euro spectra

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- Collection "Research and Development" No. 2 - Prospective benefits from the creation of a European Meteorological Computing Centre - *Report EUR 4850 d/f/e.*

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Scientific and Technical Review of the European Communities (ex-Euratom-Review)

It is probably no exaggeration to say that, of the news followed with the greatest attention over the last six or eight months, weather forecasts win hands down.

In the hope of finally hearing a spell of fine weather announced, sun-hungry Europeans have doggedly combed the daily and long-term forecasts for solace in the face of the depressing clouds, rain, cold winds and implacable expanses of low pressure areas which have prevented us from ever discarding our raincoats and have caused us to wear our hard-pressed umbrellas down to the handle.

Which of us, on going away for a few days, has not stood perplexed before his open case, wondering what else to put in it ? Which of us, a few days later, has not cursed himself for not having taken along clothing for every possible meteorological eventuality ?

However, here is good news for all: active work is in progress on the establishment of a European Weather Forecasting Centre for "medium-term" forecasts, i.e., for 4-10 days ahead. This is intended not only to enable ordinary citizens to arrange their weekends sufficiently in advance with the precision requisite for such an important undertaking, but more especially to lead to well-defined economic advantages in many sectors, e.g. agriculture, shipping, building and civil engineering and energy production, to name only a few.

This issue of "euro-spectra" contains an article on the subject. In it readers will find not only news and explanations, but also, we hope, an answer to many of their questions, as well as points of interest.

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Sun or rain ?

Use of a European Centre for Medium-Term Weather Forecasting

GERHARD HIPP

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IN MOST EUROPEAN COUNTRIES today government spending, including social security, accounts for some 30-40% of the GNP. For some years, therefore, governments and international organizations have rightly been at pains to achieve a much greater degree of rationalization, as far as the decisions which lie at the root of such spending are concerned. Equally, they are eager to arrive at an analysis which will be as quantitative as possible and will take account of all the advantages and drawbacks of a planned measure, as well as all revenue and expenditure. Efforts to this end are characterized by such concepts as "Planning/Programming/Budgeting" (*PPB*), « Rationalisation des Choix Budgétaires" (*RCB*), "cost/benefit analysis".

The Commission of the European Communities is similarly engaged in the introduction of such methods in its services. In this it is pursuing two lines simultaneously, namely, the systematic scrutiny of the various areas of work and efforts to produce exemplary analyses of large-scale projects.

The subject of the present article falls under the latter category and deals with the cost/benefit analysis of a draft scheme for scientific and technical cooperation in a public service sector, namely, the setting up of a European Centre for Medium-Term Weather Forecasting (*ECMW*). Initially this centre would carry out application-oriented research; later, in the second half of the seventies, it would supply 4 - 10 day weather forecasts on a routine basis, in addition to carrying out several other duties (e.g. special services on behalf of participant countries, data bank and training functions).

Originally 15, and later 17, European countries [1] participated in talks on this project following an initiative taken by EEC Member Countries in Brussels in 1971: in November of the same year such project was approved in principle by almost all the participants. A number of other projects (in a total of seven different fields) also came under discussion.

The study involved detailed analyses of anticipated benefit and cost. This article is devoted, in particular, to an assessment of the anticipated advantages as put forward by the Benefit Analysis Group (Secretariat and report editing: Commission of the

[1] Apart from the EEC Member Countries, there were initially: Austria, Denmark, Ireland, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Later Finland and Yugoslavia also entered the discussions, as well as Greece and Turkey towards the end.

European Communities) under the chairmanship of Dr. Schneider, Director of the *Swiss Meteorological Office*. Also discussed, relatively briefly, are costs and the cost/benefit comparison. As regards this, there are two requirements which must be taken into account at the same time:

— an interest on the part of the "*PPB*" man in methods, practical experience and problems;

— a more professional approach on the part of the meteorologist: efforts to produce cost/benefit analyses are to be observed in the meteorological field also. Specific findings on the value of medium-term forecasts may be important for other studies. Accordingly, the Benefit Analysis Group has come out in favour of publishing the full text of the report in addition to a summary (1).

PPB - from the aim to the project

PPB, it will be recalled, comprises the following: specification of aims; an analysis of the various possibilities of implementation; selection of the most favourable variants in the light of all the ascertainable advantages and drawbacks; revenue and costs (planning); classification of the most advantageous projects into a programme spanning several years with politically predetermined priorities (programming); allocation of funds required annually (budgeting).

The *ECMW* project, discussed below, coincides more or less with the end of the first phase of the process described. Scheme 1 shows the thought processes involved from the initial aim to the proposal. The "improvement of environmental conditions through the best possible exploitation of climate [2] and weather" may be regarded as the overriding aim.

Two possibilities — "Changing the climate" [3] and "Changing the weather" — fell by the wayside; as yet they held out too little prospect of success. This left "Permanent protective and beneficial measures" relating to climate and weather (these two are practically synonymous and appear only once in the scheme, under the heading of climate) and "Temporary protective and beneficial measures". From here, the path through "Based on improved information on the weather" was taken (in actual fact, the decision between permanent or temporary protection may depend on the quality of the weather forecast), with the branch leading to "For the next 4-10 days" seeming most promising and potentially beneficial: the shorter-range forecasts—which are already not too bad, anyway—are continually being improved by national meteorological services, whereas forecasts going beyond 10 days still seem to hold out too little promise. There is a considerable degree of consensus, on the other hand, about the improving prospects of the medium-range, 4-10 day forecast; this branch is so recent, moreover, that the national meteorological services of most European countries have not yet invested heavily in it, so that collaboration can actually avoid the duplication of expenditure.

The four sub-divisions shown under "Forecasts for the next 4-10 days" are not true alternatives, in that "Better interpretation of observations in forecasting" and its two aspects "Better models" and "More computing capacity" are essential prerequisites, but the end result will be still further improved if the remaining aspects are also promoted (3). The chief proposal finally made, therefore, was the establishment of a European Centre for Medium-Term Weather Forecasting (*ECMW*) having the tasks mentioned already. A technical analysis of the various approaches which were theoretically possible concluded in favour of setting it up in the form of a centralized establishment. In addition, various ways of improving the observing network were recommended, in particular the joint development of ocean meteorological buoys and the development of a European meteorological satellite by *ESRO*.

The planned *ECMW* would make an extremely valuable contribution towards the achievement of the aims of the *World Meteorological Organization* (*WMO*, Geneva).

The benefit of medium-term weather forecasts:

How can it be quantified?

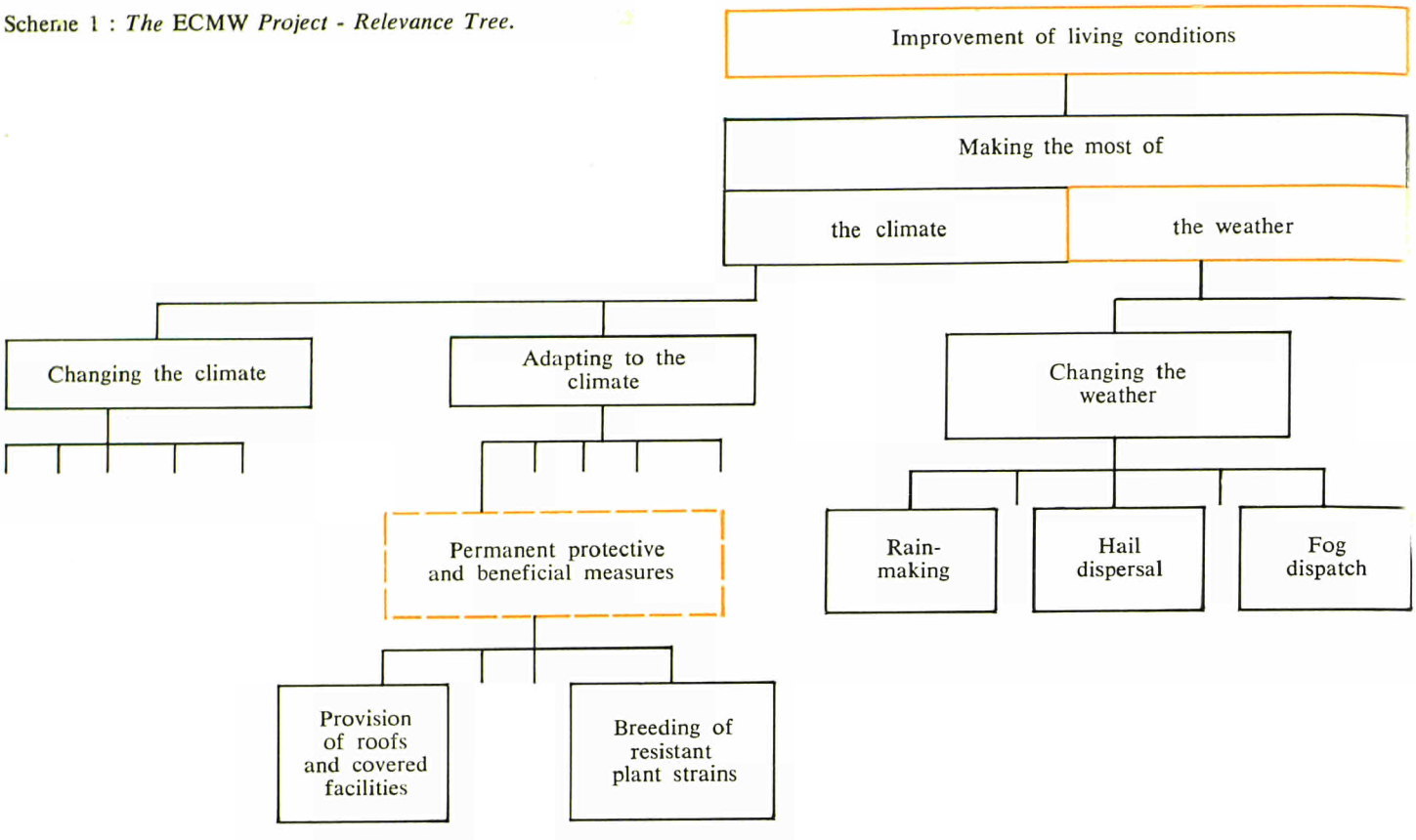
Benefit analysis in respect of the proposed project concentrated on the most important element in the tasks of the *ECMW:* applied research and (towards the end of the seventies) the routine production of 4-10 day forecasts. The benefit of the research work, which will initially predominate, could only be assessed from the value of the forecast subsequently made. Since the Centre's forecasts may be expected to improve over the years, and their practical value depends primarily on the accuracy achieved, great importance was attached to the selection of a timescale for the study. According to the proposed timetable for the Project, the *ECMW* would be in a position to prepare forecasts on a routine basis about five years after the decision to proceed, i.e. not before 1977 [4]. It would also take time before the users learned to take full advantage of this new form of information, and this process should be speeded up as much as possible by means of intensive user counselling. On the other hand, in view of the rapid advance in the field of computer technology, meaningful project cost estimates can only be

[2] The chart ("Relevance Tree" - Scheme 1) was drawn after the event, but the possible courses shown in it were actually considered.

[3] Climate: "the average course or condition of the weather at a particular place and (average) evolution of meteorological conditions characterizing such place" [translated from "Der Große Brockhaus", 1955 (2)].

[4] Not before 1978, in fact, in view of the present circumstances. The summary which follows adheres to the timing assumptions used in the original report.

Scheme 1 : *The* ECMW *Project - Relevance Tree.*



Temporary adapting to the weather

Temporary protective and beneficial measures

Based on the available weather information

Based on improved information on the weather

For the next three days

For the next 4-10 days

In the longer term

Better observational network

Better data transmission (telecommunications link)

Better interpretation of observations in forecasting

Improved dissemination of forecasts

General services

Special services

Ocean data-buoys network

Meteoro-logical satellites

More computing capacity

Better models

Greater use of existing techniques and knowledge

Research and development

ECMW

Within a national service

In the form of a central-ized facility

In the form of a link-up network

made for a medium-term period of five years, or perhaps ten years at the most. The year 1980 was therefore chosen as a time reference for the benefit analysis; in addition, however, another alternative estimate to 1985 is also given herein.

But how are we to quantify the benefit of medium-term weather forecasts produced in 1980? An overall analysis was out of the question, in view of the information available on the very different degrees to which the various branches of trade and industry are affected by the weather. Investigations on all economically important sectors were also rejected, having regard to the time available, since results had to be derived for 17 countries. The next task, therefore, was to select certain sectors. In order to take account, at least approximately, of the climatological diversity of the countries involved, they were first divided into three groups: a north-western zone with a chiefly maritime climate, and central and southern zones. The leading sectors of the economy were then listed and appraised, taking each zone in turn, against the following criteria: firstly, their contribution to the national product, and, secondly, their proneness to interference from the weather (considering their ability to make profitable use of weather information). After eliminating the less important sectors, and those comparatively unaffected by the weather, the following remained: agriculture (not including forestry and fishing), building, land and water transport, energy and, possibly, in the southern countries, water supplies. The sphere of leisure activities — high interesting in itself — had to be left out owing to basic statistical difficulties. Another very important, but non-commercial sector was added, namely, protection against disasters. Favourable circumstances made it possible to include the food industry and air transport at a later stage.

What method lent itself to establishing the benefit to this variety of spheres? Weather information is a planning aid for the farmer, the building contractor and those responsible for providing protection against disasters. Together with a greater or lesser number of other factors, it helps to mould decisions [5]. It would therefore be ideal if the possible contribution of 4-10 day forecasts to better overall results could be quantified in various conditions (i.e. the modelling of various situations) by using existing or easily constructed models. Unfortunately, however, even the simplest models, as described in the literature [(5), (6)], assume the availability of a considerable quantity of information — not only the probability of the forecast, e.g. the expected extent of the damage if no protective measures against bad weather are taken, but also the reduction in the damage by appropriate precautions and the cost of the protective measures. Allowance must also be made for the fact that operators can use climatological data derived from experience; after all, the Centre will really be of help only if its forecasts are better than climatological data.

Unfortunately, no models of this type were available. In the case of the building industry, where simulation studies might have been particularly informative, in view of the complex interplay of factors (in particular, the influence of social security systems, which is discussed below), contact was made with three establishments specializing in building research or planning. It emerged, however, that the preparation of the necessary model would have required more time (possibly nine months) and resources than appeared warranted.

Under the circumstances, the Group decided on another method, more readily usable in the available time, namely, "user opinion poll" based on a prepared list of points (the "Questionnaire exercise"). Considerable time was devoted to framing the questionnaire. As finalized, the main contents were:

[5] The importance of quantitative research on the firm was discussed in an article by R. Vandenborre and J. Vandenbulcke in *euro-spectra* (4).

1. A definition, with two examples, of the forecasts expected. In this connection, assumptions had to be made — in collaboration with specialists from the Working Party — on the forecasting accuracy that will probably be achieved by 1980 [6]. As a check, a question on the economic value of "completely satisfactory forecasts" — whatever this might mean to the user — was also included; this control question proved to be very valuable since it showed, among other things, that the subjects occasionally overestimated the performance of the *ECMW*.
2. As a guide for the research activities of the Centre, a question about the main meteorological parameters requested.
3. A request for information on what measures would flow from the forecasts, and the benefit of these measures as a percentage of turnover or value of output, both gross and after subtracting the relevant costs.
4. A question on the expected utilization of the forecasts (would all the firms in that sector use them; if not, approximately what percentage would?).
5. An enquiry about whether the sector may be expected to become relatively less weather-dependent in the longer term.

With this questionnaire, 132 interviews were conducted in 15 countries, with the collaboration of the national meteorological services. The results of

[6] The result was: "The same quality for five-day forecasts as for present-day-48-hour forecasts. Gradual falling-off in accuracy from the sixth day onwards, result for the tenth day still better than climatologically-derived data.

Table 1: *Breakdown of enquiries by country and sector (including the results of a Netherlands survey to establish how much interest in five-day forecasts there was among operators in agriculture and construction).*

	Agriculture	Building	Energy		Transport					Water supply and management	Protection against disasters	Other fields : food industry	Total
			Electricity generation	Miscellaneous fields	Marine transport	Inland water transport	Rail transport	Road transport	Air transport				
West Germany		7			1			6			1	1	16
France	9	3	1							2	1		16
Italy	1	3	2	1	6			2	1		2		18
Netherlands	8[1]	16[1]				4			1			1	30
Belgium		7	1	1								1	10
Luxembourg													
United Kingdom		1		1	1								3
Ireland	3												3
Denmark	5												5
Norway			2		2								4
Sweden		3	2		1		1			1[2]	1		9
Finland					1	3							3
Austria												2	2
Switzerland		3	3				3		3		3	4	19
Spain	8		2					3		1			14
Portugal	-[3]									-[3]			
Yugoslavia	1	1	1										3
Total	35	44	14	3	12	7	4	11	5	4	8	9	156

[1] The results from the Netherlands on the interest in five-day forecasts.
[2] Including electricity generation.
[3] Information incomplete.

a previous enquiry in the Netherlands as to how interested the agricultural and construction sectors would be in five-day forecasts constituted a further source of information.

In apportioning the planned interviews over the member countries, an attempt was made to allow for the economic importance of each sector, to include all the climatological zones, as far as was possible, and to obtain four or five answers per country. The breakdown, as it actually emerged, is shown by Table 1.

Results of the questionnaire exercise

The answers showed:

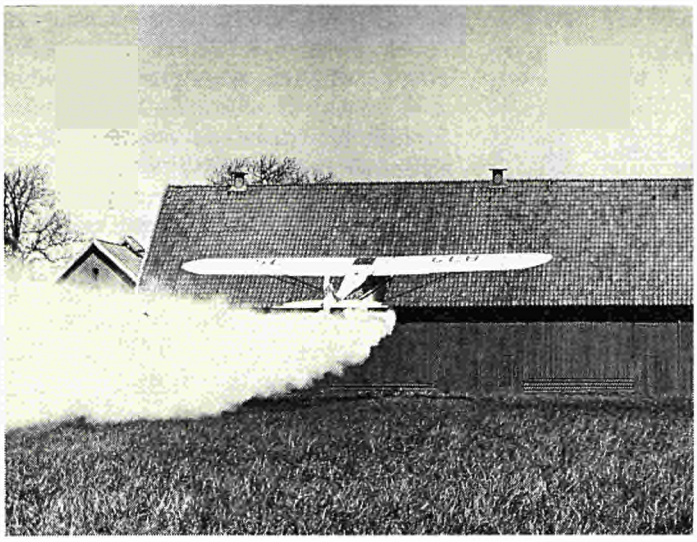
— a large and approximately quantifiable benefit from medium-term forecasts to agriculture, considerable value to building and civil engineering, hydro-electric generation, gas supply, and marine transport including the operation of ice breakers;

— a certain, roughly estimated value to trade and — even more nebulously established — for inland water transport;

— a comparatively low value to land and air transport.

The importance of 4-10 day forecasts for protection from disasters and water supply could only qualitatively be assessed.

The actual *formulation of the questionnaire* proved to be fairly good. If



the investigation were repeated, the Group would probably attempt to break down the question about the proportional benefits of the forecasts even further, i.e. into anticipated savings on materials or wages, and possibly increased production. It would be necessary to bear in mind, however, that this kind of more detailed formulation could reduce the willingness to answer: even the question about the overall benefit, being a difficult one, was answered only in the interviews, and hardly at all in the few written replies received.

In addition, of course, there is a basic interest in concurrent work on decision models. In the most important sectors the following fundamental problems cropped up: evaluation of the additional output of a heavily subsidized industry (i.e. agriculture), a possible clash between the interests of individual branches and society in general (one facet is social security in the building trade), and assessment of the possible increased turnover — perhaps due to advertising — in one branch of the distributing trade (food). If travel could have been dealt with using the available material, another problem would have been encountered, namely, that of weighing the interests of tourists against those of the hotel and catering industries (the problem of "bad weather" forecasts).

The results obtained in respect of the three sectors of the greatest economic importance — agriculture, building and the food trade — are set forth in some detail, and the remaining fields are only briefly discussed [7].

As shown below, the answers to the questionnaire have been related to highly tentative estimates of the sector output values for 1980 in order to derive data on the probable actual benefit of the forecasts:

- value of output in 1980 (in the absence of other comparable data, this takes the form of the contribution to *gross domestic product* — *GDP* — at factor cost);
- if necessary, and where possible, the percentage of total output prone to interference from the weather;
- possible net benefit (%), derived from the interviews;
- an allowance for the probable utilization of the forecasts (%).

This produces the *expected benefit* in 1980. Since the subsequent cost/benefit study is carried out by the discounting method, the expected benefit is then discounted to its present value (actually, its 1970 value, as laid down in the terms of reference) first by 8% (in real terms), and again by 5%, in order to gauge the effect of the selected discount rate on the final outcome. The figures derived using 5% are given below in brackets.

The benefit to certain sectors could only be estimated with the aid of occasionally fragmentary data and, in some cases, further assumptions.

Agriculture

Interest in medium-term forecasts was undoubtedly greatest in agriculture. In the Netherlands, for example, there was a marked preference for the production of five-day forecasts as opposed to a further improvement in short-range forecasts. Arable farming and horticulture are the most sensitive to the weather, i.e. plant production, which accounts for an average of approximately 50% of agricultural output by value, though this varies widely from country to country. Animal husbandry is less influenced by the weather, leaving aside haymaking. The projected form of forecast would enable the planning of sowing, plant protection and marketing to be improved; the payoff would take the form of higher yields (lower crop losses), better product quality, and savings of productive inputs (e.g. pesticides) and time. Furthermore, a reduction in the quantity of chemicals needed for pest-

[7] A fuller discussion will be found in (1).

control would ultimately benefit public health — an aspect which it was not possible to follow up. Most answers (some product-related) on the size of the benefit mention savings or production increments of the order of 1-5% of output value, though the percentages may be much higher in extreme years. Since it appeared hardly possible or warranted to differentiate between countries on the basis of the available answers, an average of 1.5-2% of the value output (i.e. plant production) subject to interference from the weather was assumed for all participants. Only five of those polled expressed opinions on the extent to which the forecasts would be used in practice, and they differed completely. It was therefore assumed, as the next step, that large holdings (of over 50 hectares, or approximately 20 acres, cultivable area) would obtain about 80% of the maximum possible benefit, medium-sized holdings around 50% and small holdings (of less than 10 hectares, or approximately 4 acres) only some 20%. Using this assumption, related to data on the structure of holding sizes in eight countries, an average utilization factor of 45-55% was obtained. Finally, for simplicity's sake, a figure of 50% was used for all the countries involved [8].

With a forecast value of output (contribution to *GDP* at factor cost) of around 46 billion UA in 1980, the expected benefit therefore stands at 140-190 M.UA, or, discounted at 8% (5%), a 1970 value of around 65-90 (85-120) M.UA.

In that this benefit is based on hoped-for increased production, the

[8] If it is assumed that the forecasts are fully utilized for about a third of the output, 50% utilized for another third and not used at all for the final third, an average of 50% is again arrived at.

question naturally arises whether it is all true to say that "more output = higher value" in a branch of the economy as heavily state-subsidized, directly or indirectly, as agriculture. Putting it bluntly, must not the extra output be exported under subsidy or stored at considerable expense until it finally rots? The Group took the view that this benefit analysis is of a long-term nature and that raising the long-term average productivity of agriculture by means of medium-range forecasts ultimately helps to save production factors which must benefit other sectors of the economy under a rational agricultural and industrial policy, so that, in the final analysis, the selected procedure appeared warranted [9].

[9] This problem could be investigated more thoroughly only as part of an analysis covering the whole economy.

Building

Medium-term forecasts are also of value to building and civil engineering, although here, in some cases, even greater benefit is credited to an improvement in the short-term, or even to yet longer-term (monthly) forecasts. The activities primarily affected by bad weather are, of course, those conducted out of doors, i.e. steel erection, façade coating, road building and harbour and sea-defence construction. Delays due to bad weather can also cause holdups in the subsequent stages of inside finishing work. If American findings regarding the proportion of construction-industry operations subject to weather interference are applied to Europe, this proportion can be assumed to be about half of total activity.

Heavy rain, low temperatures (below -2/-3° C) and snow are the prime sources of interference. Rain can cause serious damage to a newly laid road surface; at temperatures below -2/-3° C building sites must be provided with winter equipment, which is not cheap; snow also hinders the delivery of materials to sites. In winds above certain forces it is impossible to operate cranes or work on scaffolding.

Table 2: *Estimated net value of 4-10 day forecasts to the building and civil engineering industry (% of output value).*

	Number of answers
Practically nil *	6
> 0 (no further details)	16
Above 0 %-0.5%	15
0.5%-1.0%	7
1.0%-1.5%	4
> 1.5%	5
	53

* This answer came mainly from systems-building firms, in respect of five-day forecasts.

From the answers to the questionnaire, it appeared that 4-10 day forecasts would, above all, enable work planning and scheduling to be improved, e.g. prompter ordering of special cement from the depot if there is a likelihood of frost, protecting the site and materials from damage, speeding up certain operations or, if possible, suspending some operations in favour of others.

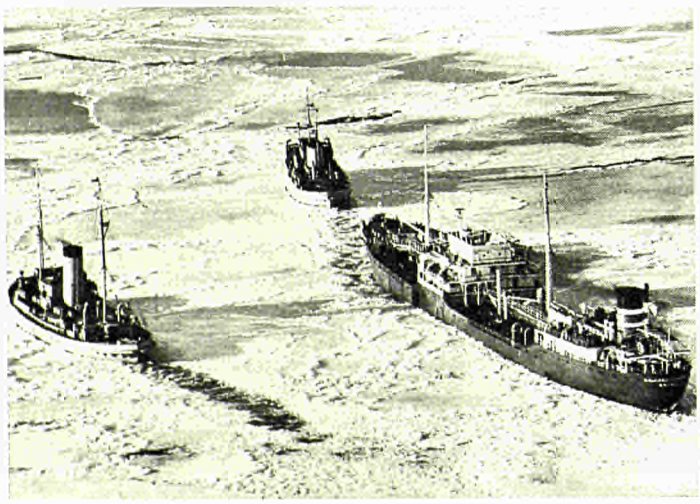
Another possible use of these 4-10 day forecasts, if available, revealed problems: certain firms in a number of countries foresee the possibility of sending their workers home early, but at the same time instructing them to report back at the site on a specified day for which the return of favourable weather conditions is forecast. This anticipated laying-off enables the employers to transfer to the social security system the costs of their employees' weather-induced idleness, which is normally the employers' liability (i.e. the community as a whole

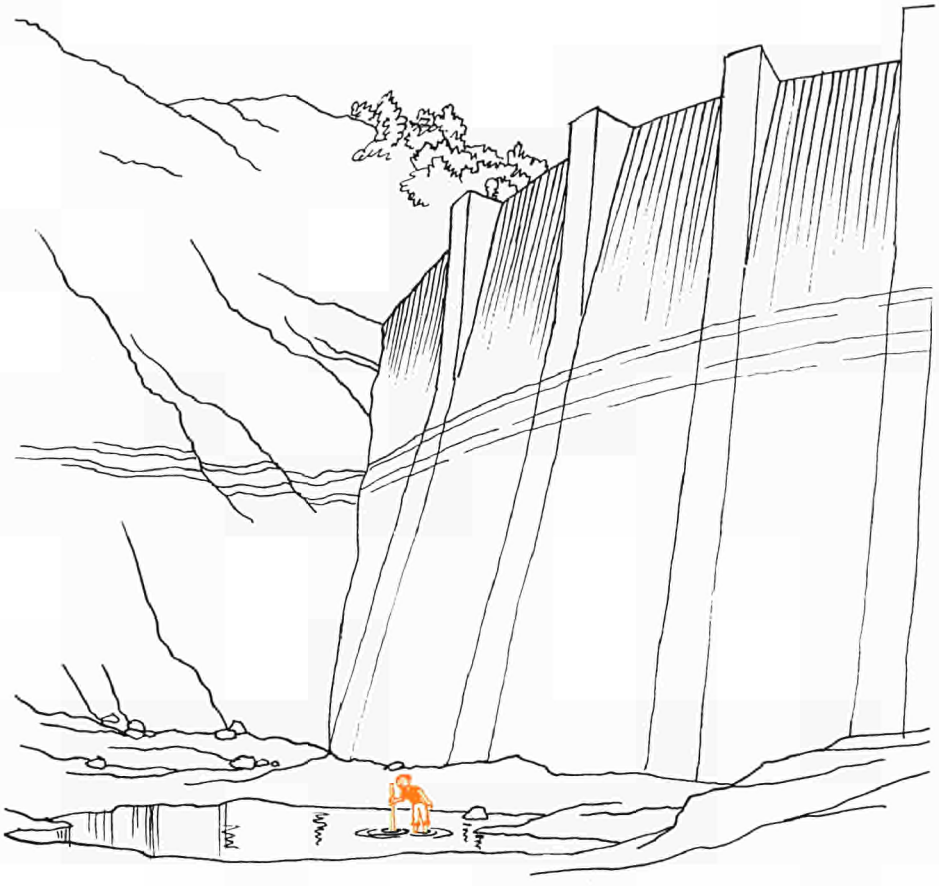
would pay, although the impact would be softened by the fact that building contractors themselves pay considerable social security contributions). The resultant earlier recall of labour, on the other hand, would permit a genuine increase in output. In the time available it was not possible to go into this matter as deeply as we wished, but it appears that the full utilization of 4-10 day forecasts by the building and civil engineering industry in various countries would necessitate amendment of the regulations governing social security payments to workers laid off owing to inclement weather.

The stated percentage benefits (based on about 50 answers) varied as shown in Table 2.

Four of the "Practically nil" answers came from systems-building firms in the Netherlands, and related to the potential value of five-day forecasts. Most of the answers were in the range of "Above 0%" to 1.5%. (Since the comparatively sparse information in civil engineering did not differ much from the remainder, the distinction between building and civil engineering was dropped.) The arithmetical mean of barely 1% appears somewhat problematical, in that some of the answers to the questionnaire related to the whole of the firms' construction business, whereas others related more especially to the weather-prone portion — sometimes by implication. Reference to the literature shows that losses due to adverse weather conditions affecting the construction industry in France, the Netherlands, the United Kingdom, Austria and the United States amount to 1-4% in a normal year and 10-15% in bad times. Since these losses could hardy be entirely avoided and various firms attached more importance to a further improvement in the short-term forecasts than to the production of medium-term ones, the possible benefit was set at 0.5% of the total volume of construction-industry business for almost all the countries. Only in the case of Spain and Portugal did a (somewhat arbitrary) reduction of this percentage, to 0.1 and 0.3% respectively, seem appropriate.

On the question of the extent to which the *ECMW* forecasts would actually be used by construction firms, a certain degree of agreement was apparent that the large undertakings, especially, would make active use of this new type of information. On the basis of certain information on the relative importance of large, medium-sized and small firms in building and civil engineering, together with the assumption that the average utilization would be 80, 50 and 20% respectively, a mean utilization factor of 50% emerged, with no attempt to identify specific values for the different countries.





With a probable volume of construction business (the sector's contribution to the *GDP* at factor costs) of over 86 billion UA in 1980, the expected benefit therefore amounts to 210-220 M.UA; discounted at 8% (5%), this gives a 1970 value of 100 (130) M.UA.

Shipping

Medium-term forecasts would also be of considerable benefit to shipping. In marine navigation "wind, seaway, currents, fog and ice... all have an effect on passage times, fuel consumption and the safety of men, ships and cargo" (8). In view of this, the preparation and use of routing recommendations are of growing importance. The availability of 4-10 day forecasts would make possible a further improvement in recommendations of this kind. The resultant timesaving alone, for all the countries involved, can be put at 11-13 M.UA in 1980, i.e. discounted at 8% (5%), a 1970 value of 5-6 (7-8) M.UA. In addition to this there would be the unquantified value of damage avoidance.

A major unexpected bonus emerged in respect of the operation of *ice breakers* in the Gulf of Bothnia and the Gulf of Finland. "Normally the operation of ice breakers is planned four days in advance, and the same time span is also required for forecasting the closure and opening of ports, and restrictions on shipping traffic owing to serious ice accumulation [10]". Given 4-10 day forecasts, the ice breakers could be more efficiently deployed, the work on board better organized, and the number of wasted days both at sea and in port could be reduced, as could the damage. Detailed studies in respect of Finland show that current losses due to the reduction in the volume of trade alone amount to some 30 million Finmarks per year; if it is assumed that 4-10 day forecasts would reduce these by only 10%, an annual saving of 3 million Finmarks (about 0.7 M.UA) would result. Additionally there would be the possible reduction in direct ice damage to ships; assuming this to be 50% of the present sum, this gives a further economy of 0.25 M.UA, so that the benefit of medium-term forecasts to Finland alone, based on the present trade volume, would be about one M.UA. A very rough application of this result to Sweden, bearing in mind that (a) only part (although a considerable one) of its trade is adversely affected by ice and (b) Swedish shipping traffic is three to four times that of Finland, pointed to a 1.5-2.0 M.UA benefit to Sweden under present-day conditions of trade.

For both countries together, it might be about 4-5 M.UA in 1980; discounted to its 1970 value, then, the total annual benefit to ice breaker deployment is two M.UA at 8% and three million at 5%.

In the case of *inland water transport*, 4-10 day forecasts primarily of water level and, related to this, precipitation, would permit greater accuracy in calculations of loaded draught. Forecasts of ice and fog would also be valuable (with a view to safety precautions). Shippers could, at a pinch, divert cargoes to ice-free routes or rail transport in the event of an ice hazard occurring. The estimated possible savings, solely for Dutch shipping traffic on the Rhine, are almost 3 M.UA in 1980. The potential value to pleasure boat operation on lakes is not insignificant, being put at 50 000 UA a year for Finland (this country's river driving of timber, which is very extensive, is more interested in an improvement in short-term forecasts).

Trade

Finally, a conference of European *dealers in foodstuffs*, held in Switzerland (8), provided an opportunity for

[10] Personal communication of D. Södermann of the *Finnish Meteorological Institute*.

a broad estimate of the potential value to this extremely important branch of trade. Many, though not all, of the first questioned considered 4-10 day forecasts valuable, especially for tailoring advertising and the lines on offer to the expected weather. The estimated benefits were 0.1-0.2% of turnover, with an expected utilization factor of 50%. If these figures, based chiefly on information for Austrian and Swiss replies, are applied to all 17 countries (again taking the value of output to be the value added by the sector), the resultant expected benefit in 1980 is 14-28 M.UA; discounted at 8%, this gives a 1970 value of 6-13 M.UA (8-17 M.UA when discounted at 5%).

In the case of trade, there are special problems with methods when it comes to assessing particular aspects of the benefit from the angle of the economy as a whole. Insofar as the 4-10 day forecasts help to avoid the costs of advertising and stocking arrangements which would be nullified by adverse weather, the interests of the sector coincide with those of the total economy. But what if publicity attuned to the weather helps to meet a certain demand at the right time but perhaps itself creates the demand in the first place? In this case it would be necessary to establish how the consumers' money would have been spent if there had been no such publicity: from the angle of the economy as a whole the net benefit due to the forecasts is chiefly of interest. Here, always, it would be a question of distinguishing between full employment and underemployment.

This matter was not pursued further in the present study. Overall, allowance has been made for the fact that the benefit to the total economy is probably less than to the sector by expressing it as percentage not of turnover, as in the information supplied, but of the considerably lower figure for the value added by the sector (about a third of turnover).

Energy

As regards energy, it was also possible to roughly quantify the benefit of medium-term forecasts to *hydro-electric power generation* and *gas supply*. In hydro-electric power generation, forecasts of precipitation make it possible to manage water reserves more efficiently and to reduce restrictions on consumption, which are still occasionally necessary. For both electricity and gas supply, 4-10 day forecasts would permit improved forward estimating of consumption, better arrangements to meet demand and more favourable planning of maintenance work. The expected benefit to the 17 countries, in respect of hydro-electric power and gas supply, might total 6-7 M.UA in 1980, i.e., discounted at 8% (5%), a 1970 value of approximately 3 (4.5) M.UA.

From the answers to the questionnaire, certain savings also appear feasible in the following areas: road maintenance (prompt deployment of snow-clearing teams; lower expenditure on rock salt for spreading, for unnecessary spreading costs of taxpayers' money, and, what is more, the salt also damages vehicles, highways, bridges, etc.), and in water supply. It was not possible to quantify this benefit, however.

Protection against disasters

Expectations in this field were not fully realized, in that the time available was too short to permit an assessment of the contribution of the *ECMW* in the most important area, namely, *protection against floods*. Warnings of impending catastrophes make particularly severe demands on the accuracy of forecasting, since one or more false alarms may result in future warnings being disregarded by the general public, possibly with disastrous consequences. The best use for the *ECMW* forecasts, therefore, will probably be obtained by routing them through internal channels to the existing warning service, which, when necessary, would thereby be brought to advanced readiness, with increased vigilance.

The standard of accuracy achievable by 1980 might not be high enough for the *avalanche warning service*; the prospects in the field of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forest fire fighting are somewhat better, since forecasts of approaching dry spells will enable the public to be better informed and fire waching to be planned more effectively.

The expected benefit to Sweden is of little overall moment, however. The proposed forecasts seemed to be of *little interest* to *land and air transport.*

Total benefits

Collating the results obtained so far, a *quantified* total benefit in the order of 400 M.UA emerges. Discounted at 8%, this gives a 1970 value of approximately 200 M.UA (260 M.UA at 5%).

The actual total benefit to the economy might be considerably greater; even in the areas analysed the advantages could only be partially measured. In addition, there is the benefit to all the other sectors of the economy: fishing, other forms of energy not covered by our survey, various manufacturing industries (e.g. building materials and textiles); trade other than in

Table 3: *Estimated total benefit to all countries, by sector.*

	Real value of output in M.UA[1].			Proportion of output (by value) subject to interference from adverse weather (%)
	1968	1980	Average annual change (%)	
	1	*2*	*3*	*4*
1. Agriculture	36 380	46 300	2.0	40 %
2. Building	45 200	86 400	5.5	Column *4* × Column *5*
3. Energy — hydroelectric power: — in TWh[2] — valued at 0.8 cent/TWh[3] — gas	(338) (2 704)	(452) (3 616)	2.6 2.6	100 %
4. Transport — marine navigation — operation of ice breakers — inland navigation (Finland + the Netherlands)				Rough calculation
5. Trade — food distribution trade	(22 000) ± 4 000 (estimate)	(28 000)		Column *4* × Column *5*
6. Total for the quantified sectors (considerably rounded off)				

[1] M.UA = million unit of account. At the time of preparation, 1 UA = 1 US $.
[2] In average water supply conditions.
[3] In the original report, this figure was derived solely from the *additional* quantities generated as a result of forecasts (relatively lower price c Norway's and Sweden's largest water power flows).
[4] Finland and the Netherlands only.

foodstuffs; tourism and associated services; open-air events (important football games, horse races, skiing competitions, etc.). Although it can hardly be expressed in money terms, the interest of private households in weather information for the next 4-10 days should also not be forgotten, be it a matter of a long weekend trip, planning a garden party for adults or children, or other activities, all of which are constantly gaining in importance in view of our increasing leisure time.

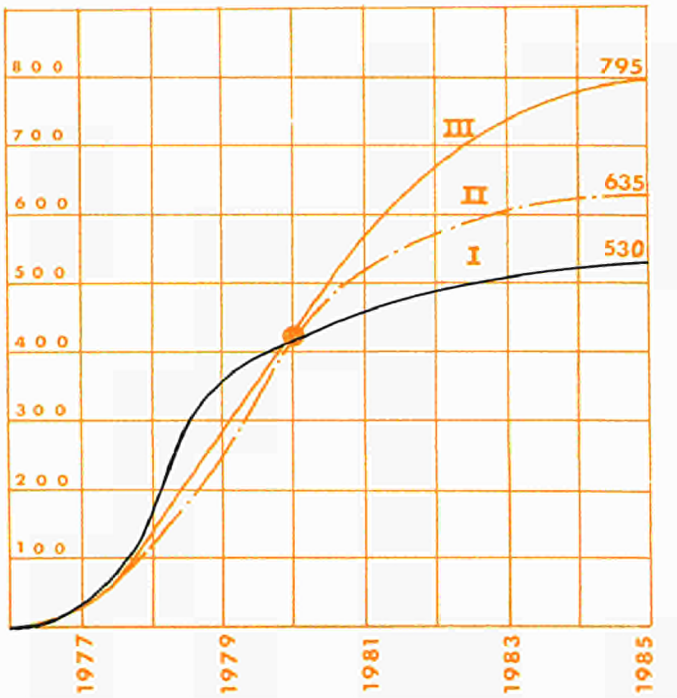
Ultimately, research into the interactions between the atmosphere and biosphere over the next 10-20 years could point to further applications for medium-term forecasts, for "of all the factors influencing our economy, the effects of changes in the weather are perhaps the least well understood" (9)

The cost/benefit ratio

Since time was short, and no similar cost/benefit studies were available in respect of the other projects under discussion (in the other fields), in its final report the Working Party confined itself to relating the benefit, discounted at 8% to its 1970 value, to the expected average annual operating costs from 1977 onwards. The result was a ratio of benefit to costs of "over 25:1".

In this connection, the following paragraphs go somewhat further than the original report, but nevertheless show that the stated 25:1 ratio appears to be an extremely good approximation.

Possible benefit, as a percentage of the weather-sensitive fraction of output	Expected actual benefit (percentage of possible benefit, i.e. utilization factor)	Expected benefit in 1980 (in M.UA) (*2 · 4 · 5 · 6*) (rounded off) approx.	Approximate present (1970) value, in M.UA discounted at:	
			5% approx.	8% approx.
5	*6*	*7*	*8*	*9*
1.5-2%	50%	140-190	85-120	65-90
= approx. 0.5%	50%	215	130	100
0.1%	90%	≈ 3	2	1.5
	(100%)	≈ 3-4	2.5	1.5
based on incomplete data		at least 11-13 4-5 at least 3[4]	at least 7-8 3 at least 2[4]	at least 5-6 2 at least 1.5[4]
= 0.1-0.2% (of turnover)	50%	14-28	8-17	6-13
		390-460	approx. 260	approx. 200



Graph 1: *Assumptions on the trend of total benefit (in M.UA) of 4-10 day forecasts between 1977 and 1985.*

A more precise appraisal of the cost/benefit ratio requires:

— a calculation of the (1970) present value of the total expected benefit, and of the total costs up to the end of the reference period;

— a calculation of the quotient from the discounted benefit and discounted total costs.

However, the original report gave no estimate of the year-by-year trend of the benefit up to 1980. It merely stated that the annual benefit "would rise from a very low level around 1977 to the level estimated for 1980". Moreover, the period 1972-1980 may even be too short for the benefit from the project to be correctly determined, and for this reason the calculations below have been taken up to 1985, on alternative assumptions, and the estimates quoted in the report for the Centre's average annual operating costs can certainly be taken as valid up to 1985. Further assumptions about the trend of the benefit after 1980 then become necessary. Since only rough calculations are involved, the following assumptions will be used, on a tentative basis:

— in 1977 the benefit will still be practically nil;

— development after 1980:

- a rise in the benefit, geared to the growth rate of the three most important sectors (agriculture, building and the food industry) over the period 1970-1980, i.e. about 25% in all, from 425 M.UA in 1980 to approximately 530 M.UA in 1985 (Alternative I);
- as Alternative I, but with a comparatively modest rise in the utilization factor to an average of 60%. Benefit in 1985: 635 M.UA (Alternative II);
- as Alternative I, but with the average utilization factor rising to a total of 75%. Benefit in 1985: 800 M.UA (rounded up from 795) (Alternative III).

The corresponding development over the years 1977-1980 is obtained by graphic interpolation in accordance with the arbitrarily assumed curves in Graph 1. Table 4 shows the current and 1970 values, the latter discounted at 8 and 5%.

The *cost analysis* cannot be discussed in detail here: the results, rounded off slightly, are given in Table 4, both in absolute terms and discounted to their 1970 values. About half the 7.5 M.UA/year average operating costs goes on the leasing charges for the large computer and rather more than a quarter on items which are wage-intensive.

In the final analysis, then, how do the *benefits* relate to the *costs*? Table 4 can be used to work out:

— the net value of the Project, given various discount rates and assumptions about future trends, i.e. the difference between the sum representing the discounted benefits and all discounted costs;

— the cost/benefit ratio, or, more precisely, the ratio of the sum of all discounted benefit values and the sum of all discounted costs;

— the break-even point (beyond which the cost benefit balance shows a surplus).

For the sake of simplicity, Table 5 shows only the cost/benefit ratios. Also given, as a matter of interest, is the ratio between the non-discounted total benefit and the related costs, although this would not be a suitable basis for a comparison with other projects.

Even if the analysis is confined to the period 1970-1980, the resultant cost/benefit ratio is approximately 15.1 although the Centre does not begin to produce any substantial economic benefit until towards the end of the decade. By 1985, on the other hand, the cost/benefit ratio varies between 30 and 40, although this is based on the assumption that the estimated average operating costs remain constant. Since almost half of the cost is accounted for by computer leasing charges, and only about a generous

Table 4: *Trends in benefits and costs in 1972-1985, on various assumptions.*

	Annual benefit in M.UA									Annual costs in M.UA		
	Current values			Present (1970) value						Current values	Present (1970) value	
	Alternative			Discounted at 5%			Discounted at 8%			(approx.)	Disc. at 5%	Disc. at 8%
	I	II	III	I	II	III	I	II	III			
	1	2	3	4	5	6	7	8	9	10	11	12
1972										1	0.91	0.86
1973										2.5	2.16	1.99
1974										2.5	2.06	1.84
1975										6.5	5.10	4.43
1976										6.5	4.85	4.10
1977										7.5	5.33	4.37
1978	150	80	80	102	54	54	81	43	43	7.5	5.08	4.05
1979	360	290	290	232	187	187	180	145	145	7.5	4.84	3.75
1980	425	425	425	261	261	261	197	197	197	7.5	4.61	3.47
1981	460	520	580	269	304	339	197	223	249	7.5	4.39	3.22
1982	490	570	680	273	317	379	195	226	270	7.5	4.18	2.98
1983	510	600	730	270	318	387	188	221	269	7.5	3.98	2.76
1984	520	630	770	263	318	389	177	214	262	7.5	3.79	2.55
1985	530	635	795	255	305	382	167	200	250	7.5	3.61	2.36
Total 1972-1980	935	795	795	595	502	502	458	385	385	49	35	29
Total 1972-1985	3 445	3 750	4 350	1 925	2 064	2 378	1 382	1 469	1 685	86.5	55	43

third by wages and salaries, maintenance and software, this assumption appears not unreasonable: the possible increase in wages and salaries to match the general rise in real incomes may, if the circumstances are right, be offset by a fall in computer costs. But even if the wage-intensive items increase at a real rate of 5%/year beyond 1980, the position is not materially affected: with a 5% discount rate, for example, the cost/benefit ratio in 1970-1985 would vary between 34 and 42, and using 8% the resultant round figures are practically unchanged.

Finally, a glance at the trend of both current and discounted annual values shows that even before 1980, in 1979 if not 1978, the benefit to the economy as a whole should pass the break-even point, beyond which the overall economic advantages outweigh the total cumulative costs, i.e. beyond which the cost benefit balance moves into the black.

The resulting high profitability to the total economy may be astonishing at first sight. This is largely due to the fact that — consciously or unconsciously — readers in Community countries will take as their yardstick cost/benefit ratios for national projects of which they are aware. In fact, a country-by-country breakdown [11] of the benefit from the *ECMW* (not reproduced here) shows a substantially lower cost/benefit ratio for a country like West Germany or France carrying out this Project alone: perhaps 5-10 in 1972-1985, instead of 30-40. It would simply not pay Belgium or the Netherlands to go it alone.

The "secret" of the high cost/benefit ratio lies precisely in the fact that cooperation on the *ECMW* Project gives the participating countries the opportunity to reap a substantial national benefit at a fraction of the "normal" cost.

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[11] As it stands, however, this is not yet valid for the increased income which the meteorological offices may derive from the additional services. How much the users will be prepared to pay for 4-10 day forecasts requires further studies.

Table 5: *Cost/benefit ratios, on various assumptions (round figures).*

	Period	
	1972-1980	1972-1985
A. Discounted values — 5% discount rate		
Alternative I	17	35
II	14	37.5
III	14	43
B. —8% Discount rate		
Alternative I	16	32
II	13	34
III	13	39
C. Current (non-discounted) values		
Alternative I	19	40
II	16	43
III	16	50

Literature : (1) *Report EUR 4850 d.f.e. :* "Prospective benefits from the Creation of a European Meteorological Computing Centre (ECMW), *Research & Development Collection*, No. 4 (1972), 82 pages, Commission of the European Communities. (2) *Webster's Third New International Dictionary*, 1964: "the average course or condition of the weather at a particular place over a period of many years...". (3) E. LINGELBACH: "The Weather Forecast - A problem in data processing", *euro-spectra* Vol. IX (1970) pp. 111-116. (4) R. VANDENBORRE, J. VANDENBULCKE: "Quantitative Research in Benelux", *euro-spectra* Vol. X (1971) No. 1, pp. 16-25. (5) RR. NELSON, S.G. WINTER Jr.: "Weather Information and Economic Decisions", a preliminary report, *The RAND Corporation*, RM-2620-NASA, August 1960 [referred by W.J. Maunder (9)]. (6) J.C. THOMPSON: "Potential Economic Benefits from Improvements in Weather Information", *Rapport de planification OMM-VMM No. 27*, Les avantages économiques des services météorologiques nationaux, Geneva (1968), p. 41. (7) H. KRUHL: "Recommandations sur les itinéraires transocéaniques", *Deutscher Wetterdienst, Seewetteramt* (17.10.1968). (8) 20th International Study Conference "Motivation", held at the *Gottlieb Duttweiler Institut für wirtschaftliche und soziale Studien*, Rüschlikon (Switzerland) 4-8 July 1971. (9) W.J. MAUNDER: "The Value of the Weather", *Methuen & Co. Ltd.*, London (1970), p. 146.

Technical Notes

The Commission's *technical notes* give descriptions of original results obtained under the Euratom research programmes. Their purpose is to enable firms to decide whether they should consider industrialising these results.

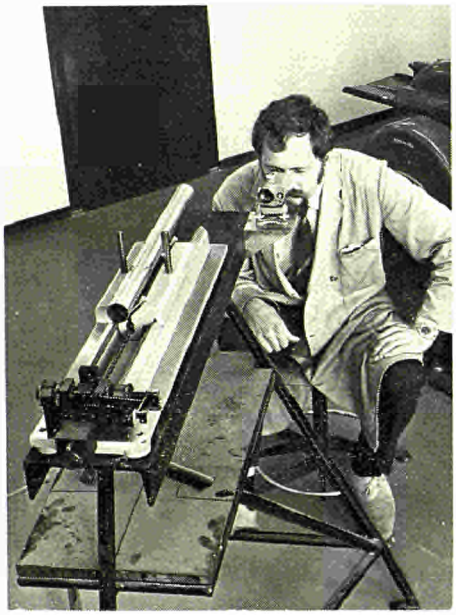
On the basis of article 12 of the Euratom Treaty, a non-exclusive licence may be granted on the results covered by patents, in so far as the licensee is in a position to make effective use of these results. The conditions of the licence, as well as the royalties for technical assistance, will, for each individual case, be fixed after joint consultation.

Requests for additional information should be sent to: Commission of the European Communities, D.G. XIII-A, 29, rue Aldringen, Luxembourg.

— 65/C : Optical measuring rig for wall-thickness measurements on tubes

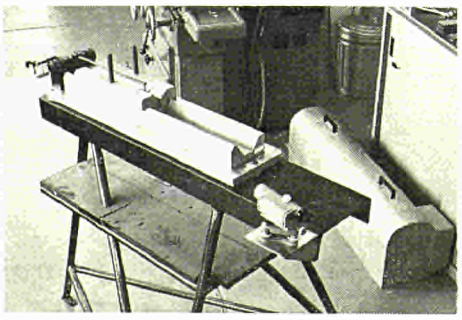
This measuring rig was developed at the *JRC*, Petten, in order to measure the wall thickness of experimental cladding tubes possessing a large length/diameter ratio and requiring very accurate, uniform wall thicknesses for reasons of irradiation technology.

These requirements were met by an internally balanced, mechanical scissors system delivering a constant measuring force, as a result of which the measured value is enlarged and read off optically.



This measuring rig can be calibrated to absolute values via slip gauges.

The practical version of the rig can be used for measuring 10-50 mm diameter tubes up to a maximum length of 600 mm.



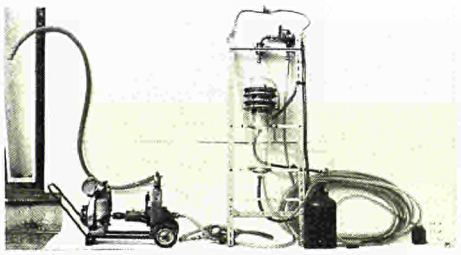
The achievable measuring accuracy depends to a large extent on the optical data selected and is in this case ± 0.002 mm.

— 66/C : Device for collecting and filtering seston

The best device for collecting all the seston in large volumes of water (100-300 litres) is that described by Johnson (see Johnson W.C., 1967: A power plankton pump with a metering device. *The progressive Fish-Culturist*, 29 (3): 182-183). The Biology Division of the Ispra Establishment of the *Joint Research Centre* has improved this device by means of the following modifications:

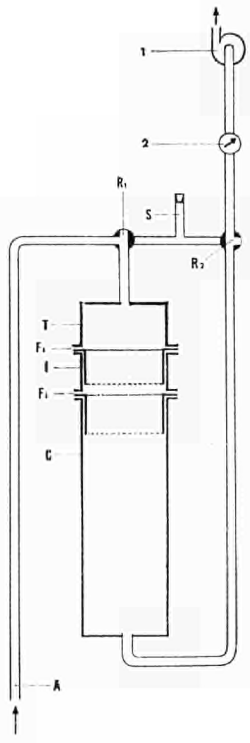
1. The single sack-shaped net (256 μ) is replaced by two Eterlon discs of different mesh size (88 and 56 μ).
2. The two-way valves prevent contamination of the sample by water from the upper layers.
3. The sample does not come into contact with metallic parts.
4. The weight of the device has been reduced from 36 to 11.8 kg.

The improved device consists of the following parts:



1. Polyethylene suction tube terminating in a glass funnel.
2. Plexiglass cylinder with two Eterlon nets (88 and 56 μ) on mobile plexiglass supports.
3. Litre counter.
4. Centrifugal pump.
5. Discharge tube.

The suction tube is immersed at a prearranged depth and is directly connected with the pump in order to refill the tube with water from the area chosen for sampling. After a



Seston collecting and filtering apparatus.

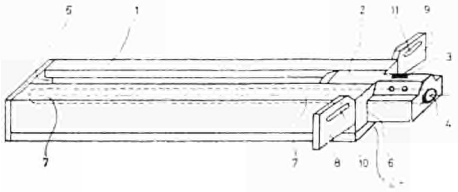
A = *suction line*
R_1 = *inlet valve*
R_2 = *outlet valve*
S = *vent*
T = *head*
F_2 = *net (88 μ mesh)*
I = *mating cylinder*
F_1 = *net (56 μ mesh)*
C = *filtration cylinder*
1 = *pump*
2 = *flow recorder*

prearranged volume of water has been drawn in, the suction tube is connected with the plexiglass cylinder by means of a two-way valve. The water is thus filtered by the two nets before passing through the litre counter and the pump. After 100-300 litres of water have been sampled, the material is removed from the two nets and the water contained in the cylinder (eight litres) is recovered through a tap. The particles less than 56 μ in diameter present in the water sample are concentrated by filtering the water over Millipore filters of known porosity (1 and 0.5 μ). Four granulometric fractions of seston are thus obtained (1>88 μ; 2 = 88 - 56 μ; 3 = 56 - 1 μ; 4 = 1 - 0.5 μ), on each of which chemical and microscopic analyses can be made. The reproducibility of the sample is satisfactory. Another improvement at present under test is to fit a cell with electrodes between the cylinder and the litre counter in order to measure certain water characteristics (e.g., pH, temperature and conductivity) during sampling.

— 769: Capsule slitter

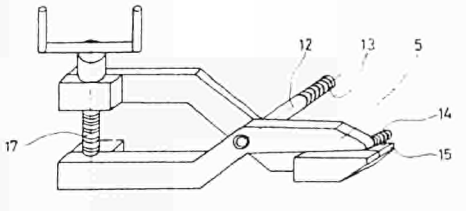
This device, with which capsules or clads can be slit open lengthwise, was developed at the *Joint Research Centre*, Petten. It can easily be operated by means of a manipulator and is therefore particularly suitable for opening irradiation capsules in a hot cell.

For this purpose the capsule is first opened at one end so that its wall can be gripped between two tongs, thus immobilizing it. The tongs are integral with the fixed bed of the capsule slitter.



A vertically adjustable blade is attached to a carriage which can move along a guide-way in the bed. While the capsule is held above the carriage by the tongs, the carriage is driven along the guide-way by means of a threaded spindle, so that the blade slits open the wall of the capsule.

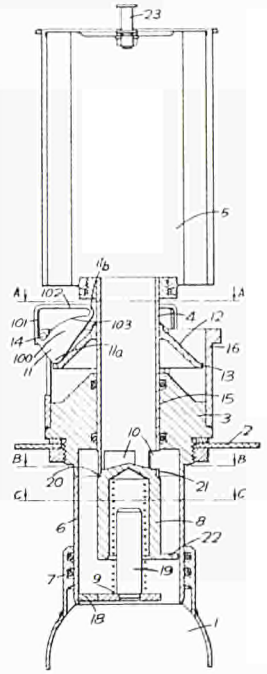
The sliting process causes no distortion of the capsule.



(French Patent No. 1 553 918; German Patent Application (Offenlegungsschrift) No. 1 589 757.)

— 786: Air filter for a hot cell

This air filter, developed at the *Joint Research Centre*, Petten, for installation in a hot-cell ventilation duct, can be replaced by means of purely axial movements. During the replacement procedure the cell is automatically cut off from the ambient air.



The filter (5), which is located inside the cell, has a cylindrical extension (4), which slides in a fluid-tight manner in a mounting (3) incorporated in the cell wall. A plug (8) blanks off the duct (15) by means of a spring (9) during the changing of a filter. A number of latches (11) are attached to the mounting at the side of the filter and are pivoted by the ramp (12) about studs (14) to lock and unlock the filter. The latches are operated by exerting an axial force at point 23 on the filter by means of a manipulator. When the filter is installed vertically the latches pivot under gravity, thus unlocking it. When the filter is installed in other attitudes springs replace gravity as the actuating force.

(French Patent Specification No. 1 559 206; German Patent Application (Offenlegungsschrift) No. 1 607 703; British Patent Specification No. 1 196 361.

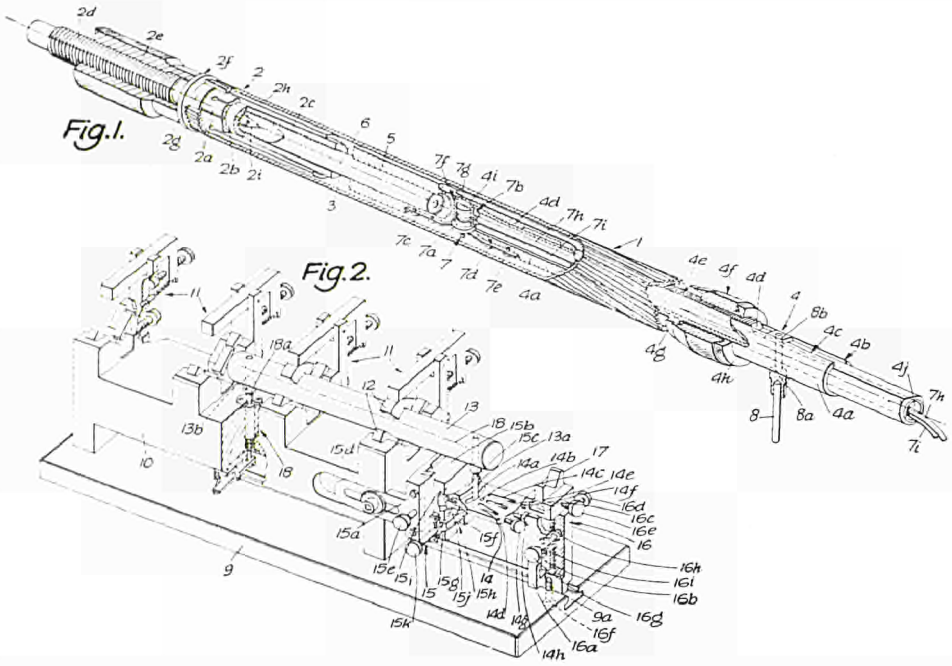
— 920 : Device for milling and drilling grooves and radial holes in the inner walls of tubes

The device concerned is a machining apparatus designed to mill grooves and radial holes of a given configuration at predetermined points on the inner walls of testpieces in the form of finned tubes, these grooves or holes either representing artificial faults or performing an active function such as accommodating a thermocouple, ducting a liquid lubricant or guiding a control element.

For operation, the device is inserted into the appropriate tube, which is in turn clamped in an adjustable jig.

The machining device and the adjustable jig are integral. The device itself is in two parts and consists of a clamping block with locating and guide pins, a manually guided insert with a centring and guide sleeve at the top and followed, at right angles to the tube axis, by a radially displaceable depth-controlled turbo-milling cutter with a follower pin attached to the end of the manual stop.

(French Patent No. 1 536 499, British Patent No. 1 189 167, US Patent No. 3 568 568.)



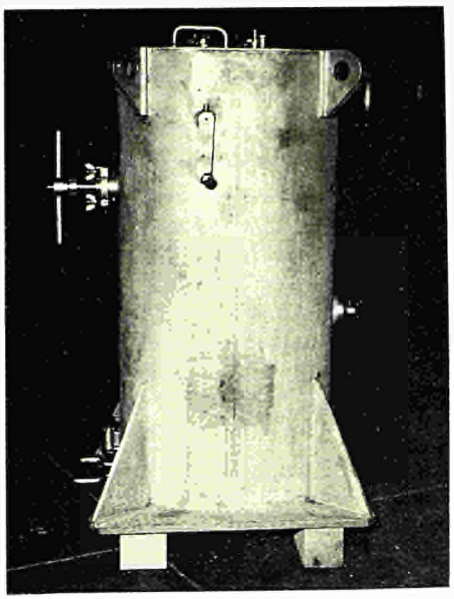
— 921: A device for extracting radioactive samples from a reactor and maintaining them at the temperature of liquid nitrogen

Radioactive samples stored at low temperatures retain the greater part of the effects of damage due to neutron bombardment. This device, which was developed at the Ispra establishment of the *Joint Research Centre*, provides a means of extracting irradiated samples from the vertical channel of a reactor and storing them at the temperature of liquid nitrogen without their undergoing any temperature variation.

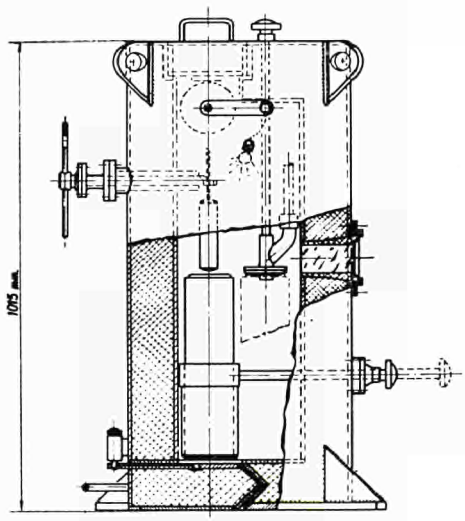
By this means, the samples can be conveyed and stored at the same temperature until their activity has decayed to the desired extent for a series of laboratory measurements to be carried out.

The unit is of small and manageable size and is provided with suitable means of extracting and handling the samples within it, both safely and precisely.

The apparatus consists of a container with biological shielding, a pulley for raising the samples, shears and a removable cylindrical receptacle of an insulating material, designed to contain the samples in a liquid nitrogen bath.



Suitable piping is fitted for introducing and extracting the nitrogen. Operations can be observed from outside through a shield window with the aid of an internal light. The complete apparatus is leaktight in operation, so that irradiated materials can be extracted without causing contamination by volatile particles or fission gas.



(Italian Patent No. 832 451, Belgian Patent No. 729 516, German Patent Application No. 1 917 565.)

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— 1062: A process for the prevention of carbon deposits on iron and steel surfaces in an environment containing carbon monoxide

A layer of carbon forms on iron and steel surfaces exposed to CO at elevated temperatures for an extended period (400-500° C, and even 600° C at high CO partial pressure) which at high CO concentrations can reach a considerable thickness.

By means of this method the deposition of a layer of carbon can be greatly reduced or entirely prevented, either by means of a short pre-treatment with an inhibitor or by discontinuously adding the inhibitor to the gas.

Volatile silicon/hydrogen compounds (silanes) have proved to be very good inhibitors: when added to the gas for short periods, even in low concentrations, they inhibit or entirely prevent the deposition of carbon. Ammonia, at higher concentrations, is also an effective inhibitor.

The method was developed at the Petten Establishment of the *Joint Research Centre,* where it is also used as a standard procedure to protect steel-sheated thermocouples from carbon deposition.

This method can probably be used in high-temperature gas-cooled reactors whose coolant contains CO, namely, to prevent or reduce the deposition of graphite on the metal surfaces, e.g. heat exchangers, and could also be used in blast-furnaces and allied processes.

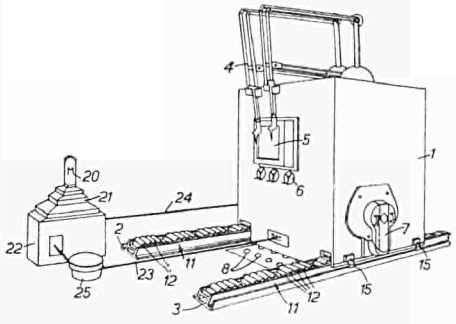
(French Patent No. 1 563 235, British Patent No. 1 189 423, US Patent No. 3 560 336.)

— 1232: Storage system for radioactive probes

In nuclear research and technology it is often necessary to store radioactive specimens for an intermediate period after irradiation in a nuclear reactor, before the specimens are analysed or otherwise disposed.

When the number of specimens is large and they have to be stored for long periods, special hot cells are known in the bottoms of which vertical storage tubes are provided, which tubes are inserted into a concrete block.

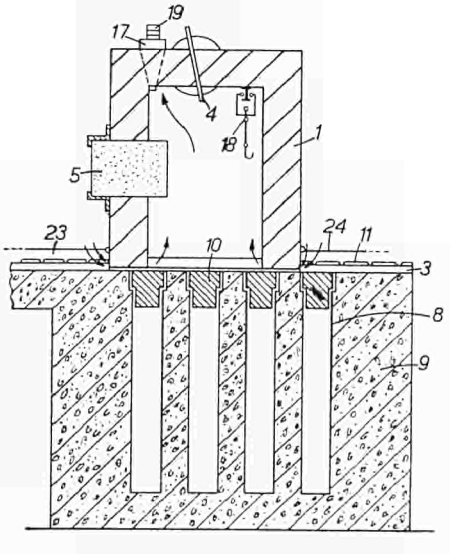
For large number of tubes an unduly large base area of the cell would be required.



The new system avoids this restriction by use of a mobile lead cell mounted on rails above the tubes area so that it can sweep all the tubes positions. This cell is constructed and equipped like a hot cell with the exception however that is has no floor.

A slight vacuum in the cell assures that the air current which cannot be avoided at the bottom of the cell is always directed to the inside. The size of the mobile cell can be reduced to the actual space necessary for the manipulators mouvement.

This storage system has been developed as part of the cooperation between the *CEN* and Euratom on operation of the *BR-2* reactor at Mol, Belgium.



(German Patent Application (Offenlegungsschrift) No. 1 639 217; French Patent Specification No. 1 596 421; British Patent Specification No. 1 225 951.)

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