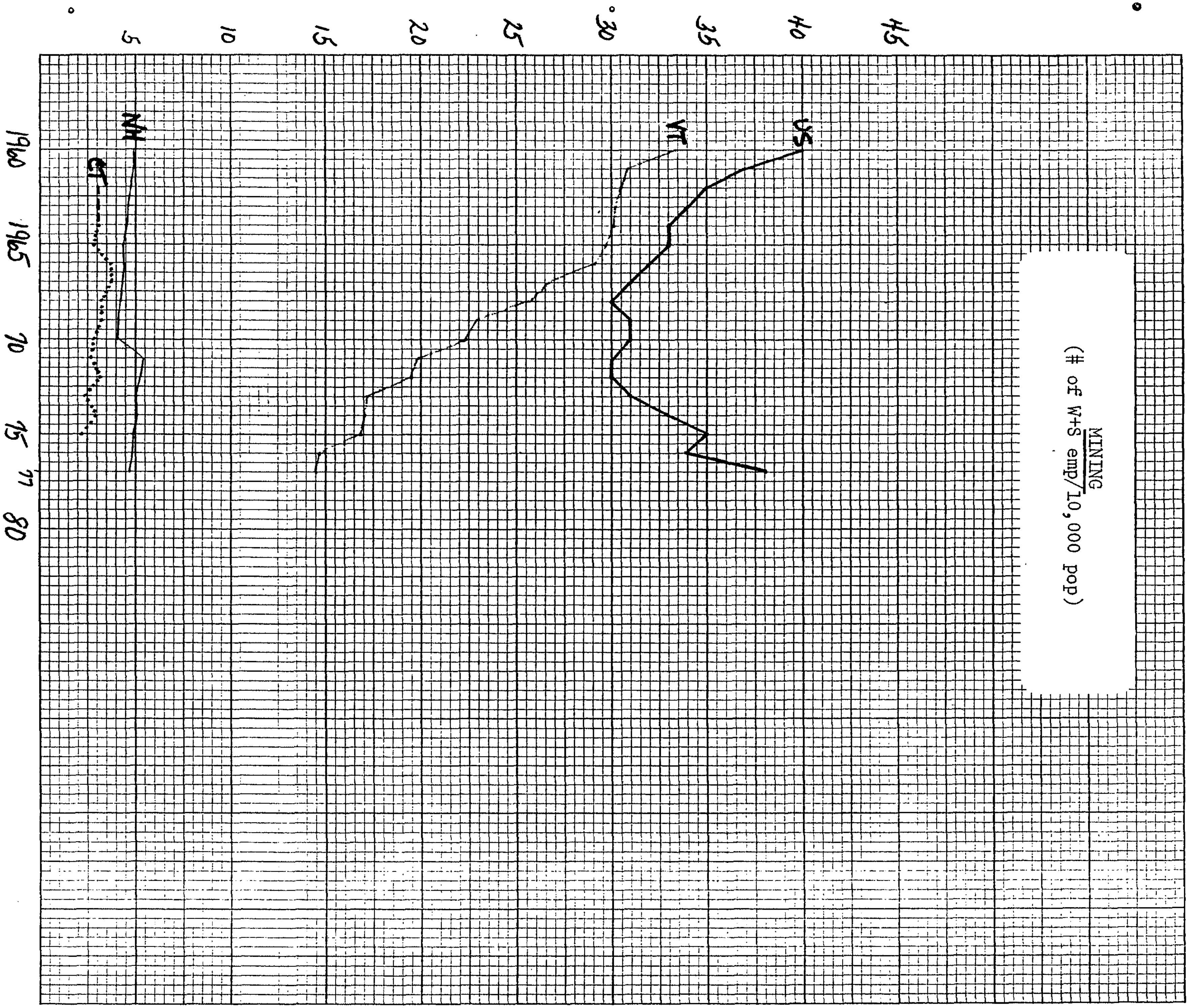
Connecticut Municipal Electric Energy Co-op (CMEEC). It is not clear whether NU is including in its sales forecast loads which these customers are planning to meet with other resources, but it appears from the growth rates in sales that NU is assuming CMEEC will have no generation before 1990. NU should at least attempt to reconcile its forecasts of sales to the municipals with the municipal's announced plans and official forecasts.

Q. Does this conclude your testimony on NU's forecast?

A. Yes.

APPENDIX A

Relative Trends in Non-Manufacturing Employment, from NEPOOL Model Documentation Number 8.


MINING
(# of W+S emp/10,000 pop)
NH
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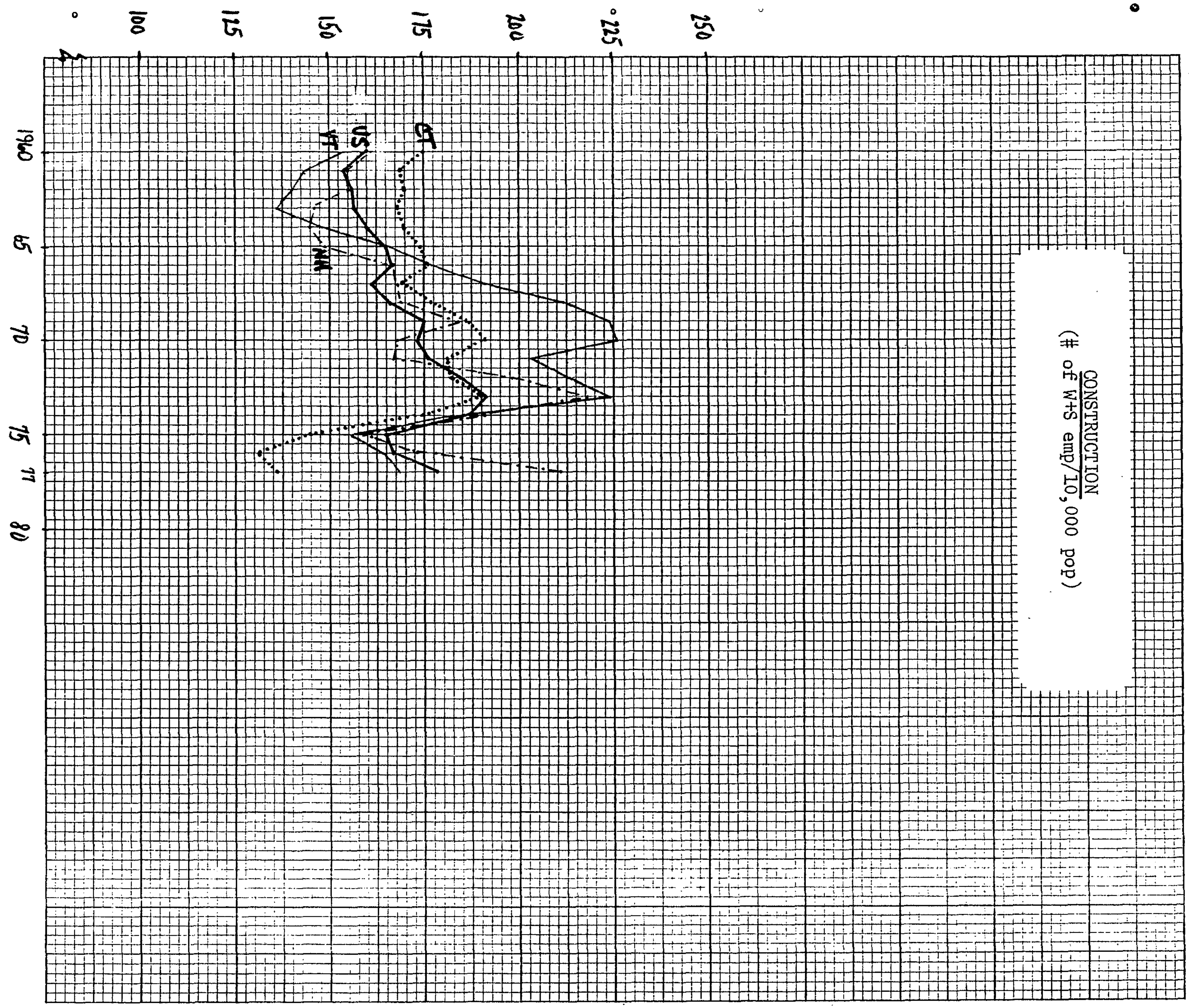
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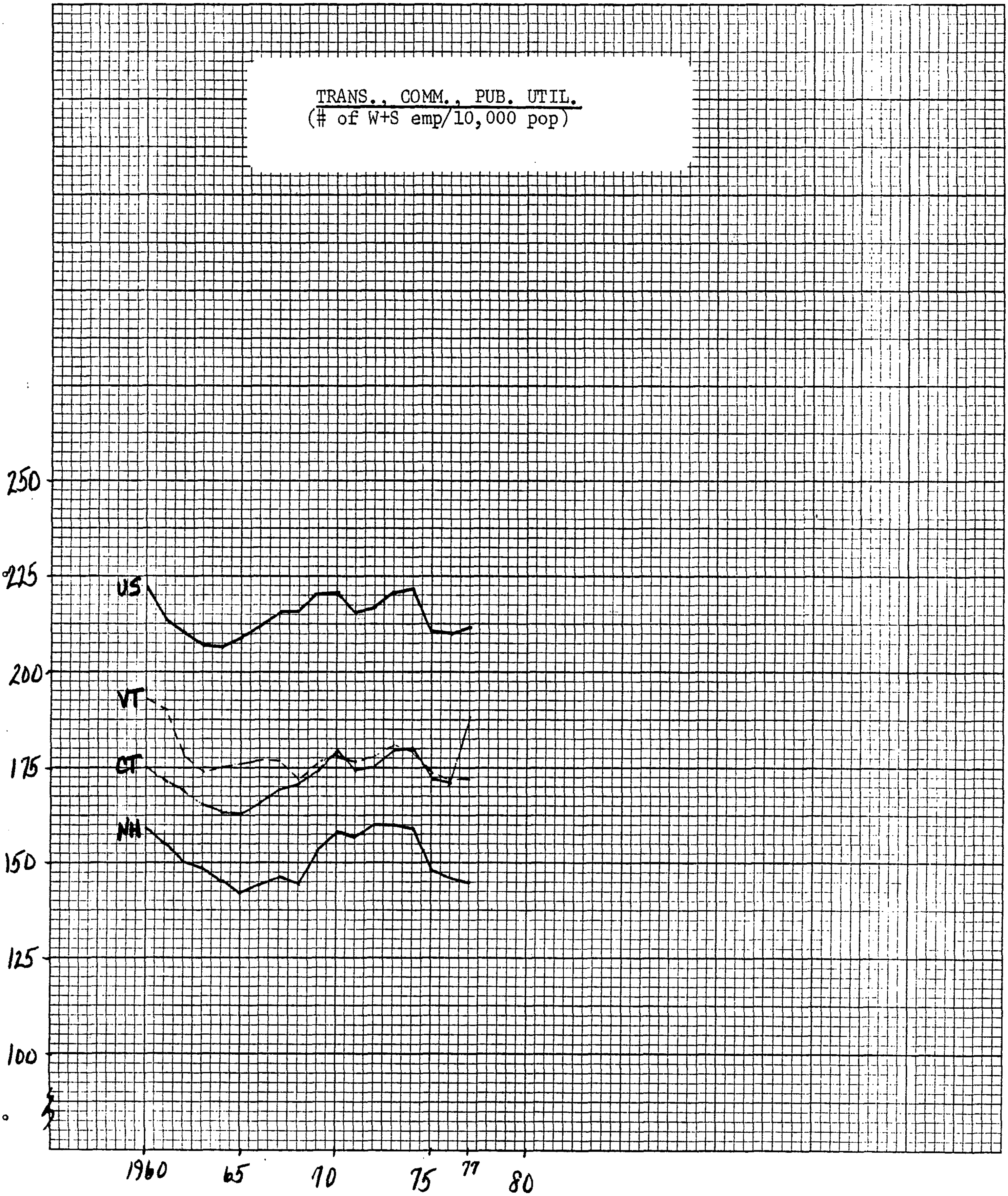

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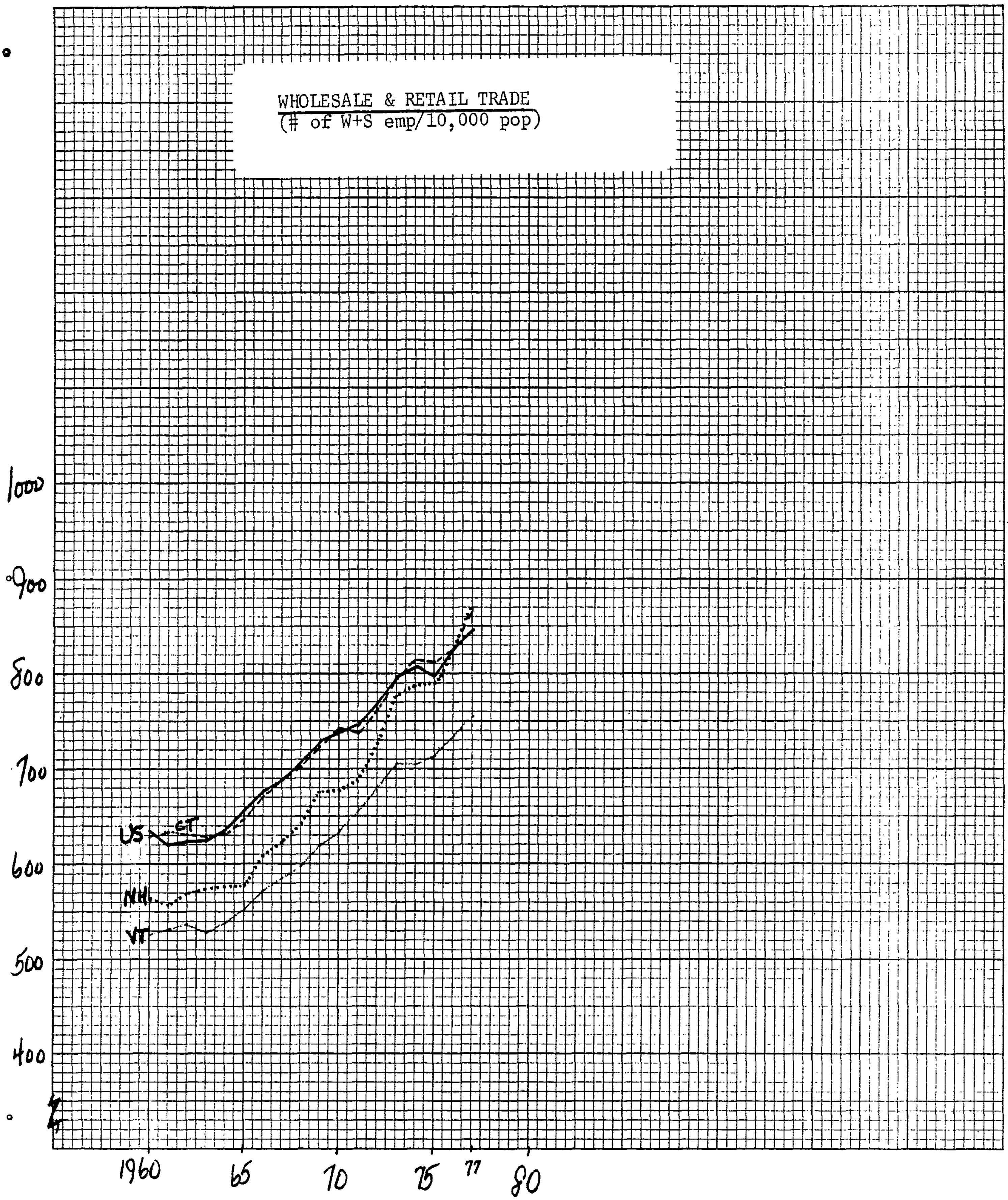
WHOLESALE & RETAIL TRADE
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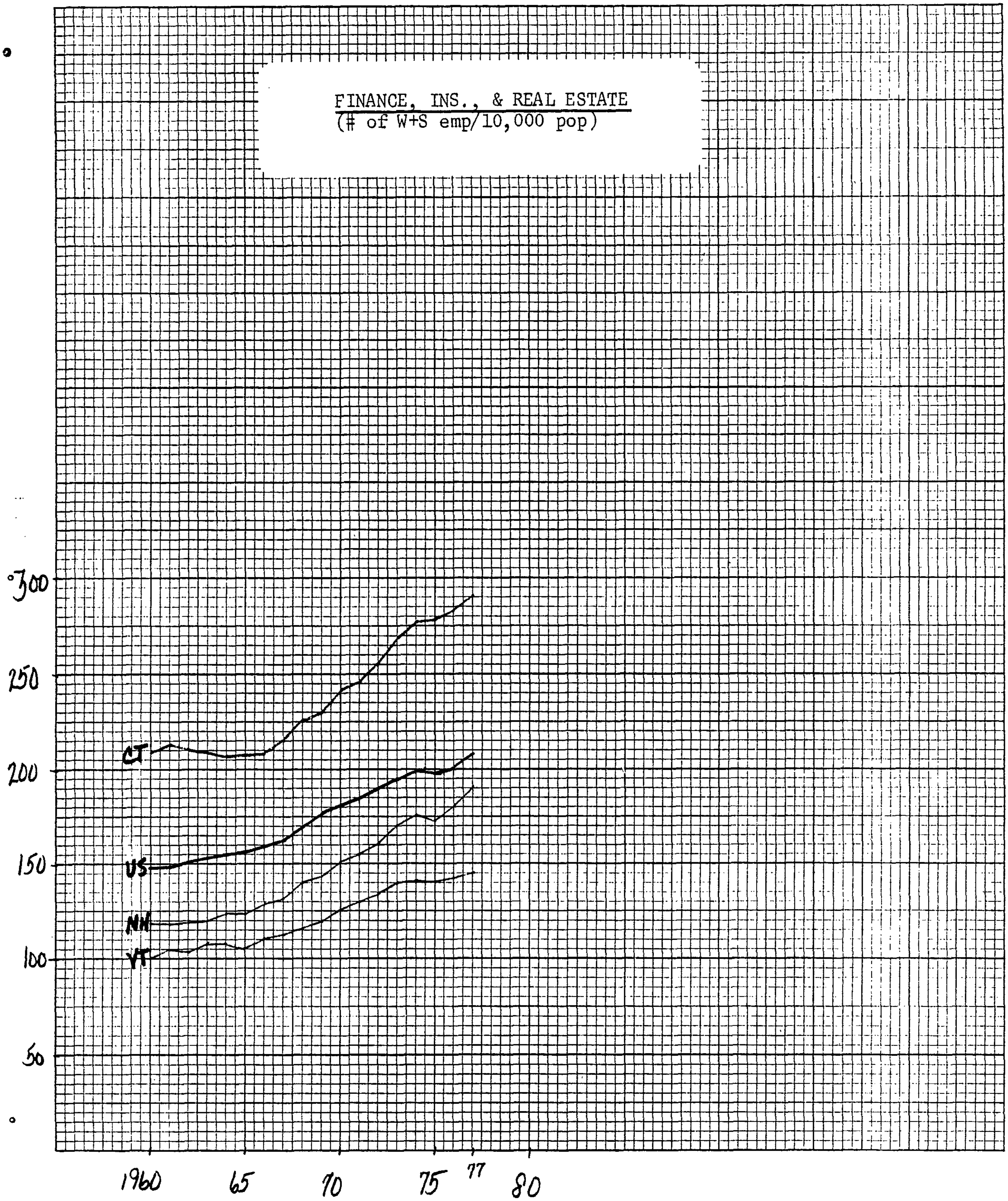
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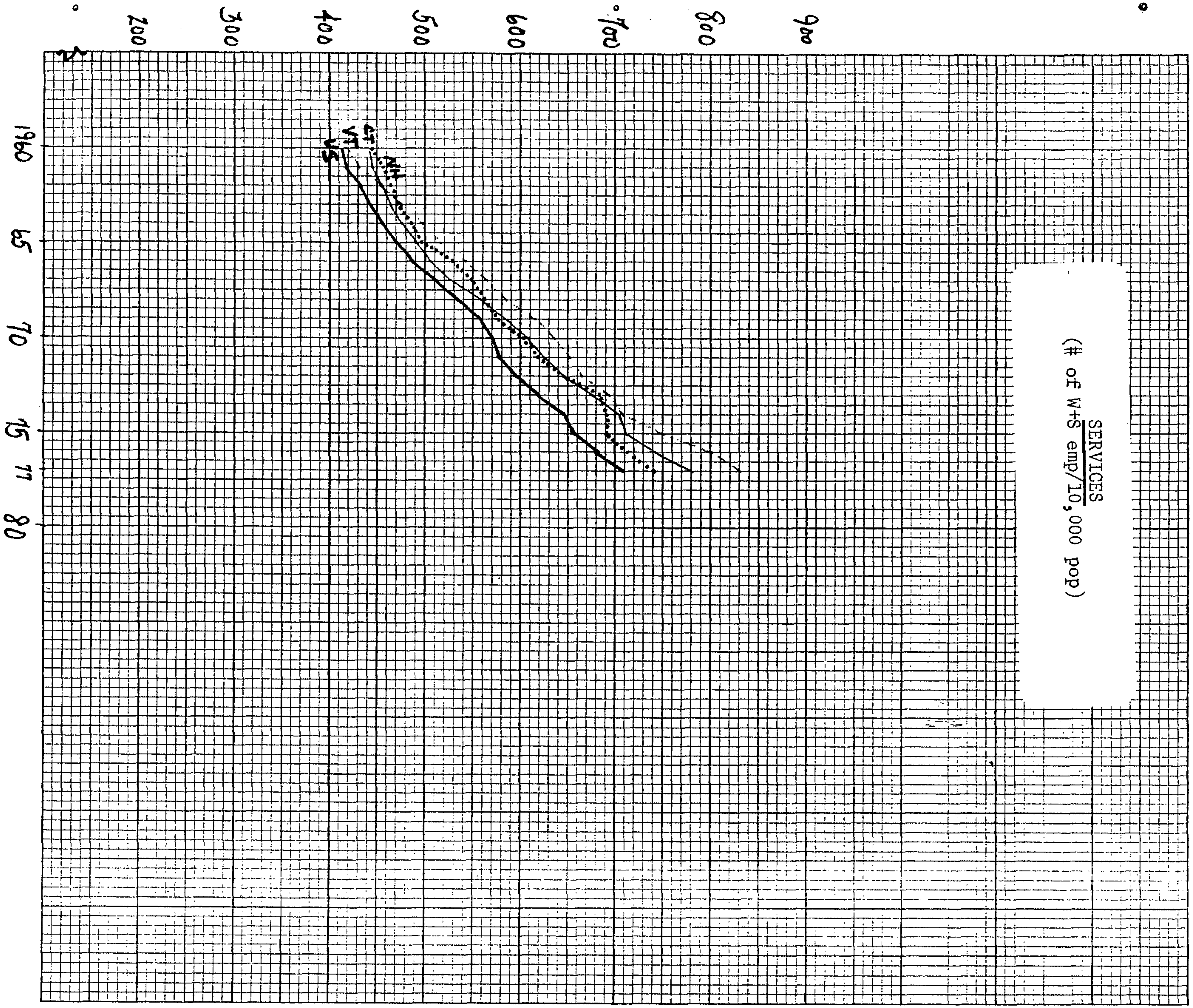
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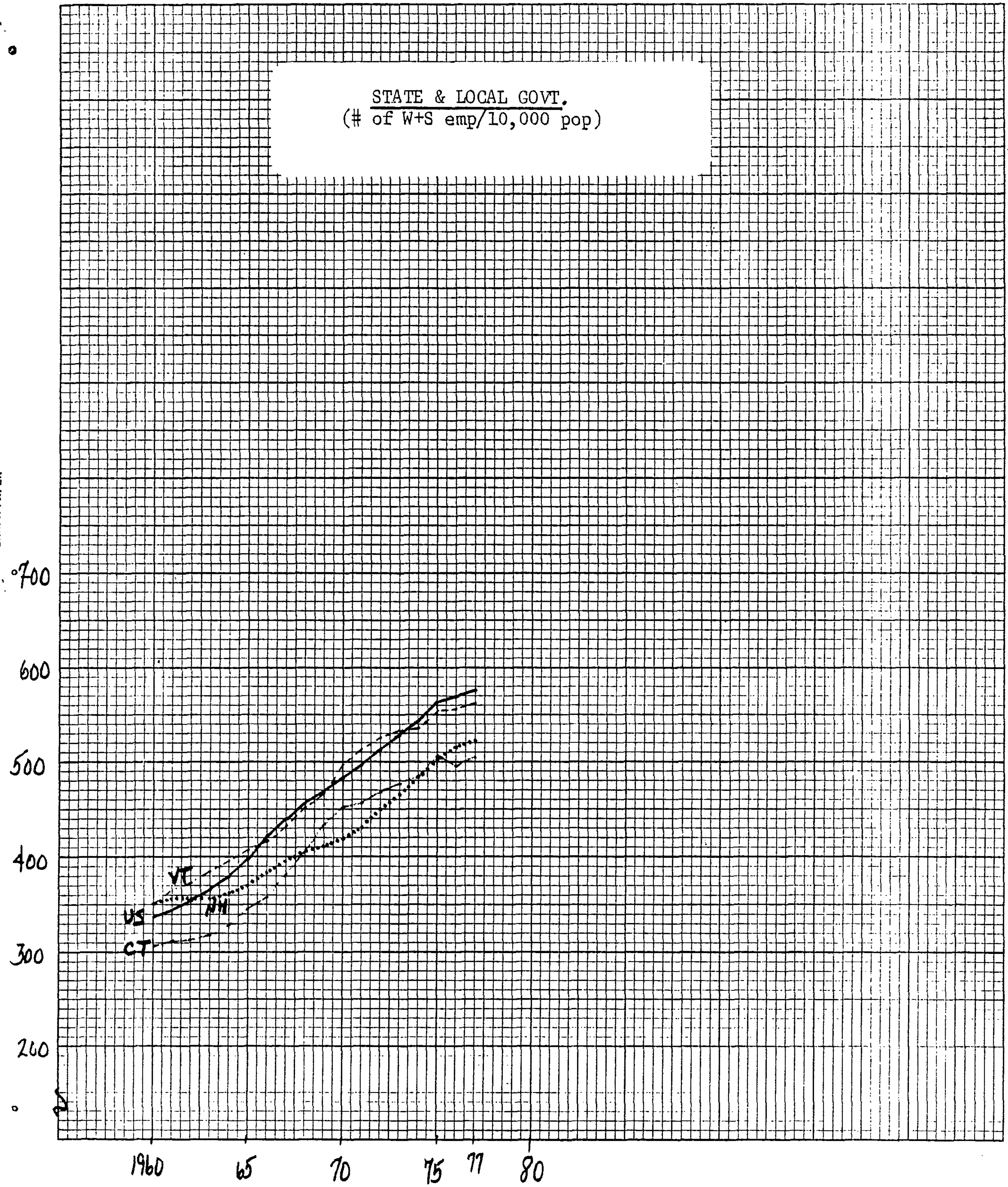
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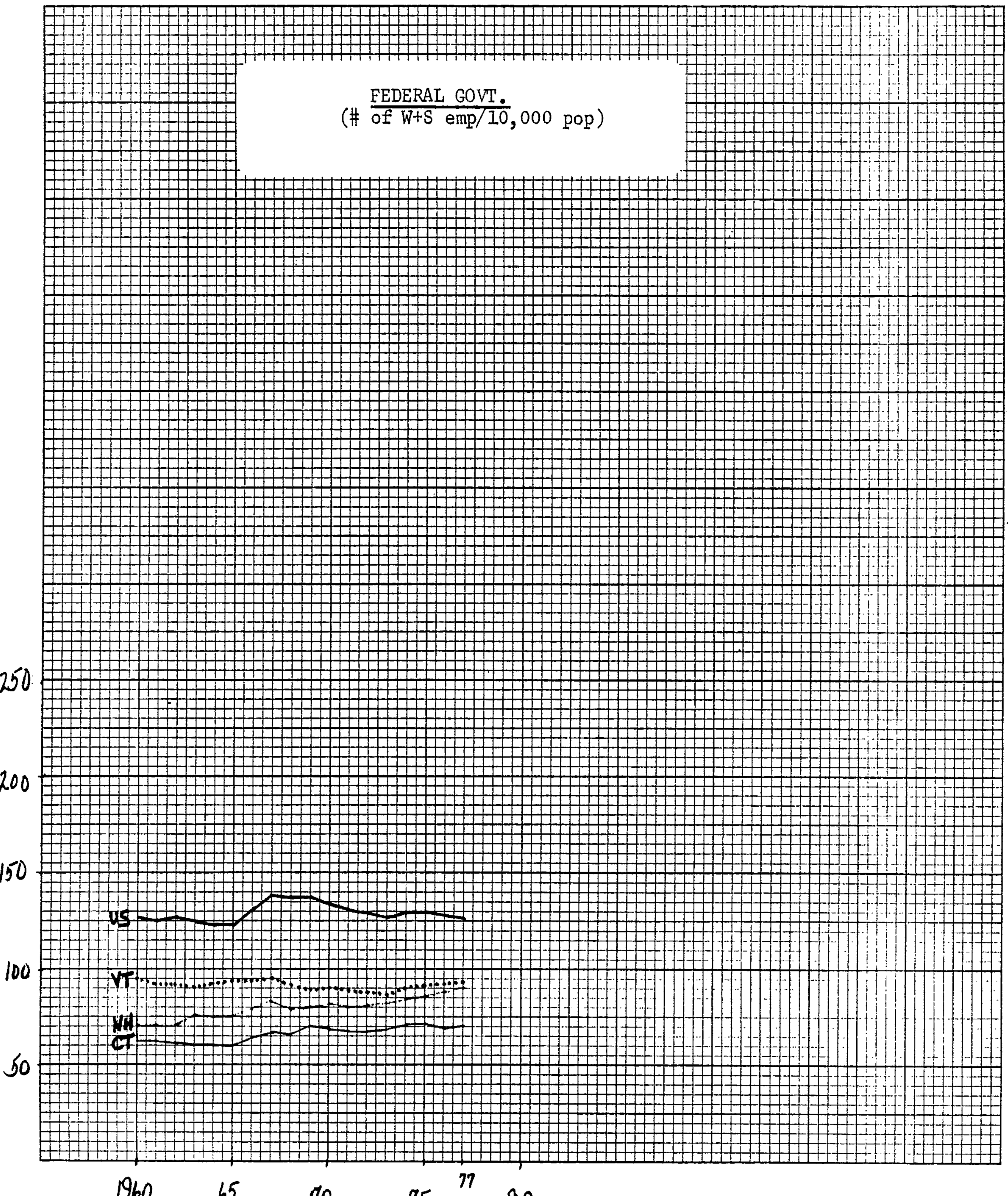

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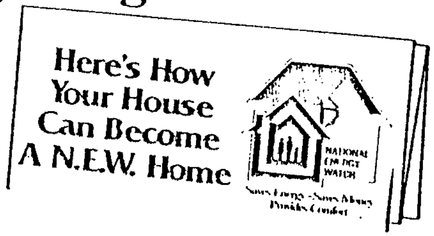
APPENDIX B

Recent NU Promotional Materials for Electric Space Heating.

National Energy Watch (N.E.W.) Program



Have you heard about our National Energy Watch (N.E.W.) program and the Energy-Efficient Home Award? NU is encouraging homeowners to take measures to improve the efficiency of energy use in the home. For details, call the Energy Management Services consultant in your local NU office.

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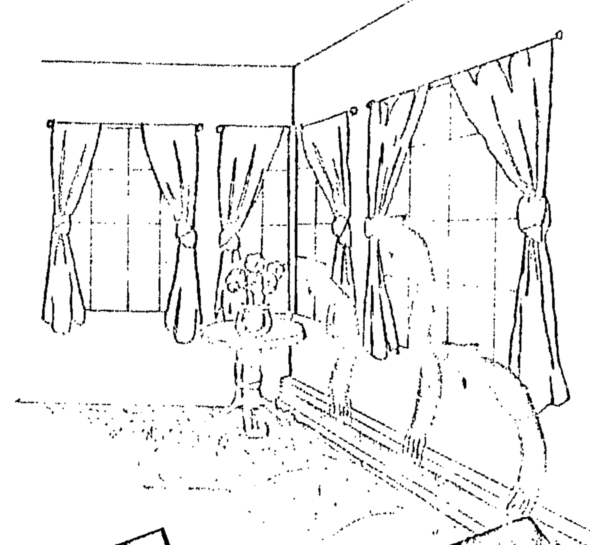
"Doing everything in our power to serve you"

ELECTRIC RESISTANCE HEAT



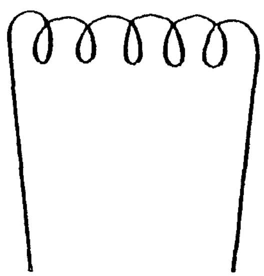
NU energy facts

One of the most important decisions the builder or buyer of a new home or an addition must make is the choice of a heating system.

Electric resistance heating is the basis for several commonly used heating systems today. If installed in a well-insulated house and careful attention is paid to the use of the thermostatic controls, electric resistance heat can be energy efficient as well as highly convenient.

How does electric resistance heating work?

Electric resistance heat is based on the phenomenon that energy is consumed and transformed into heat when an electric current is forced to pass through a material with high resistance; the activation of coils in a toaster is an illustration of this process. The amount of energy consumed and heat produced is a function of the resistance offered by the material and the pressure (voltage) with which the current is pushed.

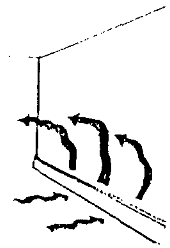


Electric space heating systems are nearly 100 percent efficient at the point of use as all the electric energy consumed is converted into heat.

Baseboard Systems

The most familiar form of electric resistance heat is the unit placed as part of the baseboard of walls within a room. The unit consists of finned tubing with a cover which has an inlet at the bottom through which cool air enters and an outlet above through which the warmed air leaves. Since warm air rises it circulates throughout the space to be heated.

This type of heating is called convection, that is, heat transfer through the gravitational mixing of a heated medium, which in this case is air.



Baseboard systems whether they are "dry" (as are electric systems) or "wet" (as in circulating hot water systems such as are used with oil-fired or gas-fired or electric boilers) are convection systems. The old-fashioned radiator also heats a space largely by convection.

Most of the 100,000 dwelling units in the NU service area which use electric resistance heating are equipped with baseboard units. The majority of the dwellings using them were built since about 1962 when electric baseboard resistance heat began to be used in this area. New houses or apartments using electric heat were almost all insulated to a higher level (R-19 in ceilings, R-11 elsewhere) than were other dwellings built at the same time. It is only in the last few years that buildings with gas- or oil-fired systems have been built with insulation up to the former "electric heat" recommended levels.

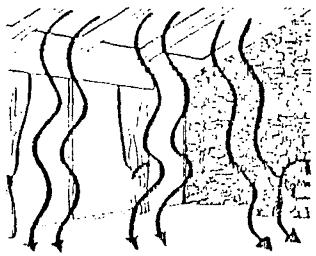
The characteristics of baseboard resistance heating that contributed to its widespread use in the 1960s and early 1970s were ease of installation, compactness (no space requirements for a boiler), low first cost, convenience (no fuel deliveries), lack of combustion in the home and the potential for economies through the use of individual room thermostats.

Electric Resistance Wall Heaters are often used for heating smaller areas in a dwelling such as bathrooms, hallways or entrance ways. They are installed in a housing which fits onto or is recessed into a wall. Sometimes a unit includes a circulating fan to provide more rapid circulation of warmed air throughout a space.

Radiant Heat

Another form of electric resistance heat is ceiling or floor radiant heat.

Radiant heat uses the principle of the transfer of heat by means of electro-magnetic radiation. Radiation is unique in that heat is transferred almost instantly over a distance, yet no discernible medium is required. The sun, for example, heats the earth without significantly warming the interplanetary space.



Radiant resistance heating systems invoive the installation of electric resistance wires in the ceiling or the floor. The heat radiating from these surfaces warms objects and persons in the space. The temperature in each room is controlled by an individual thermostat.

The most commonly used radiant systems for dwellings are those installed in ceilings. During the construction of the house, wires can be placed between layers of plasterboard which form the ceiling. Pre-wired ceiling panels are also available.

Ceiling or floor radiant systems are invisible and perfectly silent. Their use means that there is great freedom in the placement of furniture in a room and no possibility of interference with the circulation of warmed air by draperies, furniture or toys, etc., as can occasionally occur in rooms with convection units. Like baseboard electric systems, radiant systems are compact, convenient, and largely trouble-free.

Advanced Insulation

All new dwellings or additions should be built with an advanced level of insulation in the outside walls and in the ceiling. NU as part of its National Energy Watch (N.E.W.) program, recommends R-30 or R-38 in the ceiling, R-19 in the walls and in the floor over unheated spaces, double-glazed or storm windows. This is a higher level of insulation than used to be recommended for the electrically heated home, higher than that now required by state building codes but in line with the standards and regulations of most federal agencies.

In a new house of moderate size, the cost of insulating to such a level only adds about $500 to the cost of the house over the standard level of insulation now generally used. Cost evaluation studies show that this will be paid back in reduced energy bills in about three years.

How Much Do They Cost?

The cost of buying and installing an electric baseboard system in a 1,500 square-foot house insulated to the advanced level (thus making possible the use of somewhat smaller baseboard units) is about $1,500 according to a recent NU study. Every house will differ, of course, and the larger the house the higher the cost of the system.

Radiant systems are slightly more costly to install but will generally be less expensive than an oil-fired or gas- or electric-fired circulating water (hydronic) or forced air system.

The 1,500 square-foot house with advanced insulation will require about 11,000 kWh per year for heating. This would mean a heating bill of about $520 per year. By contrast, the same house insulated to the minimum code levels would use about 15,200 kWh a year and the heating bill would be about $720 a year. The savings in both energy and dollars from the use of advanced insulation are clearly evident.

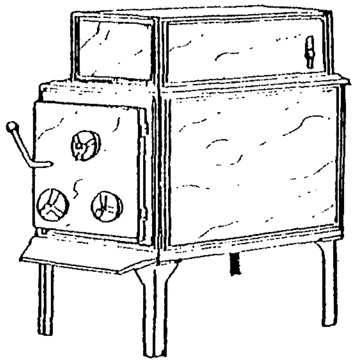
The cost of heating can be reduced further by careful use of the individual room thermostats with resistance baseboard or radiant systems to maintain lower temperatures in unoccupied rooms. Setting back the thermostats at night will also reduce energy costs on conventional rates; if time-of-day (TOD) or time-of-use (TOU) rates are used, no set back at night is recommended.

A recent study by NU of the 25-year cost of owning and operating several different home heating systems shows that an electric baseboard system is slightly less expensive than an oil hydronic system on a life-cycle basis when all costs are considered, including such items as installation, amortization of the mortgage, taxes, maintenance and fuel costs. (A copy of the pamphlet "Life-Cycle Costs: What are They?" is available from any NU office.)

Time-Of-Day (TOD) Or Time-Of-Use (TOU) Rates

Electric heating customers can take advantage of TOD or TOU rates more easily than other customers because most of the hours of high heating use are off-peak—nights and weekends (two-thirds of the hours in a week) when the lower prices per kilowatthour apply. Further savings in bills under the TOD rate will occur, moreover, if the use of other appliances (particularly the water heater) is shifted to the off-peak period and a consistent effort is made to keep thermostat settings lower during the peak hours.

Solar And Wood Supplementary Heat



Because of its compactness and low installation cost, electric resistance heating is appropriate to use in conjunction with solar space heating as a backup source of heat at night and on overcast days.

Both baseboard and radiant systems are also highly compatible with the use of wood stoves because the use of individual thermostats permits consistent temperatures to be maintained in rooms of the house other than the one being warmed by the fireplace or stove.

Electric Resistance Boilers And Warm Air Electric Resistance Furnaces

Electric resistance heat also may be used in conjunction with a boiler in a "wet" or hydronic house heating system. An electric furnace is available which heats air to be circulated throughout the dwelling. Both of these central heating systems are highly adaptable and are used for the conversion of fossil-fuel systems as well as in new construction. The electric boiler can be supplemented with a storage tank so maximum use can be made of time-of-day or time-of-use rates by doing most of the heating at night. Thermostatic control with these systems is done by zone within the house. Electric furnace warm air systems are often used in conjunction with central air conditioning systems.

Heat Pump

One form of electric heat, not described here because it does not use the resistance principle, is the heat pump. NU has prepared a leaflet on this most efficient way to heat a home which is also available in any NU office.

Is Electric Resistance Heat Economical? Energy Efficient?

Electric resistance heat in the form of baseboard units or ceiling radiant systems is both energy efficient and economical if:

- an advanced level of insulation is used in the house
- individual room thermostat controls are used carefully to avoid excessive heating of unused or little-used space.

Tips On Purchase, Installation and Maintenance

- request a heat loss analysis of your future home or addition from your architect/builder so that the system can be properly and economically sized for the job; NU energy consultants will provide estimated operating costs on request.
- buy quality units and thermostats to insure future comfort.
- in bathrooms or laundry rooms use wall or ceiling units; baseboard units in such rooms can rust, and towels and clothing can interfere with free circulation of air to such units.
- vacuum baseboard units periodically to remove dust.
- inspection and cleaning of electric boilers and furnaces should be done annually by a qualified person.

REMEMBER.

- Buy a high quality wood stove; before buying, comparison shop;
- Install the stove and its exhaust pipe to meet all building and fire code requirements. The installation must be inspected by an official in all municipalities;
- Combustion in high efficiency wood stoves which permit a long "burn" of the fuel results in lower flue gas temperatures than in open fireplaces. As a result there is the potential for building up a creosote in the stack or pipe. This creates a fire hazard. Flues should be inspected monthly during the first season the stove is in operation until the owner is aware of its operating characteristics. Flues must be cleaned annually or more often. Burning hardwood (oak, maple, hickory, etc.) will produce far less creosote than softwoods (pine, hemlock, spruce, etc.). Make sure that all wood used is properly seasoned;
- Be sure the stove is adequately vented to maintain an adequate supply of oxygen without depleting that in the space; a source of combustion air from outside brought to the stove by duct improves the efficiency of the stove.

NATIONAL ENERGY WATCH (N.E.W.) PROGRAM.

Have you heard about our National Energy Watch (N.E.W.) program and the Energy-Efficient Home Award? NU is encouraging homeowners to take measures to improve the efficiency of energy use in the home. For details, call the Energy Management Services consultant in your local NU office.

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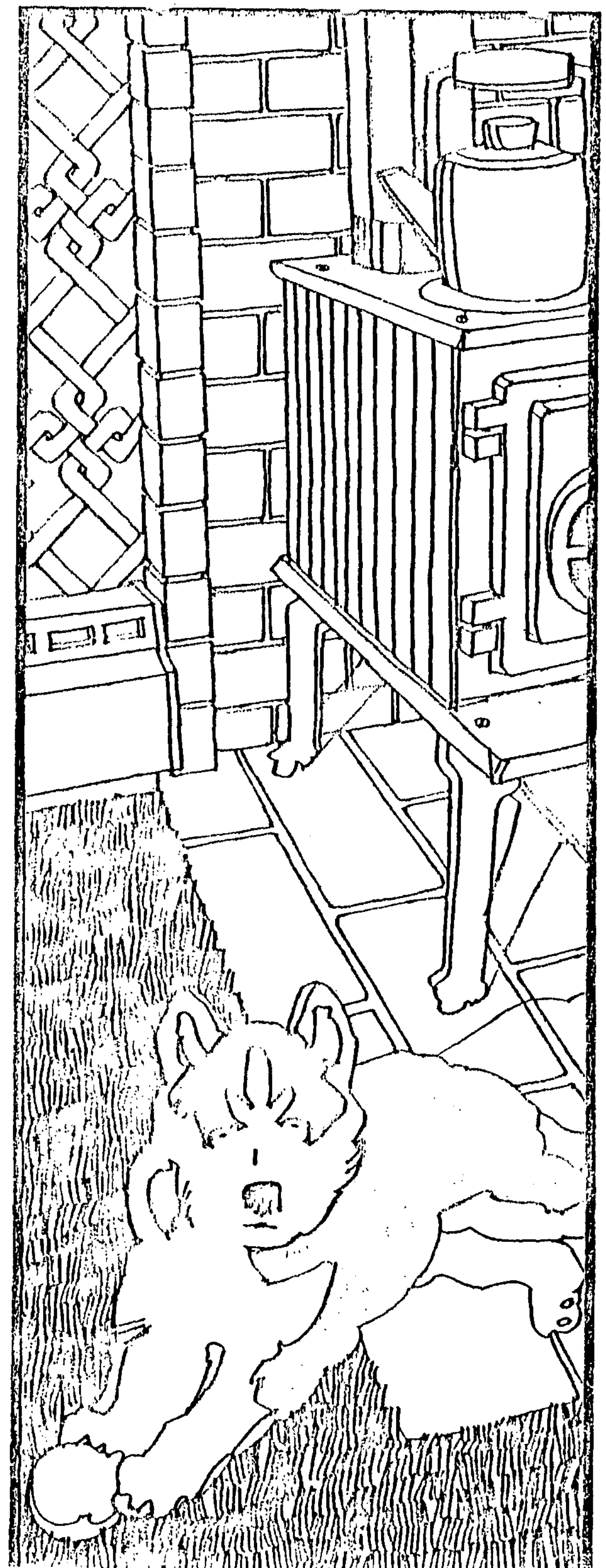
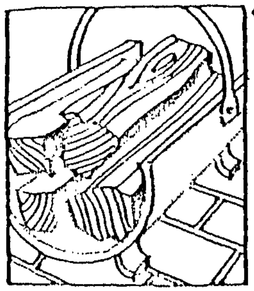


ENERGY ANSWER

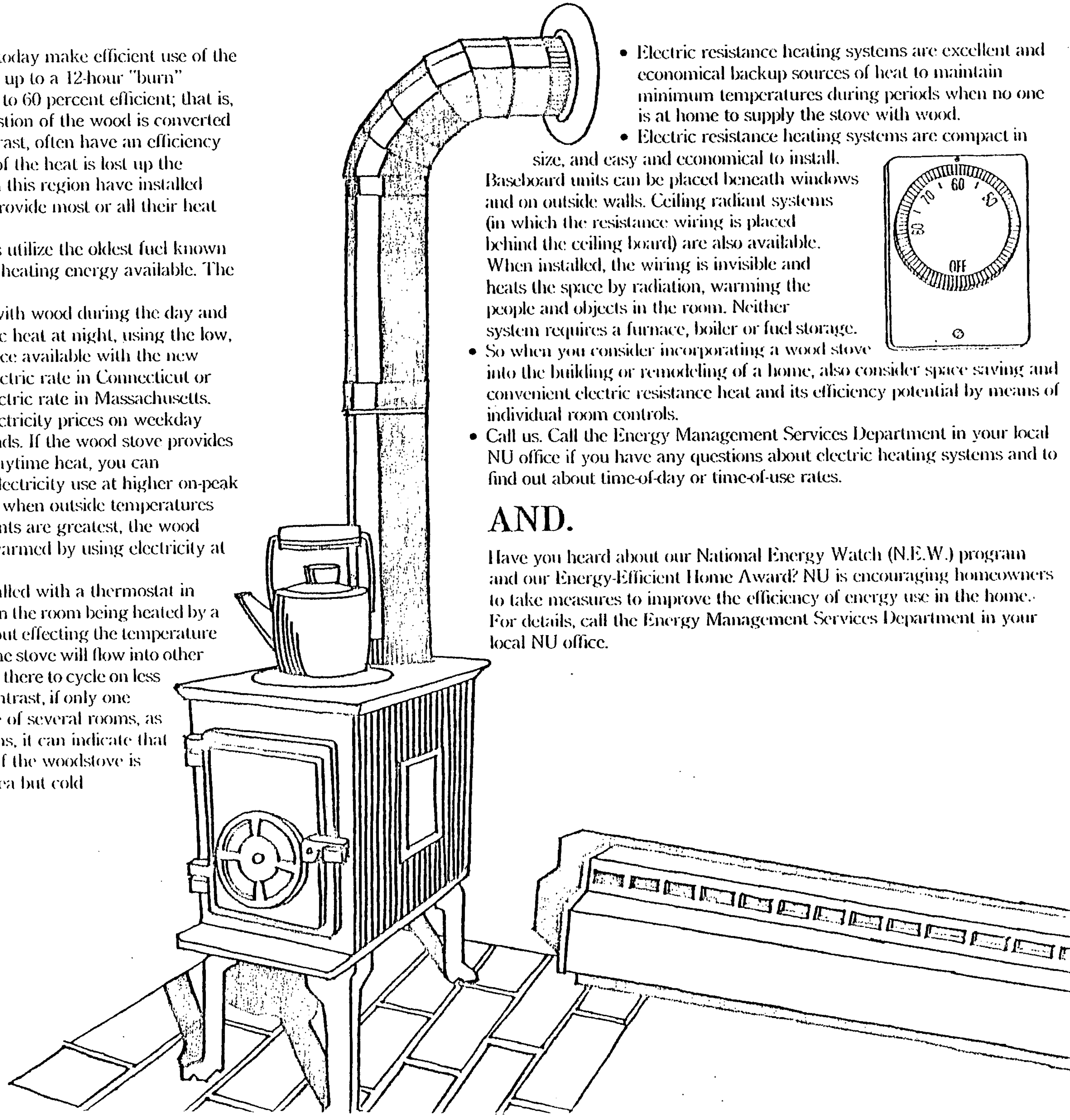
Wood Stove and Electric Resistance Heating

Many high quality wood stoves available today make efficient use of the energy from burning wood and provide up to a 12-hour "burn" without refueling. Some of these stoves are up to 60 percent efficient; that is, 60 percent of the heat energy from the combustion of the wood is converted to useful heat in the home. Fireplaces, by contrast, often have an efficiency of 10 percent or even lower because so much of the heat is lost up the chimney. Tens of thousands of homeowners in this region have installed wood stoves in recent years and use them to provide most or all their heat throughout the cold weather months.

Wood stoves and resistance heating systems utilize the oldest fuel known to man with one of the most modern forms of heating energy available. The combination is economical and convenient.



- Heat living quarters with wood during the day and bedrooms with electric heat at night, using the low, off-peak electricity price available with the new time-of-day (TOD) electric rate in Connecticut or time-of-use (TOU) electric rate in Massachusetts. This means lower electricity prices on weekday nights and all weekends. If the wood stove provides most of the house's daytime heat, you can significantly reduce electricity use at higher on-peak price times. At night, when outside temperatures are generally lowest and heating requirements are greatest, the wood stove can be supplemented and bedrooms warmed by using electricity at economical off-peak prices.
- Electric resistance heating systems are installed with a thermostat in each room. This means that the thermostat in the room being heated by a wood stove will automatically turn off, without effecting the temperature of the other rooms in the house. Heat from the stove will flow into other rooms and cause the electric resistance units there to cycle on less frequently and thus produce less heat. By contrast, if only one central thermostat controls the temperature of several rooms, as is common with fossil fueled heating systems, it can indicate that the desired heating level has been reached if the woodstove is nearby. The result is a hot central living area but cold outer rooms.



- Electric resistance heating systems are excellent and economical backup sources of heat to maintain minimum temperatures during periods when no one is at home to supply the stove with wood.
- Electric resistance heating systems are compact in size, and easy and economical to install. Baseboard units can be placed beneath windows and on outside walls. Ceiling radiant systems (in which the resistance wiring is placed behind the ceiling board) are also available. When installed, the wiring is invisible and heats the space by radiation, warming the people and objects in the room. Neither system requires a furnace, boiler or fuel storage.

- So when you consider incorporating a wood stove into the building or remodeling of a home, also consider space saving and convenient electric resistance heat and its efficiency potential by means of individual room controls.
- Call us. Call the Energy Management Services Department in your local NU office if you have any questions about electric heating systems and to find out about time-of-day or time-of-use rates.

AND.

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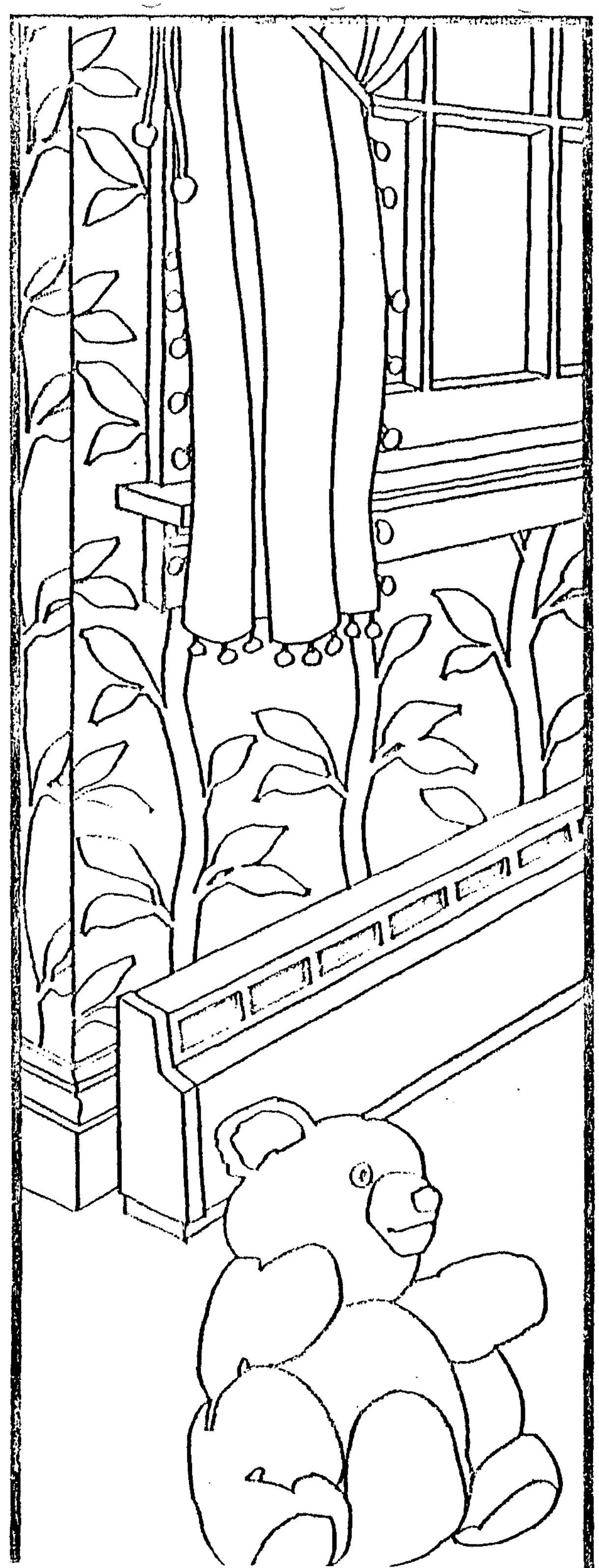
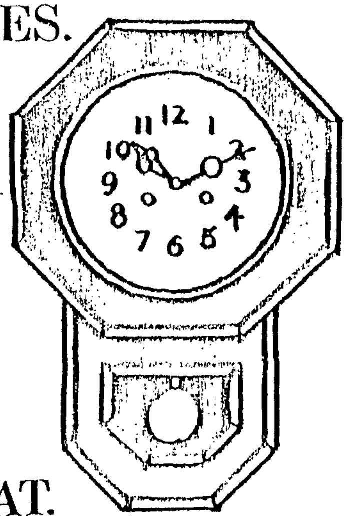


ENERGY ANSWER

Electric Resistance Heat

A recent NU study of the 25-year cost of owning and operating several different home heating systems shows that, on a life-cycle basis electric baseboard systems are slightly less expensive than oil hydronic systems when all costs are considered. This includes such items as installation, amortization of the mortgage, taxes, maintenance and fuel costs. (A copy of the pamphlet "Life-Cycle Costs; What are They?" is available from any NU office.)

TIME-OF-DAY (TOD) OR TIME-OF-USE (TOU) RATES.



Electric heating customers can take advantage of TOD or TOU rates more easily than other customers because most of the hours of high heating use are off-peak — nights and weekends (two thirds of the hours in a week) when the lower prices per kilowatthour apply. Further savings in bills under the TOD rate will occur, moreover, if the use of other appliances (particularly the water heater) is shifted to the off-peak period and a consistent effort is made to keep thermostat settings lower during the peak hours.

SOLAR & WOOD SUPPLEMENTARY HEAT.

Because of its compactness and low installation cost, electric resistance heating is appropriate to use in conjunction with solar space heating as a back up source of heat at night and on overcast days.

Both baseboard and radiant systems are also highly compatible with the use of wood stoves because the use of individual thermostats permits consistent temperatures to be maintained in rooms of the house other than the one being warmed by the fireplace or stove.

ELECTRIC RESISTANCE BOILERS & WARM AIR ELECTRIC RESISTANCE FURNACES.

Electric resistance heat also may be used in conjunction with a boiler in a "wet" or hydronic house heating system. An electric furnace is available which heats air to be circulated throughout the dwelling. Both of these central heating systems are highly adaptable and are used for the conversion of fossil-fuel systems as well as in new construction. The electric boiler can be supplemented with a storage tank so maximum use can be made of time-of-day or time-of-use rates by doing most of the heating at night. Thermostatic control with these systems is done by zone within the house. Electric furnace warm air systems are often used in conjunction with central air conditioning systems.

IS ELECTRIC RESISTANCE HEAT ECONOMICAL? ENERGY EFFICIENT?

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- an advanced level of insulation is used in the house
- individual room thermostat controls are used carefully to avoid excessive heating of unused or little-used space.

TIPS ON PURCHASE, INSTALLATION & MAINTENANCE.

- request a heat loss analysis of your future home or addition from your architect/builder so that the system can be properly and economically sized for the job; NU energy consultants will provide estimated operating costs on request.
- buy quality units and thermostats to insure future comfort.
- in bathrooms or laundry rooms use wall or ceiling units; baseboard units in such rooms can rust, and towels and clothing can interfere with free circulation of air to such units.
- vacuum baseboard units periodically to remove dust.
- inspection and cleaning of electric boilers and furnaces should be done annually by a qualified person.

HOW MUCH DOES IT COST?

Equipment and installation costs for a solar water heating system range from $2,000 to $3,000. On the average, the installed cost of a solar water heating system will approximate $1,800 including Federal tax credits. This is four to five times the cost of a fossil fuel or electric controlled storage water heater.

Solar supplementary heat will reduce annual purchased energy costs. A comparison of the cost of electricity for a water heater for a family of four under regular residential rates shows first year savings of approximately $100 through the use of a solar supplementary system, with lesser savings of approximately $75 realized through the use of a controlled electric water heater option to the residential rate. Both examples assume a 40 percent solar contribution and 1980 level CL&P rates. The savings would of course be somewhat greater if the solar share of water heating energy were to be greater.

PAYBACK.

The payback of the greater initial cost of a solar water heating system through reduced electricity costs may take ten years or more, depending on maintenance costs for the solar system and the escalation in the future cost of purchased energy.

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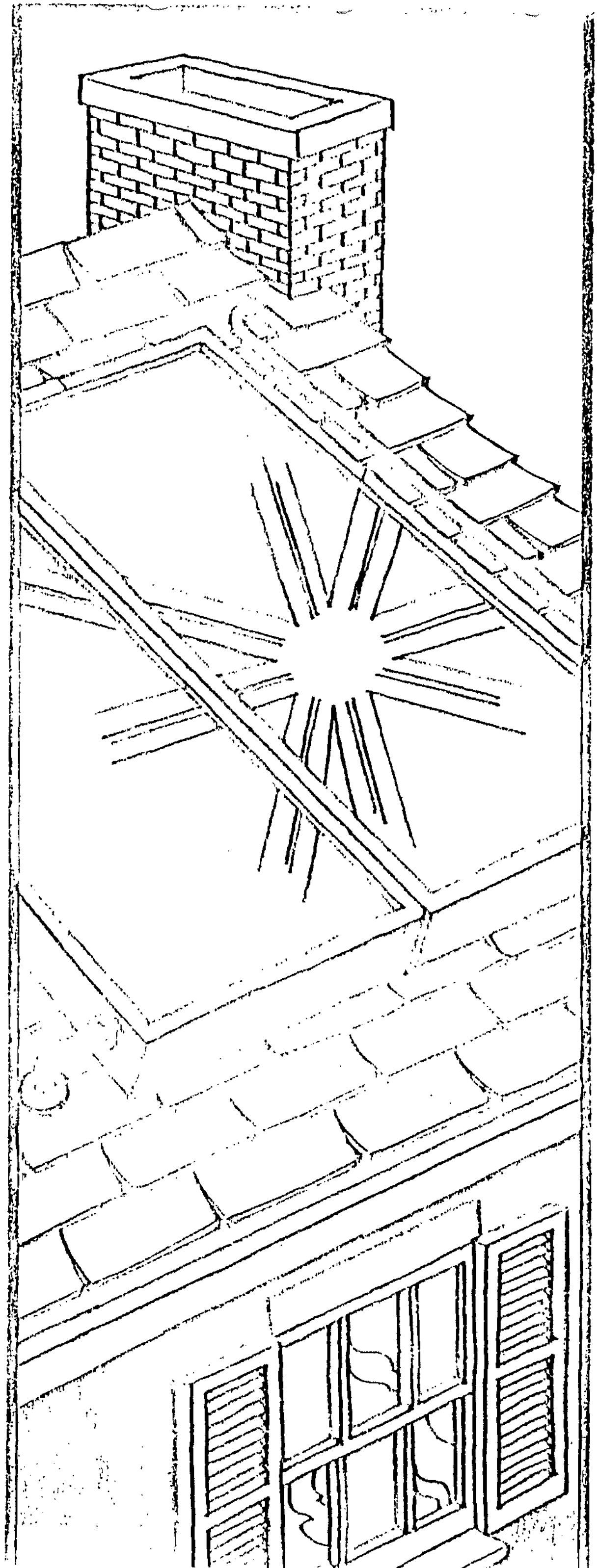


ENERGY ANSWER

Solar/Electric Water Heating

he most common direct application of solar energy for residential use in this region is as a supplemental source for water heating. Several hundred solar heaters for domestic water are in operation in Connecticut and Massachusetts at this time.

Solar energy in most commercially available systems provides from 40 to 50 percent of the heat energy for a household's hot water needs when properly designed and installed. The solar energy preheats the water; the supplementary, purchased energy source – electricity, oil or gas – brings the preheated water to the temperature level established by the thermostat and helps maintain it at that level.

ELECTRICITY BACKUP.

Electricity as a backup energy source for a solar water heating system has several advantages. It permits flexible location of the tank, as no outside vents or combustion are required. It is compact, requiring no fuel storage. Time-of-day (Connecticut) or time-of-use (Massachusetts) rates, or a special rate for a separately metered solar/electric water heater, are available, offering operating cost advantages with some solar systems.

USE GOOD JUDGMENT WHEN PURCHASING A SYSTEM.

Solar water heating systems, whatever the source of backup energy, are more complicated than conventional storage water heaters and are several times as costly to buy and install. Numerous systems are on the market, and the quality of design, manufacture, installation and service backup varies widely. The prospective buyer should examine the system and the experience of the dealer or installer carefully before making a purchase.

This leaflet gives a rudimentary description of how a solar water heating system operates and offers several suggestions regarding purchase and installation. A more detailed discussion has been prepared by NU and is available on request to the Energy Management Services manager in your local office, along with other informational materials on solar energy.

INSULATION.

All piping and the tank or tanks must be insulated to reduce heat lo practical minimum in order to take maximum advantage of the sola

Solar water heating systems do reduce purchased energy use in th and do provide a partial hedge against inflation in energy prices over

Selection of a reputable manufacturer and installer who will provid adequate warranties and continuing service backup is essential to insu satisfactory performance.

RECOMMENDATIONS.

1 Comparison shop: Examine the literature and speak to representativ several manufacturers. Speak to purchasers of the systems.

2 Buy quality: The economics of a solar system depend on long-term operation. It makes no sense to buy a major component that will not l 15 years or more.

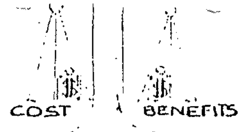
3 Choose the installer carefully: Experience and good reputation are key. Many well-established contractors are now installing solar systems.

4 Insist on adequate warranties: A two-year warranty on all parts and labor should be requested, effective following the final inspection by the building inspector. A five-year warranty on major components should also be requested.

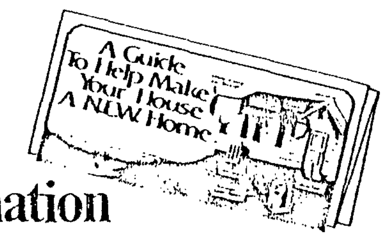
5 Be sure there is service backup: A reliable manufacturer and installer will provide adequate service backup. It is essential that there be knowledgeable help available if the system malfunctions.

6 Use an advantageous rate for the electric backup rate: The most economical NU electric rate available for off-peak operation is the time-of-day or time-of-use rate. Also available is a controlled water heat rate (CL&P, HELCO, Rate 18, for example). Both of these rates would be appropriate for use with a system with 80 to 100 gallons or more of storage capacity. For systems with lesser storage capacity, the conventional residential rate may be more economic.

What Should You Do?



You can see by the results of the life-cycle study that gas and electric space-heating systems under similar assumptions have a competitive edge over oil systems on a life-cycle cost basis. You will have to make your decision on which to purchase and install on the basis of your own judgement about the future cost and availability of fuels. Our study dealt only with costs associated with a prototypical house. Your house will surely be different and there will be different costs. There are also other factors to consider such as the type of heating system you want, — — convection, radiant, forced (warm) air, or "wet" (hydronic) or "dry" (baseboard electric) systems, etc. .There are also many other systems than have not been analyzed in our life-cycle cost study. You have a wide field from which to choose. It is important to remember from our study, though, that looking at one cost alone—initial cost or first-year energy cost—is not enough. Remember that true comparisons can only be made when all costs are considered.



More Information

If you want to find out more about NU's space heating life-cycle cost study, we would be glad to send you or show you a copy of the 120-page report. We would also like to share with you other information we have about home heating systems and the National Energy Watch (N.E.W.) program and the Energy-Efficient Home Award. Call the Energy Management Services consultant at your local NU office.

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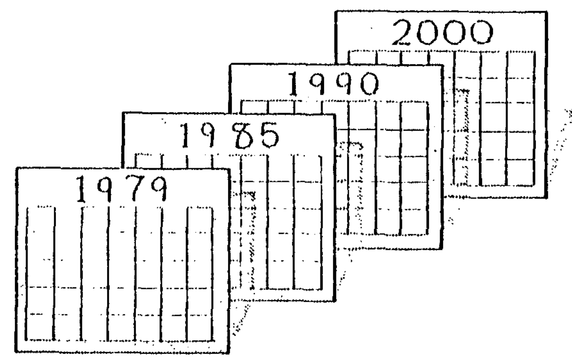
Life-Cycle Costs Of Space-Heating Systems

What Are They?



NU energy facts

Which Home Space-Heating System Is Most Economical?

If you are building or buying a new house, one of the important choices you have to make has to do with the type of heating system. All prospective homeowners have an interest in a fundamental question about a home-heating system:
Is it economical to own and operate compared to other systems?

It is not an easy question to answer. Some systems have a relatively high first cost for purchase of equipment and installation, but the yearly operating costs may be somewhat lower than those of other systems. Or the reverse may be true. There may be a low first cost for purchase and installation and higher annual costs for energy.
Do these differences balance out over the long run?
What will be the cost of repaying that part of the mortgage covering the heating system?
What will be the effect of inflation on property taxes and maintenance?
What will be the cost of energy in future years?
And, summing up all these and other questions, what are likely to be the total costs of one system versus another system over the lifetime of a mortgage?

Life-Cycle Cost Analysis

NU has applied a method called life-cycle cost analysis to several home space-heating systems. Using the computer, it provides a way of developing total costs including the initial cost, mortgage payments on that initial cost (amortization), property tax and energy costs. The computer program is able to include different rates for inflation and for increases in the cost of energy for comparative purposes.

Required to start the analysis is an assumption as to the type and cost of the heating system, the amount of energy it uses annually and its cost in the first year, the mortgage costs, property tax and tax credits (as for solar units), tax deductions and maintenance costs. Then, when assumptions are made as to the inflation rate (which affects the tax and maintenance costs over the years) and the increases in the cost of energy, the computer produces for each of the 25 years of the assumed life of the mortgage the total costs of the heating system in that year. It also develops the total life-cycle cost of the system, summing the 25 yearly costs either in current dollars or in "present value" dollars, that is future dollars discounted to reflect the earning power of an alternative investment made in the initial year, in this case 1977. This total, which runs into the thousands of dollars, can be compared to the totals for other systems to determine which is

Installation And First Year Costs Compared

Here are examples of the installation and operating costs used to establish the first-year costs for the systems. Conventional electric rates and the use of an advanced level of insulation (recommended by NU) are assumed for all the systems.

Initial Cost (1977) and First-Year Operating Costs (1978)
1978 First-Year Costs

Heating System	1977 Initial Cost	Mortgage Interest	Mortgage Principal	Property Tax
Electric Baseboard	$1,948	$175	$ 23	$ 61
Electric Heat Pump	3,851	347	45	122
Oil Hydronic (hot water)	2,788	251	33	89
Gas Hydronic (hot water)	2,445	220	29	77
Solar with electric supplement	9,956	896	118	85

Heating System	Tax Deduction or Credit	Energy Costs	Maintenance	Total
Electric Baseboard	$ (59)	$429	$ 11	$ 640
Electric Heat Pump	(117)	286	80	763
Oil Hydronic (hot water)	(85)	393	53	734
Gas Hydronic (hot water)	(74)	321	27	600
Solar with electric supplement	(246)	191	219	1,263

( ) = Deduction

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...d First-Year Operating Costs (1978)
...'8 First-Year Costs

...77 ...ial ...st	Mortgage Interest	Principal	Property Tax
...48	$175	$ 23	$ 61
...51	347	45	122
...88	251	33	89
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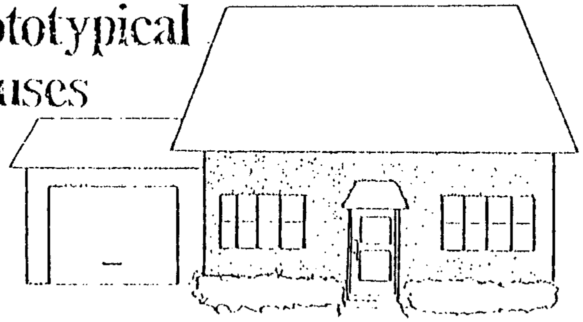
...ax ...uction ...or ...edit	Energy Costs	Maintenance	Total
(59)	$429	$ 11	$ 640
117)	286	80	763
(85)	393	53	734
(74)	321	27	600
46)	191	219	1,263

and the lowest energy cost. The electric baseboard system has the lowest initial cost. However, it and the oil hydronic system have the highest first-year energy costs followed by gas. It is evident that the electric baseboard and gas hydronic systems have the lowest total first-year costs.

Prototypical Houses



The systems were assumed to be installed in identical "prototypical" houses, each a two-story frame construction colonial with attached garage, 1,536 square feet of living area, three bedrooms, two bathrooms, full basement, fireplace with chimney. In one set of life-cycle analyses it was assumed that the prototypical houses were insulated to a conventional standard (R-19 in the ceiling or attic, R-11 in the walls, R-11 over unheated spaces). In another analysis it was assumed they were insulated to an advanced standard such as advocated by NU (R-38, R-19, R-19). Energy costs were assumed to escalate at 6, 8 or 10 percent annually. All-electric systems were assumed to be on conventional rates.

Principal conclusions of the life-cycle cost analysis

1. **Advanced insulation levels are cost justified for every type of heating system.**

Look at these yearly energy cost savings:

First-Year (1978) Heating Energy Cost
Standard Versus Advanced Insulation

Total Heating Fuel Cost

Heating System	Standard Insulation	Advanced Insulation	Savings Through use of Advanced Insulation $	%
Electric Baseboard	$590	$429	$161	27%
Electric Heat Pump	$394	$286	$108	27%
Oil Hydronic	$522	$393	$129	25%
Gas Hydronic	$471	$321	$150	32%
Solar/Electric	$352	$191	$161	46%

The savings from the use of advanced insulation are impressive for all the systems. (You can also use the table to compare the annual heating energy costs among the

Savings with gas systems are larger than those with the electric or oil systems because the smaller burner size means reduced cycling of the furnace and thus more efficient utilization of fuel with less waste of heat through the stack. The substantial savings found with the use of advanced insulation with a solar/electric system occur because the solar array is the same size as with standard insulation and thus can contribute a larger share of the total energy used in the home. The total 25-year life-cycle savings are even more dramatic with advanced insulation.

Total 25-Year Life-Cycle Cost Savings
Advanced Insulation versus Standard Insulation
Savings in 1977 Dollars

Electric Baseboard	$2,800
Electric Heat Pump	$2,200
Oil Hydronic	$2,200
Gas Hydronic	$2,500
Solar/Electric	$2,800

Since the incremental cost of advanced insulation in a new house is assumed to be $500, it can be seen that over 25 years, it is repaid several times over, even in 1977 "present value" dollars as shown above. Advanced insulation is a superb investment!

2. **Assuming the same energy cost escalation rate, gas and electric space heating systems have lower life-cycle costs than the oil hydronic system or the solar/electric system.**

Comparative 25-Year Life-Cycle Costs (1977 Dollars)

Heating System	Energy Cost Escalation Rates @ 6%	@ 8%	@ 10%
Gas Hydronic	$10,300	$12,000	$14,300
Electric Resistance	$11,400	$13,700	$16,800
Electric Heat Pump	$12,600	$14,100	$16,200
Oil Hydronic	$12,700	$14,800	$17,600
Solar/Electric	$18,600	$19,700	$21,000

There are considerable differences in the total cost of the systems under the different energy cost escalation rates. You can make your own comparisons between the different columns.

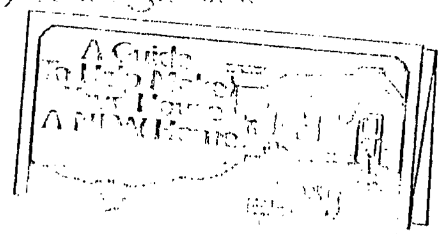
It is consistently true that if the prices of oil, electricity or gas increase at the same rate, the electric and gas systems are somewhat less expensive than oil, although the differences are not large.

The solar/electric system remains the most expensive of all because of its high initial cost.

4. Make sure ductwork design and installation is adequate.
   - a quality heat pump will not give satisfactory performance if the ducts are too small or if they are noisy in operation.

5. Maintain constant thermostat levels as much as possible.
   - frequent resetting of the thermostat levels will result in higher energy costs, as the supplementary units will come on if the level is raised in order to bring the house quickly to the desired temperature. It is best to maintain a constant setting. If you are away from the house for many hours or days, a lower setting is desirable.
   - the operation of the heat pump is compatible with current time-of-day rates because daytime temperatures usually are higher and the heat pump will operate more efficiently and with less use of electricity than at night. An estimated 70 percent of electricity use for the heat pump in the heating months is used in the off-peak periods now in effect for those NU customers who have selected the TOD or TOU rate.

National Energy Watch (N.E.W.) Program



Have you heard about our National Energy Watch (N.E.W.) program and the Energy-Efficient Home Award? NU is encouraging homeowners to take measures to improve the efficiency of energy use in the home. For details, call the Energy Management Services consultant in your local NU office.

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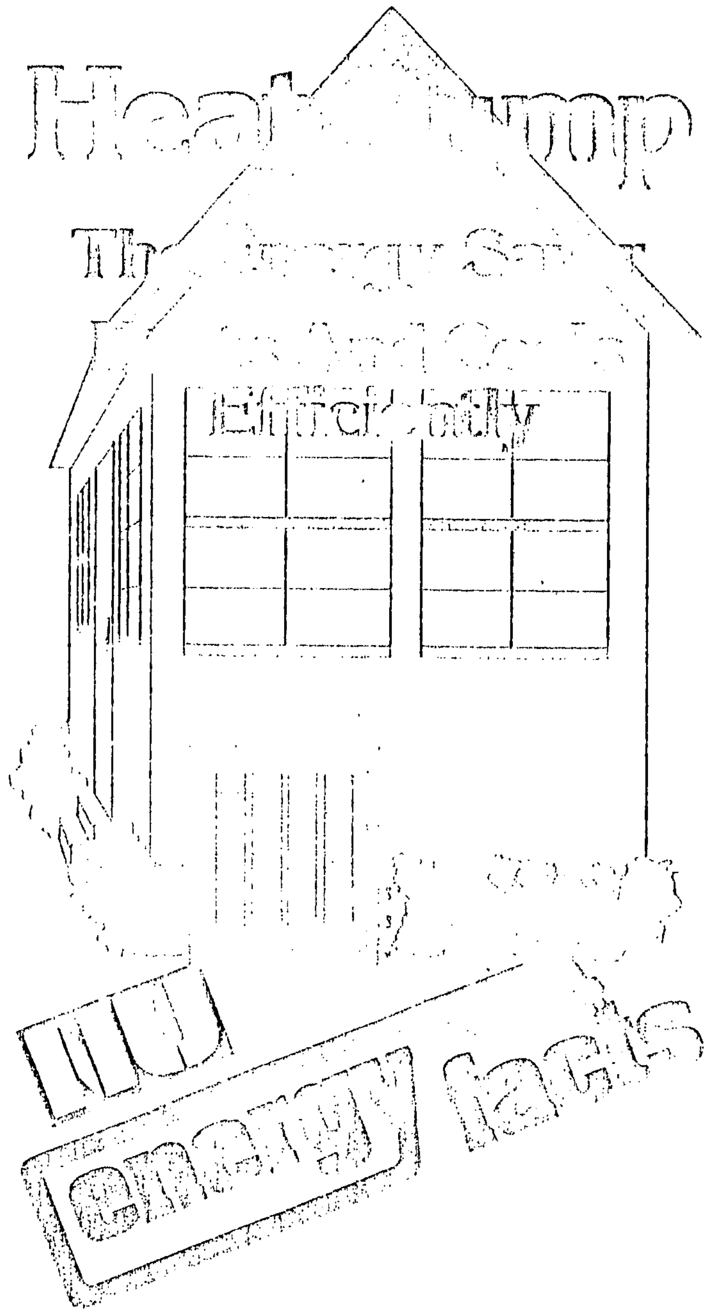


NU energy facts

...theast Utilities is encouraging homeowners and builders to achieve a high standard of energy efficiency in dwellings. The heat pump is a modern and highly efficient way of heating and cooling a dwelling and should be considered by anyone building a new home.

... Heat Pump?

...he heat pump is being used in increasing numbers in the area to heat and cool dwellings. In 1977 there were ...,000 heat pumps installed in homes in the U.S., ...ly outside New England. They are just now beginning to be introduced in northern New England and in this area. The heat pump is highly efficient because over ... percent of the heating energy it supplies to the house comes from the outside air. For this reason the heat pump has been widely recognized as an energy-efficient way of heating a home appropriate for a time when reducing heating costs and energy use is desirable for everyone.

... Heat from the ... Air

The heat pump, when it is used for heating, transfers heat from the outside air to the inside. Even on the coldest days, there is heat available in the outside air—a surprising fact to many people. Even though it feels cold at 0°F, there is still 82 percent of the heat in the air that was available at 100°F. It is only at −460°F, absolute zero, that no heat exists in the air.

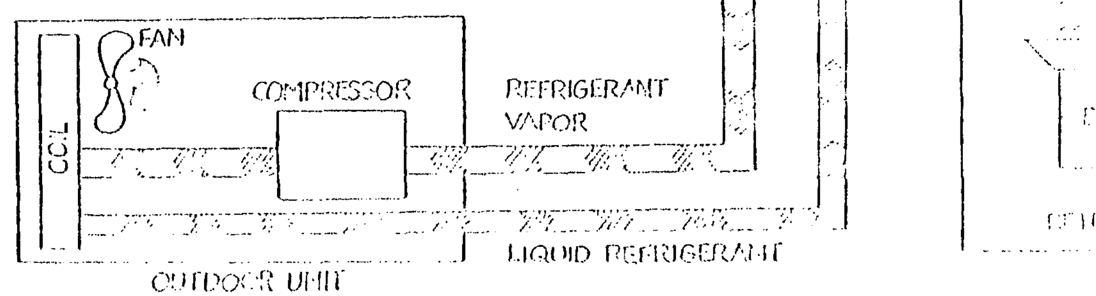
How a Heat Pump Works:

Cooling...

The outdoor unit compressor feeds liquid refrigerant through its coil to the indoor coil. Warm indoor air is forced over the coil by the blower. The liquid refrigerant changes to vapor and absorbs heat, lowering the temperature of the indoor air blowing over the coil.

Refrigerant vapor goes back to the outdoor unit. It is compressed and flows through the outdoor coil where its stored heat is released to the air and it returns to a liquid. This is a continuous process as long as there is a need for cooling.

OUTDOORS

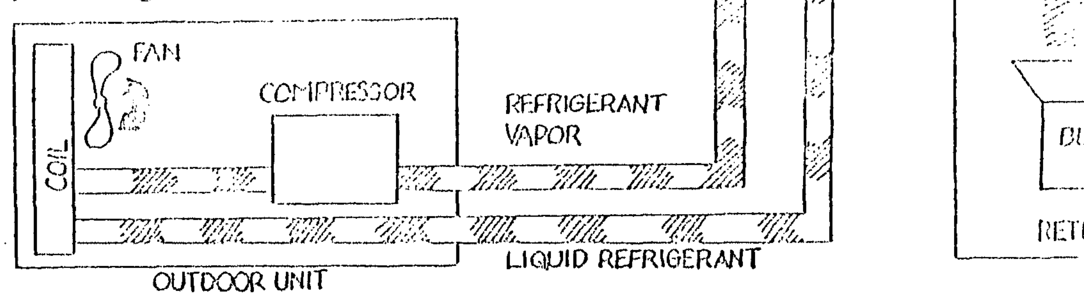


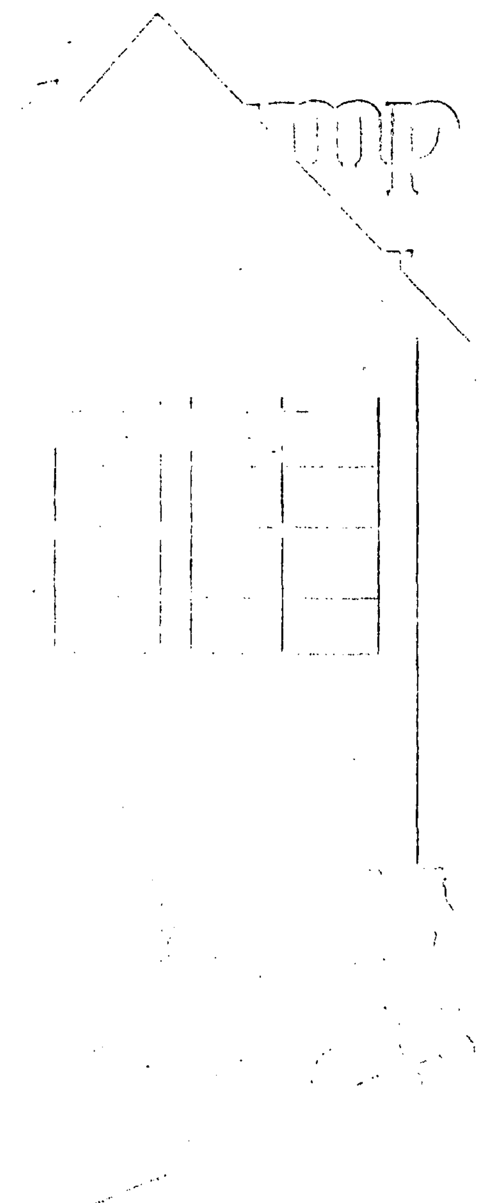
Heating...

Changeover from cooling to heating is controlled by the thermostat. It works through the heat pump controls to reverse the refrigerant flow.

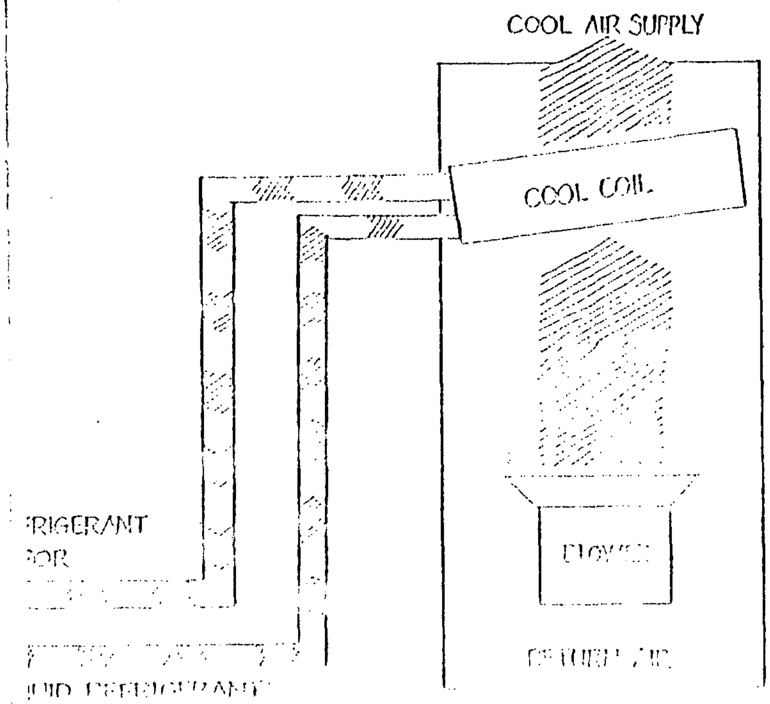
Refrigerant in the outdoor coil absorbs heat from the air (even when the temperature is quite low) and the compressor pumps it, in hot vapor form, to the indoor coil. Heat is picked up from the warm coil by circulating indoor air. Liquid refrigerant returns to the outdoor coil to continue the cycle as long as there is a need for heat.

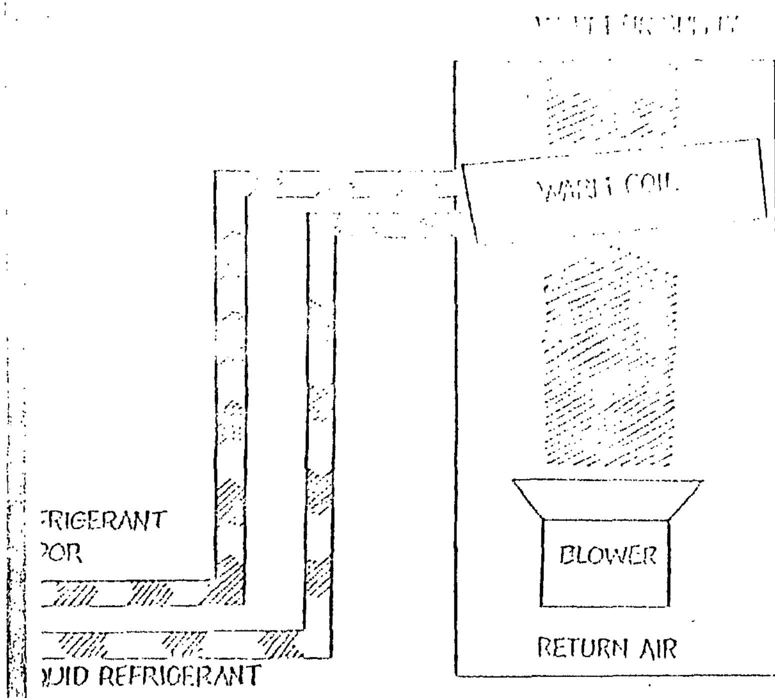
OUTDOORS





Pump Works:





Supplementary Heat

As the outside temperature drops, there is less heat in the outside air. But at the same time, the house needs more heat. When the output of the heat pump is equal to the heat requirement of the house the "balance point" is reached. Below this level (usually around 30°F) supplementary heat is needed. Electric resistance heating units supply this heat in most currently available heat pumps. They are activated at the "balance point" and provide warmth to the circulating air. They are also activated when the thermostat is turned to warm the space to the desired temperature.

There are also dual-fuel heat pump systems in which an oil or gas furnace provides supplementary heat.

Advanced heat pump systems are being developed which incorporate a heat storage system consisting of a water tank heated by off-peak electricity or by solar power. In such systems, the stored heat provides a heat source for the heat pump in periods of extreme cold weather.

The electric heat pump is one of the most energy efficient heating systems commercially available today.

The efficiency of a heat pump is usually measured by its Seasonal Performance Factor (SPF). Most heat pump models available today have an SPF of between 1.5 and 2.0 in operation in this region. An SPF of 1.5 means, for example, that over the entire heating season for each unit of electricity used the heat pump will transfer 1.5 units of heat to the dwelling. This SPF can be compared with the SPF of an electric resistance system which is 1.0. An oil burner can be expected to have an SPF of .5 to .6.

The efficiency of a heat pump varies with the outside temperature. It is greater at 45°F than at 35°F, for example. For this reason, the average efficiency over an entire season on SPF is the most widely used measure of performance.

For heating, the heat pump uses about one third less energy than would electric resistance heat in use in an identical dwelling at the same temperature level throughout the house.

In its cooling mode, the heat pump is about as efficient as a conventional central air conditioner.