MARCHETTI-1 Pt.1

On Society and Nuclear Energy

A Historical Analysis of the Interaction between Society and Nuclear Technology with Examples Taken from Other Innovations

Final Report for contract no. PSS 0039/A between IIASA and the **European Atomic Energy Commission**, represented by the **Commission of the European Communities**, for a study on "Nuclear Energy, the Problems of Introducing a Large Technology in a Historical Context."

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Executive Summary

The objective of this study is to use the hard methods of systems analysis to study the soft area of legislative activity, news coverage, reactor accidents and nuclear energy penetration. We have in fact employed, for the first time in an analysis of press coverage and of reactor accidents, a model developed already in the 1920s whose potential was fully developed at IIASA during the last decade. According to this model the behavior of society is the consequence of cultural diffusion waves. *Ideas*, in the sense of cultural packets, are generated somehow and, if successfully selected, diffuse into the system and induce corresponding behavioral patterns. The model is quantitative, predictive, and mathematically very parsimonious. The basic constraint is that the diffusion process has a maximum potential, *the niche*. The concept is formally identical to that of biological niches and its Malthusian consequences. Competition, e.g., through innovation, brings a succession of occupants into the niche, whose dynamics are described by the model.

Press coverage is studied extensively in the United States for two reasons. First, because there is a capillary monitoring of the US media, reliable data on time series are available. However, the same methodology can be applied to news coverage in Europe, and we have used it to analyze in detail the magazine *Der Spiegel* in relation to its coverage of nuclear energy. The second reason is that, due to the large number of reactors and not too sophisticated operator crews, the USA has a long list of reactor accidents from which significant signals can be extracted. The USA has also two very distinct waves of reactor construction, which makes the system more articulate and transparent.

The Results of the Study

1. Legislative activity in the area of environmental protection, which most directly affects nuclear energy, can be quantified and predicted with the model. Basically the maximum intensity point is over. Legislative intensity will fade out within a ten-year period. We have examined the European Economic Community (EEC), the EEC Commission, the United States, and the area of international agreements.

2. Reactor construction start-ups for the USA and connections to grid (GW_e) have been modeled for most Western countries and the world. They follow precisely the lines of penetration of new technologies, under the control of the niche and of economic Kondratieff cycles. This means their penetration will reach a limit during the next ten years, only to start again with the new Kondratieff wave due to begin in 1995.

3. Media attention to nuclear energy problems in the USA has been modeled for the last 30 years on the periodic press and some 15 years for television. The result is that this activity, measuring the amount of space in articles or the number of television news segments devoted to nuclear energy, follows precisely the diffusion paradigm. Once set, the model allocates number of articles per year in a descriptive and predictive mode so that the evolution of press interest can be charted. In the case of two events, Three Mile Island and Chernobyl, the rule is broken in the sense that a very brief (about three weeks) flash of articles is injected, however with all characteristics of a diffusion process. *Der Spiegel* had no Three Mile Island flash but had one in 1977 with no apparent cause. We studied this event in some detail and christened it "The Green Monster" because in arguments and style it appears to be a byproduct of the Greens movement.

4. Reactor accidents in the USA have also been studied using the diffusion model. The unexpected result is that their time sequence fits the model. This time structure raises many questions about the macro-mechanisms of the accidents, as it could be reduced to a sort of epidemic. Maybe the interaction of the press, public opinion, and the nuclear operator's fatal

sloppiness should be analyzed very carefully (studies on air accidents show that they too are not random, as purely technical causes would require).

5. The model permits us to deal with set of events as single blocks (like all television stories on nuclear plants in the USA), quantitatively characterized, and to look for connections and causalities at this higher level of aggregation. It is striking that the worst nuclear accident in the USA occurred at the flex of the press attention curve, i.e., when the number of articles per year was at the maximum. Due to the feedback nature of the press coverage, one can also say it occurred when public attention was at the maximum. A set of presumably significant juxtapositions has been presented in the report for the expert to use and explain. We think that systems analysts have to step back at a certain point to avoid being obliged to take sides.

6. The general picture that emerges from the analysis of a numerous set of factors, such as laws, reactors, television, press, accidents, is that contrary to our personal intuition, the system appears extremely orderly and smooth. Quantities follow their time trajectories as if they were celestial bodies. In fact, a more cogent image is that of a ship following a precise route in spite of waves, tides, rocks, and winds, through a complex feedback of forces and the determined will of captain and crew.

7. "The Green Monster," a head-on attack made by *Der Spiegel* on nuclear power in 1977, did not generate a ripple in the deployment of the FRG's nuclear program, when studied ten years later. A general conclusion also from the analysis of past technologies, reported in the appendices, *is that the final result of opposition is not to impede the events, but to have them socially qualified.* All together a worthwhile objective.

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1. SETTING THE PROBLEM

The withdrawal, if temporary, of Italy from the nuclear business has created a sensation. The press tends to stress the negative, in the sense that gray information about nuclear energy tends to appear black and white information does not appear at all. The logic for not doing things in this area is becoming more and more unclear. The very rational and often quantitative arguments of technological defendants of nuclear energy have to face indestructible, if empty, syntactical constructions from the opponents. Construction of nuclear power plants is coming to a standstill everywhere, with plants under construction – sometimes for ten years – poking lazily ahead to completion. Almost nothing new is being started.

1.1. Is this the End of the Nuclear Era?

The scope of this study is to try to bring the methodology of systems analysis into the task of creating a self-consistent image and a quantitative model of what is happening to provide a water print for strategies and future action.

A problem of *a priori* similar aspect was attacked by a team of researchers at IIASA in 1974, and the methodology applied then brought the solution in the form of a consistent logical image and a quantitative (predictive) model. It was the problem of dynamics and rationale of energy markets during the last 100 years. In 1974 the situation of energy, as seen from the press, the prices, the political action or inaction, and the flurry of papers and books, was certainly no less confusing than that of nuclear energy today. Further application of this technique showed their extreme flexibility and generality, in particular, in the area of social behavior, when quantitative measurements provided the necessary grip.

2. CONCEPTUAL AND METHODOLOGICAL GUIDELINES

Innovation is a tool for competition and adaptation to changes in boundary conditions. As is, is the best zero level strategy for a society. In sociology called Romer's Rule states that the initial survival value of a favorable innovation is conservative, in that it makes possible the maintenance of a traditional way of life in the face of changed circumstances.

Societies are highly self-regulated systems; they were so long before the establishment of formal legislation. Customs, habits, and religion still have a very important and perhaps dominant share in this regulation.

Many analyses of social and personal behavior we have done quantitatively, and sociologists, qualitatively, tend to indicate that "rational man" is a rational construct. Most actions are run by intuition, and instinct to be rationalized *a posteriori*. This means in practice that perfectly rational arguments may be powerless to modify people's attitudes and behavior, and that establishing the acceptability of a technology is basically a social procedure. As T. Kuhn has shown, also in the temple of rationality, science – acceptance of a new "truth," i.e., a new technique to model the external world – must go through a social acceptance procedure.

These points basically state that the acceptance procedures are independent of the object to be accepted, so that historical analysis of the introduction of new technologies may cast light on the pangs of delivery for the electro-nuclear system. The search for more sophisticated safety measures, if intrinsically important to reduce the objective risk to society, may have no impact at all on social attitudes unless the appropriate and not necessarily rational social channels are used to convey a personal sense of security.

This study is based as much as possible on objective quantitative evidence. Nevertheless, numbers can be misleading. According to unimpeachable polls, most Britons read the *London Times*. They buy, however, the *Daily Mirror*. Actions are clearer indicators of deep movements than words. In this sense the action of buying a newspaper, or that of putting in the newspaper an article expected to please the audience, appears to be a more objective device than taking polls. This point is important because much of the estimates on pro- or anti-nuclear feelings are now derived from polls.

Another mirror of the interest of society on a certain subject is legislative activity. Much resistance to new technology is aggregated under the general heading of "ecology." Because anything new produces change, the concept of preserving the environment provides a variety of rational arguments for rationalizing resistance. We will show that ecological legislation, only occasionally produced during the nineteenth century, increased two orders of magnitude starting around 1945. Following the typical course of a cultural pulse for all Western countries, interest in this type of legislation *will fade in ten years or so.*

Many indicators of social and economic activity show a clear pulsation of about 55 years, in tune with the famous *Kondratieff cycle*. Introduction of new technologies in the past, e.g., railways, cars, airplanes, show a powerful modulation by the cycle. All technologies do in fact grow in leaps inside these 55-year cycles. Nuclear power does not escape the rule, and this leads to a saturation (standstill) for new plants around the middle of the next decade.

It may appear strange that in an analysis striving for objectivity, "rational" facts will not play a primary role. This is not just an attempt to compensate for the excessive faith engineers and scientists involved in the technological game have in the assumption that man is rational and acts rationally. Social forces are very old and still deeply embedded in metaphysical metaphors anthropologists classify as being thought of as sacred. The statement "the chief has a great mana" can be seen as a tribal tenet, but it can be said also for the president of General Electric. The phrase "Pharao is the living Horus" could be relegated to Egyptian prehistory, but "Henry is by Grace of God King." The United States is "one nation under god," and its officers take oaths when they assume their duties. In this context, the fact that nuclear energy is ten times less carcinogenic than coal may not change attitudes, unless some sanctified statement is introduced or removed.

The basic analytical methodology is based on the assumption, tested in thousands of cases, that human affairs can be precisely modeled, using some special solutions of Volterra-Lotka equations. "*Action prototypes*" are generated and selected in certain places in society and, if successful, *spread* by progressively filling a certain potential (or market): the *niche*. The diffusion process always has the same functional aspect, obviously with parameters depending on the specific case, and can be modeled with utmost simplicity and generality. This technique was originally used in a primitive form in 1845 by the Belgian Verhulst for modeling biological populations. It had a new lease on life in the 1920s mainly through the work of Haldane, Lotka, and Volterra. Its potential for mapping sociological phenomena was well perceived and sometimes applied. A penetrating paper by Pemberton (1936) unravels that potential and reports some striking examples. A resurgence occurred in the 1970s with the work of Fisher and Pry, then at General Electric, where many cases of diffusion were empirically examined in very diversified fields of technology. They also introduced a handy transform for the logistic diffusion equations, which is used in our charts.

A large effort to apply these models to map social phenomena has taken place at IIASA during the last 15 years, analyzing approximately 2000 case histories, first in the area of energy and then spreading out in all sorts of social phenomena. The study of energy, where various technologies compete at the same time, led us to introduce algorithms for dealing with multiple diffusion. Some rudiments for the application of the model are given in the Appendix A.

3. THREE SITUATIONS TO CONSIDER

3.1. Sixteenth Century Witch Hunts

Opposition to a new technology, using irrational arguments and releasing emotions, is often defined as *witch hunting*. Very few people realize, however, that the two match in fine details. People in the business of defending nuclear energy should, e.g., very attentively read about the European witch craze of the sixteenth and seventeenth centuries in the work by H.R. Trevor-Roper (1969) to get a highly professional synthetic view of this situation.

When a craze is building momentum, no person of reason or authority can resist it. All logic is refused if it goes against the grain. More than that, the most balanced personalities go schizophrenic. Taking one example from Trevor-Roper:

> Heinrich Julius, Duke of Brunswick (at the end of the 16th century), was considered as unquestionably the most learned prince of his time. He was skilled in mathematics, chemistry, natural sciences, Latin, Greek, and Hebrew. He was a jurist who preferred the Pandects to the Bible and read the codex rather than a romance, an architect who designed the buildings of his new university, a poet, and a playwright. But in his plays he dwelt on the moral duty of princes to burn witches and he never failed his duty. In his lifetime, says a chronicle, the Lechelnholze Square in Wolfenbüttel looked like a little forest, so crowded were the stakes. At his death, his court preacher, enumerating his virtues, dwelt especially on his zeal in burning witches "according to God's will."

He is only one of the many. The intelligentsia of the time, who created the foundation of Western science, philosophy, and law, was completely for burning witches. Or at least nobody dared to speak against it. A lenient judge was suspected of being a witch himself and often burnt to keep the judiciary system above suspicion.

In retrospect the craze looks like a gigantic tragicomedy, which cost the life of hundreds of thousands innocent people in the course of a few centuries. But of most interest is how the craze ended. Like the pest in Manzoni's novel *Promessi Sposi*, its force faded out. In Trevor-Roper's words:

> Third rank intellectuals and officials started saying that the craze was unjust and irrational. And what they said was taken for granted. Then came the intelligentsia, showing that what it said for two centuries was basically wrong because of some minor detail in the interpretation of the scriptures. And that was the end of the process.

The scheme is general. As shown in many examples, or what I call "cultural pulses," the cumulative actions related to the pulse, e.g., number of witches burnt, has a characteristic logistic growth, and when this saturates the pulse fades out (Figure 1).

Figure 1 is an example of actions consequent to a cultural impulse. The figure shows the cumulative number of witches prosecuted in Scotland spanning almost two centuries of persecution. The process is not stochastic, but it has a long-term structure as represented in this case by a logistic growth equation. The number in parentheses indicates the "size of the niche," i.e., the asymptote for the logistic.

As indicated in the Appendix A, this asymptote can be calculated by a best fit of the empirical data. This means that a certain level of forecasting is possible, even in such a complex process where so many rational and irrational pulses did converge and melt.

The ΔT is the time constant giving a measure of the time spread for the cultural pulse or, more precisely, of the action that descends from it. The time constant is the time *between* the point when the function reaches 10% of the saturation level and that when it reaches 90% of the saturation level. It can also be seen as the time between 1% and 50% of the saturation level.

The chart is presented in the form of a Fisher and Pry transform. In this normalized form, F is the fraction at a given time of the asymptotic value. The function reported in the ordinates is Log F/1-F, the fraction of the niche already occupied divided by the fraction not yet occupied. The main reason for this kind of normalized presentation is that one can superimpose different events in the same chart, provided there is a common base.

3.2. The Waldheim Case

Analyzing the way in which situations were dealt with in the past may help people introducing new technologies to face the inevitable tide of opposition – yielding when the wave is coming and swinging forward when the crest is through. A current example of the rise and fall of this type of wave and the appropriate reaction can be illustrated in the Kurt Waldheim case (Figure 2). The figure gives an example of intense interest in a special political case – the reaction of the international press to the Waldheim case. The chart shows the cumulative number of articles appearing in a set of international newspapers, currently scrutinized by President Waldheim's press office. The original idea behind this analysis was to check if the attention pulse by the press was logistic in order to be able to forecast

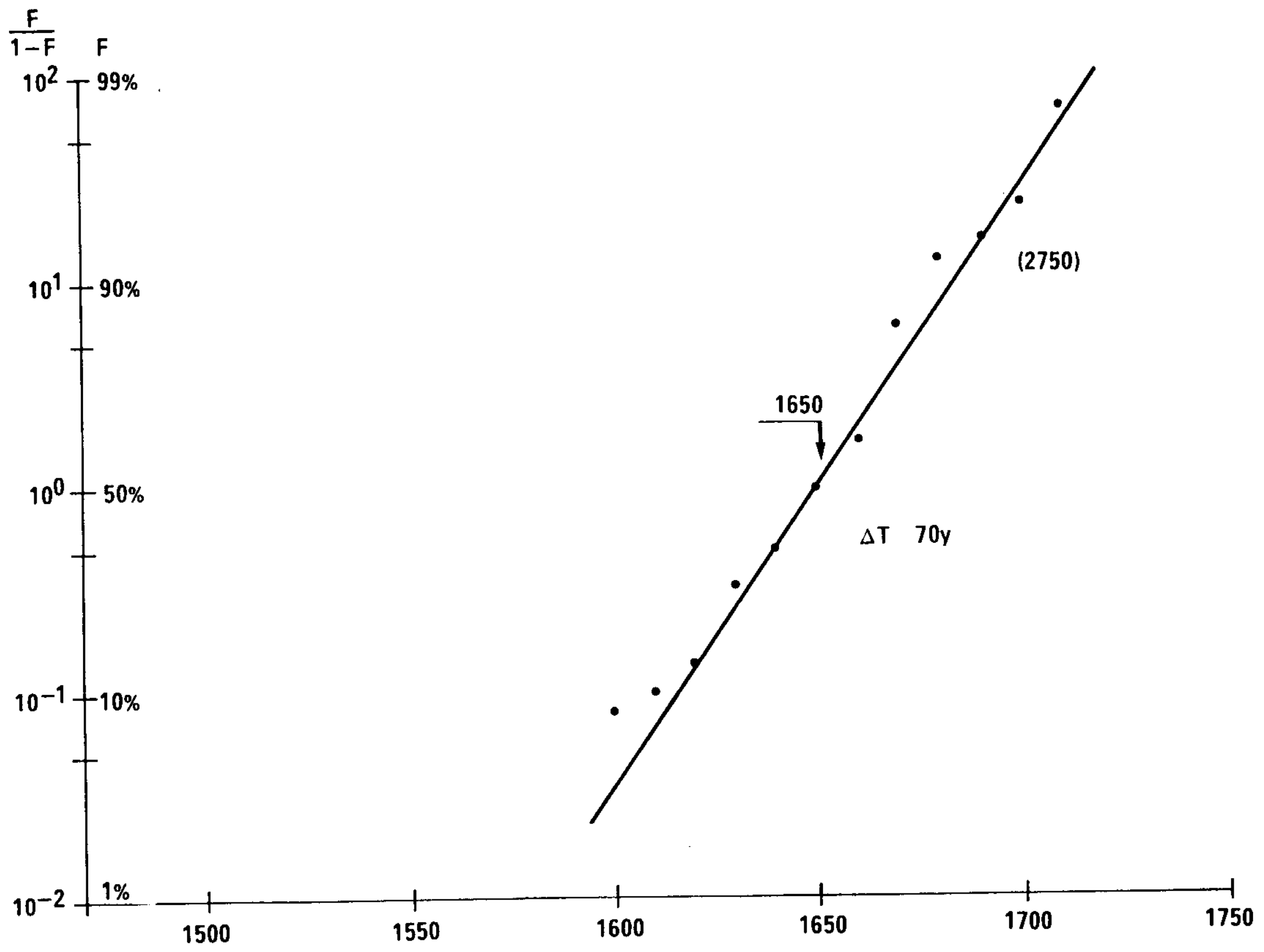

FIGURE 1. Prosecutions for Witchcraft in Scotland in the Sixteenth to Eighteenth Centuries.
SOURCE: Clanner (1981), *The Enemies of God.*

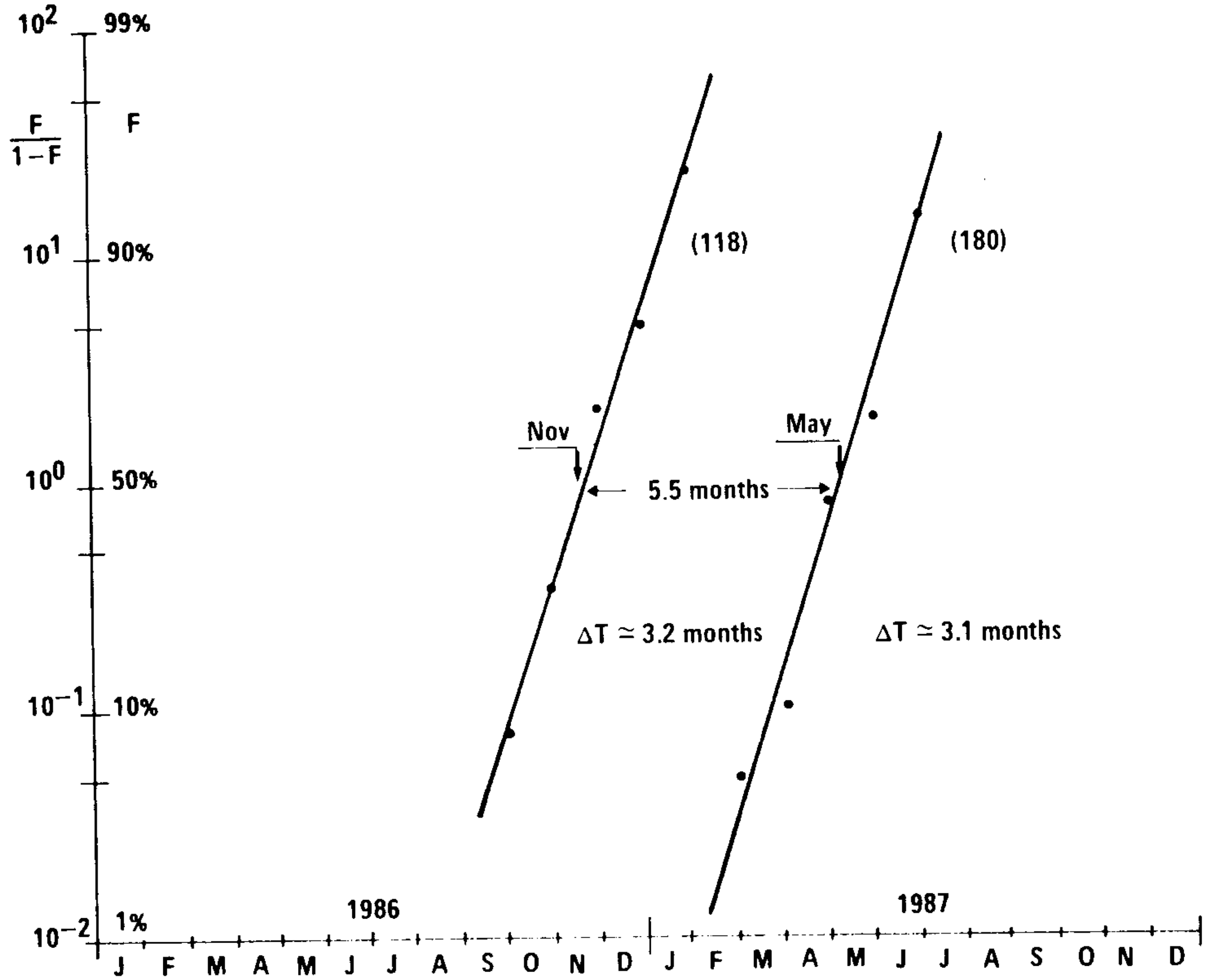

FIGURE 2. Frequency of international articles on the Waldheim Affair.
SOURCE: Christian Office.

when it would fade out. The fact that there were two pulses actually undermined the objective since a third pulse could, in principle, materialize. For the moment (end 1988) it did not happen, showing that the Waldheim tactic of not reacting and not answering questions was basically sound.

Incidentally, the analysis shows a peculiar time structure of public attention on a hot subject. A similar situation, which will be discussed later in the report, occurred when nuclear news advanced to the front page. Here the time constant of each pulse was about three months, showing the quintessential lability of public attention. In the cases of Three Mile Island and Chernobyl the attention pulses were even shorter.

3.3. Beduins and the Medina Railway

It is very important to show the way in which certain attitudes and arguments are universally expressed. The opposition of Beduins to the (1900) construction and operation of the Hedschas railway in Saudi Arabia, which links the Western network to Medina, is detailed in the work by H.J. Philip, *Die Welt des Islams XXV* (1985). An extract from that work helps to illustrate this point. The formal arguments for rationalizing the continuous attacks, sabotages, and destructions of the railway that finally led to it to be discontinued were that there was no hint about railways in the Holy Books of Islam; so the "unholy Frankish thing" could only be a discovery of the devil; the speed of the train (23 km/h), *as all haste*, came from the devil; and the prophet Mohammed demanded humility and privations from the pilgrims forcing them to travel on foot or on the back of an animal, so the comfort of the train was a sacrilege. To make a long story short, Beduins have ever since transported pilgrims to Mecca on foot or rented camels.

4. LEGISLATIVE ACTIVITY AS AN INDICATOR OF PUBLIC INTEREST

Legislation is one indicator of popular moods. A tight link exists between members of a parliament and their electorate in Western democracies, and any question that can raise their image is brought to the Capitol to become, if possible, a legislative issue. Nuclear energy is in many ways incorporated into the ecological issue and, in fact, the Green Party appears to be the most important organized antagonist. This section analyzes the evolution of legislation concerning ecology, produced during the *last two centuries* for all EEC states for the Commission, for the USA and for international agreements taken as the formal equivalent of national laws. The data are taken from an EEC-sponsored publication.

A first survey of the data shows that before World War II environmental legislation was nominal. Just a few laws were issued, even taking all of the nineteenth century into account. After the war a rush of legislation began. This flurry of legislation represents the "cultural pulse", referred to in the introduction, i.e., the diffusion process of a certain ideology, and consequently the facts, i.e., the laws, are mapped with logistic growth curves in Figures 3 through 15. As the figures show, the cumulative number of laws at the national, supranational (as for the European Communities), and international levels show an excellent fit with the equation.

The advantage of this mathematical process formalization is that it provides a simple image of its evolution (incidentally identical with that of a product life cycle), which can define the state of maturity, so to speak, and, with a certain precision, determines at what level the process will stop and when.

In the case of the EEC countries, the legislative activity concerning the environment has passed its maximum rate point (the flex in the logistic) and is moving toward saturation, an important indicator of decreasing interest on the subject.

There is always the possibility of a second wave, but as the first wave was well encapsulated in the Kondratieff cycle (1940-1995) one may expect a revival – if any– starting around the year 2000, leaving in between a dozen very quiet years. The synoptic table for all EEC countries and the world reports the saturation points in parentheses. These are the numbers of laws expected at saturation, and curiously their great diversity gives a prolix 450 laws for France and a most synthetic 55 for the Netherlands, a country notoriously devoted to the environment.

EEC as the Commission appears in the middle class for number of laws, with a very short time constant of 12 years. It saturates first with 200 laws.. The period of maximum legislative activity was 1980. This relatively early saturation might lead to a new start in the 1990s, perhaps by 1992. From the start, however, pickup speed is slow. This means that legislation on the environment by the Commission will be reduced numerically during the next few years, a forecast that lends itself to easy verification. With the exception of the EEC Commission, the slopes of the various lines are quite similar, and the central points (at 50% level for F) are less than ten years away – showing a single cultural pulse spread over Europe.

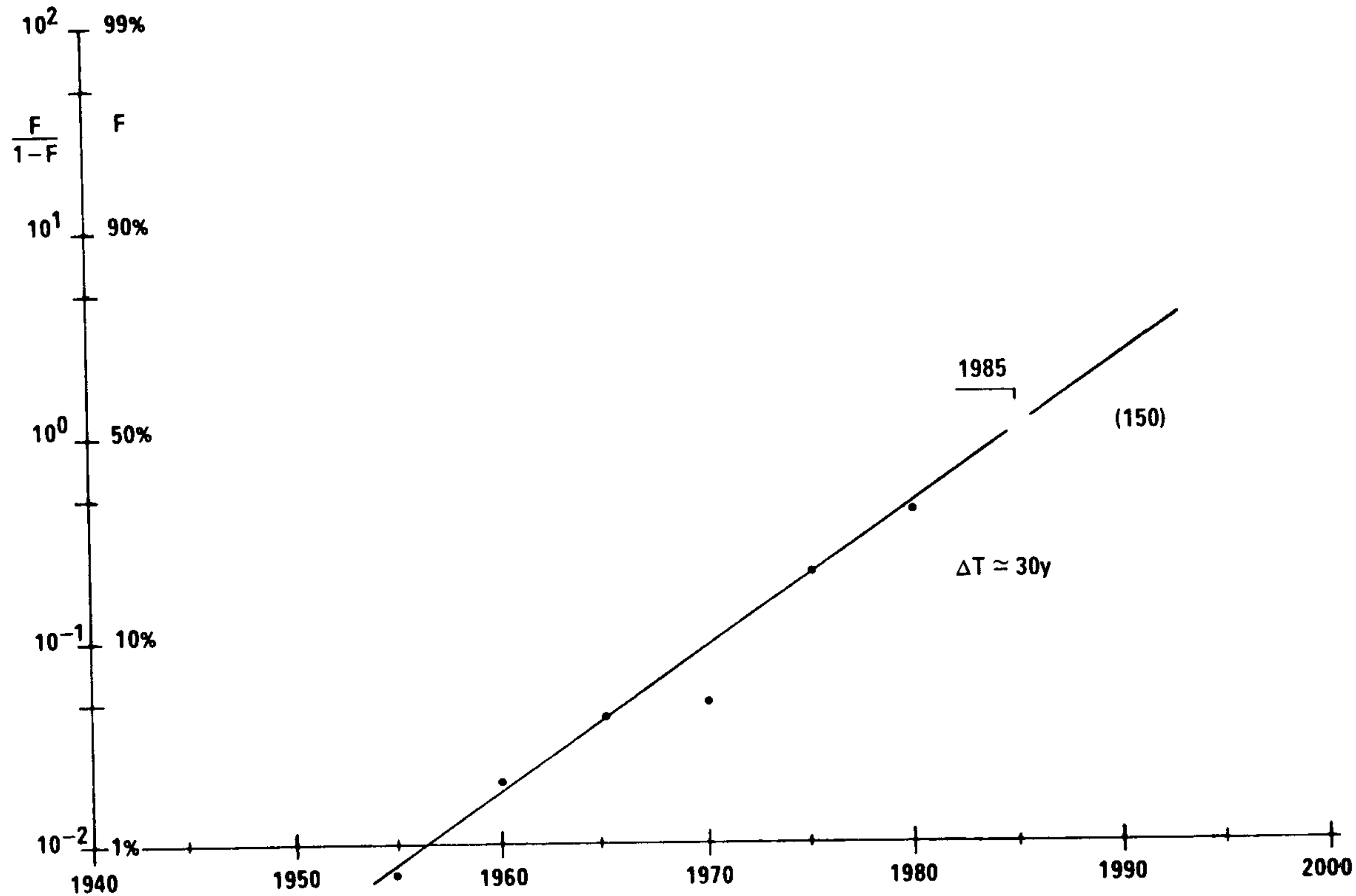

FIGURE 3. Belgium: Legislation on Environment. Number of laws and arretés.
DATA SOURCE: European Environment Yearbook (1987).

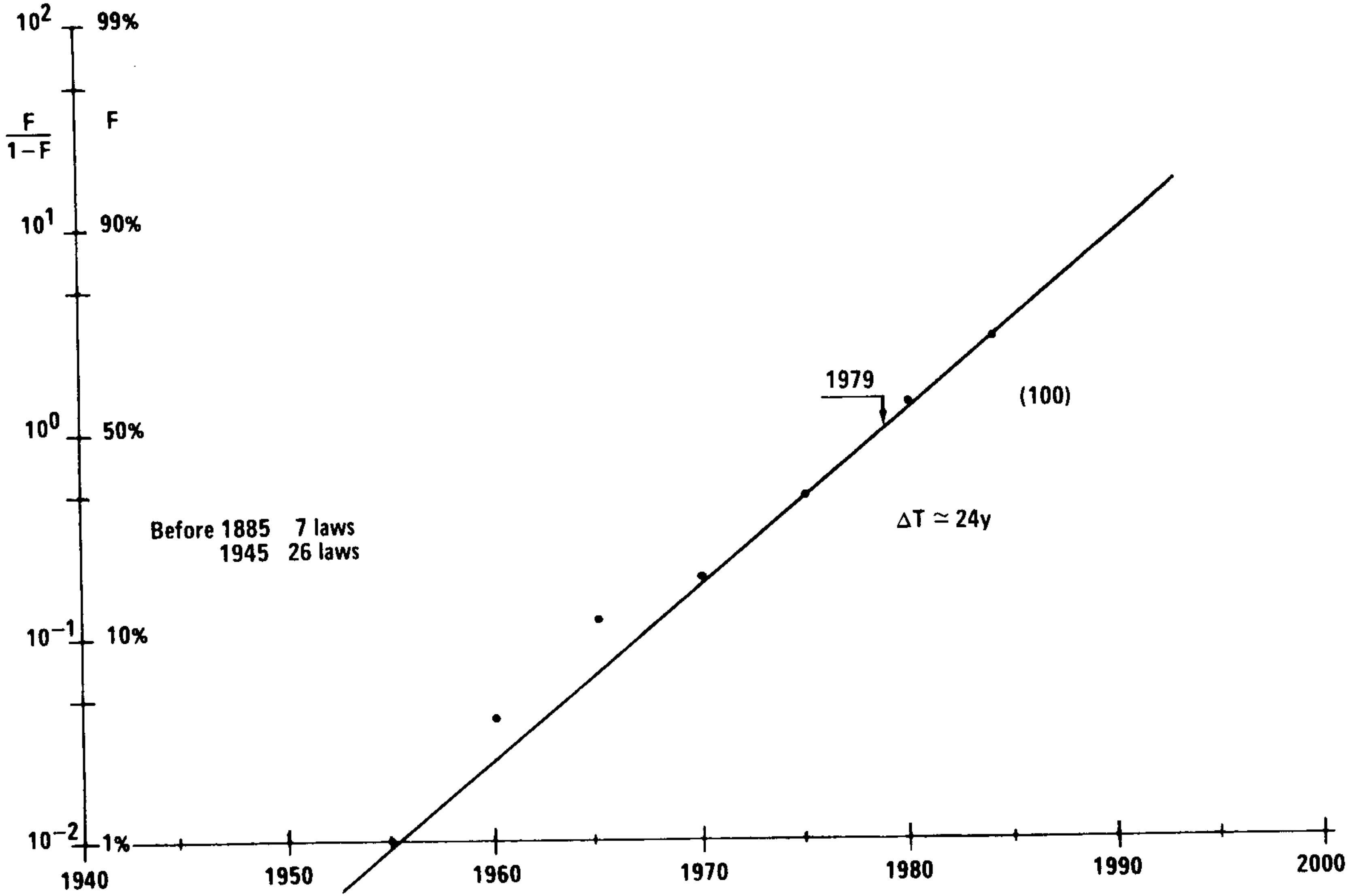

FIGURE 4. Denmark: Legislation on Environment. Number of laws.
DATA SOURCE: European Environment Yearbook (1987).

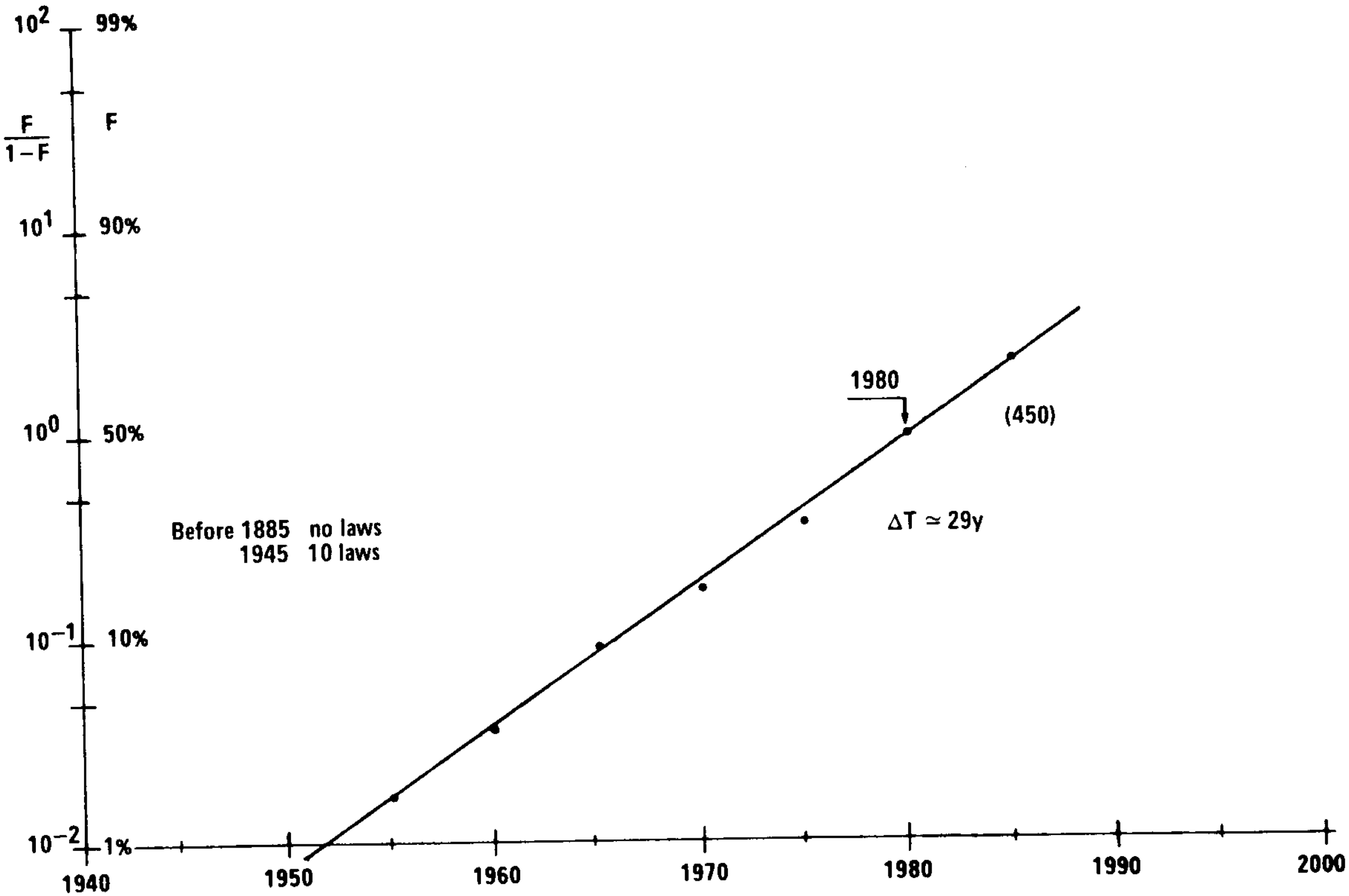

FIGURE 5. France: Legislation on Environment. Number of laws, arretés, decrets, et circulaires.
DATA SOURCE: European Environment Yearbook (1987).

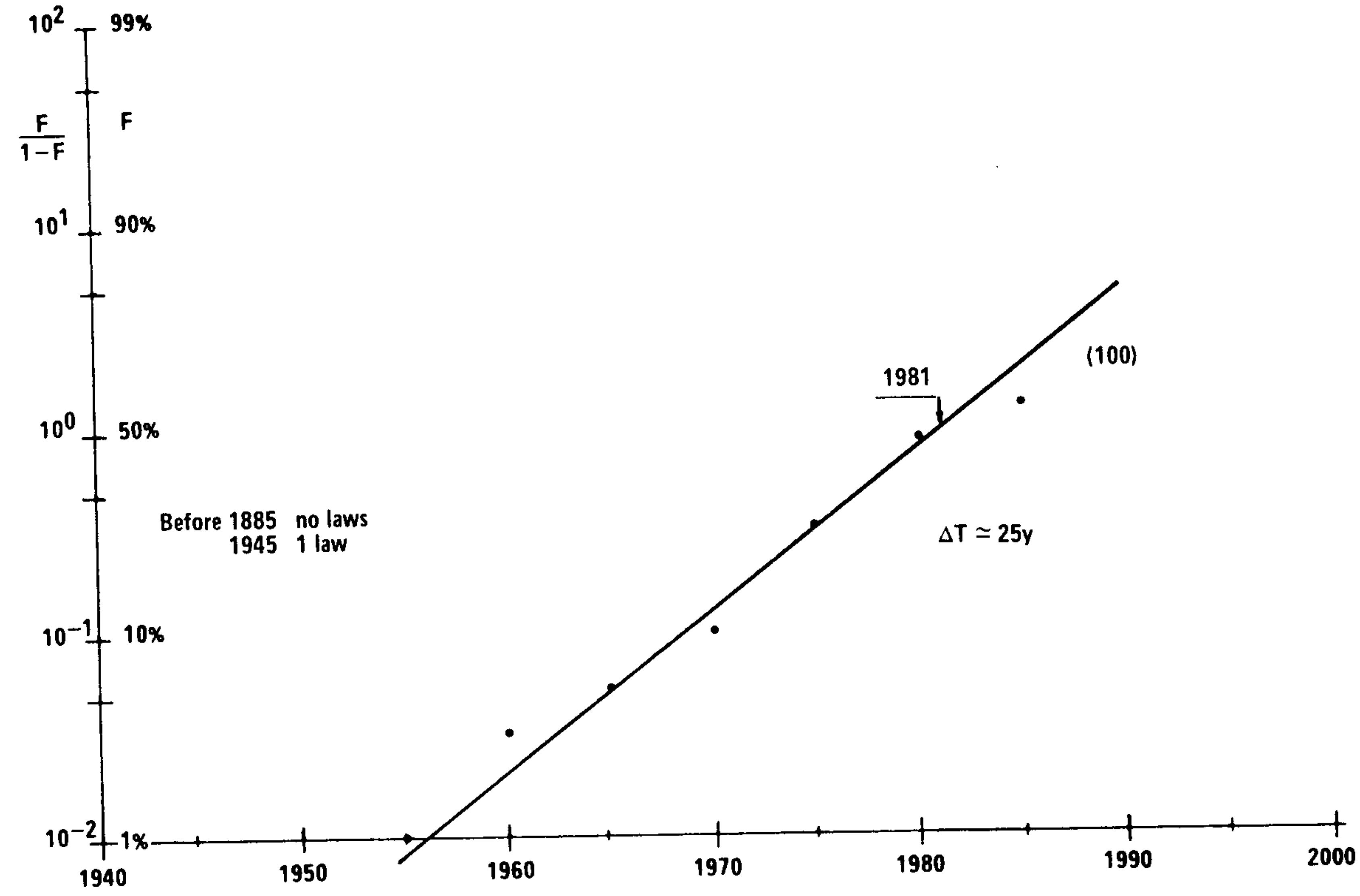

FIGURE 6. Federal Republic of Germany: Legislation on Environment.
DATA SOURCE: European Environment Yearbook (1984).

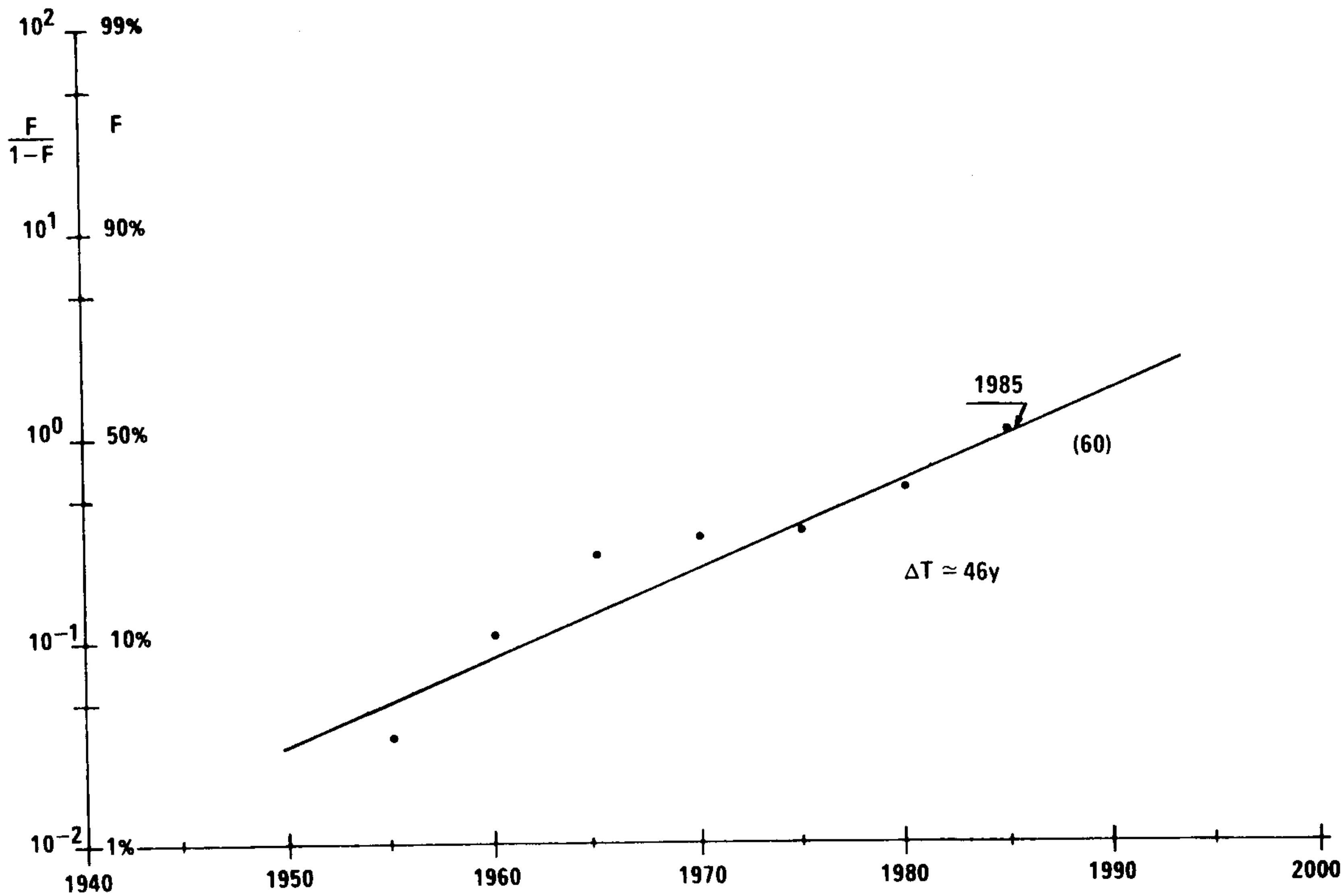

FIGURE 7. Ireland: Legislation on Environment.
DATA SOURCE: European Environment Yearbook (1987).

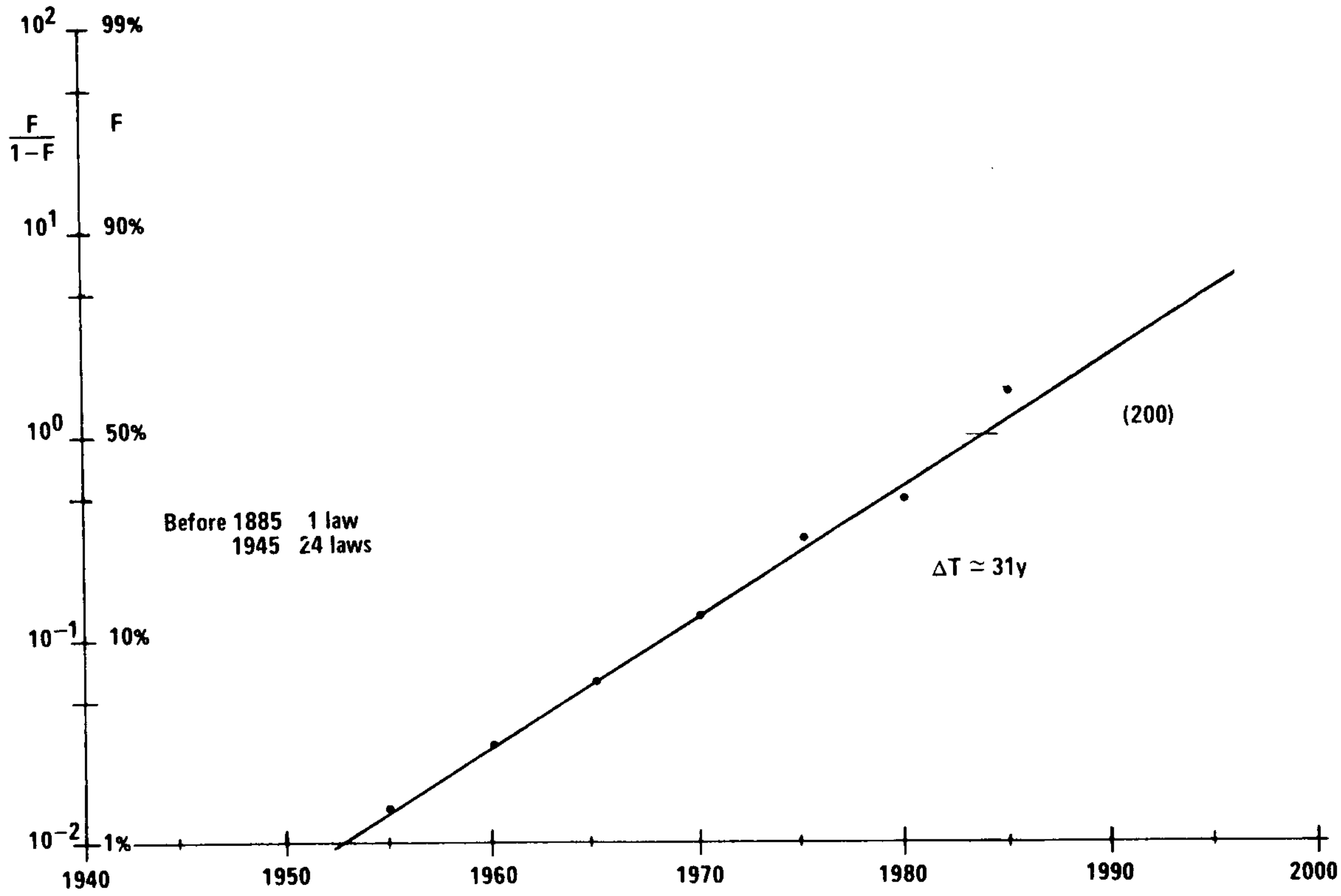

FIGURE 8. Italy: Legislation on Environment. Numbers of laws, decrees, and circulars.
DATA SOURCE: European Environment Yearbook (1987).

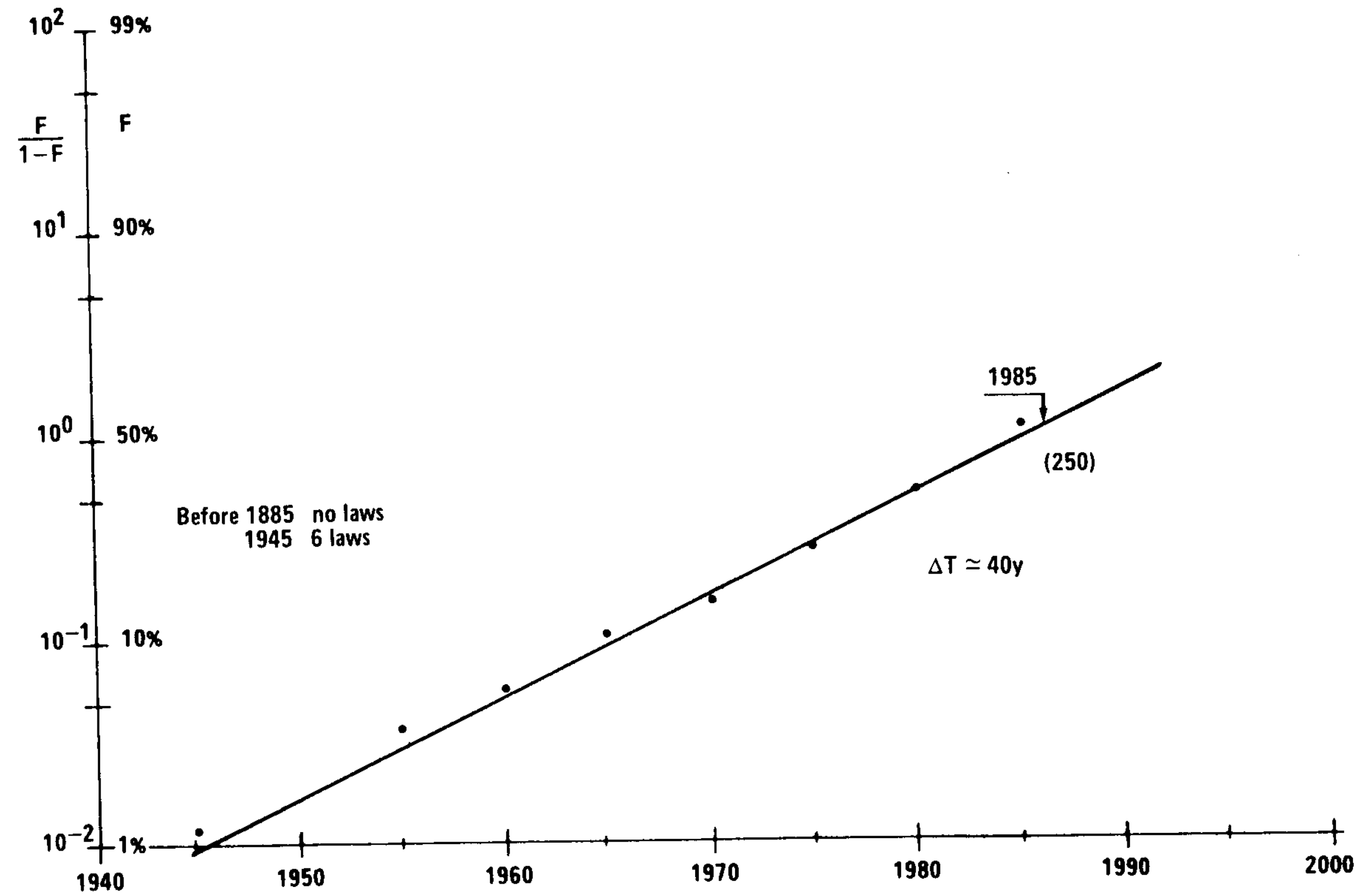

FIGURE 9. Spain: Legislation on Environment. Number of laws, decrees, and ratifications.
DATA SOURCE: European Environment Yearbook (1987).

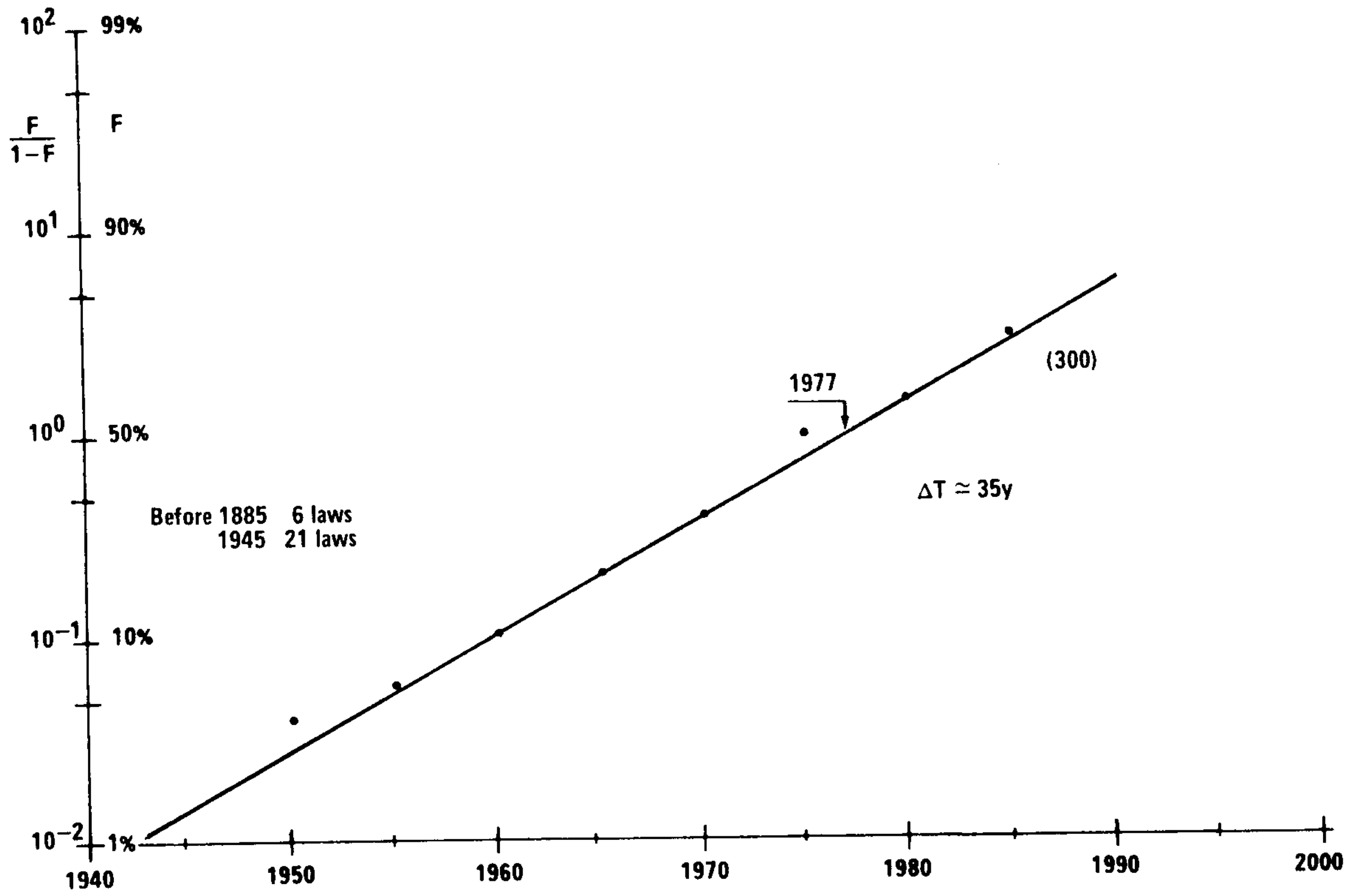

FIGURE 10. United Kingdom: Legislation on Environment. Number of acts and regulations.
DATA SOURCE: European Environment Yearbook (1987).

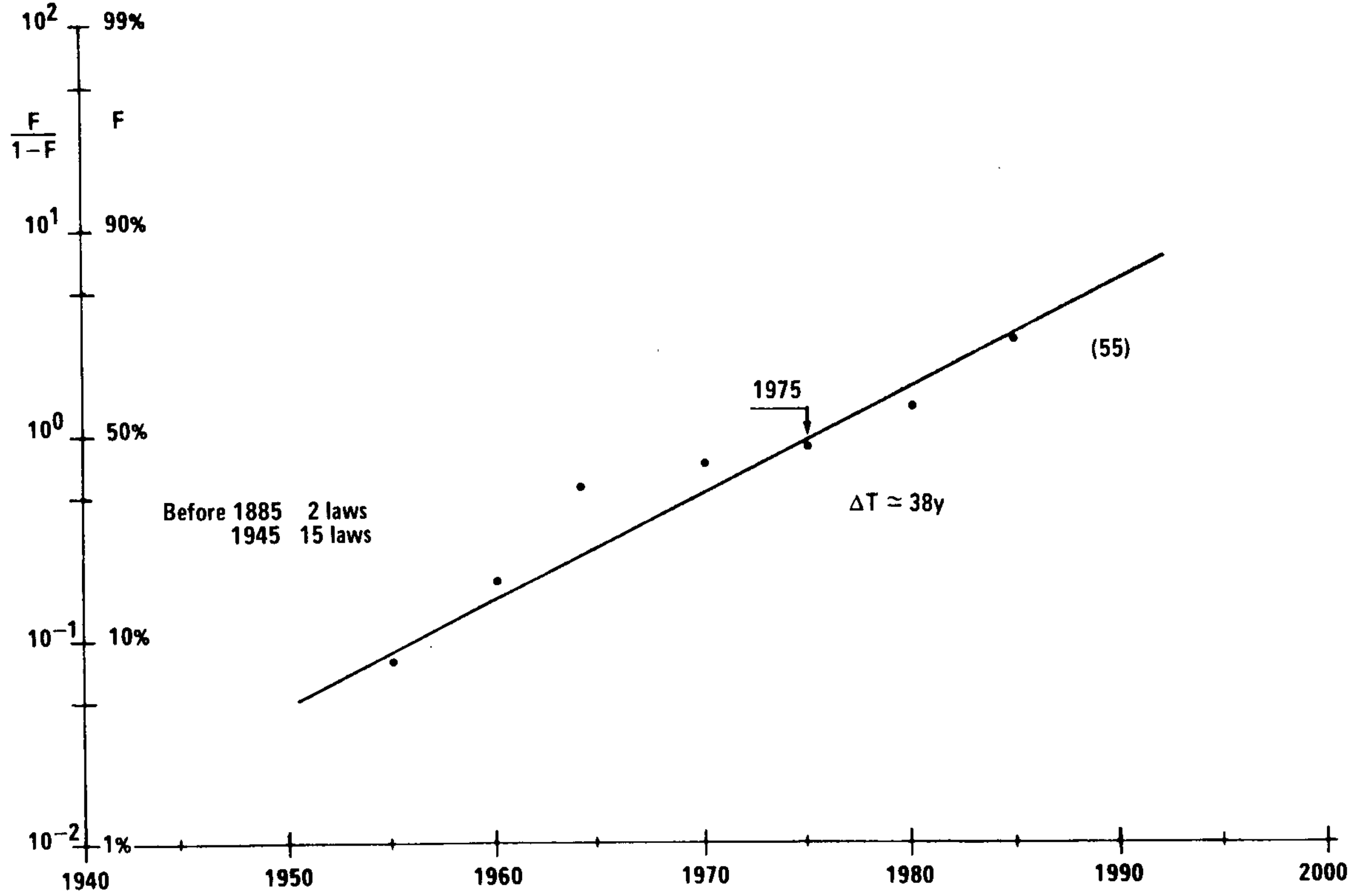

FIGURE 11. The Netherlands: Legislation on Environment. Number of acts still in force (amendments not reported). DATA SOURCE: European Environment Yearbook (1987).

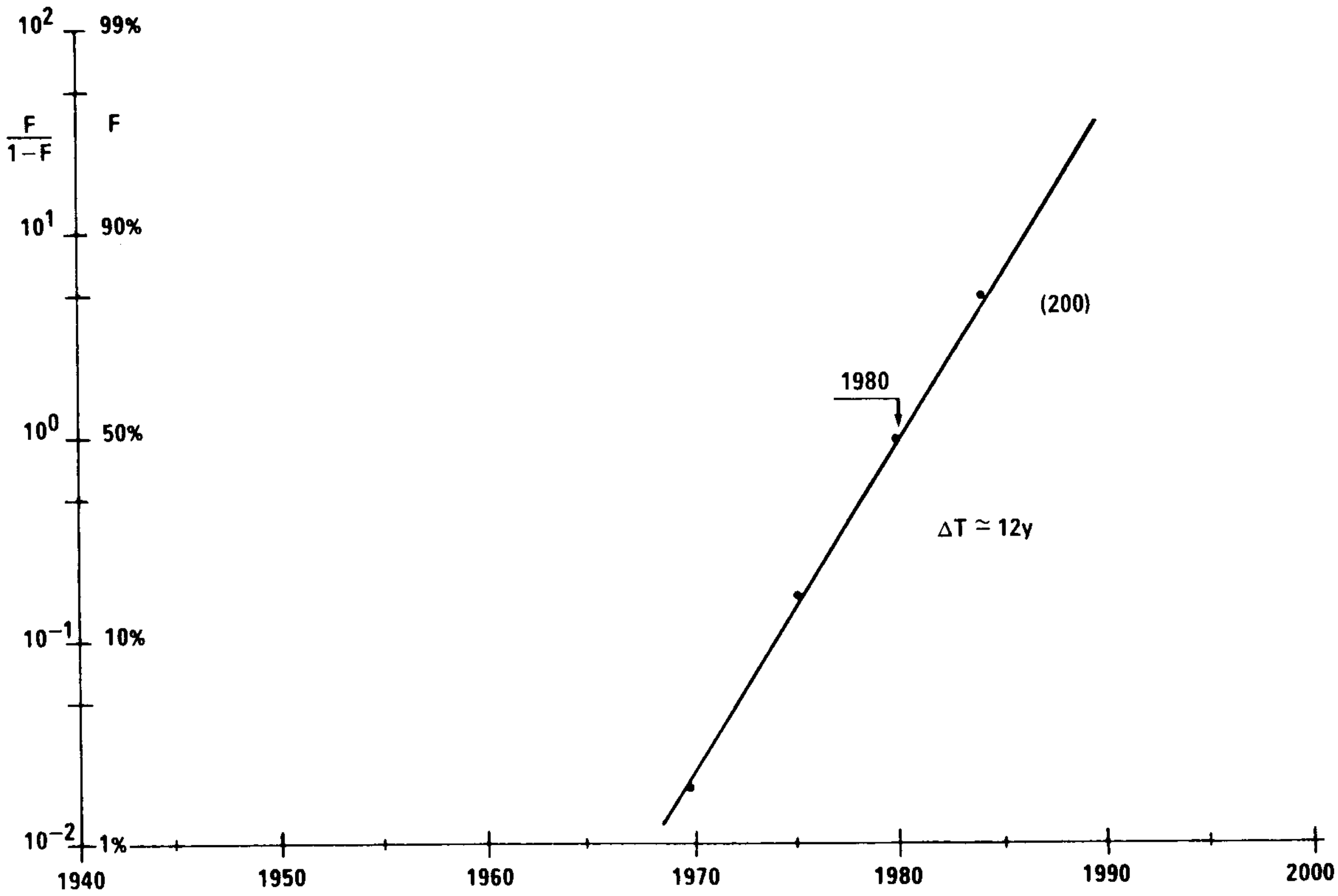

FIGURE 12. EEC: Legislation on Environment. Number of directives and decisions.
DATA SOURCE: European Environment Yearbook (1987).

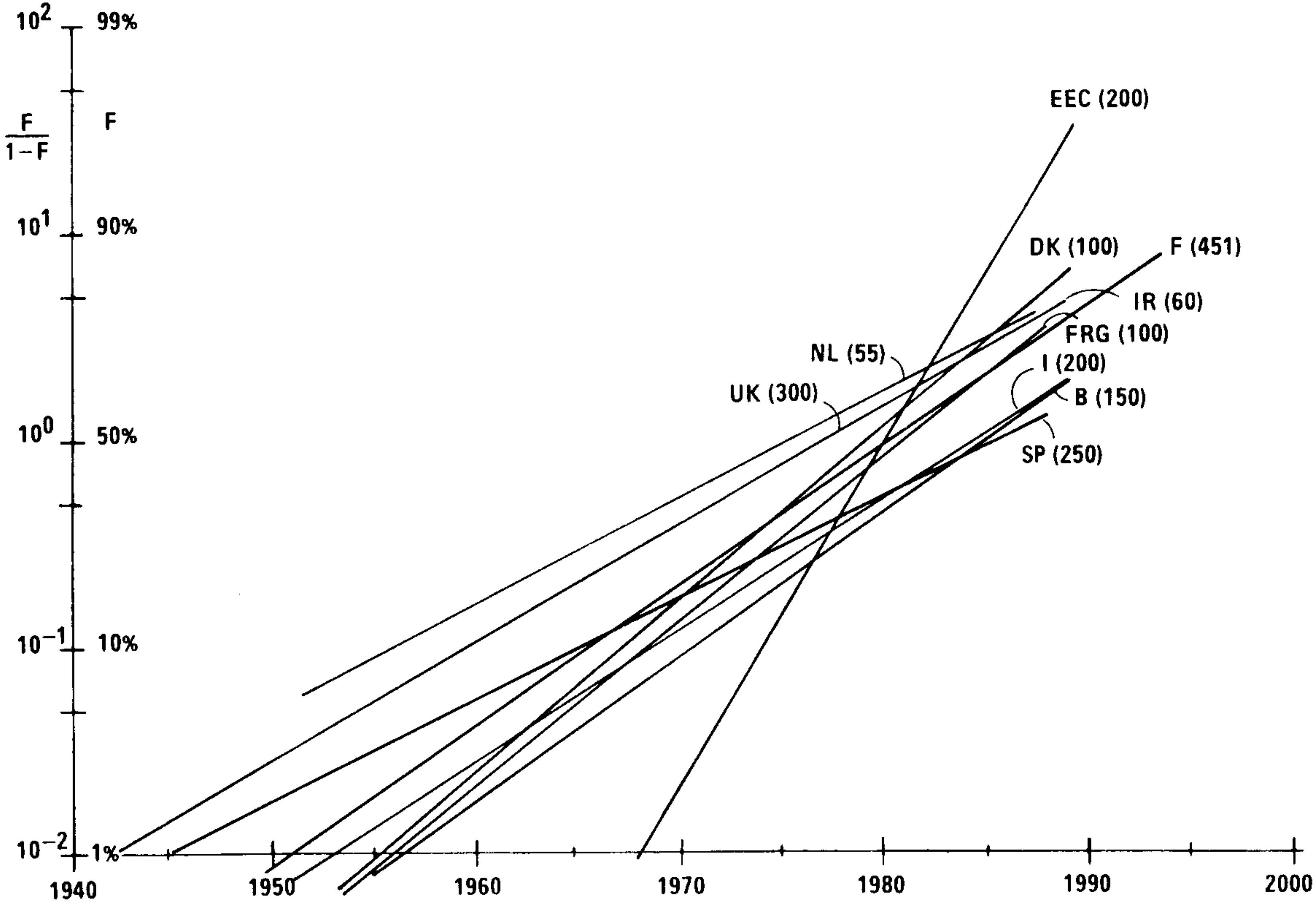

FIGURE 13. Countries and EEC. Environmental Legislation for EEC.
DATA SOURCE: European Environment Yearbook (1987).

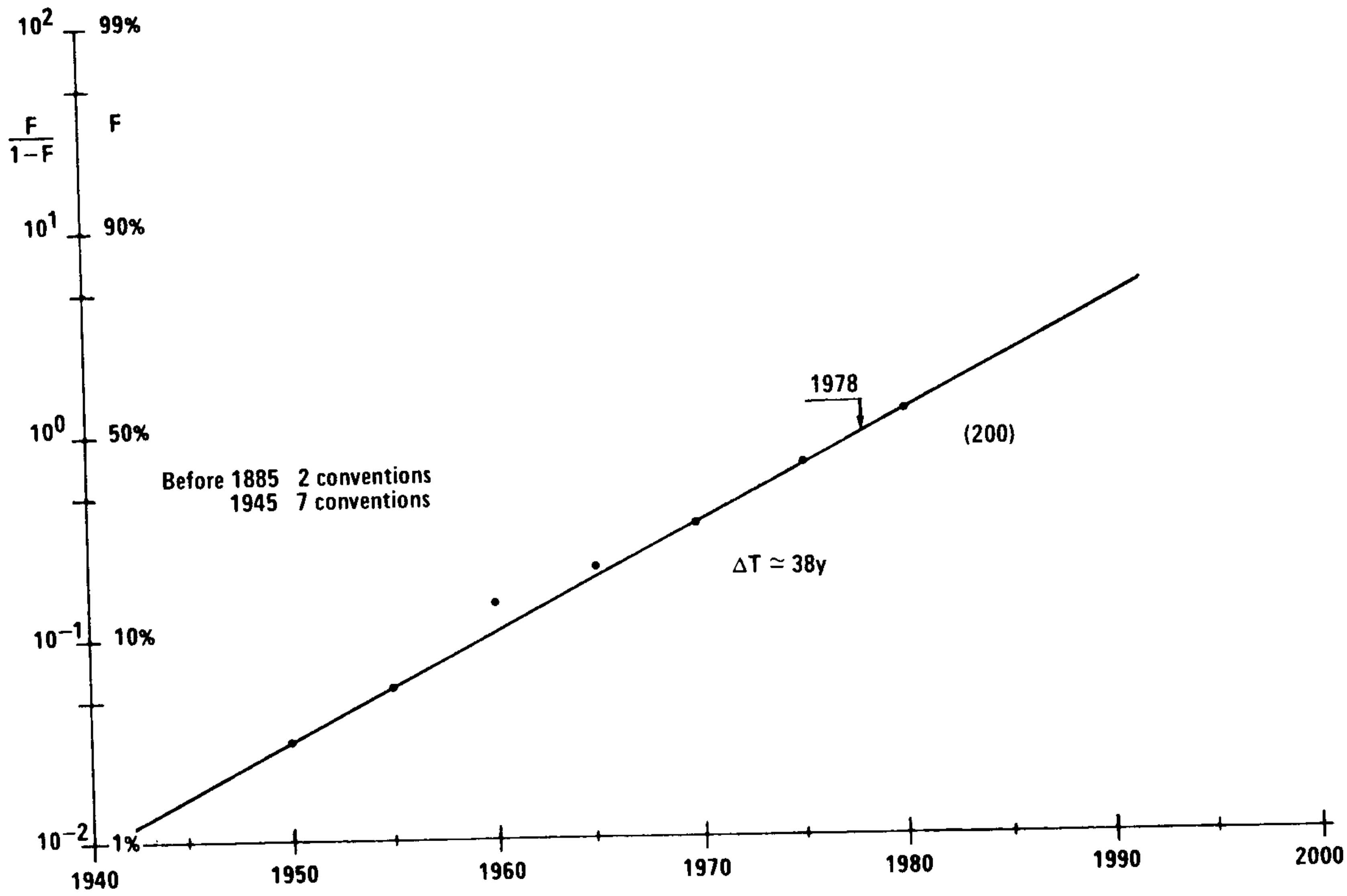

FIGURE 14. Cumulative Number of International Conventions on Environment.
DATA SOURCE: European Environment Yearbook (1987).

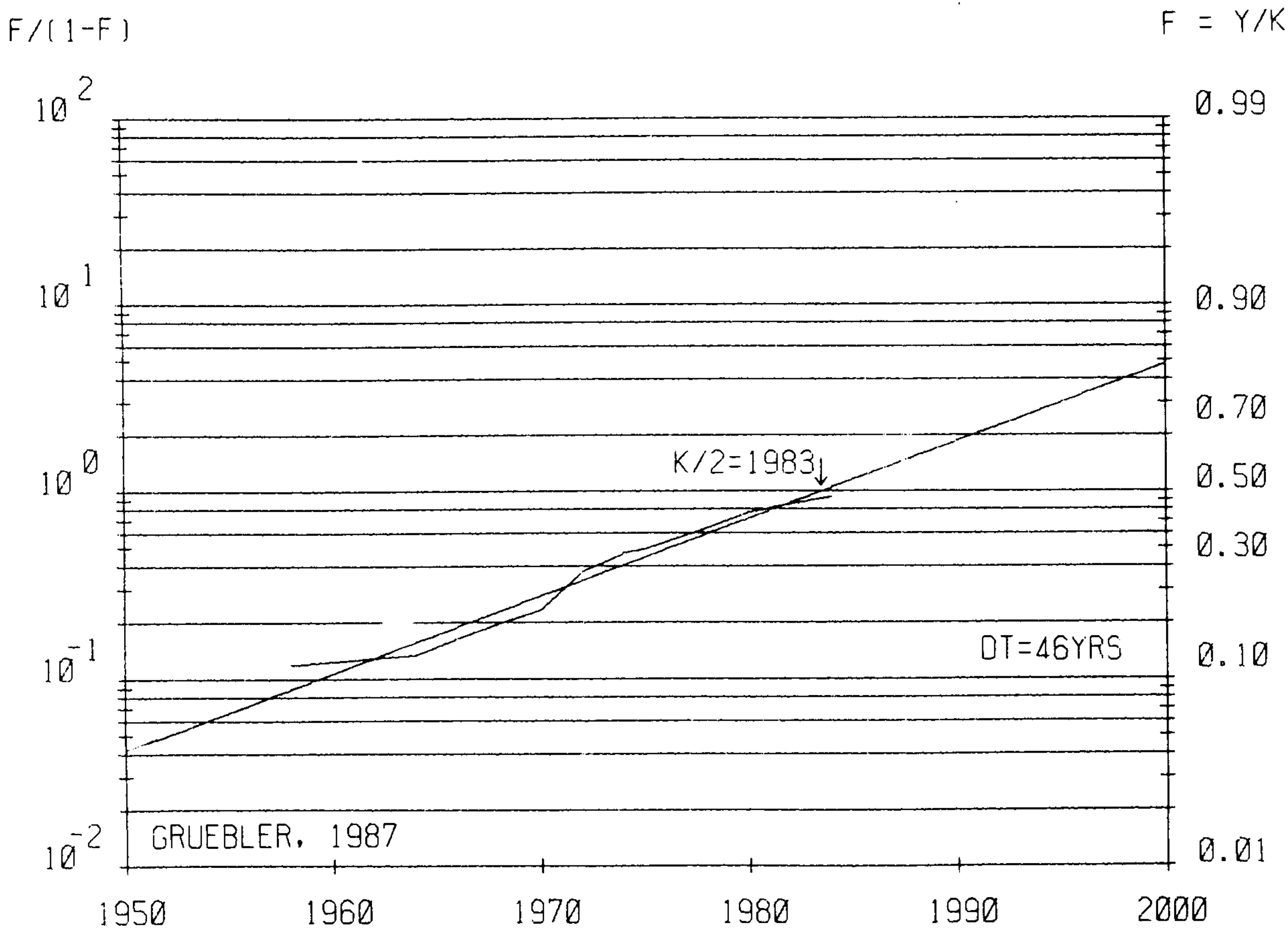

FIGURE 15. USA: Legislation on Environment.
SOURCE: Grübler (1987).

5. NUCLEAR ENERGY AND THE KONDRATIEFF CYCLES

The analysis of legislative activity concerning ecological issues shows that activities in different countries are closely packed in time; this can be attributed to the effect of Kondratieff cycles. Because these cycles affect all sorts of economic and technological activity, they will inevitably reflect the construction rates of nuclear plants, an important question when trying to clarify what is happening.

As already observed by Schumpeter (1939), innovations come in waves, and they diffuse, in the sense of filling markets with products or services. When the markets are saturated, i.e., the production becomes based on maintaining current levels, they will be substantially stable. This no growth situation together with a continuous increase in productivity, automatically generates an increase in unemployment. Also, it creates an unemployment situation for capital because of the stationarity of the system.

Both problems are removed, slowly and progressively, by the introduction of a new set of innovations, giving rise to a new pulse of growth and so on. The process can be illustrated quantitatively starting from 1800, although attempts have been made to check its existence in previous times (beginning with custom documents from the 1600s). The most important result is that all sorts of activities come to a standstill toward the end of the cycle (zero growth), and nuclear plant constructions, as we will see, are no exception.

The cycles have a length of about 55 years, and the last one ended around 1940. The present one will terminate around 1995. To give a quantitative example of this cyclicity see Figure 16. The figure charts world production of steel from 1870. Capacity increases in two logistic pulses, one saturating around 100 million tons per year and the second growing by another 750 million tons per year. The v's at the top of the figure indicate the end of Kondratieff cycles. The tuning with the Kondratieff cycle is clear. World War I (WW1) is the probable cause of the early oscillation that appears in the second part of the logistic. When a system approaches saturation, however, the effects of the size of the niche are more evident, and the system reacts by trying to stop the braking action imposed by the restricted room for growth. As a consequence, when saturation is approached there are usually oscillations, and they normally start around 90% of the saturation point. At this level of analysis one cannot say what kind of logistic will occur in the next cycle, but it is in principle possible to predict the next cycle at more abstract levels. Currently, about 100 cases have been analyzed in all fields of human activity for Kondratieff driven pulsations.

Nuclear energy is no exception. Figures 17 through 25 were originally done in a rush in the spring of 1985 for a paper to be given at a conference commemorating Alvin Weinberg's 75th birthday, and they are in many ways imperfect. However, they seem to stand the test of time, and comparing them with the 1988 issue of the Reference Data Series No. 1, by the International Atomic Energy Agency, the saturation points calculated then match the actual level of megawatt (MW) in operation and in construction by 10% (in excess) with the exception of Japan, which overshot the saturation point (see numbers marked under saturation brackets). The nuclear gigawatt-electric (GW_e) linked to the grid are fitted with logistic functions. In every case penetration proceeds in a way similar to that of the steel industry demonstrated in Figure 16. According to these charts, nuclear power growth will stop around 1995, indicating the end of the Kondratieff cycle. They represent GW in operation or under construction in eight countries. Ten percent in excess means all programs are in the range of 90% (or more) of the niche level as calculated then.

Figure 26 brings all the lines together to show the clustering of the saturation points. It seems clear again that the Kondratieff barrier plays a central role. Just to show that this is business as usual, a similar analysis, done for the penetration of cars in various countries, is reported in Figure 27.

This information seems to indicate that the further penetration of nuclear energy or, more precisely, the construction of new nuclear plants, seems to be influenced more by the Kondratieff cycle than by public opinion. Certainly public opinion seems to be hostile, or at least the noisy minority shows a lot of hostility. This may be temporarily utilized for political issues, as it is currently on the political agenda. As shown in the following sections, public opinion as represented by the media follows a precise script.

To conclude, a normal penetration process seems at work on the development of nuclear energy in various countries. The system is seeing the completion of many reactors under construction. Just to give an example (IAEA data), in 1984 the USA had 62 GW nuclear in operation and 55 under construction. In 1988 the plants in operation amounted to 93 GW, and 15 GW under construction. Incidentally, this totals 108 GW and can be compared with the 110 GW given as the saturation point for the pulses of the US nuclear growth as reported in Figure 24.

For Western Europe the situation is reflected in the fact that 67 GW were in operation in 1984, with 61 GW under construction. The situation in 1988 is 107 GW in operation and 20.5 GW under construction. As the sums show, there were no "losses" on the road. The residual 20% of construction will presumably be completed before 1995 – just in time for the Kondratieff appointment.

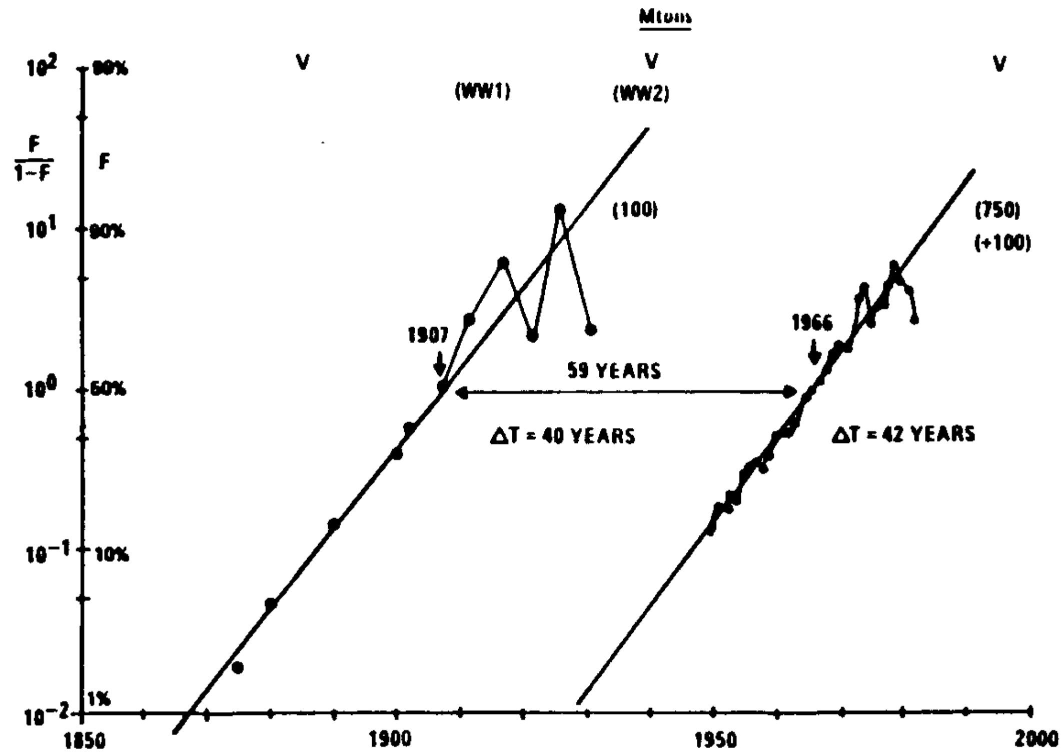

FIGURE 16. The Kondratieff Cycle of World Steel Production.
DATA SOURCE: Japan Steel Associates Statistics (1983).

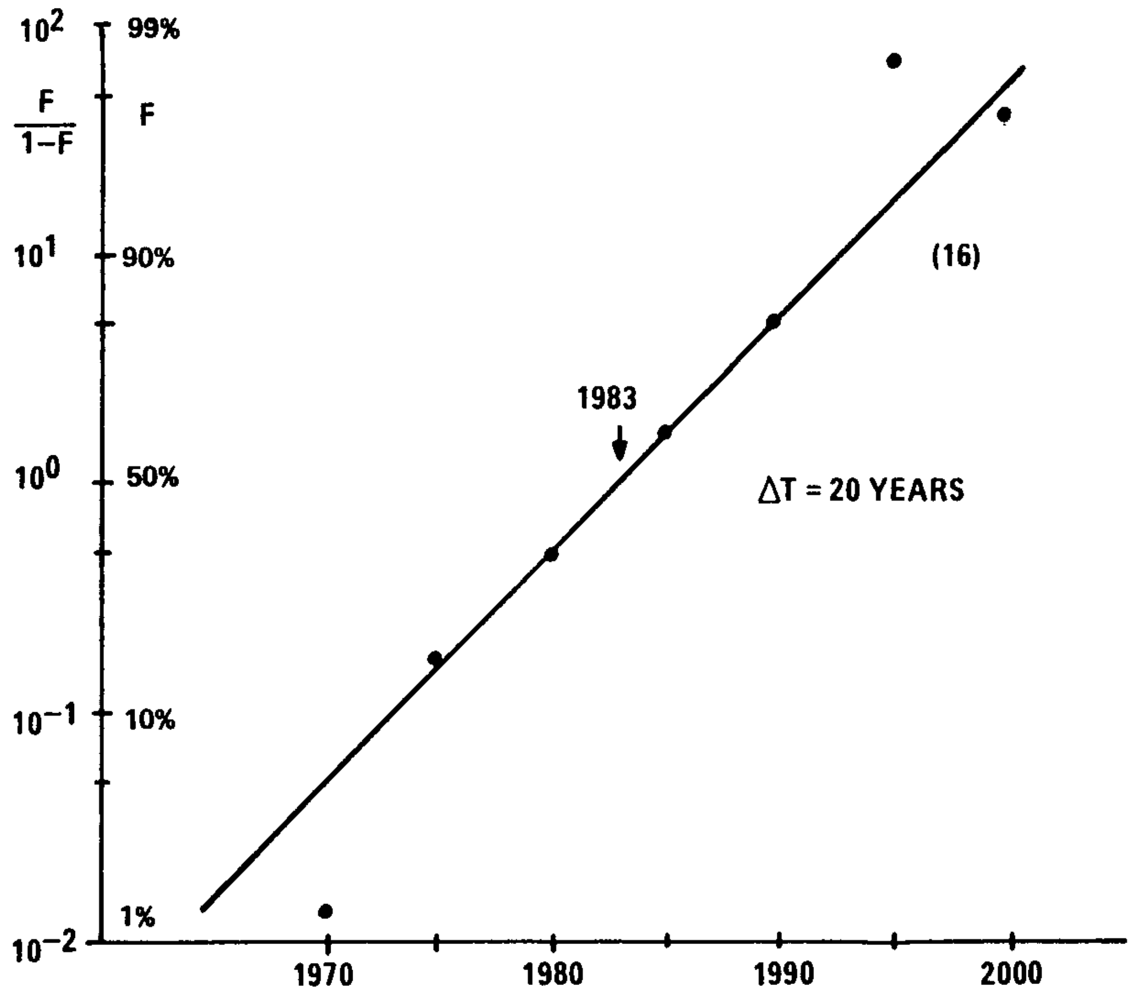

FIGURE 17. Canada: Installed Nuclear Power Plants (GW).
DATA AND FORECAST: Nukem (1981).

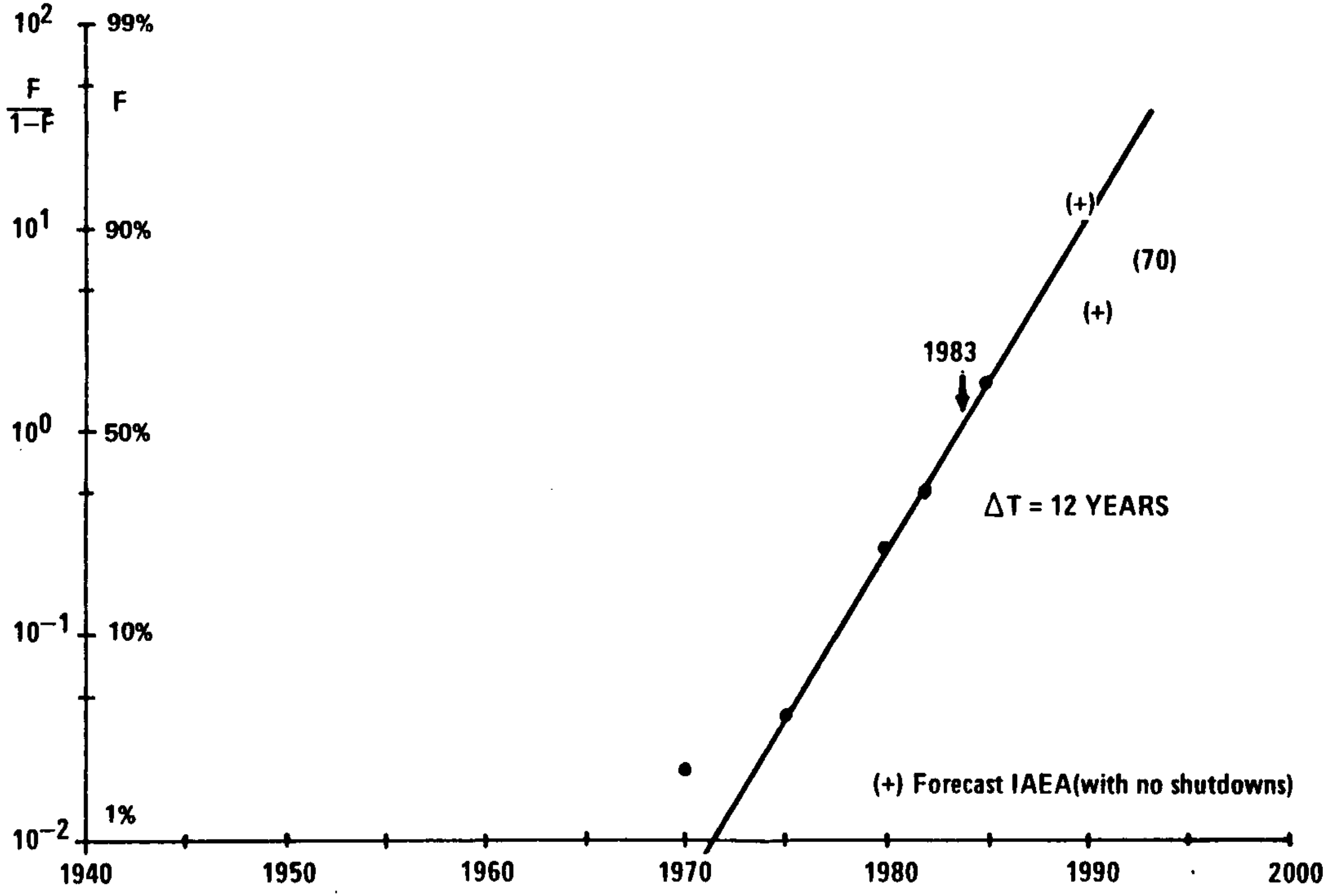

FIGURE 18. France: Nuclear Power Plants (GW) Connected to Grid.
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

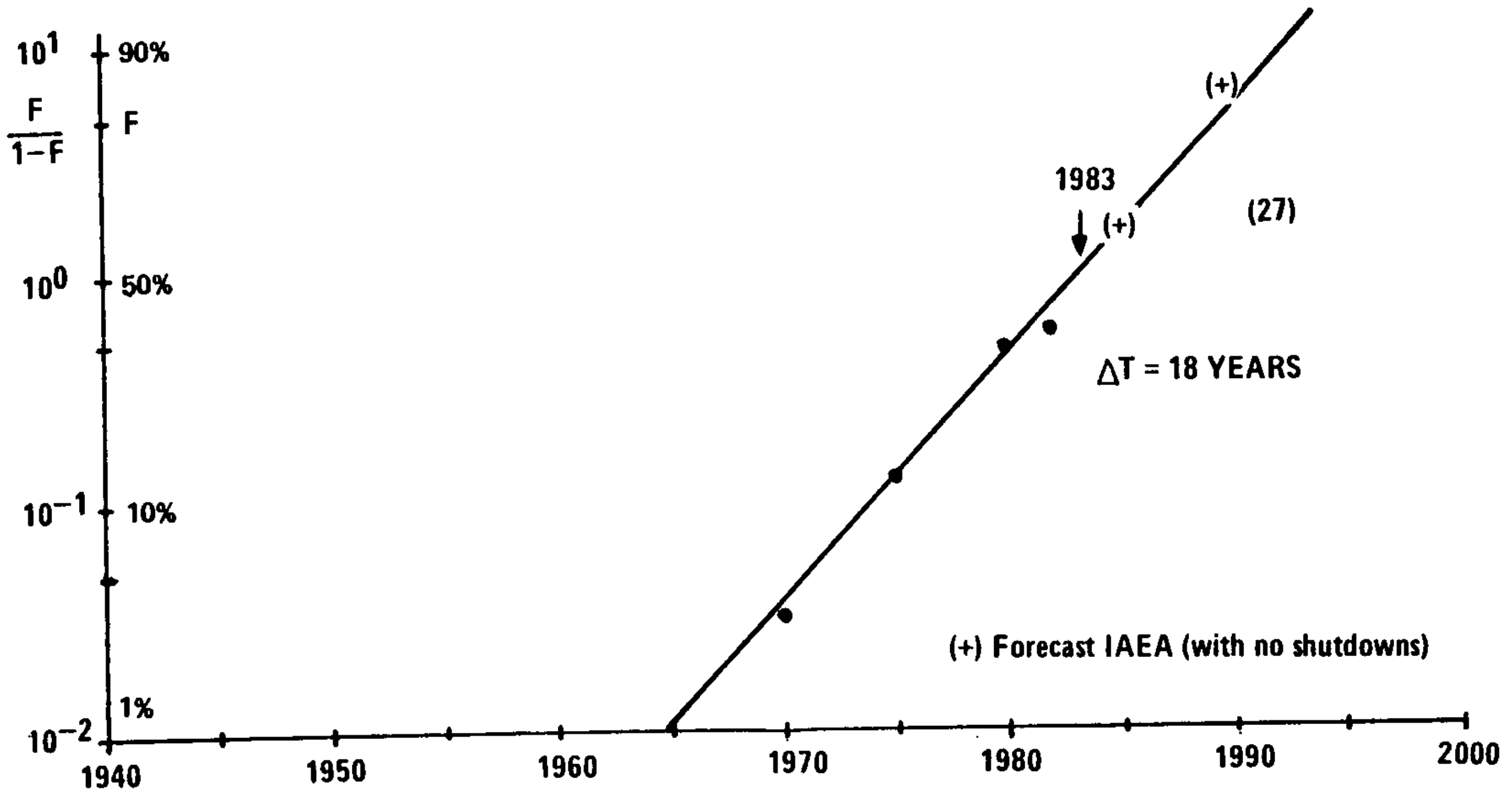

FIGURE 19. Federal Republic of Germany: Nuclear Power Plants (GW).
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

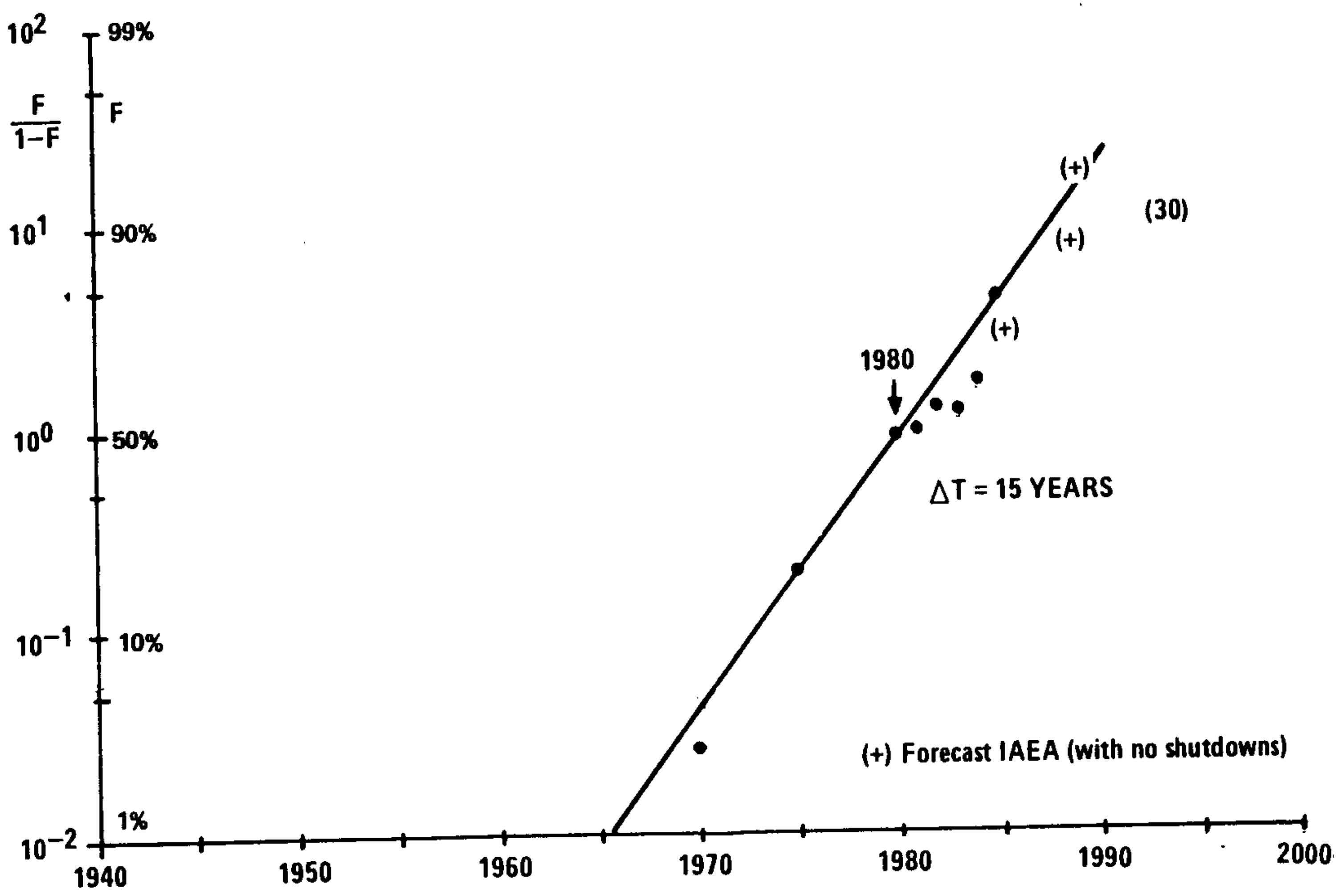

FIGURE 20. Japan: Nuclear Power Plants (GW) Connected to Grid.
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

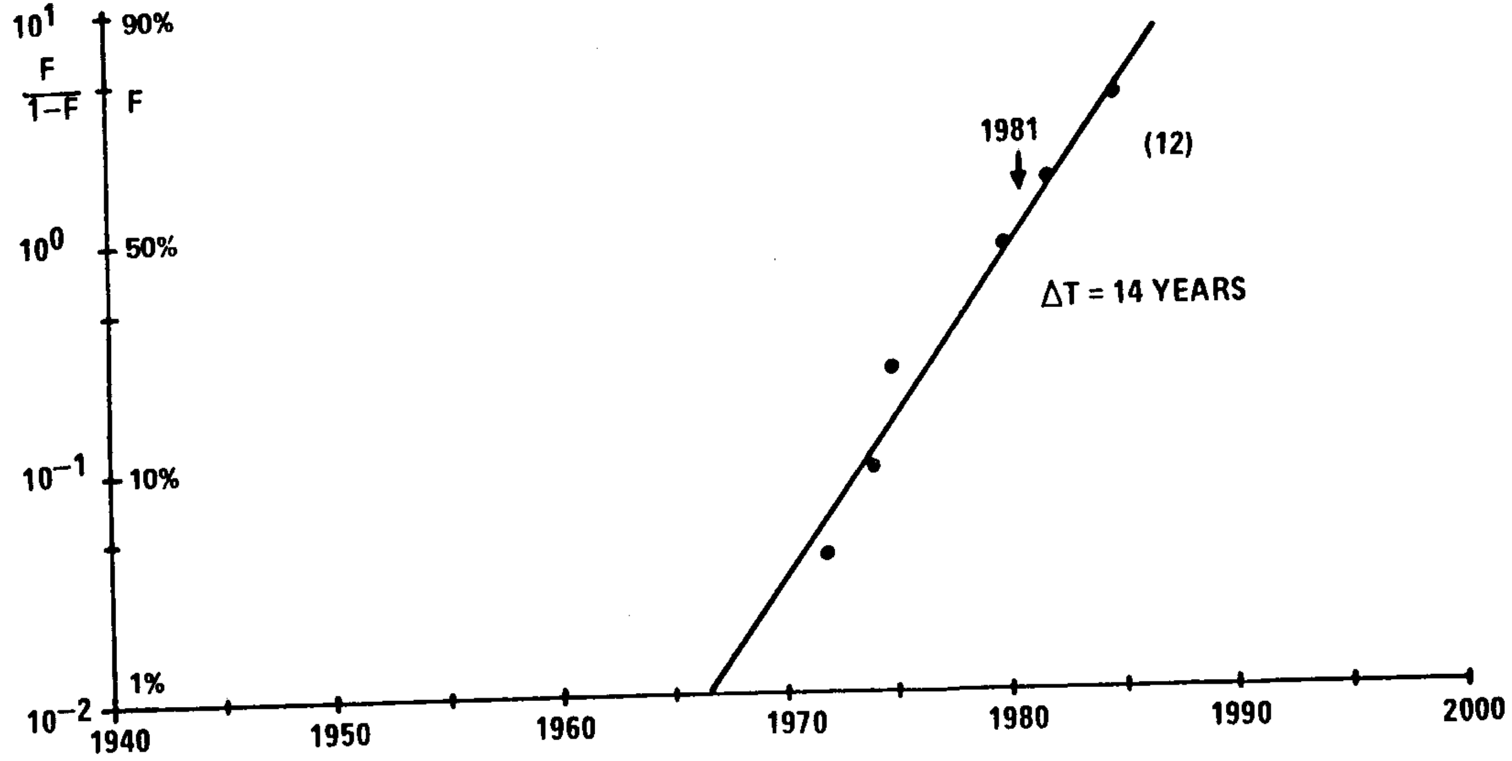

FIGURE 21. Sweden: Nuclear Power Plants (GW).
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

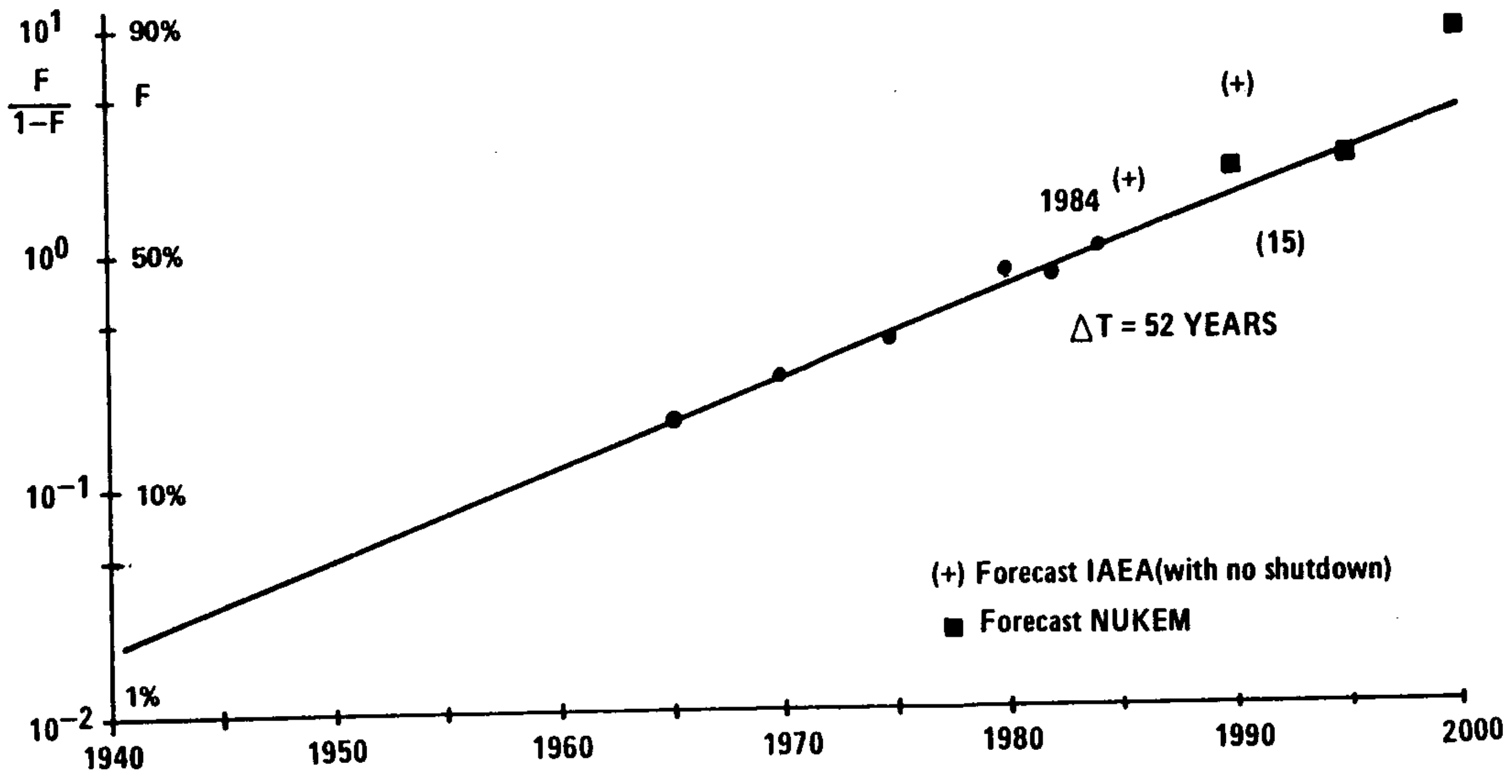

FIGURE 22. United Kingdom: Nuclear Power Plants (GW) Connected to Grid.
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

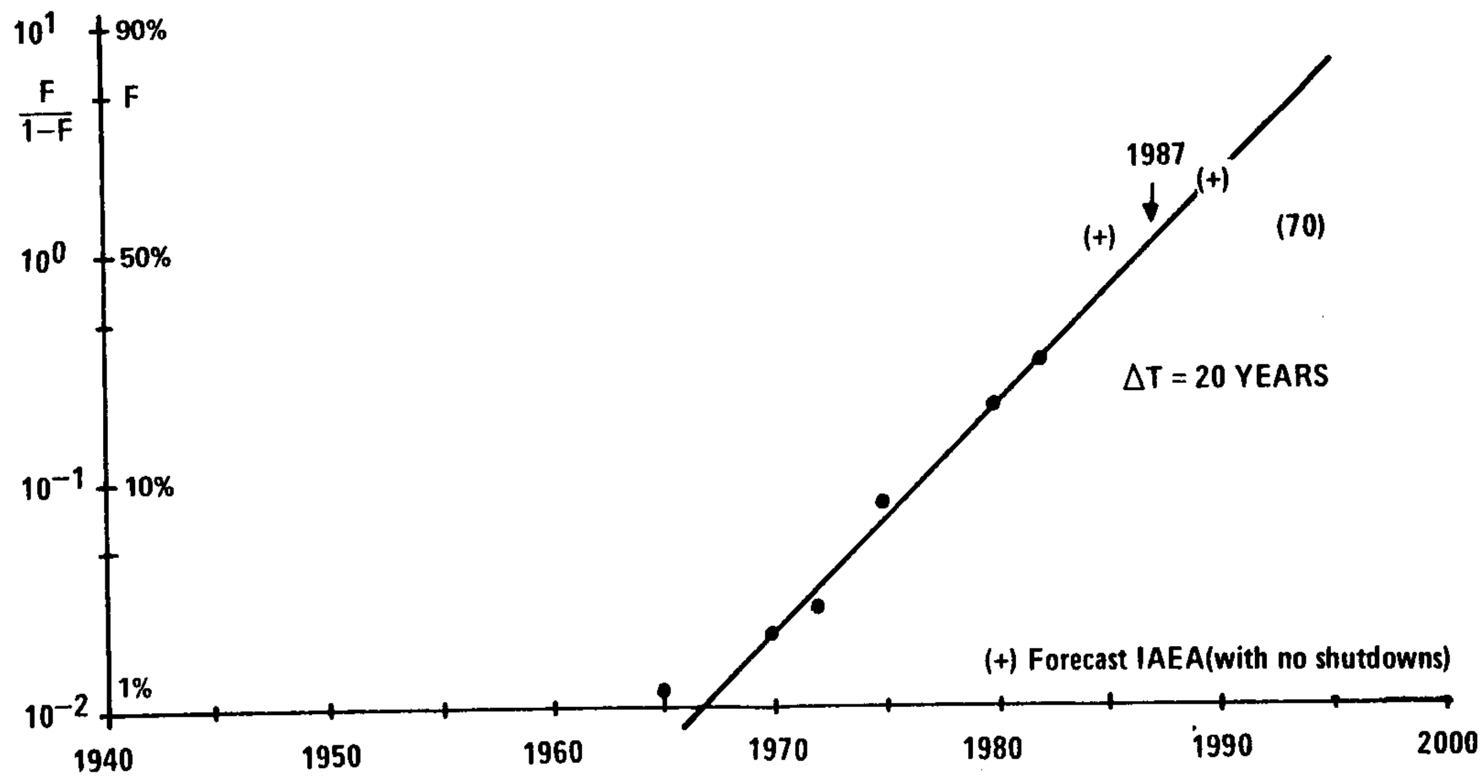

FIGURE 23. USSR: Nuclear Power Plants (GW) Connected to Grid.
DATA SOURCE: Nuclear Power Reactors, IAEA (1983).

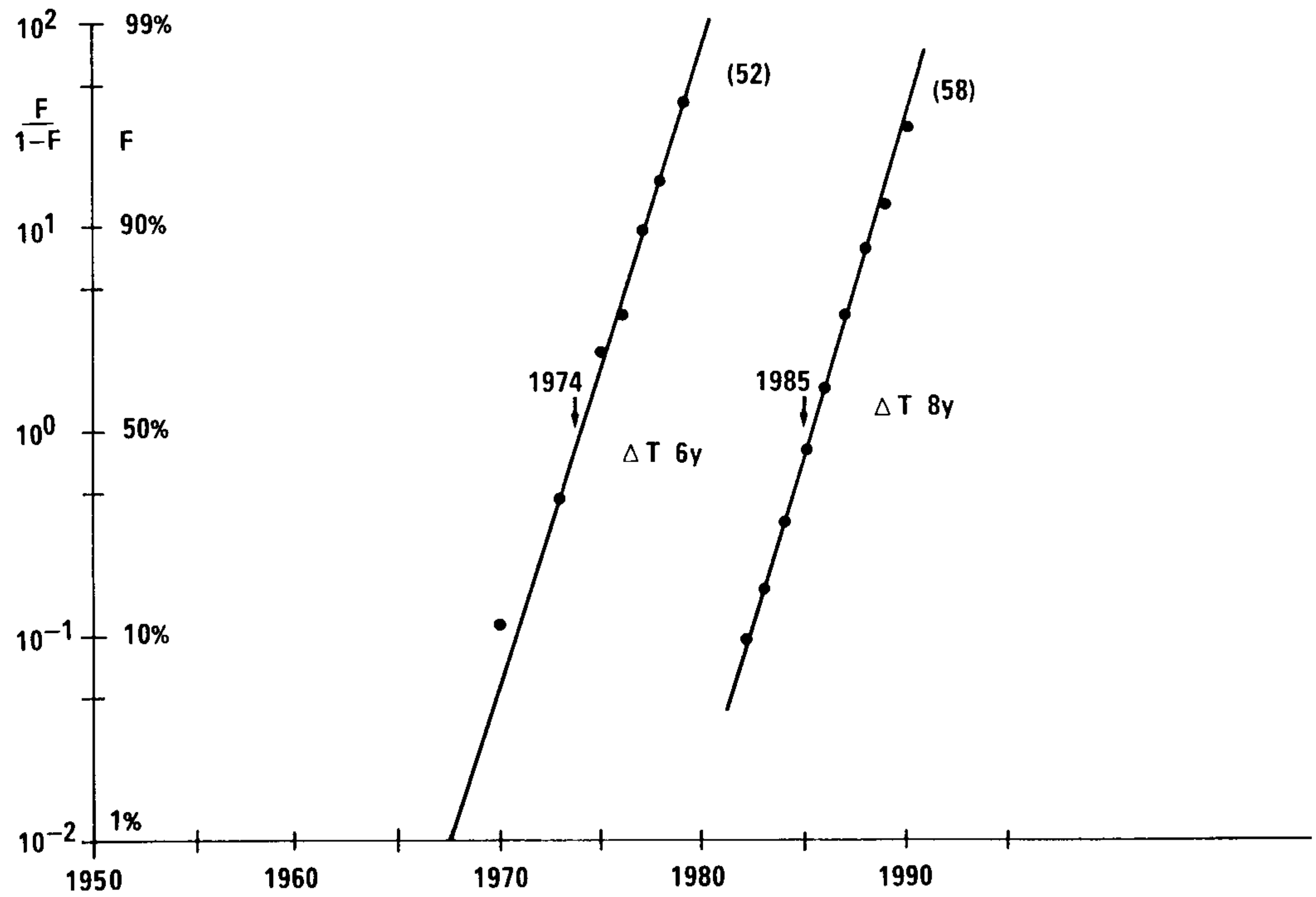

FIGURE 24. US: Installed Nuclear Capacity (GW net).
DATA AND FORECAST: Nukem (1980) and Nukem (1984).

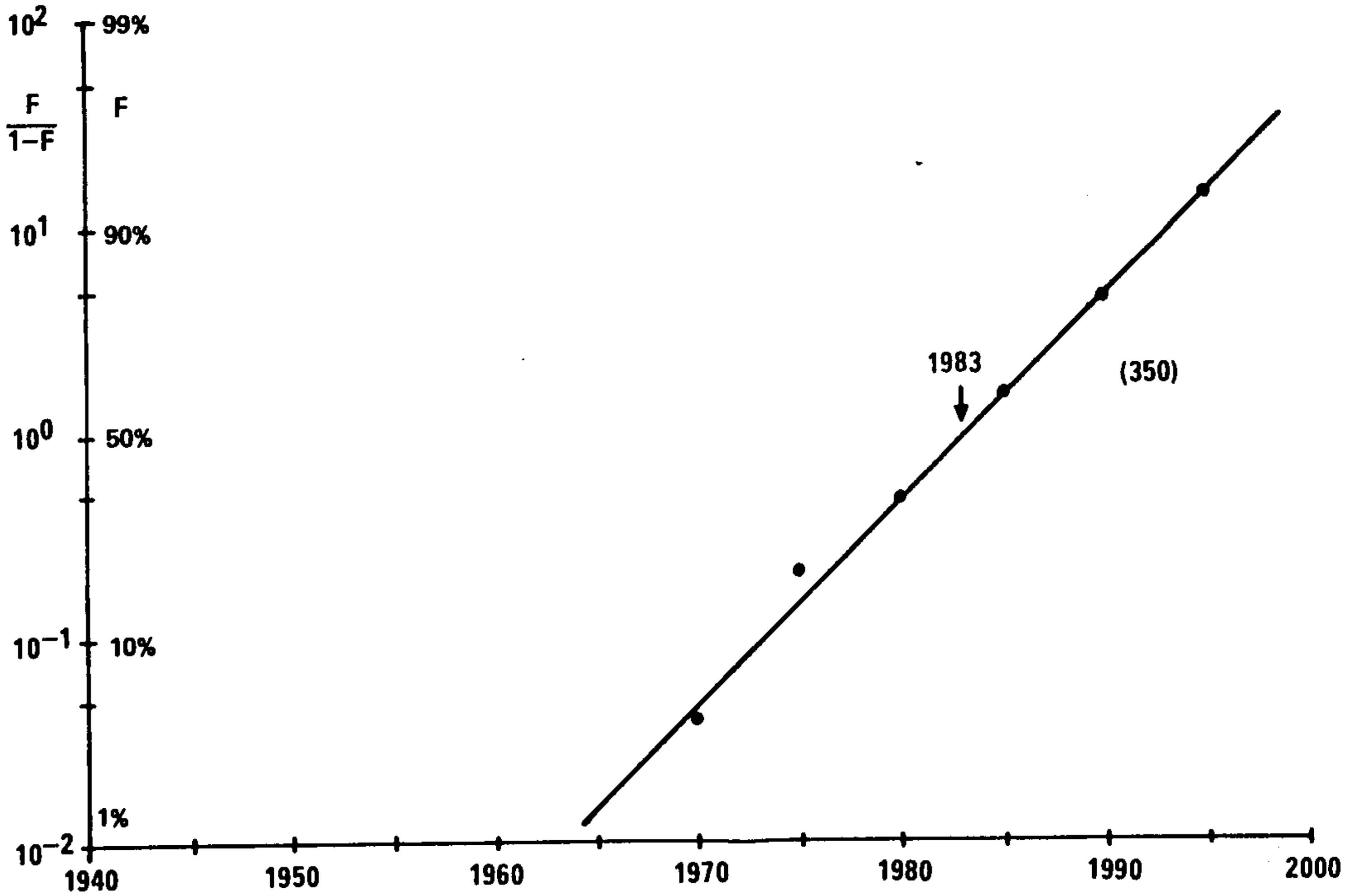

FIGURE 25. Western World: Installed Nuclear Power Plants (GW).
DATA AND FORECAST: Nukem (1984).

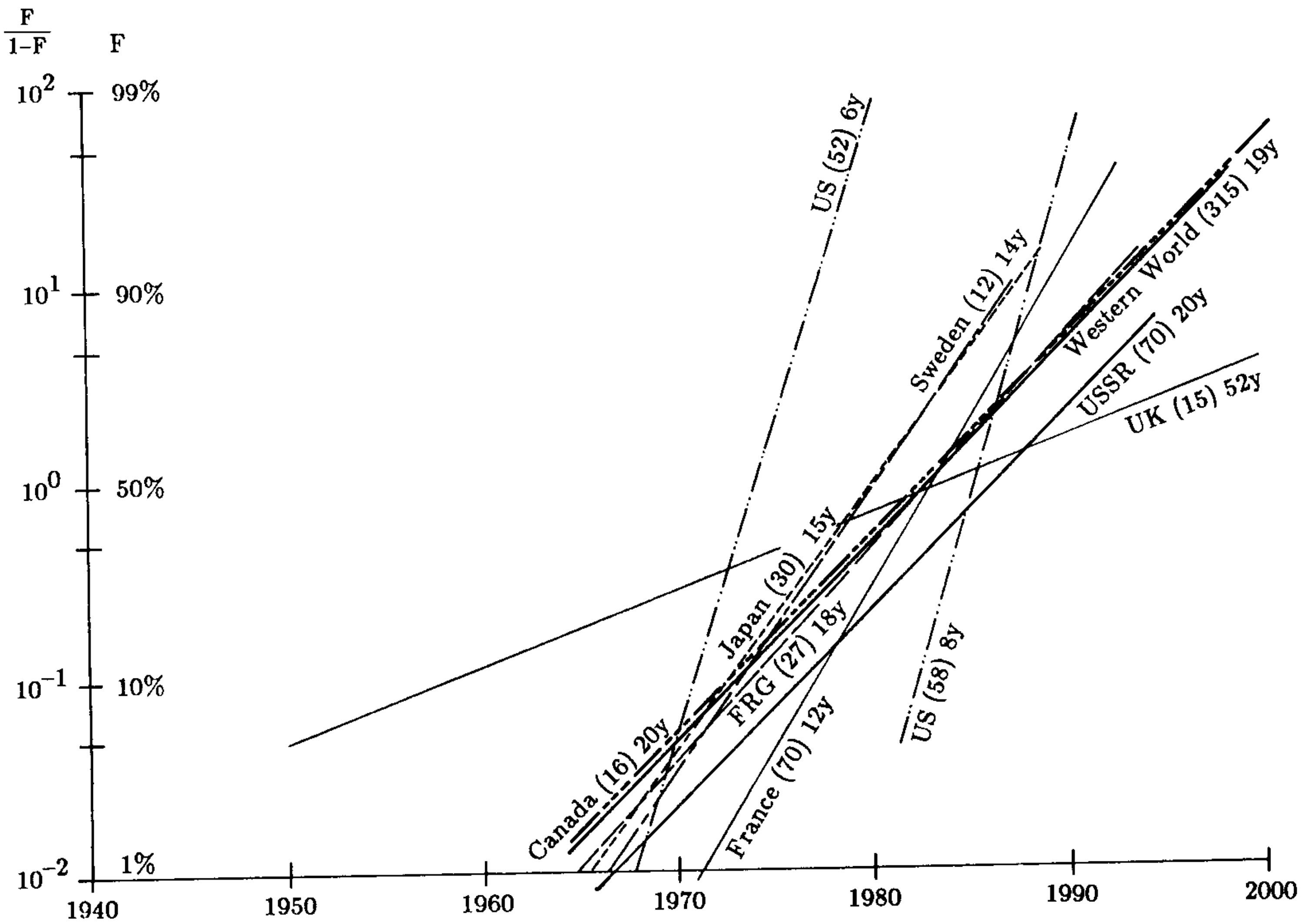

FIGURE 26. Penetration of Nuclear Power in World Nations (saturation, GW_e) and Time Constant.

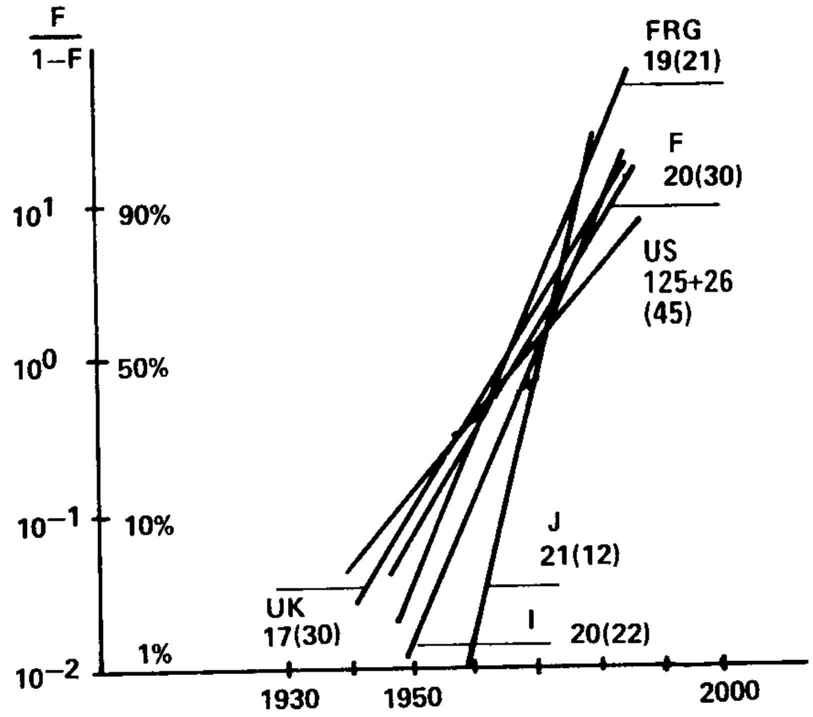

FIGURE 27. Car Population is Six Different Countries as Percentage of Saturation Level.

6. THE MEDIA

6.1. The US Case

An indicator of great importance to assess public interest is the level of coverage of a certain subject in the media: television, daily press, and periodicals. On the one hand, it is a common belief that the media are instrumental in defining the shape of public opinion. On the other hand, a successful media manager seems to be the one who knows what the audience wants. This feedback mechanism makes the media system *also* a resonating cavity of public opinions and concerns. Causality can be seen both ways in feedback systems.

For this reason caution should be taken in giving the media a decisive part to play in the raising of issues, as Mazur did in a series of articles concerning the interaction among the media, public opinion, and the nuclear power industry. A very important thing he did, however, was to measure quantitatively the media's interest, through amount of space dedicated to a certain issue or number of stories referring to that issue.

He counted the number of articles under the heading "atomic power plants" listed in the *Reader's Guide to Periodical Literature*. He also counted the number of pages under the heading "atomic energy and weapons – US – electric power and light" through 1980, and then under the new heading "atomic energy" listed in the *New York Times Index*. For television networks news he counted the number of stories in *Television News: Index and Abstracts* categorized under the heading "atomic energy and power" after deleting stories concerned with nuclear power weapons. His data are reported in his papers in the form of charts or listed in tables, without any in-depth processing to discover internal structures and invariants. As said before, we assume that human actions follow certain precise patterns defined by the "cultural diffusion" processes, which are in a sense similar to fashion diffusion processes, and to look for these patterns also in "soft" areas like coverage of an issue.

The data from Mazur (1984a), i.e., in terms of cumulative number of stories in the evening news for the US television networks are reported in Table 1. They are analyzed (using our procedure) in Figure 28. The first point does not appear because it is below the 1% line and the last is over the scale. The fitting to a logistic equation is very good, and one can recognize the important parameters of the wave: the time constant – seven years – measuring the spread of the attention wave and the flex – 1978 – when coverage was at a maximum. The total number is not amazingly high – 450 – in view of the long time span covered.

Six of the most important nuclear accidents, as determined by Mazur, are indicated in the figure. Curiously, the accident believed to be the worst – Three Mile Island – and had the highest emotional response sits right at the center of the "interest wave" for nuclear energy. This will be discussed in more detail in later sections.

When Mazur surveyed the periodic press, which supposely is more distant and sedate than the daily press, he measured the approximate amount of space periodicals gave to nuclear plants. Figure 29 shows the index cumulated along the wave of interest, which is obviously a proxy for measuring the total intensity of the wave. Here the center point is again 1978 showing that television and periodic press are finely tuned. However, the slightly higher ΔT shows a larger spread, i.e., the periodic press became interested in the subject a little earlier and will end a little later. Apparently no extra relevant information can be extracted analyzing them separately. This was considered a good reason not to extend further the search on US television.

A curious observation about television and periodic press coverage, as measured year by year, is that a very resonant accident such as Three Mile Island did not change the yearly budget of articles or television stories allocated by the underlying logistic equations. It generated, however, an independent "graft," with the characteristics of a cultural pulse (Figure 30). The peak of the pulse is about one week after the accident, and the time constant is only 18 days. This means that after one month the impact of the accident had practically faded out.

To complement Mazur's data, here at IIASA we scanned the *US Reader's Guide to Periodic Literature* from 1969–1984. The analysis in this case was done by counting articles on nuclear subjects, obviously excluding nuclear power weapons, small experimental reactors, and basic nuclear research. About 1450 articles were counted, and their time distribution is best fitted by two logistic pulses – one centered in 1972 and the other in 1979 (Figure 31). Mazur's search had obviously missed the first pulse; he started his time base in 1972.

Upon further investigation of the *US Reader's Guide to Periodic Literature*, the IIASA team found an attention flash of logistic structure just after the Three Mile Island incident, followed by a smaller flash about five months later in September which had escaped Mazur's analysis because it was listed under a different heading. These discoveries are reported in Figure 32 to show the analogy with the television attention pulse. The nine-day delay between the center points can be explained by the fact that many of the journals are weekly, and also by the fact that the interest spreads over a little longer period of time – 25 days instead of 18 days. The mark of lability seems to be there in any case.

That the process has in a sense an omnipresent structure is shown by looking at the reactions of the US periodic press to the Chernobyl accident (Figure 33). Here the reaction is a little slower, no doubt because of the blackout imposed on the Russian media. Once the gate was opened, the flow of articles follows the same patterns. The time constant is 21 days (instead of 25), and the saturation point about 59 articles instead of 36 (in the first flash).

Returning to our long-term analysis, it is curious that there are two waves of press attention given to nuclear power. We have already seen that the US nuclear industry has had two pulses of nuclear starts and of grid connections (GW), which incidentally are almost identical as in the case of the press attention pulses. Identical in the sense that both have a time constant of eight years. However, their size is quite different, with a 255-articles asymptote for the first pulse and an increase of almost fivefold, 1200-articles asymptote, for the second pulse.

It could be assumed that the facts, which raise most of the press attention, are linked to the decision to build a power station rather than to the final quest to connect it to the net. Furthermore, the number of reactors to be constructed seems *a priori* to be stimulating more interest than their intrinsic power. For these reasons Figure 34 reports the construction starts (cumulative numbers) for US power stations and the periodic press attention waves. Examining the chart, it seems that a deep meshing between the decisions and the press interventions is completely absent.

The only hint that might help in establishing a connection is that the center points of the attention given by the press are about five years apart and that the starting points are very near. In other words, the two sets of waves, the construction waves and the press waves, started more or less together and then each one proceeded under its own momentum.

It may be unfair to make connections between power utility presidents (time constant four years) and magazine editors (time constant eight years), as the last time constant might well be linked to the buildup of steam in the public. In a somewhat parallel case we found a similar time constant in the diffusion of a new way of addressing the public in advertising in Sweden.

To scrutinize all possible connections, Figure 35 charts the periodic press and the grid connection waves for the USA. Here the links appear even more tenuous than they did with the construction start waves as had been expected.

The possible correlations adumbrated above are of structural character. This means they were made by looking at the temporal distribution of construction pulses or article publication pulses, they do not hint at the size of the pulses themselves. In fact, the construction pulses had 75 and 45 reactors, respectively; the publication pulses had 255 and 1200 articles, respectively. Obviously the interest in nuclear energy was greatly intensified even though there was no obvious connection with the reactor-building activity. If the connection is correct, the "intensifier" has yet to be found.

6.2. The "Der Spiegel" Case

One may suppose such precisely geared structures are characteristic of a large well-organized structure like the USA. One may also observe that many actors make up the members of the periodic press or television networks or the variegated set of US utilities. To see if the complex structure was the casue for regularity, we decided to look at a single object, the core of the power system in the Federal Republic of Germany.

With this very specialized inquiry, *chemin faisant*, the research report moves from the initial objective of a historical review on the introduction of new technologies, illuminated by quantitative analyses, to an unexplored quantitative analysis of the media and their relationship with nuclear industry – breaking new ground, methodologically speaking.

Beginning the case study of *Der Spiegel*, it was decided that all issues dating to 1969 would be analyzed. All the articles under the keyword "nuclear energy" were counted. A logistic was then fit to the finding, comparable to that which was done on the US press. As Figure 36 shows it *almost* works, with a disruption in 1977. Having seen before that an event stimulating intense interest may well inject a pulse of extra "run of the mill" material into the system, a detailed survey of the distribution of articles in *Der Spiegel* for 1977 was made (Table 2). As a result, a large pulse centered around the eighth issue followed by a small one centered on the 17th issue was found, a structure typical to the reaction of the US weekly press, e.g., to the Three Mile Island accident.

Extracting that block, which came in without evident external causes (the situation will be discussed in more detail later), the run of the mill seems perfectly smooth with a center point in 1979 (the year of Three Mile Island) (Figure 37), not different from that of the US media, and a somewhat longer time constant of ten years. The result of the analysis was not substantially different from the eight years in the US press.

Der Spiegel did not show a specific interest pulse in connection with Three Mile Island in 1979, although there is an intensification of articles occurring along the year. In a sense this intensification compensated for a certain lack of interest that took place in 1980 (as referred to the subjacent logistic) so that finally nothing appears in the chart. The big pulse was in 1977, well before Three Mile Island.

As one would have expected, Chernobyl generated a fairly intense pulse with 21 articles and a very long time constant of nine weeks (Figure 38). This refers to articles specifically dealing with Chernobyl. But the turbulence generated obviously moved a lot of objects laying in the background, and in fact the cumulative number of articles related to nuclear energy inside the period of the Chernobyl pulse amounts to 61 with a time constant of seven weeks (Figure 39). The center points are only slightly displaced by about one week.

A first direct result of the analysis is that, functionally, a single journal like *Der Spiegel* operates exactly as the press as a whole. Furthermore, the tuning of the central point of interest intensity with that of the American weekly press is perfect. The analysis and comment about the "spurious" attention pulse of 1977 is reported in Appendix B.

Table 1. Attention to nucler power plants.

Year	Evening News on Television Networks (Number of stories)	*The New York Times* (Index of coverage)	Periodicals (Index of coverage)
1972	1	0.14	0.15
1973	6	0.17	0.17
1974	12	0.22	0.24
1975	22	0.20	0.28
1976	45	0.34	0.43
1977	50	0.38	0.25
1978	41	0.32	0.28
1979	98	1.00	1.00
1980	58	0.53	0.40
1981	49	0.38	0.55
1982	37		0.30
1983	58		0.25

DATA SOURCE: Mazur, A. (1984a).

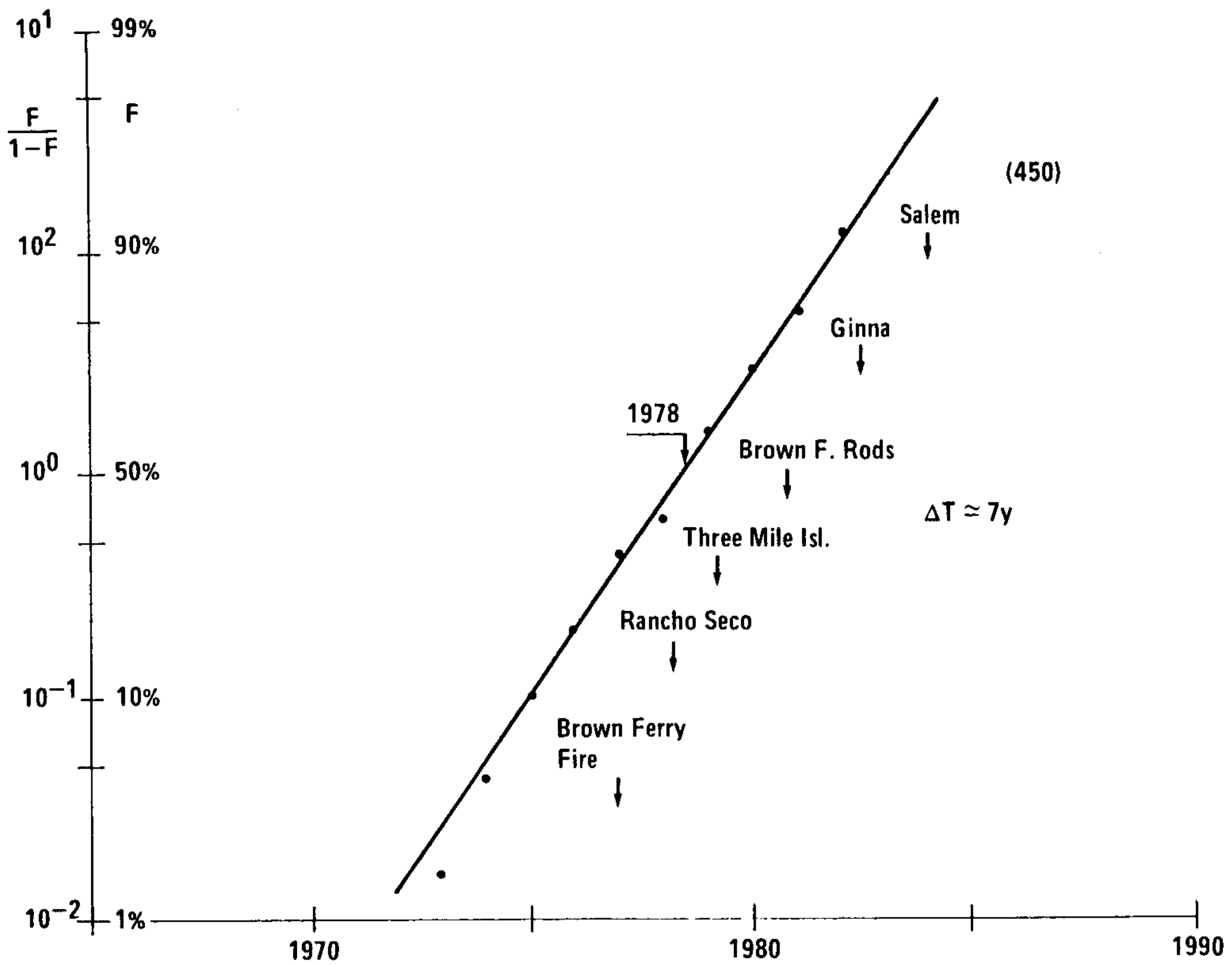

FIGURE 28. Cumulative Number of Stories in Evening News. US Television Networks about Nuclear Power Plants. DATA SOURCE: Mazur (1984a).

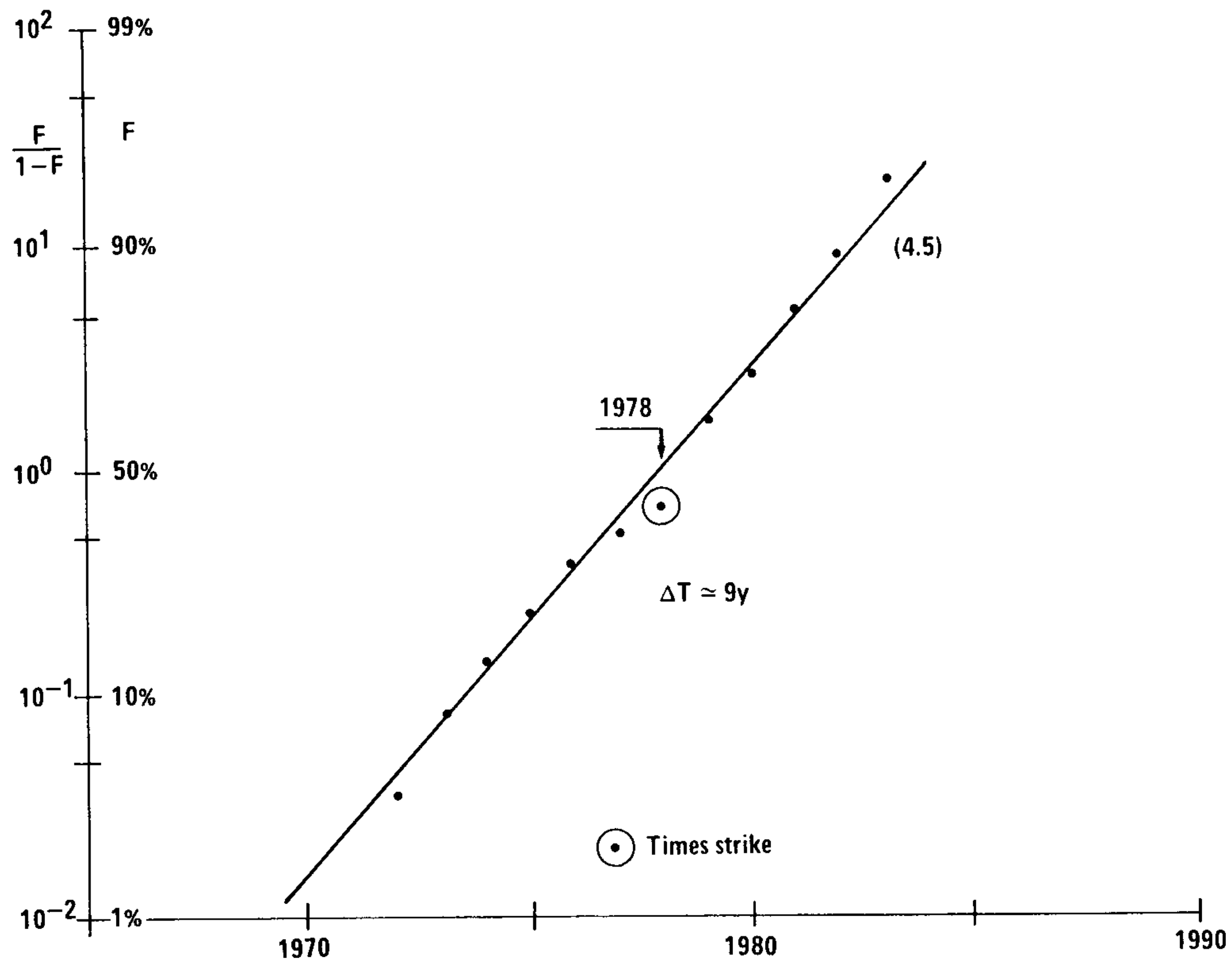

FIGURE 29. Cumulative Index of Coverage by US Periodicals on Nuclear Power Plants (arbitrary units). DATA SOURCE: Mazur (1984b).

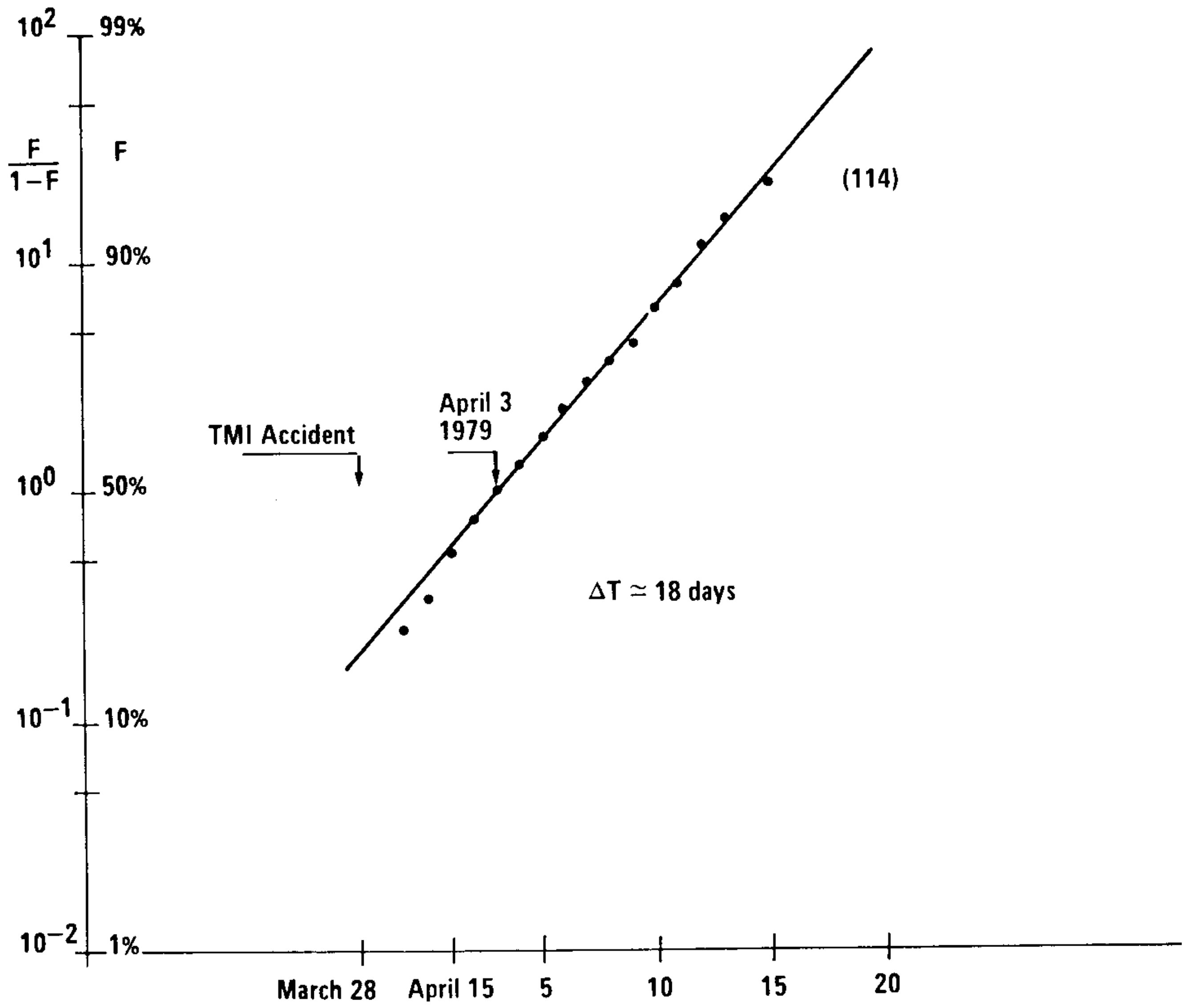

FIGURE 30. Television Evening New Stories in the USA on Three Mile Island Accident.
DATA SOURCE: Television Evening News Covers Nuclear Energy: A Ten Year Perspective, the Media Institute, Washington (1979).

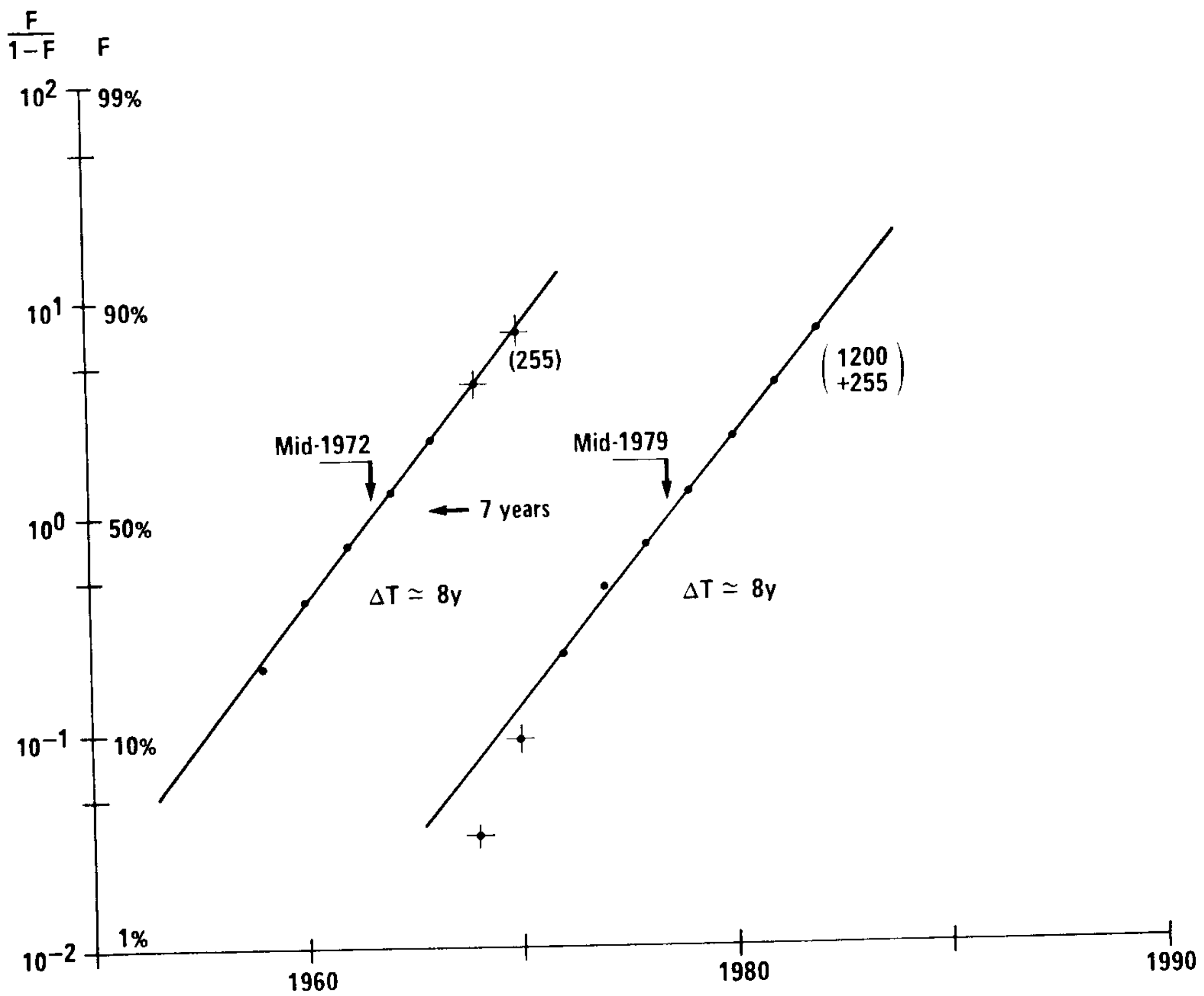

FIGURE 31. Long-Term Attention Pulse on US Periodical Literature. Cumulative number of articles on nuclear subjects. DATA SOURCE: *Reader's Guide to Periodical Literature.*

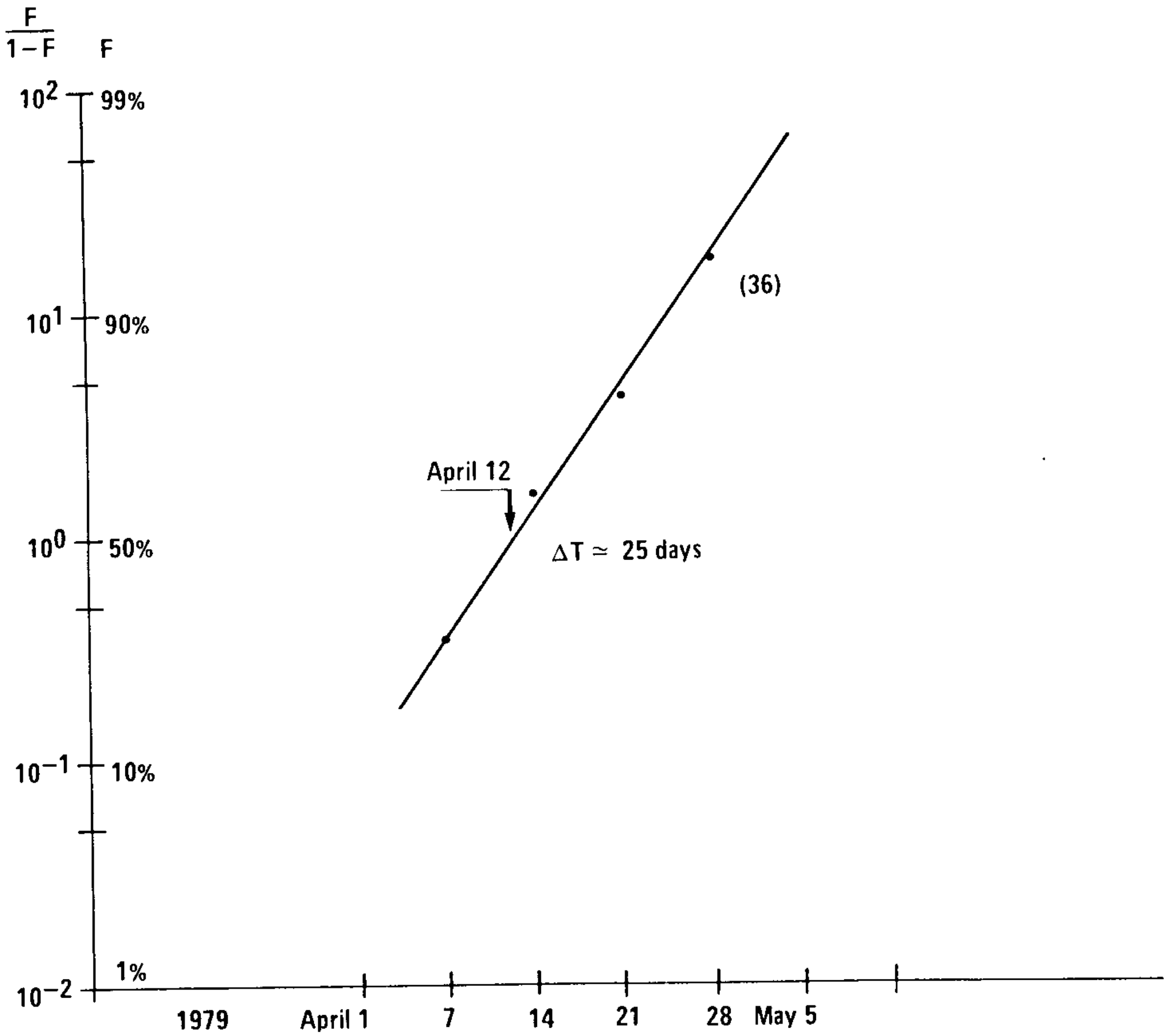

FIGURE 32. Three Mile Island: Attention Pulse in US Periodical Literature. Cumulative number of articles. DATA SOURCE: *Reader's Guide to Periodical Literature* (1979).

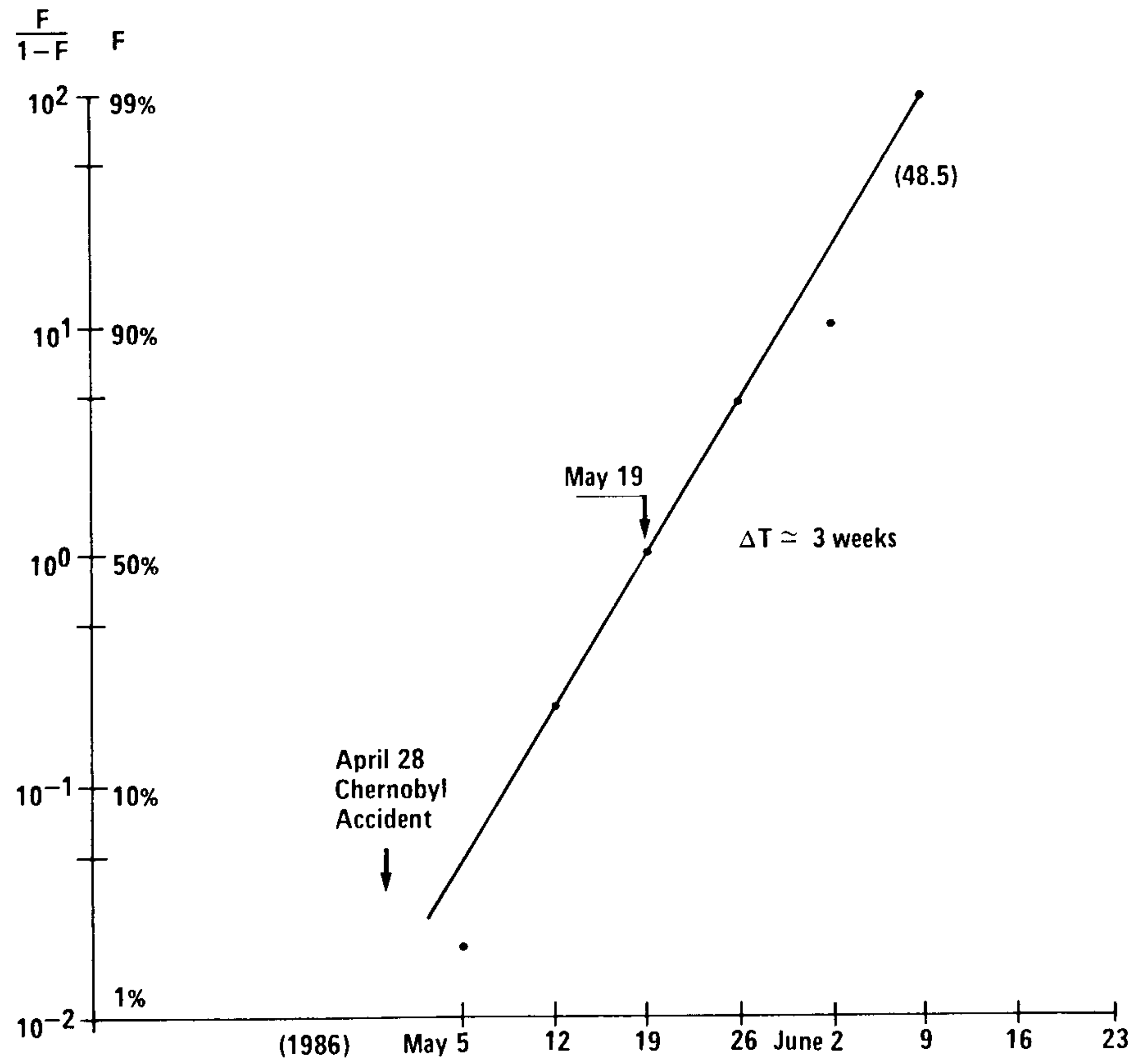

FIGURE 33. The Chernobyl Attention Pulse in US Periodical Literature. Cumulative Number of Articles.
DATA SOURCE: *Reader's Guide to Periodical Literature* (1986).