Cranfield Institute of Technology

INTERIM REPORT ON AN INVESTIGATION

ON MECHANISED INFORMATION RETRIEVAL SERVICE

IN A SPECIALISED SUBJECT AREA

by

C.W CLEVERDON and P HARDING

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SUMMARY

The report covers the work undertaken in establishing and operating for a period of six months an S.D.I. service in the field of precision engineering. The performance and costs of the system are given and the problems which would be involved in a commercial operation are considered. The view is taken that it would be difficult for a system of this type to be economically viable in the short term.

CONTENTS

INTRODUCTION

In 1967 a preliminary investigation was made into the possibility of establishing a mechanised I.R. service in the field of transport, this being related to a proposal that transport engineering should be a major area of study at the College of Aeronautics, Cranfield. An application was made to the Ministry of Technology for a grant of £130,000 to set up the system; of this sum Mr. R. Maxwell of Pergamon Press agreed to contribute up to £50,000. However, as the expected development of the subject at Cranfield did not take place, the proposal was withdrawn.

Pergamon Press continued to express interest in supporting work in the field of mechanised information retrieval systems, and as a result a proposal was prepared for a system in the subject area of Precision Engineering. Cranfield had received a major grant for the establishment of a Unit in Precision Engineering, and it could be assumed that an information service in this field would be of value to the Unit. Equally so, the Unit would be able to provide practical support for the project, and this was offered by Professor J. Loxham, then Director of the Unit, and Mr. P. McKeown, originally Deputy Director and now Director of the Unit.

As a result of the proposal, a letter of agreement was received from Pergamon Press (see Appendix A). The financial provision was for a grant of up to £10,000 to cover a two year period. Subsequently an arrangement was made whereby International Computers Limited (I.C.L.) agreed to share the costs of the project.

PURPOSE OF PROJECT

There is nothing novel in setting up a mechanised I.R. service; hundreds of such services are now in existence. Still not novel, but certainly more unusual, is that a mechanised service should be shown to be economically viable. In-house services have no need to demonstrate this; in the public domain, services such as Medlars or NASA tend to be wholly or mainly subsidised. An exception to this is the ASCA service offered by the Institute of Scientific Information, but with this organisation very different considerations apply to those in the project. At Cranfield the subject coverage was, relatively, very narrow, at the same level as might be covered by a single technical journal issued by Pergamon Press. The investigation was intended to show what would be the costs involved in setting up a mechanised service in a specialised subject field, what would be the running costs when it was once established and finally to give some indication whether sufficient support might be obtained for such a service. To have any chance of meeting the requirement of being financially self-supporting, it was vital that initial costs and operational costs should be as low as possible, and it was this, more than any other aspect, which could be considered as giving the project a research content.

As a generalisation it can be said that, within limits, an increase

in the costs of the system will result in an improvement in its performance. Following on from the earlier research work at Cranfield it is now generally accepted that "perfect" performance is impossible to obtain in an I.R. system. Perfect performance is defined as 100% recall and 100% precision, which means that every relevant document is retrieved without any non-relevant documents being retrieved. There is, in fact, always an inverse relationship between recall and precision; as more relevant documents are retrieved, there will be an increased proportion of non-relevant documents retrieved, as is illustrated in Figure 1 which shows

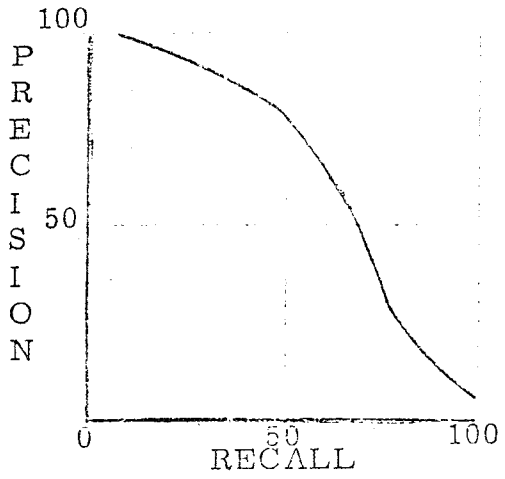

FIGURE 1

TYPICAL INFORMATION RETRIEVAL SYSTEM PERFORMANCE CURVE

a typical I.R. system performance curve. One must not imply an ability on the part of the system operators to control performance exactly, but it is reasonable to say that if there is a requirement that the recall ratio should be a minimum of 90%, then there will be a different operational policy than if the requirement is for a recall ratio of only 50%. It is at this point that cost effectiveness enters the discussion, for the system managers have a number of options which can be used to obtain a given performance figure as is illustrated in the following simplified example, (Figure 2).

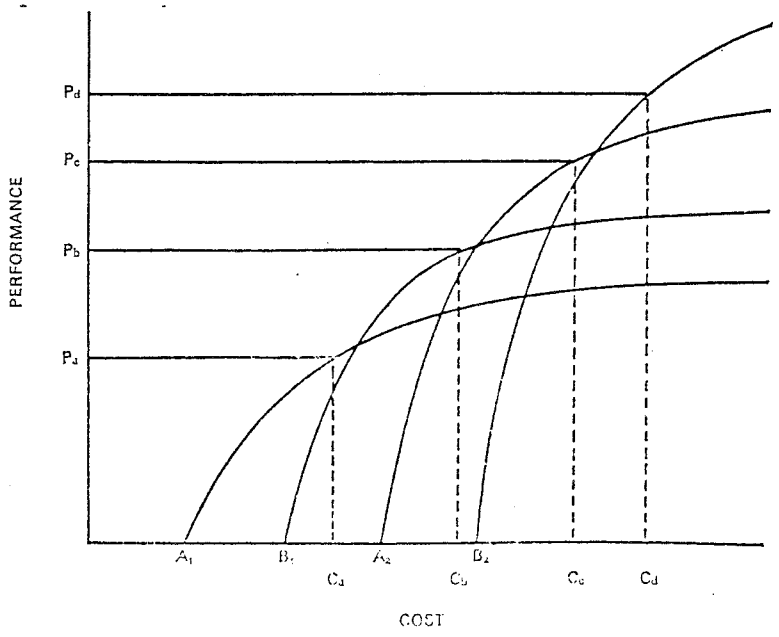

FIGURE 2

COST-EFFECTIVENESS CURVES FOR I.R. SYSTEMS

A_1 represents a system which covers one hundred journals, while B_1 represents a similar system where coverage is extended to two hundred. In both these systems, no indexing is done and the input consists of the terms in the titles of the journal articles. A_2 and B_2 are taken to represent the same two collections of journals, but now the articles have been exhaustively indexed. The points A_1, B_1, A_2, and B_2 represent the basic costs of acquisitions and input for the four systems. If to these are added variable search costs, the performance/cost graph is obtained, from which it can be seen that if performance P_a is required, then system A_1 should be used; at P_b system B_1 is most effective, at P_c system A_2, and P_d system B_2 is required. Alternatively one could say that if costs must be restricted to C_a then system A_1 should be used.

The system managers have many alternative options which will enable a required performance to be obtained, and it is necessary to select those options which will allow the requirements of the user to be met at the lowest possible cost. In an operational environment there may be a common pattern of information requirement amongst the users, but it is certain that there will be some individuals who will have different requirements from the majority. The system should, therefore, also have a built-in flexibility which will enable it to accommodate different needs.

One interesting point that might be mentioned here is that this project is one of relatively few where the users have been engineers. Most systems - and certainly most investigations - have been designed for scientists, such as medical researchers, physicists and chemists.

TEST DESIGN

Information systems serve one of two main purposes; either they meet the requirements of those who have an immediate need for information to assist with a specific problem; the latter are intended to keep a group of users up-to-date in their general subject interest. From the viewpoint of establishing a system, retrospective searches require more initial effort, since a relatively large amount of data must be input to the system before it can be effectively used. The minimum requirement is a matter for argument, but it seems that at least two years input of articles and research papers would be necessary. On the other hand, a current awareness system can operate as soon as a couple of weeks input is available.

The original Cranfield proposal in the field of transportation had been in relation to a retrospective search system and it was a similar type of system that was originally envisaged in this project. However in the course of the early discussions it became clear that, for a number of reasons, it would be better for the investigation to deal with a current awareness system. This had a number of advantages from the viewpoint of testing, but more particularly the indications are that a current awareness system is likely to have a better chance of being economically viable.

The test design included an initial period of six months for preliminary investigations, with a further six months for experimental testing, during which an evaluation of possible alternative systems would be made. To follow this there would be six months of what might be termed an experimental operational phase when a group of users would receive output on a regular basis. The remainder of the time would be concerned with analysis and reporting.

The system became known as C.R.I.S.P.E. (Computerised Retrieval Information Service in Precision Engineering).

STAFF

The Director of the Project, Mr. Cyril Cleverdon, Librarian of Cranfield Institute of Technology (formerly the College of Aeronautics) has been engaged on research projects into information retrieval systems continuously since 1957. This series of investigations, reported in References 1 - 4, was supported in the main by grants from the National Science Foundation in Washington and latterly by the Office of Scientific and Technical Information. Two particular matters relevant to this present project which came from the Cranfield tests were the now generally accepted techniques for the evaluation of information retrieval systems and the unexpected finding that a controlled index language appeared to have little, if any, advantage over the use of natural language. While the research work at Cranfield was carried out on manual systems, Mr. Cleverdon has had wide experience of computerised systems, in particular as consultant in an evaluation of the Medlars system at the National Library of Medicine in Washington and as a consultant to the INSPEC mechanised system of the Institution of Electrical Engineers.

To work full-time on the project, Mr. Peter Harding was appointed. A graduate of Newcastle University, Mr. Harding had worked at the National Lending Library before going to Loughborough University of Technology where he obtained an MSc for a thesis in the field of Precision Engineering. In carrying out the experimental work involved in his thesis, he had written a number of computer programs to be used on a I.C.L. 1905, the same machine as was available at Cranfield.

As a part-time Consultant, Mrs. Jean Aitchison worked a total of 70 days. Mrs. Aitchison had previously been closely involved in the

Indexing and Index Language

A guiding principle in the project was that the costs should be kept to the absolute minimum, consistent with obtaining a satisfactory performance. Conventional indexing is necessarily an expensive operation and it is for this reason that many systems (e.g. Chemical Titles or ASCA) have dispensed with indexers and indexing and use instead the terms as found in the titles. In these cases the motive has been entirely economic, but the results of Cranfield II showed that natural index language terms were just as effective as a set of controlled terms from a thesaurus or classification. Therefore, from the beginning there was no doubt but that the index language would be based on natural language terms.

The second major factor affecting performance is the level of exhaustivity of indexing. Here again Cranfield II had demonstrated that there was an optimum in any given situation. More or less terms than the optimum will result in a loss in performance. However, economic factors must also be considered in an operational situation; the more terms used in indexing each document, the greater will be the input and search costs, and it might be reasonable to accept a drop of 5% in performance if it resulted in a saving of 50% in computer costs.

It was a characteristic of the document collection that most of the journals were issued by commercial publishers rather than learned societies, and from this it follows that the titles were less descriptive than those found in the scientific literature. Some titles, for instance, consisted of single terms such as 'Servomotors', 'Fluidics', 'Electroforming' or 'Lasers'. Other titles were non-sensical, for example, 'Tooling for a big bird', 'More pinch to the inch', or 'Even the elephants look up'. It would therefore have been unwise to have had a system based simply on the use of the terms in the titles.

Cleverdon has hypothesised that index terms to the required level of exhaustivity can be satisfactorily selected from abstracts by a clerical operator working to given rules, a view partly confirmed by a recent test. However, there was no chance of this being done in the present project since only a small proportion of the articles which were indexed had abstracts.

The inevitable decision, therefore, was that the selection of index terms should be done on an intellectual basis, although full use would be made of "good" titles and abstracts when these were available. Initially the indexing was to be done at three levels of exhaustivity with an average of 5, 10 and 15 terms respectively at each level. An example of the master indexing sheet for document 210 is shown in Figure 3.

During this initial phase of the project, Mr. Harding spend much of his time in indexing periodicals.

DOCUMENT NO.	AUTHOR / TITLE / REFERENCE	INDEXER	DATE
210	AUTHOR ROBERTSON, C.W. TITLE Industrial measurement with lasers REFERENCE Industrial Electronics, 1968, 6, Jan, p.11	FH	3/6/69

TERM 1	TERM 2	TERM 3
industrial	helium - neon laser	monochromatic source
measurement	measuring	length standard
(with)	displacement	interferometer
lasers	alignment	machine tool control
		frequency - stabilized

FIGURE 3 MASTER INDEXING SHEET FOR DOCUMENT 210
(Term 1, Term 2 and Term 3 represent increasing levels of exhaustivity.)

TERMS

10	Measur*	11 (cont.)	Microinch	12 (cont.)	Micrometer
	Metrology		Point*		Microscop*
	Inspect*		Polygon*		Monochromator
			Parallel		Pivot
11	Ang*		Pressure		Project*
	Area		Radius		Pantograph
	Align*		Round		Protractor
	Axi*		Rough*		Rul*
	Centr*		Straight*		Spherometer
	Curvature		Surface		Stylus
	Circular		Square		Telescope
	Dimension*		Texture		Theodolite
	Depth		Volume*		Tallyrand
	Diamet*		Size		Tallsurf
	Displacement				Vernier
	End	12	Autocollim*		
	External		Collim	13	Kinematic*
	Flat		Comparator		Optic*
	Height		Circle		Laser
	Involute		Caliper		
	Internal		Clinometer	14	Co-ordinate
	Linear		Divid*		Coordinate
	Level		Dial		Confocal
	Limit		Gauge		Clearance
	Length		Gear		Tolerance
	Misalign*		Grating		
	Position		Interferom*	15	Screw
	Profile		Indicat*		Thread
	Micron*		Holograph*	16	Calibrat*

LOGICAL STATEMENT 10.(11+12+13+14+15+16) + 11.(12+13+14) + 12.(13+15+16) + (15.16)

FIGURE 4. EXAMPLE OF ORIGINAL SEARCH PROFILE

The output was available in two groups, either according to the Boolean or logical statement (Figure 5) or according to coordination levels, (Figure 6). In each of the groups, separate results were available for the three stages of exhaustivity of indexing and also for titles. This double facility for presenting the results either according to a logical statement or according to coordination levels is unusual, but it had some important consequences.

At this stage the main concern was in estimating the performance of the system rather than simulating an S. D. I. operation. For this reason, before any output was sent to the users, Mr. Harding personally checked every document which had been retrieved and indicated all those which in his view had any possibility of being relevant. With some profiles this came to more than 20 documents, in which case 20 papers were selected at random and full copies of the papers were sent to the user. In those cases where less than 20 documents appeared to be relevant, the sub-set sent to the user was brought up to this number by adding documents listed in the print-out. To each document a slip was attached, which the user was asked to complete by indicating whether the document was of major interest, minor interest, or of no interest. When these slips were returned, it was possible to determine the recall and precision ratios for the system in relation to that profile. As the method of doing this is somewhat involved, a simplified example is considered.

Assume the output for a given question is as follows:

Logical statement	Documents	1, 10, 30, 50, 70, 100, 150, 200
Coordination level of 6	"	16, 100
5	"	10, 75, 85, 150, 175, 210
4	"	1, 35, 50, 77, 97, 117, 137, 200, 207
3	"	9, 19, 30, 39, 49, 79, 99, 139, 160 179, 199, 209.
2	"	6, 16, 26, 46, 70, 96, 116, 136, 146, 148, 156, 168, 176, 188, 196, 206, 208
1	"	3, 13, 23, 32, 33, 42, 43, 53, 63, 83, 93, 103, 113, 123, 133, 143, 153, 163, 173, 183, 193, 202, 203, 212, 213.

Further, assume that in the assessment of each document, Mr. Harding had decided that the following 31 documents, as shown in the first column were possibly relevant.

A007	9/0	36/0	97/0			Titles
A007	36/0	97/0				Terms 1
A007	9/0	36/0	83/0	97/0	207/0	Terms 1 and 2
A007	9/0	36/0	83/0	97/0	207/0	Terms 1, 2 and 3.

FIGURE 5. BOOLEAN OR LOGICAL STATEMENT OUTPUT FOR SEARCH A007 AT VARYING LEVELS OF EXHAUSTIVITY

ORD	DOCUMENTS RETRIEVED				TITLES		
4	90/0	92/0	152/0				
3	36/0	45/0	104/0	142/0	164/0	165/0	167/0
2	13/0	19/0	32/0	38/0	83/0	93/0	94/0
	106/0	116/0	134/0	141/0	145/0	169/0	171/0
	181/0	197/0	201/0	205/0			
1	2/0	9/0	10/0	28/0	29/0	30/0	46/0
	47/0	52/0	56/0	67/0	68/0	69/0	71/0
	80/0	84/0	85/0	86/0	88/0	91/0	96/0
	97/0	98/0	102/0	107/0	108/0	110/0	111/0
	112/0	113/0	117/0	121/0	123/0	126/0	135/0
	138/0	139/0	147/0	151/0	153/0	154/0	155/0
	158/0	161/0	162/0	163/0	168/0	178/0	185/0
	186/0	188/0	198/0	203/0	206/0	210/0	211/0

ORD	DOCUMENTS RETRIEVED				TERMS		
5	211/0						
4	90/0	151/0	152/0				
3	36/0	104/0	145/0	165/0	167/0	180/0	
2	13/0	32/0	38/0	45/0	56/0	83/0	84/0
	93/0	97/0	106/0	116/0	141/0	142/0	150/0
	155/0	164/0	169/0	171/0	197/0	201/0	205/0
1	2/0	8/0	10/0	19/0	24/0	28/0	29/0
	30/0	46/0	52/0	53/0	67/0	68/0	69/0
	71/0	72/0	86/0	88/0	91/0	98/0	102/0
	107/0	109/0	110/0	111/0	112/0	113/0	117/0
	121/0	123/0	128/0	135/0	138/0	139/0	147/0
	149/0	153/0	154/0	158/0	161/0	162/0	163/0
	170/0	178/0	185/0	186/0	188/0	198/0	203/0
	206/0						

URE 6 COORDINATION LEVEL FOR SEARCH A007 AT VARYING LEVEL OF EXHAUSTIVITY (Continued on page 14)

TERMS 1 and 2

COORD	DOCUMENTS RETRIEVED						
13	211/0						
6	207/0						
5	145/0	180/0					
4	38/0	83/0	90/0	92/0	151/0	152/0	153/0
	165/0	167/0					
3	9/0	13/0	36/0	45/0	93/0	104/0	150/0
	163/0	171/0	197/0	201/0	205/0	210/0	
2	5/0	19/0	28/0	31/0	32/0	56/0	72/0
	84/0	85/0	86/0	87/0	94/0	97/0	98/0
	106/0	116/0	134/0	138/0	141/0	142/0	155/0
	161/0	162/0	164/0	169/0	181/0	184/0	196/0
	198/0	199/0					
1	2/0	3/0	6/0	8/0	10/0	14/0	21/0
	23/0	24/0	25/0	29/0	30/0	39/0	46/0
	47/0	50/0	51/0	52/0	53/0	59/0	64/0
	66/0	67/0	68/0	69/0	70/0	71/0	73/0
	80/0	88/0	89/0	91/0	96/0	100/0	102/0
	107/0	109/0	110/0	111/0	112/0		

TERMS 1, 2 and 3

COORD	DOCUMENTS RETRIEVED						
13	211/0						
7	210/0						
6	83/0	180/0	207/0				
5	45/0	106/0	145/0				
4	5/0	38/0	85/0	90/0	92/0	93/0	151/0
	152/0	153/0	165/0	167/0			
3	9/0	13/0	36/0	68/0	87/0	94/0	104/0
	150/0	163/0	169/0	171/0	178/0	181/0	197/0
	201/0	205/0					
2	19/0	23/0	28/0	31/0	32/0	52/0	56/0
	59/0	69/0	72/0	73/0	84/0	86/0	89/0
	97/0	98/0	99/0	116/0	120/0	121/0	134/0
	138/0	141/0	142/0	154/0	155/0	161/0	162/0
	164/0	166/0	184/0	186/0	188/0	196/0	198/0
	199/0						
1	2/0	3/0	6/0	8/0	10/0	14/0	21/0
	24/0	25/0	29/0	30/0	33/0	34/0	37/0
	39/0	46/0	47/0	50/0	51/0	53/0	54/0
	57/0	60/0	64/0	66/0			

FIGURE 6 (continued from page 13)

	Considered relevant	Sent to users	User's relevance decisions
Document No.	1	-	-
" "	9	9	2
" "	15	15	1
" "	16	-	-
" "	23	23	1
" "	30	30	1
" "	35	35	1
" "	46	46	2
" "	49	-	-
" "	63	-	-
" "	70	70	2
" "	75	-	-
" "	77	77	2
" "	79	-	-
" "	85	85	2
" "	93	93	X
" "	99	-	-
" "	100	100	1
" "	117	-	-
" "	123	123	2
" "	136	136	1
" "	148	148	X
" "	153	-	-
" "	175	175	2
" "	176	-	-
" "	199	199	X
" "	200	200	X
" "	206	-	-
" "	207	207	2
" "	210	210	1
" "	213	213	X

From these 31 documents, 20 are selected at random, and the user would therefore receive copies of the 20 documents shown in the second column. We now assume that the user determines the relevance of each document he receives as shown in the third column, (1 = major interest, 2 = minor interest, X = no interest). From these results the following performance figures can be calculated.

		Documents Retrieved	Documents Selected	Documents Sent	Rel. 1	Rel. 2	Non Rel.
Logical Statements		8	5	4	2	1	1
Coordination level	6	2	2	2	2	0	0
	5	6	4	3	1	2	0
	4	9	6	4	1	2	1
	3	12	6	3	1	1	1
	2	17	7	4	1	2	1
	1	25	6	4	0	2	2

In calculating the recall and precision figures, two assumptions are made:

(a) The selected documents not sent would have the same pattern of performance as the documents that were sent.

(b) That all non-selected documents are non-relevant.

The first assumption is purely statistical and is clearly unlikely when applied to a single profile, but becomes more reliable when results are accumulated for a set of profiles. The second assumption is dependent on the ability of Mr. Harding to recognise possibly relevant documents. It is unlikely to be absolutely true, but is reasonable for the approximation which was required for this test.

The method of determining recall was as follows: Of the 20 documents sent to the users, 6 were judged to be of major interest, 9 of minor interest and 5 of no interest. To simplify the argument, all the relevant documents will be grouped, so it can be said that 15 documents out of 20 were relevant. Since these 20 documents were randomly taken from 31 selected documents, the total number of relevant documents for this search was $\frac{15 \times 31}{20} = 23.3$. To consider the result with the logical statement, 3 of the 4 documents sent were judged relevant. As five documents were selected, the total calculated relevant documents retrieved would be $\frac{3 \times 5}{4} = 3.75$. Using these two calculated figures, it can be said that the recall ratio with the logical statement was $\frac{3.75 \times 100}{23.3} = 16\%$. By a similar process, the recall ratio for the various coordination levels can also be calculated.

To estimate the precision ratio, one takes the calculated figure for relevant documents retrieved (i.e. 3.75 for the logical statement) and the known total of documents retrieved (i.e. 8), thus giving a precision ratio of $\frac{100 \times 3.75}{8} = 46.9\%$. The complete set of performance figures for the example shown would therefore be as follows:

	Recall	Precision
Logical Statement	15.5%	46.9%
Coordination 6	9%	100%
5	26%	75%
4	46%	62%
3	63%	50%
2	86%	43%
1	100%	32%

This method of calculating performance figures cannot be considered as exact as, for instance, the technique involved for the evaluation of Medlars. It is, however, relatively simple and gives a reasonable

approximation for the purpose of the test, permitting comparison to be made between different methods.

The second computer run was based on the same collection of documents, but was related to a new group of users. In essence the two runs could be considered as two parts of the same run, so the results are combined in a single set of performance figures and presented in Figure 9. As far as performance in relation to user satisfaction was concerned, these results could not be considered representative because of the screening method of selecting the documents which were sent to the users. However, as stated earlier, we were more concerned at this stage in determining the general level of the system performance, and this appeared reasonably satisfactory, with the analysis showing one particularly interesting point. The decision to send each user some 20 documents was based on two points. Previous experience had shown that this represented approximately the maximum number of documents for which it was reasonable to expect valid relevance judgements from a user who was collaborating in the experiment. Ideally, of course, one would have wished to send them the whole collection, but this would be quite unrealistic. Secondly, it was assumed that something around the figure of 20 would be a reasonable number of documents to send a user in an operational situation. Rightly or wrongly it was felt that the users of such a system would prefer to have a fairly regular level of output rather than one which fluctuated wildly. The level might vary for different people, but there appeared to be an advantage in keeping it reasonably consistent. However, there is considerable difficulty, in normal search strategies, of achieving this consistency.

The conventional method of carrying out searches is by a Boolean or logical statement. This was done in the test, but the programs also gave the facility for matching on coordination levels. The unexpected finding of the preliminary analysis was that it appeared that the logical statements were not as effective as the coordination levels. This is to say that if ten documents were retrieved by the logical statement, it was unlikely that there would be as many relevant documents in this set as in the ten documents retrieved at the highest coordination levels. This could be explained by arguing that the logical statements were inefficient, which was probably true in some cases. Another possibility was that it was the use of natural language which had inhibited the performance with logical statements. Both these assumptions were investigated in a further test, for which Mrs. Aitchison translated the natural language of the indexing of the 214 documents used in Run 1 into a controlled language based on the English Electric Company 'Thesaurofacet' which she had recently prepared (Ref. 6). 28 profiles were similarily translated, the whole input to the computer and a new set of output obtained. Relevance judgements, as originally given by the users, were available and by analysis of the new output it was possible to obtain a direct comparison between natural and controlled language.

The complete results have been written up in a detailed report by

Total documents selected	739
Total documents sent to users	307
Documents judged relevant	230
Calculated number of relevant documents	551
Non-relevant documents selected	188

User Performance

Calculated Recall Ratio	Precision Ratio
100%	74%

FIGURE 9a. USER PERFORMANCE FIGURES FOR RUN 1.

Number of sub-searches	37
Calculated number of relevant documents	551

	Total Retrieved	Total Relevant	Non-Relevant	Recall Ratio	Precision Ratio
Boolean Statement	344	175	169	30%	51%
Coordination Level 9+	6	6	0	1%	100%
8+	~~18~~ 12	12	0	2%	100%
7+	26	26	0	5%	100%
6+	59	57	2	10%	97%
5+	143	116	27	21%	81%
4+	314	214	100	39%	68%
3+	606	409	197	74%	67%
2+	1588	546	1044 ~~2~~	99%	34%

FIGURE 9b. SYSTEM PERFORMANCE FIGURES FOR RUN 1

(as in "Optimizing ...")

14 searches

Mrs. Aitchison, but summarised (Figure 10), they show that although there is an improvement in the logical statement in regard to recall, this, as would be expected, results in a drop in precision. For the coordination level results, the natural language shows a definite superiority over the whole performance curve.

	Controlled Language		Natural Language	
	Recall	Precision	Recall	Precision
User performance	82%	61%	100%	74%
Boolean Statement	52%	27%	30%	51%
Coordination levels				
9	1%	100%	1%	100%
8	2%	100%	2%	100%
7	3%	99%	5%	100%
6	7%	97%	10%	97%
5	12%	80%	21%	81%
4	25%	69%	39%	68%
3	65%	61%	74%	67%
2	90%	30%	99%	34%

FIGURE 10 COMPARATIVE RESULTS USING NATURAL AND CONTROLLED LANGUAGES FOR RUN 1.

In the analysis of the 'failures' by either of the two methods, the usual pattern of behaviour was found. In some cases the controlled language retrieved relevant documents because the indexer was forced to use a broader term; in other cases the precoordination of the controlled language made the term so specific that there was no match with the profile terms.

The position at this stage of the project was that there was reliable evidence to show that the use of nautral language was a correct decision. There was insufficient evidence to decide for certain on the level of indexing exhaustivity, although it appeared that the highest level would be required. The document collection was producing a reasonable number of relevant documents for the majority of the users, and there was the surprising indication that coordination levels might provide a more satisfactory basis for determining retrieval than logical

statements. The search profiles were satisfactory in the main although in some cases the relevance judgements had indicated the need for changes.

The second experimental run was completed on August 20th 1969. It was based on 151 documents and on this occasion the users were sent the documents retrieved at the highest coordination levels. No intellectual editing was done in regard to this output and it was therefore satisfactory to find that 40% of the documents were judged to be of major interest, with a further 32% of minor interest. There was no accurate way for determining the recall ratio, although an approximation could be made by reference to the assumed total of relevance documents in the first run. In that run there had been 214 documents in the test set, and for the 28 different profiles used in the second run, this original set of documents had a total of 480 relevant documents. Assuming that the 151 documents in the second run were, in general, similar in content to those in the first run, then it might be expected that there would be a total of $\frac{480 \times 151}{214} = 340$ relevant documents. Since it was known that 234 documents in the second run were judged relevent by the users, on this basis the recall ratio could be estimated as $\frac{234 \times 100}{340} = 69\%$.

For the third run, further changes were made to some of the search profiles and in particular the logical statements were carefully checked, since it was intended that this run should be used to make a further check on their comparative efficiency. The output sent to the user included all the documents retrieved by the logical statement, but when the number available fell seriously below the desired level, further documents were taken from the coordination level output. The particular purpose of this run was to find whether our earlier view of the superiority of coordination levels was correct, and the results certainly confirmed this. The logical statement output gave a precision ratio of only 54% as against 72% achieved in the second run, and the estimated recall also dropped from 69% to 45%.

This third run which was completed on October 10, 1969 was intended to be the final run in the experimental phase of the project. However, there was now sufficient data concerning relevance judgements to enable an investigation to be made into a method of optimising the cost-effectiveness of search profiles. The analysis so that this could be done was performed clerically, but confined to tasks which could, with suitable programs, be carried out on the computer. As stated earlier, the use of natural language meant that it was necessary to include a large number of alternative terms in the search profile, this being as high as 97, with an average of 60. This in turn meant that the search costs were proportionately that much higher than if fewer terms had been used, and for economic reasons it was desirable to reduce the number of terms if this could be done without seriously affecting performance. In carrying out such an exercise one must start from the realistic viewpoint that performance will not be perfect, i.e. one will not obtain either 100% recall or 100% precision. The reaction of the users to the experimental output showed that they did

not expect or require this, so the basic concern was how to obtain the existing level of performance at the lowest cost.

The feedback of relevance judgements made by the users provided a simple statistical method for optimising performance. It was a straightforward task to check the indexing of each relevant document and ascertain which term in the indexing had matched the term in the profile. When this had been done for the relevant documents in the three runs, one found the following pattern, as in Profile S. 1.

Number of terms in profile	60
Number of different terms retrieving relevant documents in Run 1	22
Additional different terms retrieving relevant documents in Run 2	13
Additional different terms retrieving relevant documents in Run 3	4

From this it was reasonable to argue that there were 23 terms in the profile whose presence resulted in no improvement in the recall performance, but whose absence would have saved some 40% of the computer search time. Admittedly their removal would mean that in future runs the recall performance might be adversely affected, since there was always a possibility that a term might be used in future indexing, but it was unlikely that the effect would be serious. Conversely, the analysis showed that certain terms were recurring frequently in the relevant documents and it was hypothesised that performance could be improved if these terms were weighted. The simplest method of achieving this with the computer programs available was to repeat such terms in the profile and this was done two, three or four times. Such a weighted profile is shown in Figure 12. The curves shown in Figures 13 and 14 are based on the analysis that was made for a number of profiles, and in both cases there is an indication that very few new terms might be expected to match after six runs.

The clerical work involved in the requisite analysis was very time-consuming and could not be contemplated in a real-life situation. However, the work was of a nature that could be simply and rapidly carried out on a computer. The automatic optimisation of search profiles in a mechanised S. D. I. system is a task which could not only be done at a relatively low cost, but also with a greater degree of sophistication than was used in the clerical experiment. For example, one could ascertain the terms which were responsible for the non-relevant documents being retrieved, and could arrange for such terms which had a predominantly baneful influence to be removed or to count in a negative sense.

In order to check whether the weighting of terms gave an improvement in performance, an experimental run was made on the documents used in Run 2 for all those profiles where relevance judgements had been received. The output was then analysed and, in

10	ax*
11	align*
12	ang*
13	ang*
14	autocoll*
15	coordinat*
	co ordinate*
16	comparator
17	collimat*
18	dimension*
19	dimension*
20	diameter
21	displacement
22	gaug*
23	gear
24	grating
25	holog*
26	instrument*
27	instrument*
28	interferom*
29	inspect*
30	inspect*
31	inspect*
32	indicat*
33	kinemat*
34	limit
35	laser
36	laser
37	measur*
38	measur*
39	metrol*
40	optic*
41	position*
42	profil*
43	project*
44	round*
45	squar*
46	surface
47	screw
48	thread
49	tolerance*
50	tolerance*
51	telescope
52	tally*
	taly*
53	pressure
	prism
	polygon
	photo

FIGURE 12. AMENDED PROFILE INCLUDING WEIGHTING OF USEFUL RETRIEVAL TERMS.

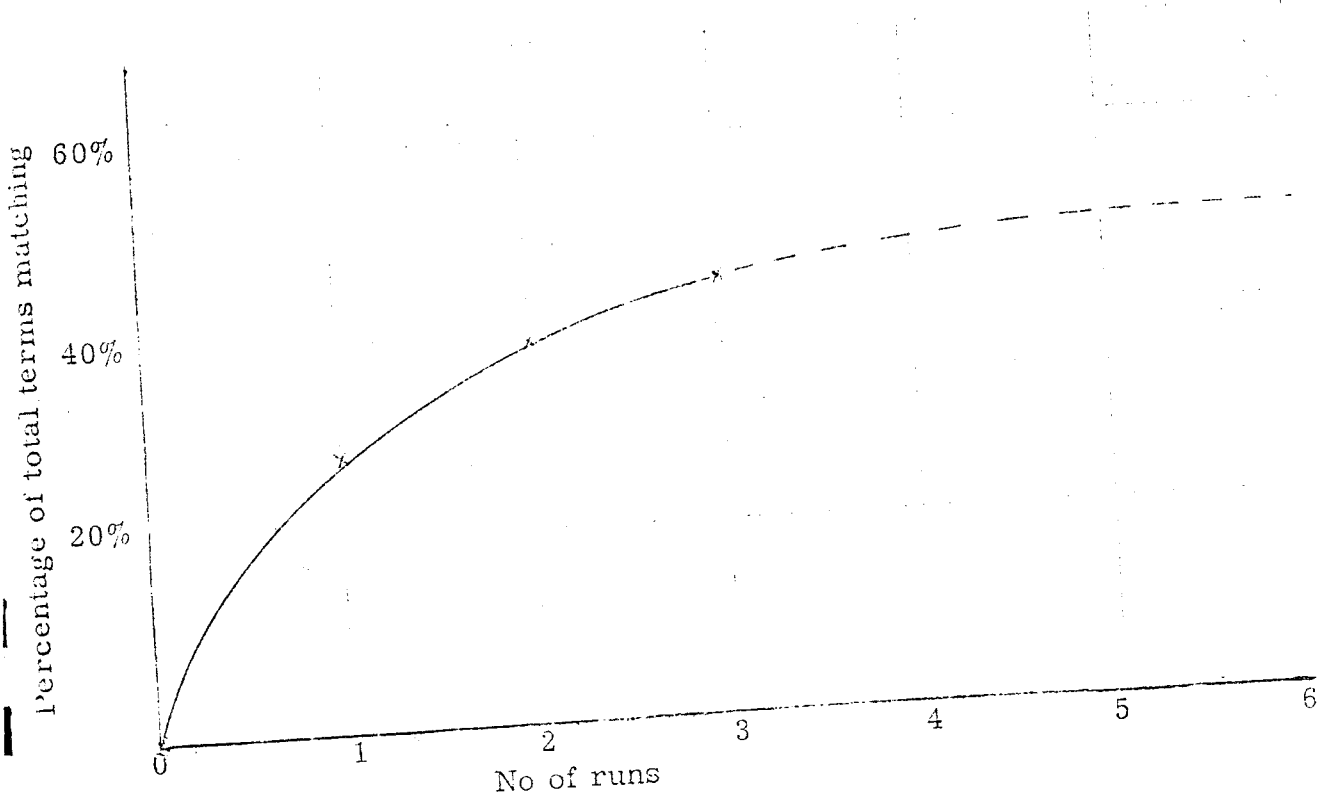

FIGURE 13 PERCENTAGE OF TOTAL TERM MATCHES FROM ORIGINAL SEARCH PROFILES

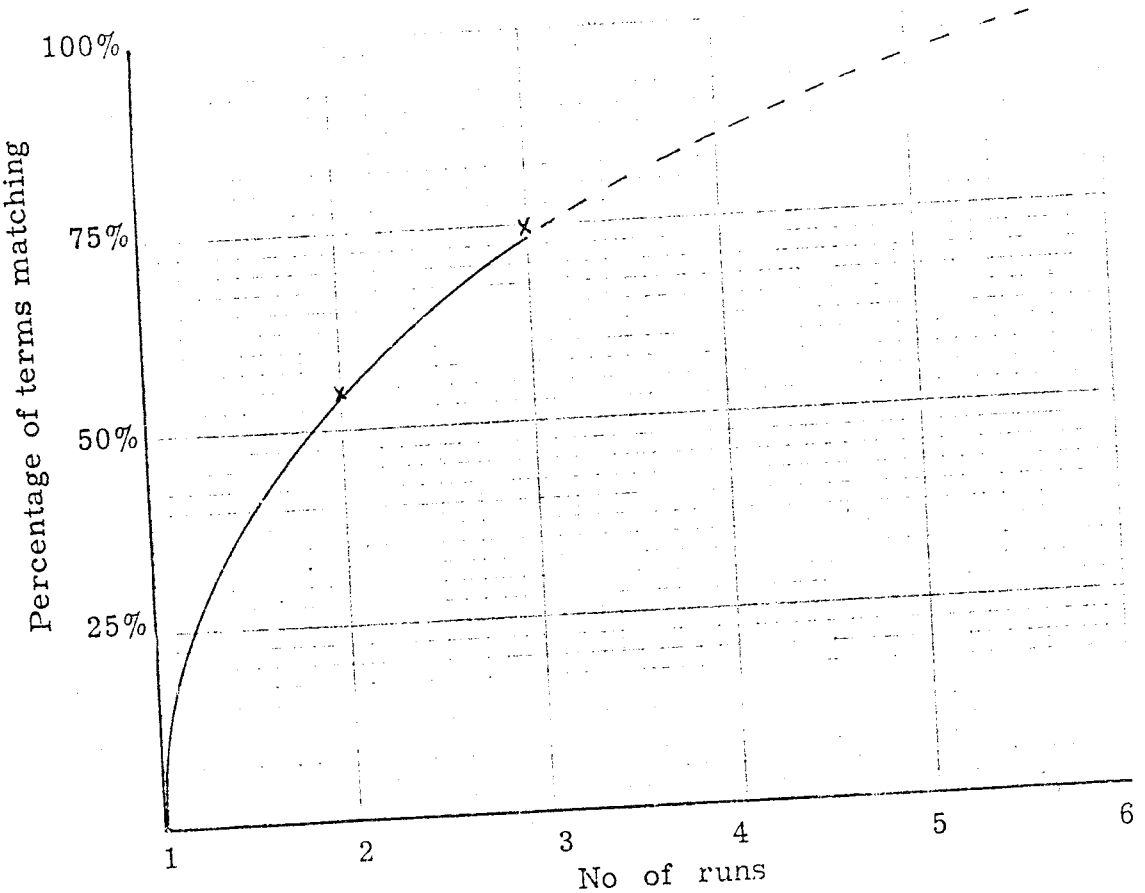

FIGURE 14. PERCENTAGE OF TERMS MATCHING THE SAME AS FOR ORIGINAL SEARCH PROFILES

comparison with Run 2, there was an improvement in the precision ratio from 34% to 61% with major relevance documents and 66% to 80% for all relevant documents.

There was another useful by-product of this weighting of terms. In effect the coordination level output is a rough form of ranking, far less sophisticated than that used in the SMART system, but working in much the same way. A major practical difference was that the SMART system normally provided a positive rank order for each individual document, whereas we were ranking in blocks of documents, with the blocks increasing in size as the coordination level dropped. However, the inclusion of the additional weighted terms resulted in a stretching of the coordination levels; for a search, say, where the maximum coordination level had been nine, for the new search the maximum coordination level could be sixteen. This had the effect of decreasing the number of documents in each of the blocks, thereby simulating more closely a positive ranking, and making it simpler to obtain a satisfactory cut-off around the desired level of twenty documents.

From the technical viewpoint, the superiority of coordination levels over logical statements in a mechanised system was certainly the most interesting result in the project. There had been previous suggestions that such might be the case, but experimental evidence had been lacking. We would not wish to give the impression that the results obtained in this test can be considered as conclusive; all that can be said is that they are sufficiently interesting to merit further controlled investigation.

It is not too difficult to find a logical explanation of why coordination levels should be superior in performance or why the logical statement has been the normal method of operation in mechanised systems. Post-coordinate indexing systems, before they graduated to computer operation, depended on some form of clerical searching, either of edge-punched cards or Peek-a-boo (Batten) cards. To obtain a coordination level output by the hand searching of such cards would be a very long and tedious process and could hardly be contemplated in normal circumstances. A search based on a logical statement reduces the searching to managable proportions, and therefore this became the common practice in clerical systems. The habit was carried over to computerised systems without it being realised that the necessity for it no longer existed. It is however only fair to add that the logical statement had the outward appearance of being the better method.

The reason for the superiority of coordination levels is not difficult to argue. Although logical statements often appear complex, in practice in most operational systems there is normally only a requirement for A AND B, or in a small percentage of searches, a requirement for A AND B AND C, where A, B and C will consist of a number of alternative terms. In total there may often be some fifty terms, but all will be alternatives under either A or B. The requirement of the logical statement can therefore be met if a document has term A_{10} AND B_6 or A_{15} AND B_3.

The argument against coordination levels has been that, although four terms are present, these might be A_3, A_6, A_{10} and A_{15}, and therefore would fail to meet the requirements of the logical statement, since no B term was present. However it appears that while this is possible, in practice it does not happen very often. In this test the coordination levels have been relatively high and the output at these high coordination levels has a better chance of being relevant than many documents which meet the requirements of the logical statement.

An attempt was made to find how the users were reacting, in particular as regards the size and quality of the output they were receiving. The performance figures already quoted were averages based on a number of profiles, and there were of course individual variations. To each user a letter was sent, explaining what had been the purpose of the project and summarising the performance which had been obtained for each user. From the analysis of the general system performance it was possible to offer alternative options to the user as in the following quoted example:

"You have been receiving an average of 20 items of which 5 have been of major interest, 9 have been of minor interest, and 6 have been of no interest. On the other hand, we believe that there are probably a further 6 or so references which have not been sent to you that would be of at least minor interest. Possible alternative outputs are therefore as follows:

1) As at present with 20 documents being sent of which 14 are of interest.

2) Reducing the output to, say, 10 documents of which 8 or 9 would be of interest.

3) Increasing the output so that you receive all the references of interest but which would mean that you would receive some 65 or more papers of which 45 would be of no interest".

Of the users who replied to this enquiry, all preferred their present level of operation in comparison with the alternatives offered.

OPERATIONAL PHASE - January to June 1970

Although this is described as an operational phase, there was a continuing influx of new users who had to be assimilated into the system. Each of these new users received complete copies of the articles to enable them to make valid relevance judgements, and continued to do this until a satisfactory level of performance had been attained. From the operational aspect it was planned to make regular runs at intervals of three weeks, the input consisting of papers which had been published during the preceeding three week period. In the experimental phase the users had received full copies of the documents so as to be able

to make valid relevance judgements. In this phase the user would only receive cards giving bibliographical details.

The summary of runs done during this period is as follows:

	Date	No. of Profiles	No. of Users	No. of Documents
Run 4	14. 1.70	34	22	112
5	10. 2.70	50	33	190
6	3. 3.70	52	37	245
7	24. 3.70	44	40	155
8	22. 4.70	47	42	232
9	12. 5.70	43	40	226
10	10. 6.70	48	44	247
11	1. 7.70	51	44	238

It will be seen that the objective of regular output was maintained reasonably well.

There is little comment necessary concerning these runs; for Run 11 all the users were sent complete copies of the articles and asked to send their relevance judgements, so that it might be possible to make a check on the level of performance and find whether the interests of the users had changed significantly over the operational period. The overall user performance with the 33 replies which have been received, indicate a precision ratio of 73%. The detailed analysis of the results to enable an estimate to be made of the effect of changes of interest is set out in Appendix M Apart from this, the users were not asked for relevance judgements, but with the final run each user was sent a questionnaire (see Appendix J), the replies to which will be considered in the next section.

During this phase an attempt was made to determine the efficiency of the DEVIL programs and estimate the effect of the individual programs. Detailed timing figures were obtained for three S.D.I. runs and certain supplementary runs were made in order to obtain more data, such as one run where three questions were searched against 1,500 documents. From this it has been possible to work out time and cost for different situations; details of these are given in Appendix K.

ANALYSIS

It is necessary to make recommendations on the possible economic viability of the system, based on the analysis of results that are at present available.

It is inevitable that there are particular economic problems in operating a system within a specialised subject area. A major inter-disciplinary system, such as the Citation Index of the Institute of Scientific Information, covers some two thousand journals; for these journals there are no intellectual decisions as to whether any individual article should be indexed, for the inclusion of the journal means that

automatically every article will be included. In large, but single disciplinary systems such as Physics Abstracts, while there will be a selection of articles from many journals, there is a core of some 200 journals for which every article will be included, and articles from this set of journals will, in fact, make up the major part of the data base. In contrast to these situations, a major part of the work of Mr. Harding in this project was, as indexer, in deciding whether or not a given article should be included in the system, and the decision to reject any particular article might take even longer than would be involved in indexing an obviously suitable article. It was found that for every hundred articles which were considered in detail, only forty were finally included in the system.

This is a very severe restraint on the economic efficiency of the system, but to have adopted more relaxed criteria for inclusion would have resulted in additional costs at the input and search stages. As it was, approximately 77% of the articles included were sent out to users, of which some 85% were judged to be relevant by at least one person. For a population of less than fifty users this can be accepted as a reasonable level of coverage.

The corollary of the necessity of selecting papers is that high quality technical staff must be employed on this task and there is therefore no possibility of using clerical techniques in the indexing stage. Some clerical assistance could have cut down the work that was performed by Mr. Harding, but overall this would not have resulted in an appreciable saving of his time. In Appendix K details are given of indexing and input times and costs, showing that the average cost for indexing and inputting a single document was in the region of 7/-d

The statement was made earlier that the computer programs used on the project were originally written for a single experiment and therefore were not expected or intended to be particularly efficient. In fact, within the limitations of what can be determined and compared for different operational situations, the programs appeared to be more effective than had originally been implied. An average run, for about two hundred documents and fifty searches took eighty-five minutes, made up of forty minutes for the creation of the master file, five minutes for validating and editing, and forty minutes for search and print-out. (see Appendix K for details). The charge for the computer at Cranfield was £22. 10. 0d an hour, so this represents a cost of approximately £31 for a complete run. With time-sharing during the input stage and certain other improvements that could be made, it is considered that there should be a reasonable possibility of reducing the cost to approximately £20 a run. With the present computer capacity, the system was working very near the limit of the number of matches that could be made in a single run and this means that if there were a hundred profiles instead of fifty profiles, a second pass would be necessary. This would not involve any increase in the input time and the cost might be expected to rise to £33. With one hundred and fifty profiles the cost would be £46.

An equation for estimating computer search time is given in

Appendix K and from this it has been possible to work out possible costs for retrospective search runs on larger collections. Various examples are given; for instance, a single question searched on five thousand documents would cost £11. 12. 6d, whereas a batch of ten questions on ten thousand documents would result in a cost of £4. 7. 6d per question.

When one has a specialised subject area, then the potential user group is also limited, that is there are fewer customers over whom the overheads can be spread. However, the narrowness of the subject means that there are a limited number of what we have termed search sub-profiles, that is basic subject aspects which, sometimes in combination, can meet the stated interests of the user. The number of users has not been sufficient positively to confirm this point, but there are reasonable indications that if the user group reached 150, then a majority of additional users could be supplied from the existing set of sub-profiles, which it is expected might then number one hundred or so. This has important economic considerations since it means that additional costs for each user would be significantly decreased once this number of users had been reached.

Regarding the cost of journals, for the purpose of this experiment, these have all been available in the Library of the Cranfield Institute of Technology. Realistically for costing purposes they should be treated as a charge to the system; the cost would be approximately £900 for the complete set of journals; alternatively one could say that 15 journals which supplied 58% of the input would cost £120. However, in an operational service one would have to accept the necessity of covering more foreign language literature and these journals could increase the cost appreciably. Overhead costs are difficult to estimate without knowing the particular circumstances. In this project, the Institute has covered all these, but with an operational system an allowance must be made. Bearing these matters in mind, an estimate has been made of the operating costs for an S.D.I. system. These costs are divided between the basic costs which are irrespective of the number of users and those which will vary according to the number of users. The assumption is that 5,000 articles will be indexed each year and there will be 25 runs a year. The output sent to the user would be catalogue cards containing author, title (expanded where required) and bibliographic details. On this basis provisional costs are shown in Figure 15. In Figure 16 the effect of this is given in a plot of costs compared to number of users of the system. It must be emphasised that these are considered to be the absolute minimum costs, with the possible exception of those for the computer. As has been mentioned, the relatively small store (32K) of the present Cranfield computer would make it impossible to carry out more than 50 searches at a single pass. A larger computer would remove this restriction and might thereby reduce the costs. However this would not bring any major saving, since the computer search costs are a relatively small proportion of the whole (14% - 17%).

The Users

Of the 44 users of the system at the conclusion of the operational

BASIC COSTS

Journals	£ 500
5,000 articles at 7/-d	1,750
Administrative duties ($\frac{1}{3}$ Indexer's time)	800
Clerical duties ($\frac{1}{2}$ time)	300
Overheads	1,000
	£4,350

USER COSTS

No of users	100	150	200	300	500	1,000
Search costs	£ 800	£1,000	£1,100	£1,200	£1,300	£1,400
Search profiles	500	650	750	850	950	1,100
Card output, postage etc.	200	300	400	600	1,000	2,000
	£1,500	£1,950	£2,250	£2,650	£3,250	£4,500
TOTAL COSTS	£5,850	£6,300	£6,550	£7,000	£7,600	£8,850
Cost per user	£58	£47	£33	£24	£15	£9

FIGURE 15 ESTIMATE OF COSTS OF S.D.I. SERVICE

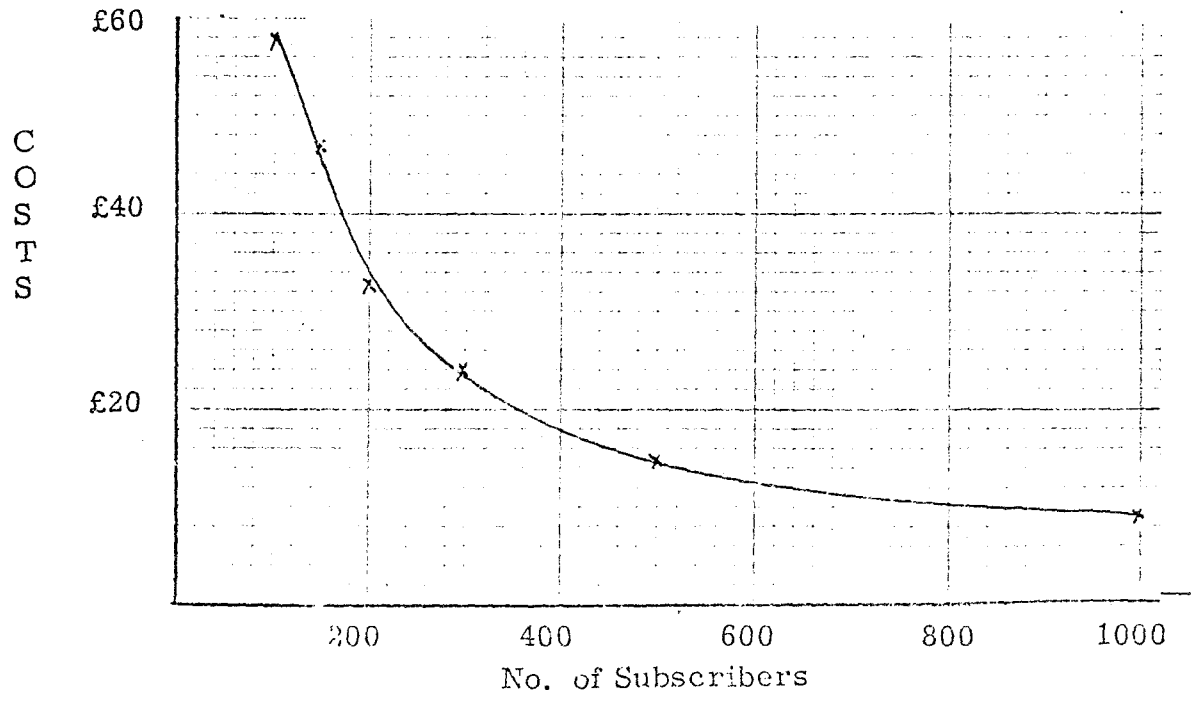

FIGURE 16. VARIATION OF COST PER SUBSCRIBER

phase, completed questionnaires have been received from 35. Detailed breakdown of the answers is given in Appendix N, but here we will only be concerned with those relevant to the economic aspects of the system.

A significant difference might be expected for users working in industrial organisations, in government or research associations and in academic institutions. In these three categories the general reaction to the scheme is as follows:

	Total replies	Most useful	Useful	Little use	No use	Satisfied	Too many non-relevant	Relevant missed
Industrial	8	0	4	4	0	3	5	1
Government or Research	17	2	11	4	0	10	4	7
Academic	10	2	4	4	0	8	4	2

Some of the additional comments regarding user reactions are given in Appendix P.

The first question in Section C of the questionnaire asked if the user would wish to continue to receive the service if it were free. Three persons gave a blunt negative to this question and therefore did not answer any other questions in this section. Of the remaining 32, ten considered it essential to cover German literature, six to cover Russian, but only one to cover French. On types of literature, 17 considered conference proceedings to be most important, three wanted manufacturers literature included, two asked for patents, and one required standards. On the matter of abstracts there was an almost equal breakdown between those who thought them desirable and those who would be satisfied with titles only, but 19 showed a preference for cards as against five who would prefer a list. All would accept four weeks as satisfactory, with the exception of three who considered three weeks was the maximum acceptable and one who considered two weeks. It may be noted that a four weekly run as against a two weekly run would result in a very small saving, certainly not more than £1 per user.

In the final question the users were asked to state the maximum price which they would accept as reasonable in order to recommend the purchase of the service, with the three options of

(a) card output with titles only.
(b) card output with abstracts
(c) copies of complete articles.

The range of prices varied, but in all cases the first figure was £0. This enabled the user to show a complete non-acceptance of such a service; for example, one user said that he would consider as acceptable £25 for (a), £25 for (b) and £0 for (c). This implies that he would be equally satisfied with titles (a) or abstracts (b), but that he did not wish

to receive full copies (c). Not all replies are so easy to interpret as this, but most people have indicated their preferences and opinions.

As mentioned earlier, three users replied that they could not recommend any payment for any type of service visualised. One of these came from a user at a University who said that no funds could be made available; a similar answer was given by a user in an industrial organisation which is at present having severe financial problems. The third person in a research association considered that he was adequately served by an existing service. However, with the remaining 32, for whom replies to the questionnaire have been received, the position regarding the willingness to pay for alternative services is as shown below.

Willing to pay at least	Titles	Abstracts	Full copies
£45	-	-	2
£40	-	-	3 (5)
£35	-	1	0
£30	1	2 (3)	2 (7)
£25	2 (3)	3 (6)	5 (12)
£20	1 (4)	5 (11)	4 (16)
£15	4 (8)	8 (19)	-
£10	12 (20)	-	-
£ 0	15	16	19

(Figures in brackets represent cumulated totals)

The only majority preference that comes within the possible range is that where 19 users were willing to pay £15 or more for a service covering abstracts. This is the absolute minimum figure for a card service covering titles only for a minimum of 500 users. The feasibility of including abstracts is to some extent dependent on what is meant by "an abstract". A two-line notation or a 30-line summary are both covered by the term; the former might be possible to include without serious additional costs, but the latter would certainly raise the cost by at least 50%.

The possibility of additional income from a retrospective search service must be considered but the economics do not look particularly attractive in regard to mechanised searching. The only way in which one could contemplate such a service operating reasonably would be in close conjunction with a research and consultancy service, such as the Cranfield Unit of Precision Engineering. On its own, divorced from any such association, it would be unlikely to attract sufficient custom for searches to be done at anything approaching an economic level.

The computer programs were hired for the duration of the test from the Institution of Electrical Engineers. Assuming that new programs had

to be written, it is unlikely that this could be done at a cost of less than £5,000.

CONCLUSIONS

One can consider this matter in either of two ways. From the aspect of operating this controlled service in the subject area of precision engineering, the possibility of being able to do this on an economic basis is not very encouraging. One is beset by the high comparative costs involved in organising a service in a narrow subject field. Regarding the users, one is dealing with a group of people, i.e. engineers, who, speaking generally, are known to take a very equivocal attitude towards recorded information; investigations have shown that, more than scientists, engineers, particularly in industrial organisations, prefer to obtain information from colleagues, suppliers etc., rather than in consulting the literature. This is shown up in an interesting way in the table on page 30 relating to the comments regarding the output. Of the users in research associations, seven were concerned about missing relevant papers, while only four considered they received too many non-relevant papers. Of the industrial users, only one worried about missing relevant papers, while five felt they were receiving too many non-relevant papers. However, there are some 3,000 engineering firms in the country with 100 employees or more, and one could argue that this number of organisations would profit from having such a service. What are the possibilities of persuading 20% of that number to take out at least one subscription?

The second viewpoint is to consider the project as having been an investigation into services of this particular type, an investigation in which the subject area just happened to be precision engineering. This, in fact, was part of the original intention; in other words the project was to investigate a system which could act as a prototype in a number of different subject areas. Therefore we can ask the question whether sufficient publicity and marketing could sell the concept of specialised information services in a number of different subject fields.

During the two years of the project, there have been important developments in regard to mechanised information retrieval services; in this country the Chemical Society is marketing an S.D.I. service based on Chemical Abstracts. The Institution of Electrical Engineers is now offering a service in electronics research, and from 1971 will have a service which covers all the subjects included in their three abstract journals, (Physics Abstracts, Electrical and Electronic Abstracts, and Computer and Control Abstracts). The Institute of Scientific Information in Philadelphia has a number of customers in this country for their current-awareness services. From Paris the European Space Research Organisation offers specialised services based on NASA tapes. All the evidence suggests that these organisations are finding it difficult to make their services economically viable, in spite of the fact that in all cases the services are additional to the basic service, which is itself

either self-supporting (e.g. Physics Abstracts) or is subsidised, (e.g. NASA STAR). As an example of the effect of this, our estimated cost for getting a single article onto tape was 7/1d; the Chemical Society are able to obtain their tapes ready for searching at a cost which works out at less than 0.5d per article.

The major difficulty in achieving financial stability, in this country at least, lies in the unresolved problem as to who shall pay for such services. Essentially an S.D.I. service is intended to be for individuals, therefore the library or information service of an organisation does not consider it reasonable that it should pay for a service to benefit one member of the staff, when there may be dozens of other persons with an equal claim to have the same or comparable services. On the other hand, the concept of paying for information services from a technical budget is not generally accepted. In this country - contrary to the position in the United States - information is not an item which can be directly charged against contracts or grants, so in academic organisations in particular there is great difficulty in finding the necessary funds.

To answer the questions posed earlier, we do not consider there is any possibility of going over to a commercial operation of the present service and making it economically viable in the foreseeable future. On the basis of the costs as given in Figure 15, assuming a charge of £15 were made for a service providing annotated references, one would hazard a guess that a subsidy of £6,000 would be necessary for the service to operate for a two year period, but would still have doubts as to whether by then it would have reached a break-even point. This sum would not include the initial costs of programming or advertising.

From the context of setting up a chain of systems, this could be achieved only if one believes that there will be a gradual change in the general attitude towards information retrieval and rapid developments in the cost-effectiveness of the systems available. We believe, without any particular evidence to justify the belief, that this will come about and that by 1980 S.D.I. services of one kind of the other will be rivalling the abstract journals of today.

At least one commercial organisation (Institute for Scientific Information) has been able to operate in this area, and Crowell, Collier & MacMillan Inc., with the purchase and publication of Pandex, is an example of a publishing house who are trying to exploit the field. Whether they will succeed against the scientific and technical institutions - all directly or indirectly subsidised - and the Government agencies who are already operation on a large scale is difficult to say, but one has the feeling that, for an additional organisation to prove successful, there would have to be a major investment; one thing that is certain is that there is no short-cut to success.

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APPENDIX A

Excerpt from the letter of agreement from Pergamon Press, dated August 8, 1968.

I am writing to confirm Pergamon's willingness and ability to contribute a figure of up to £10,000 to cover a period of two years for the following purpose:

1. To establish a mechanised information service in precision engineering covering an information retrieval service, an SDI service and a current awareness bulletin.

2. In the course of the two years of the grant these services will be fully evaluated.

3. Pergamon will appoint Mr. McDaniel, formerly of the National Physical Laboratory, now of our Information Storage and Retrieval Division, as liaison officer to give technical assistance and advice in the setting up of this information system.

4. At the end of the first year we suggest that discussions be held to discuss the possibility of offering some parts of the service on a commercial basis and if the project is a commercial success we propose that all profits earned from the sale of the service be shared equally between Pergamon Press and your Precision Engineering Unit.

5. At the end of the two-year period Pergamon to have the option of taking over the system and to organise it on a commercial basis. If this were done it would continue to be operated at Cranfield if the College so wished, and the staff of the precision engineering unit would have free access to the system for its own use.

I hope that your Committee will agree to accept this grant and start advertising for staff with a view to being ready sometime in the Spring when the necessary programmes will be completed so that the punching of data may begin as soon as possible with a view to offering the service on a trial basis within a year from now.

APPENDIX B

DEVII (Direct EValuation of Index Languages) System

Description of Computer System

1. Creation of Master file of Questions and Documents

Programs DEVI, INSI, and INMX form part of the file maintenance system, which creates and amends files on magnetic tape.

DEVI creates a file on magnetic tape called INSDECINTAPE by reading the question and document records punched on paper-tape. It prints out a list of all the question numbers and document numbers created on the file and partially validates the records with an error listing (e.g. 'F' means that the following SORT program will not accept this record).

INSI sorts the questions and documents created on INSPECINTAPE into numerical order, with the questions at the front of the tape, and creates a file called INSPECINSORT.

INMX merges the new records on INSPECINSORT with the previously created Master file called ILUNEDITEDFI (Generation X) to create a new Master file of the same name, but generation X+1. DEVP gives a listing of all the new documents and questions merged with the master file (or if required can be used to give a listing of the whole file).

DEV2 validates and edits ILUNEDITEDFI to ensure that it meets the data format requirements of the search programs, creates a file called ILEDITEDFILE, and lists any errors detected by the program. This program validates all question and document records for logical, or format errors, and edits text fields by removing such characters as upper case shift, the terminating 's' from simple plurals, and hyphens.

2. Document searching

The subset of the Question/Document file required for each run is specified by input of a parameter tape to DEV3.

The required questions are then extracted from the master file, and a sub-file is produced. The descriptors in the questions are listed - any which occur in more than one question are listed once only. For any subsequent questions containing these same descriptors, a note is made in the 'Duplicates' file.

Each document is then read by the computer (from the masterfile), and the text is compared a word at a time with the descriptor list. When a descriptor is found to match with part of a document, a match record is created, identifying the descriptor, the document, and the index language. These matches are then sorted by INS2.

The lists of descriptors and duplicates are merged by DEV4 to form a file giving the specific field (i.e. the descriptor number) and the question number for all questions containing that descriptor. The descriptors are then sorted by INS3.

This, together with the list of matches, is used in DEV5 to create complete match records, which indicate that a given field (i.e. descriptor) of a particular question has matched a specific document, and identifies the particular index language field in which the match has occurred.

3. Creation of Output listing

This file is then sorted by INS4 and read by DEV6, which also uses the question sub-file, and creates overall match records of two types.

First, it examines the Boolean expression for each question, and determines whether or not the matches found for this question on each document satisfy the requirements dictated by the logical expression. If they do, a Boolean match is recorded for that particular question and document. Secondly, the number of single descriptor matches obtained between each question and document is recorded.

The resulting file is sorted by INS5, and then DEV7 prints the results both in detail and in summary form, together with a mathematical interpretation of the efficiency of the retrieval system in terms of recall, precision and fallout (if relevant documents are known).

4. Hardware requirements

The computer configuration used to run the DEVIL system at Cranfield was:-

(ICL 1905 digital computer)

1 Central Processor having 32K of 2 microsecondcore store
1 Paper Tape Reader (300 characters per sec.)
1 Line Printer (300 lines per minute)
4 Magnetic Tape Transports for 556 bits per inch (20K2)
1 Disc Store Transport, having the capacity of 4M characters
1 Card Reader (300 cards per minute)

The search program DEV3 stores all question descriptors in core before commencing the matching process. The program requires on the average 4 words per question descriptor, and on a 32K machine the space available is 10,000 words, hence the limitation is to 2,500 descriptors.

With an average of 50 descriptors per question the number of questions is limited to 50.

On a 64K machine an additional 28K is available and hence up to 150 questions coult be dealt with. However, there are other limitations to the maximum possible, which depend on the match frequency, which in turn depend on the size and type of document records.
The matching program loads into 21K.

In a typical search of 200 documents by 50 questions, 20,000 extended matches were produced.

Each match record is 5 words in length, hence 100,000 words of backing store are required for this file (the largest file in the system). In fact, the file size allocated on the disc is 600,000 words.

The use of discs rather than tapes enables the run time to be reduced considerably, particularly because of the much quicker sort times available on this medium.

DEVIL SYSTEM FILE UPDATE (PHASE 1)

Use PLT on Tape [ ]. System requires 5 scratch tapes, of which 1 is left free at the end

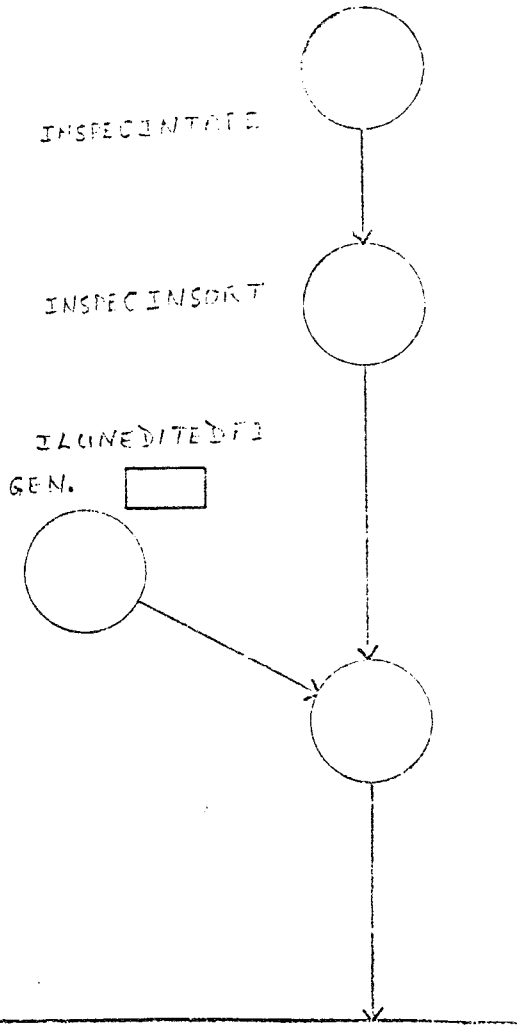
1 FI//DEV1//TAPE
2 GO 20
3 Load data tapes 1 to [ ] in sequence
INSPECINTAPE is created: listing given
4 HALTED: END OF RUN
ERROR ACTION GO 29

5 FI//INS1//TAPE 20000
6 Remove WPR from INSPECINTAPE
7 GO 22
Sorts INSPECINTAPE to INSPECINSORT
8 HALTED: END OF SOR, FINAL O/P REEL ON UNIT X

9 FI//INDX//TAPE
10 Remove WPR from INSPECINSORT
11 Load ILUNEDITEDFI tape [ ]
12 GO 20
ILUNEDITEDFI is created
13 HALTED: END OF INDX
ERROR ACTION GO 29

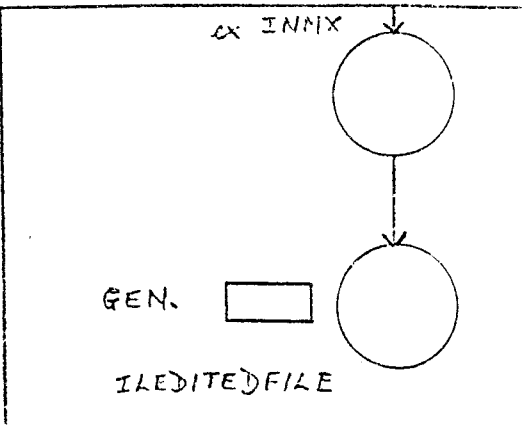
14 FI//DEV2//TAPE
15 Remove WPR from ILUNEDITEDFI on UNIT X
16 GI X 1

18 GO 21
Listing of file is given
19 HALTED OK
ERROR ACTION GO 29



DEVIL SYSTEM VALIDATE AND EDIT (PHASE 2)

20 FI//DEV2//TAPE
21 Load ILUNEDITEDFI tape [ ] without WPR
22 GO 20
23 HALTED: INPUT FILE GEN. NO.
24 AL 4 [ ]
25 GO
ILEDITEDFILE is created: listing given
26 HALTED: END OF RUN
ERROR ACTION GO 29



DEVIL SYSTEM SEARCH (PHASE 3)

RUN NUMBER [ ] DATE [ ]

OPERATOR INSTRUCTIONS ESTIMATED RUN TIME [ ]

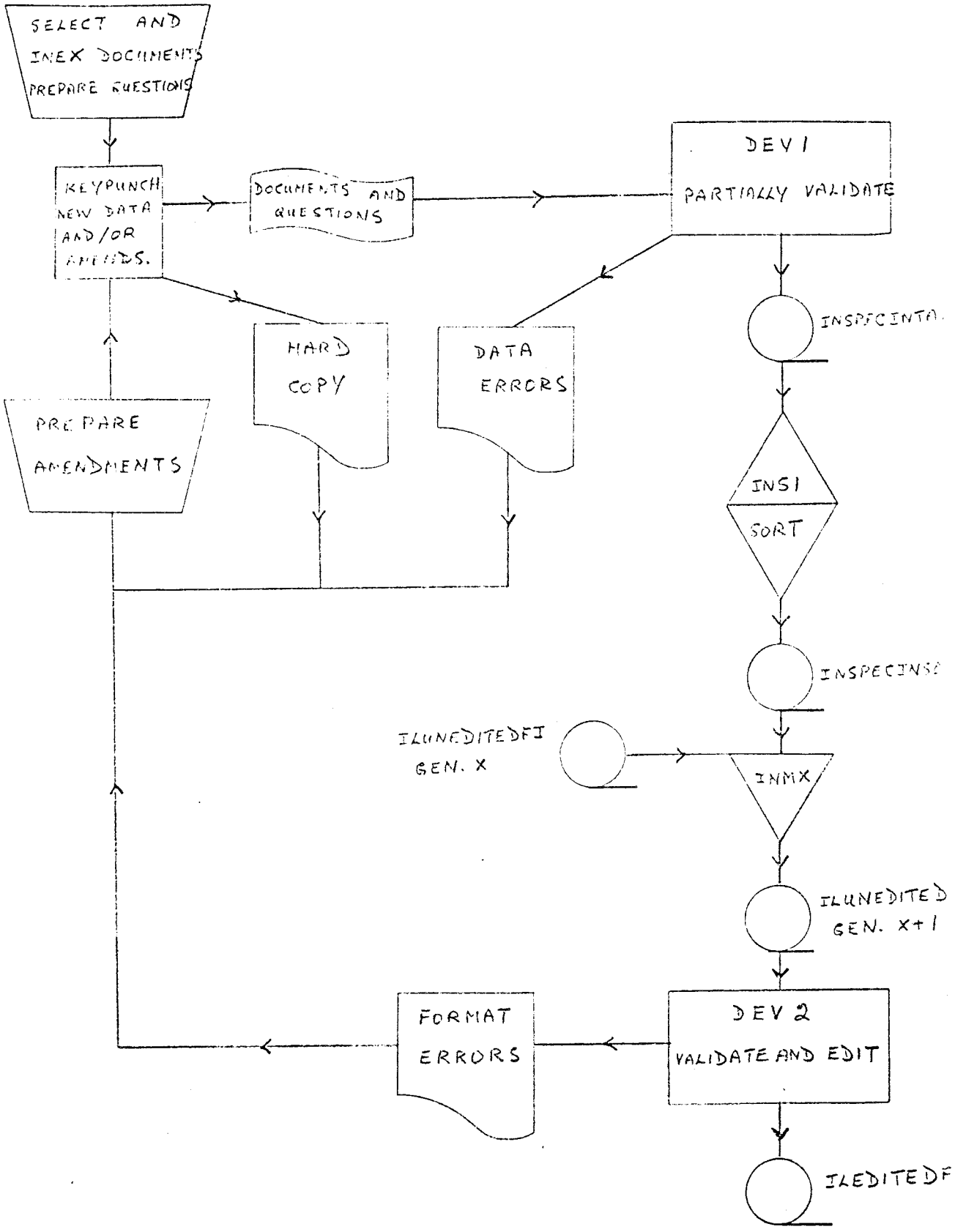
1. SET UP DISC(S) [ ]
2. SET UP QUESTIONS AND DOCUMENTS FILE N.T. 'INDEXED FILE' [ ]
3. PROGRAM LIBRARY TAPE IS [ ]
4. LOAD RUN PARAMETERS IN P.T.R. IN C.R.
5. FI//DEV3//TAPE
   GO 20
   'PARAMETERS VALID'
   AT END ' [ ] MATCHING PHRASES FOUND
6. FI//INS2//TAPE
   ON 21 GO 21
7. FI//DEV4//TAPE
   GO 20
8. FI//INS3//TAPE
   ON 21 GO 21
   [ ] RECORDS
9. FI//DEV5//TAPE
   GO 20
10. FI//INS4//TAPE
    ON 21 GO 21
    [ ] RECORDS
11. FI//DEV6//TAPE
    ON 21 GO 21
12. FI//INS5//TAPE
    ON 21 GO 21
    [ ] RECORDS
13. FI//DEV7//TAPE
    GO 20
    'END OF RUN'

ERROR ACTION

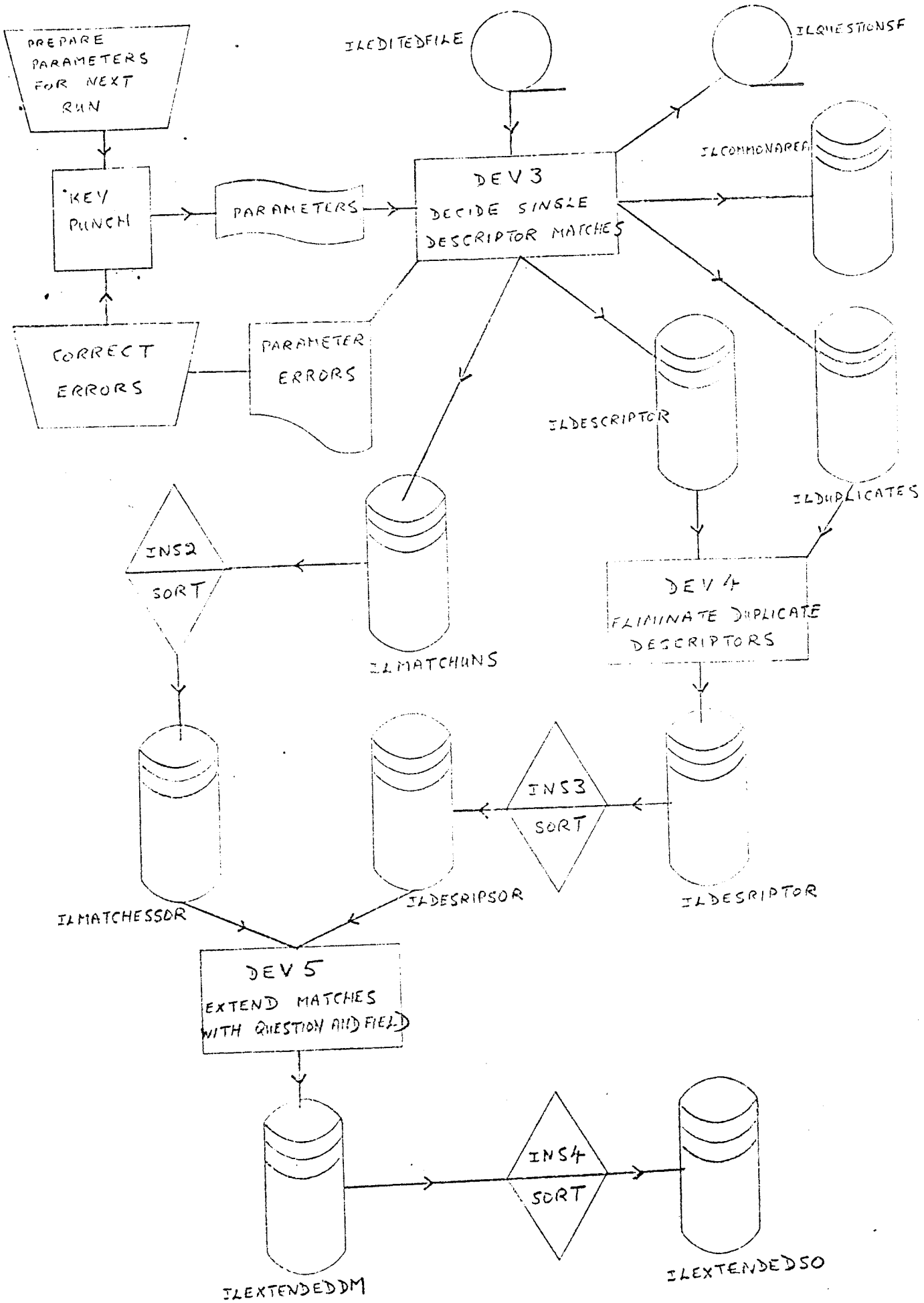
IF 'PARAMETERS INVALID' OR HALT, ILLEGAL, etc. GO 29 and ABANDON RUN

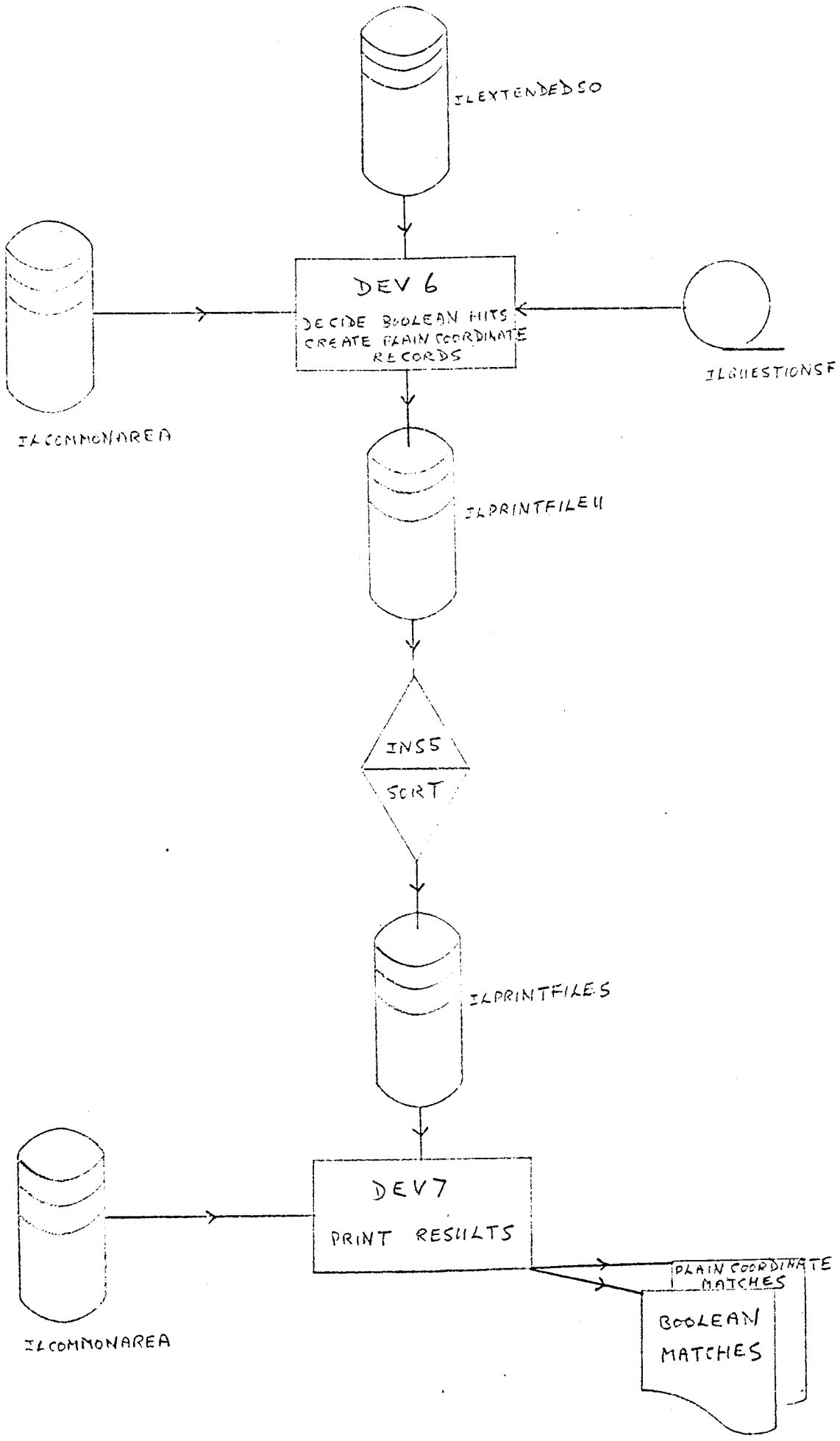
FLOW DIAGRAM OF DEVIL SYSTEM

PHASE 1 (CREATE FILE OF DOCUMENTS AND QUESTIONS)



PHASE 2 (DOCUMENT SEARCH)




ILEXTENDEDSO
DEV 6
DECIDE BOOLEAN HITS
CREATE PLAIN COORDINATE
RECORDS
ILCOMMONAREA
ILQUESTIONSF
ILPRINTFILE4
INSS
SORT
ILPRINTFILE5
DEV7
PRINT RESULTS
ILCOMMONAREA
PLAIN COORDINATE
MATCHES
BOOLEAN
MATCHES

APPENDIX C

Letter and form sent to possible users of the system

Dear Sir,

You are no doubt aware of the formation of the Cranfield Unit of Precision Engineering, directed by Professor John Loxham. In connection with the work of the Unit, it has been decided to establish a mechanised information retrieval service in Precision Engineering. This project is being organised by the staff of the Unit and of the College of Aeronautics, and is being supported by a joint grant from the Pergamon Press and International Computers Ltd.

Eventually it is intended to offer a full retrospective search service, but this will only be possible when a reasonable number of documents have been included in the system. However, in the meantime we intend to provide, on an experimental and complimentary basis, a selective dissemination service, and hope to commence this in June.

With such a service, each person taking part would be asked to define his particular sphere of interest, to give what is usually termed a "profile" of his information needs. Every two weeks or so, the documents that have been indexed during that period will be matched with the profile, and the computer will print out a list of all those items which are likely to be of interest. This listing will be sent to the individual who will thus receive, at regular intervals, notifications concerning recent papers of interest to him.

There is much preliminary work that has to be done, including the preparation of suitable computer programs and decisions on indexing techniques. The most important task, however, is to determine the scope of the subject area, and this can only be done with the help of those who are closely concerned with the subject. Professor Loxham has suggested that you might be willing to help us in this stage of the work, and I should certainly be very grateful if you could spare the time to complete the enclosed brief questionnaire. This asks you to state your interest profile, to list a few journals which you consult regularly and finally to list any papers which you have seen recently and which are directly related to your main interest. Such information will be of great value in helping us to design the system, so that when we commence the service in July, I hope we shall be able to send you notifications of useful papers.

Please let me know if there is any more information which I can give you concerning this project.

Yours faithfully,

INFORMATION SERVICE IN PRECISION ENGINEERING

1. Assume that there was a service available which would send you regularly a list of the papers which were of interest to you. Please describe as precisely as possible that aspect of Precision Engineering which is your principal interest.

2. Would you please give the reference of a few papers which you have read recently and which are directly related to your main subject interest as expressed above.

3. Would you please list up to six scientific or technical journals which are of particular interest to you.

Please return to: P. Harding,
The Library,
The College of Aeronautics,
Cranfield,
BEDFORD

APPENDIX D

LIST OF USERS

	Date first output sent	No. of outputs sent
Dr. J. F. Archard University of Leicester. Department of Engineering	10/2/70	7
Mr. C. P. Auger Lucas Group Research Centre. Solihull	10/6/70	2
Mr. D. A. Boffey University of Edinburgh	10/6/70	2
Mr. B. R. Bottomley Churchill Machine Tool Co. Ltd. Altrincham	10/2/70	7
Mr. N. A. Brandon Inspectorate of Fighting Vehicles and Mechanical Equipment. Kidbroke	20/8/69	11
Mr. C. Burgon Machine Tool Industry R.A. Macclesfield	24/3/70	3
Prof. J. Cherry Cranfield Institute of Technology. Production Department	14/1/70	8
Mr. P. Cooke Cranfield Unit of Precision Engineering.	16/6/69	11
Mr. G. Coultas Skefco Ball Bearing Co. Ltd. Luton	3/3/70	4
Mr. J. Dinsdale Cranfield Unit of Precision Engineering.	26/6/69	10
Mr. H. J. Elton Inspectorate of Fighting Vehicles & Mechanical Equipment. Kidbroke	16/6/69	11
Mr. G. H. Farnworth Loughborough University of Technology. Department of Industrial Engineering and Management	16/6/69	11
Mr. P. J. Few Skefco Ball Bearing Co. Ltd. Luton	3/3/70	4
Dr. L. Finkelstein City University. Department of Automation Engineering	14/1/70	8
Mr. A. Flett Molins Ltd. High Wycombe	22/4/70	2
Mr. P. W. Harrison National Physical Laboratory. Division of Optical Metrology	16/6/69	11
Mr. D. G. Hjertzen Skefco Ball Bearing Co. Ltd. Luton	3/3/70	4
Mr. K. Kirk A. A. Jones & Skipman Ltd. Leicester	14/1/70	8
Mr. G. Knight Rolls-Royce Ltd. Hillington	24/3/70	2

	Date first output sent	No. of outputs sent
Mr. R. L. Knowles Rolls-Royce Ltd. Derby	16/6/69	11
Mr. J. D. Lane Cranfield Unit of Precision Engineering.	14/1/70	8
Mr. L. Lindsay Machine Tool Industry R.A. Macclesfield	24/3/70	4
Mr. K. J. Marsh National Engineering Laboratory.	2/1/70	8
Mr. S. Nolian Advanced School of Automobile Engineering. Cranfield Institute of Technology	10/2/70	7
Mr. I. G. Morgan National Physical Laboratory. Division of Quantum Metrology	26/6/70	11
Mr. A. Munday University of Southampton	14/1/70	8
Mr. L. W. Nickols National Physical Laboratory. Metrology Division	2/1/70	8
Mr. H. Ogden Ferranti Ltd. Dalkeith	16/6/69	11
Mr. F. L. Oswald Scientific Instruments R.A. Systems Group	2/1/70	8
Mr. P. Pandy Machine Tool Industry R.A. Macclesfield	24/3/70	4
Prof. J. Peklenik University of Birmingham. Department of Mechanical Engineering	26/6/69	11
Mr. J. C. Rae Rolls-Royce Ltd. Hillington	26/6/69	11
Dr. W. B. Rowe Lanchester College of Technology.	10/2/70	7
Mr. W. R. C. Rowley National Physical Laboratory.	3/3/70	6
Mr. C. Rubenstein University of Manchester Institute of Science and Technology. Department of Mechanical Engineering	2/1/70	8
Mr. B. A. J. Rule Newall Engineering Co. Ltd. Peterborough	16/6/69	11
Mr. M. R. Sinclair Skefco Ball Bearing Co. Ltd. Luton	3/3/70	4

	Date first output sent	No. of outputs sent
Mr. D. A. Smith University of Leeds. Industrial Unit of Tribology	16/6/69	11
Mr. F. M. Stansfield Machine Tool Industry R.A. Macclesfield	3/3/70	6
Prof. S. A. Tobias University of Birmingham. Department of Mechanical Engineering	16/6/69	11
Mr. T. West Paisley College of Technology. Department of Production Engineering	16/6/69	11
Mr. W. J. Wills-Moren Cranfield Unit of Precision Engineering	14/1/70	8
Mr. R. G. Woolacott National Engineering Laboratory. Machinery Group	2/1/70	8
Mr. G. Sweeney Machine Tool Industry R.A.	24/3/70	4

APPENDIX E

LIST OF PERIODICALS REGULARLY SCANNED

Advances in Machine Tool Design & Research
Aeronautical J.
A. I. A. A. J.
American Machinist
Annals C. I. R. P.
Automation
Automation and Remote Control

British Plastics
Brown Boveri Review
Bulletin J. S. M. E.

Canadian Machinery and Metalworking
Chartered Mechanical Engineer
Control
Control and Instrumentation
Control (Engineering)
Cryogenics

Design Engineering
D. I. S. A. Information

E. D. N.
Electrical Review
Electronic Design
Electronic Engineering
Electronics
Electronics & Power
Electronics Letters
Electro-Technology
Engineer
Engineering
Engineering Fracture Mechanics
Engineering Materials & Design (E. M. & D.)
Engineer's Digest
Environmental Engineering
Esher Wyss News
Experimental Mechanics

Fluid Power International
Fluidics International
Fluidics Quarterly

Hydraulics/Pneumatics

IBM J. Research & Development
Industrial Diamond Review
Instrument & Control Engineering
Instrument Practice
Instrument and Control
Instrument Technology

Instruments & Control Systems
International J. of Control
International J. Machine Tool Design & Research
International J. Mechanical Sciences
International J. Production Research
Iron & Steel
Iron Age

Jena Review
Journal Astronautical Sciences
Journal Mechanical Engineering Science
Journal Mechanisms
Journal Metals
Journal Physics E - Scientific Instruments
Journal Sound and Vibration
Journal Spacecraft and Rockets
Journal Strain Analysis

Lubrication Engineering

Machine & Tool Blue Book
Machine Design
Machine Tool Review
Machinery (N. Y.)
Machinery and Production Engineering
Machinery Market
Machines & Tooling
Mass Production
Measurement and Control
Mechanical Engineering
Metal Construction & British Welding J.
Metal Progress
Metallurgia
Metalworking Production
Metrology & Inspection
Microelectronics and Reliability
Microtecnic
Modern Plastics

Plastics
Precision Metal
Product Engineering
Production Engineer

Quality Engineer
Quality Progress

Review Scientific Instruments
Russian Engineering Journal

S. A. E. J.
Sheet Metal Industries
S. I. R. A. Review

Steel
Systems Technology

Tool & Manufacturing Engineer
Tooling
Tooling & Production
Transactions A.S.L.E.
Transactions ASME - J. Applied Mechanics
J. Basic Engineering
J. Engineering for Industry
J. Lubrication Technology
Tribology

Wear
Welding & Metal Fabrication
Welding Engineer

APPENDIX F

LIST OF REQUEST PROFILES

(Interests as stated by the user)

Request Profile Number	Statement of Interests	Search Profile Number
R1	Most aspects of tribology. The metrology and structure of surfaces and their manufacture.	S1
R2	Accuracy of manufacture of gears and involute profiles - Methods of measurement.	S2
	Measurement and interpretation of surface finishes on machined components.	S1
	Lead screw technology	S3
	Lubrication, boundary and hydrodynamics of machine elements operating with thin films and small clearances.	S4
R3	The stability of gas lubricated bearings	S4
R4	Precision grinding	
	Abrasive machinery and high speed grinding	S5
	Numerical control as applied to grinding machines	
	Air and hydrostatic bearings	S6
R5	Infra-red	S7
R6	Direct computer control of machine tools; the equipment and applications to component manufacture	S8
	Part programming, post processors, system details	
	Stepping motors, applications to machine tools	S9
R7	Precision mechanisms	S10
	Structures	S11
	Hydro-mechanical amplification	S12
	Measuring instruments and machinery	S13
	Positional transducers	S14
	Hydrostatic bearing - oil and air	S6
R8	Finish machining - metal cutting - grinding - machinability - tool life, economics of machining - tool materials. Pre-set tooling	S15
R9	Production engineering and machine tools -medium/large batch precision manufacture - Metal forming, turning, grinding, finishing, assembly, inspection - mainly automatic	S16
R10	Control systems, generally using electronics, to control motor, etc. in positioning moving elements at the desired spot with a very high degree of precision	S17
R11	The measurement during production of formed and machined parts. This includes production from numerically controlled and conventional machines.	
	Information on "in-built" measuring devices in production machines - design and development of equipment using new measuring techniques e.g. lasers - long measurement	

	techniques up to 30' - high precision of small parts, e.g. gears, etc.	S18
R12	Numerical control of machine tools, economic and technical aspects	S19
	Machinability, economic and technical aspects	S15
R13	Vibration analysis and control	
	Tribological aspects:- load capacity of and friction in bearings	S4
	Rigidity of machine parts:- shafts; bearing housings	
R14	Instrument control	
	Automatic inspection	
	Precision measurement of dimensions and statistical treatment of errors	S20
R15	All aspects of high precision machine tools	
	Alignment testing of machine tools	
	Dynamic performance of machine tools	
	Measuring methods - machine tool accuracy and alignment	S21
	Identification of error sources in machine tool manufacture	
	Identification of error sources in controlled machine tool operation	
	Adaptive control	
R16	Engineering metrology (the science of the measurement of length and angle in all its forms) with particular reference to optical techniques having an industrial application.	S22
R17	The application of rolling bearings to work spindles of all types of precision m/c tools	S6
	Hydrostatic bearings applied to rotating work spindles and slides (linear). Lubrication of high speed spindles.	
R18	Metrology	S23
	Quality control	S24
R19	N.C. machine capability and accuracy assessment	S21
	Developments in co-ordinate measuring machines.	S25
R20	Control systems (a) As applied to numerical control machine tools	
	(b) Manufacturer's hardware description's	
	Adaptive controls (a) For numerical control machine tools	S26
	(b) Techniques for optimizing metal removal	
R21	Large scale manufacturing techniques in precision engineering.	S6
	The mass production of hydrostatic and air bearings and their applications, the various philosophies of machine tool design, ergonomics and other aids to more precise movement and control in metal manipulation.	S16
R22	Machine tool foundations, design, etc. Performance of bolts embedded in concrete.	
	Structural analysis, particular reference to finite element methods.	

	Cross-sectional properties of structural elements (beams) in torsion and shear.	S27
	Fabrication (welding), forging, casting, of ferrous materials. Developments and engineering metallurgy of these processes.	S28
	Developments in alloys of magnesium and aluminium and in reinforced plastics	S29
R23	The fatigue strength of materials and structures. In particular the following aspects of metal fatigue: 1. Fatigue under varying stress amplitudes (cumulative damage). 2. Fatigue of structures or components under random or service-recorded stress histories. 3. Fatigue crack propagation. 4. Fatigue of vessels under cyclic internal pressure.	S30
R24	Mechanisms - also appears as machine elements, theory of machines, dynamics of machines, machine design, kinematics, linkages, mechanical linkages.	S31
R25	Measurement of linear dimensions, angle, geometrical form, surface finish, at all levels from workshop to standards laboratory. Theoretical and practical aspects of techniques, instruments and standards for such measurements. Behaviour of engineering materials, e.g. elastic deformation, thermal deformation, affecting accuracy of measurement and accuracy of machinery.	S32
R26	Precision boring machines Single point cutting tools (particularly diamonds)	S33
R27	Engineering metrology Design of measuring instruments New measuring techniques	S34
R28	Numerical control, particularly N.C. measurement, linear and rotational; read-out, print-out, and on-line computer facilities. In-process measurement Inspection and measurement engine Optical grating manufacture	S35 S36 S37
R29	Design of precision machanisms Fine movements Flexure devices Precision linear and pivot bearings Fine mechanics Precision manufacturing techniques Precision optical engineering Metrology - roundness and geometric form measurement surface metrology	S31 S16 S38 S23
R30	Use of hydraulics in control of machine tools Design and operation of such control systems Bearings for machine tools. Design and performance of all types.	S12 S6

	Materials for machine tool slideways, selection and wear properties.	S39
R31	Theory of accuracy and accuracy problems in production Accuracy of machine tools, particularly N.C.-controlled gauging in-process systems.	S40
R32	The measurement and inspection of aero space production components on a 1-off, semi-automatic or fully automated basis. Any information relating to control of manufacturing engineering components. e.g. 1. Systems of in-process control of machines 2. Quality controls applied to any type of numerical control machine tools 3. Information relating to process controls and quality control systems as applied to high energy rate forming of metals.	S41 S42
R33	Grinding and grinding machine design and Bearings Particularly centreless grinding machines	S6 S5
R34	Precision measurement of linear dimensions, particularly by interferometry	S22
R35	Mechanics of cutting process - static and dynamic wear mechanisms in cutting Mechanism of metal removal in grinding Workhardening and surface integrity after machining.	S15
R36	Metrology Inspection Machine-tool alignments Machine-tool accuracy Laser interferometers. Their development and use in the engineering laboratory and workshop. Metrication	S43 S21 S44
R37	Quality engineering Fluidics Measuring methods	S24 S45 S23
R38	Total application to gas bearings and rolling bearings: surface finish roundness dimensional tolerances Flat surfaces: surface finish, roughness, production of flat surfaces, measuring surface roughness.	S6 S1
R39	The relationships found to exist, by experimental and theoretical methods, between the features of the design of manual and N.C. machine tools and their performance characteristics, with particular respect to accuracy of position and motion, short term repeatability and long-term stability. Features of design which might be of interest are those affecting structural stiffness, thermal distortion, wear. Also of interest are the comparative performance of machanisms, measuring devices and control systems.	S46

R40	Grinding process, use of higher wheel speeds. Effect on machine design. Guarding of wheels.	S5
R41	General interest in the more fundamental aspects of manufacture, in particular machine tool design, computer-aided design, static and dynamic behaviour of machine tools, automation, N/C control. All aspects of forming, with particular reference to high speed processes as applied to forging, cold forming, sheering, cropping, blanking, compaction.	S27 S19 S20
R42	Fluidics: technology of Pneumatics Hydraulics special circuits Metrology: advanced techniques Design: new devices (mechanical)	S47 S23 S31
R43	High precision manufacturing measuring techniques including - The design of high precision machine tools and measuring machines. The metrology of large machines with particular reference to dimensional stability problems. Machine tool measuring systems.	S35 S16
R44	The design of mechanical engineering plant, machines, assemblies, details with especial reference to the use of computers and associated equipment. Specific interest in plain bearing design.	S40

APPENDIX G

LIST OF SEARCH PROFILES

Search Profile Number	Title	Refers to request profile
S1	Flat surfaces (finish, production, measurement, tribology)	R1 R2 R38
S2	Gears and involute profiles (accuracy of manufacture and methods of measurement)	R2
S3	Lead screw technology	R2
S4	Bearings, shafts, housings, machine elements, (tribology, rigidity, vibration)	R2 R3 R13
S5	Grinding (process, machine, design, high wheel-speed, wheel guarding, centreless)	R4 R33 R40
S6	Bearings (hydrostatic, air, gas, spindles, lubrication)	R4 R7 R17 R21 R30 R33 R38
S7	Infra-red	R5
S8	Direct computer control of machine tools	R6
S9	Stepping motors	R6
S10	Precision mechanisms (not theory)	R7
S11	Structures (machine tools, not theory or beams etc.)	R7
S12	Hydro-mechanical amplification (particulary its use in control of machine tools)	R7 R30
S13	Measuring instruments and machinery	R7
S14	Positional transducers	R7
S15	Machinability, economic and technical aspects (machining, cutting, grinding, tools)	R8 R12 R35
S16	Precision production and manufacturing techniques (large scale, machine tools, assembly, inspection)	R9 R21 R29 R43
S17	Control systems for accurate positioning (generally using electronics)	R10
S18	Engineering metrology, measurement techniques, transducers	R11
S19	Numerical control of machine tools	R12 R41
S20	Precision measurement of dimensions (instrument control, automatic inspection) and statistical treatment of errors	R14

S21	Machine tool accuracy, alignment, performance	R15 R19 R36
S22	Engineering metrology (particularly optical and interferometry techniques)	R16 R34
S23	Engineering metrology (particularly roundness and geometric form measurement, surface metrology)	R18 R29 R37 R42
S24	Quality control	R18 R37
S25	Co-ordinate measuring machines	R19
S26	Control systems and adaptive controls for numerical control machine tools (hardware, metal removal techniques)	R20
S27	Machine tool design and behaviour (structural analysis)	R22 R41
S28	Forming and fabrication processes (high speed, engineering metallurgy)	R22 R41
S29	Alloys (magnesium and aluminium) and reinforced plastics	R22
S30	Fatigue strength of materials and structures (metal fatigue, cracks, fracture)	R23
S31	Mechanisms and mechanical devices (design)	R24 R29 R42
S32	Engineering metrology, standards, metrication, and accuracy of measurement (thermal, elastic and wear effects)	R25
S33	Precision boring machines and single point cutting tools	R26
S34	Engineering metrology (design of measuring instruments, new measuring techniques)	R27
S35	Numerical control (measurement)	R28
S36	Dimensional inspection and measurement	R28 R43
S37	Optical gratings (manufacture)	R28
S38	Precision optical engineering	R29
S39	Machine tool slideways (materials, wear)	R30
S40	Accuracy (theory, production, machine tools, NC - controlled gauging in-process systems)	R31
S41	Quality controls (NC machine tools, high energy rate forming of metals)	R32

APPENDIX H

TITLE AND REFERENCE OF DOCUMENTS 1-214

1 Problems of undercarriage design for VSTOL Aircraft
Aeronautical Journal, 1969, Feb., p. 157

2 All-weather operation for helicopters: Flight control system for helicopters
Aeronautical Journal, 1969, Feb., p. 129

3 Development of the Buccaneer
Aeronautical Journal, 1969, Feb., p. 111

4 Aerodynamic design
Aeronautical Journal, 1969, Feb., p. 101

5 Production engineering in the pump industry
Machinery Market, 1969, Feb. 27th, p. 27

6 An up-to-date look at magnetic forming
Metalworking Production, 1969, Feb. 6th, p. 64

7 Vibration wastes diamonds
Metalworking Production, 1969, Feb. 26th, p. 61

8 Family grouping on the transfer line
Metalworking Production, 1969, Feb. 26th, p. 58

9 NC joins with electron beam welder
Metalworking Production, 1969, Feb. 26th, p. 53

10 Effect of size factor on condition of machined surfaces
Russian Engineering Journal, 1968, (1) p. 78-79

11 Grinding the new high-alloy roll steels
Russian Engineering Journal, 1968, (1), p. 76

12 Optimum steel grinding speeds and feeds using synthetic diamond wheels
Russian Engineering Journal, 1968, (1), p 73

13 Determining the axial dimensions of gap gauges
Russian Engineering Journal, 1968, (1), p. 59

14 Improving the characteristics in selective assembly
Russian Engineering Journal, 1968, (1), p. 54

15 Increasing the contact of steel gears by electrolytic polishing
Russian Engineering Journal, 1968, (1), p. 44-45

16 Wear on ball bearings working in an aqueous medium
Russian Engineering Journal, 1968, (1), p. 36-39

17 Helical gear transmissions with thrust collars
Russian Engineering Journal, 1968, (1), p. 31-34

18 Optimum surface finish on centrifugal pump flow channels
Russian Engineering Journal, 1968, (1), p. 27

19 Characteristics of counter-rotation conditions of single-stage torgue converters
Russian Engineering Journal, 1968, (1), p. 22

20 Construction and design features of a high torgue hydraulic motor
Russian Engineering Journal, 1968, (1), p. 18-21

21 Probability strength calculation under steady cyclic loading and fatigue similarity conditions
Russian Engineering Journal, 1968, (1), p. 12

22 Use of friction and wear in developing component design
Russian Engineering Journal, 1968, (1), p. 6

23 Oceanology's brave show underlines need for stronger action
Engineer 1969, Feb. 21st, p. 276

24 How to use the new guide to sintered carbides
Metalworking Production, 1969, Feb. 19th, p. 59

25 Mould making developments
British Plastics, 1969, Feb., p. 83-84, 87-90

26 Plastics coating of metal components
British Plastics, 1969, Feb., p. 51-55

27 Low heat capacity carbon thermometers
Cryogenics, 1969, Feb., p. 60

28 Dual-slope intergrator-comparatorless, a d converter
Control, 1969, Feb., p. 141

29 Pseudo-random signal testing applied to a diesel engine
Control, 1969, Feb., p. 137

30 Thermal characteristics of the printed motor
Control, 1 69, Feb., p. 134

31 Novel high-resolution optical pressure sensor
Control, 1969, Feb., p. 124-128

32 Harmonic and transient behaviour of an electrohydraulic servo-mechanism test rig
Control, 1969, Feb., p 118-123

33 Actuators for every industry
Engineering, 1969, Feb. 29, p 362

34 Training with a two-shaft gas turbine
Engineering, 1969, Feb. 28, p. 358

35 Determining centre of flexure of uniform bar of asymmetric cross section
Engineer, 1969, Feb. 28, p. 328

36 N.C. drafting machine draws aircraft components
Engineer, 1969, Feb. 28, p. 324

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Electrical Review Supplement, 1969, Feb. 28, p. 23-24, 927

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Electrical Review Supplement, 1969, Feb. 28, p. 36, 39, 40

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Electrical Review Supplement, 1969, Feb. 28, p. 30, 35, 36

40 Magnetic bearing system for meters
Electrical Review, 1969, Feb. 28th, p. 304

41 Calibrating fluorescent tubes with tungsten lamps
Electrical Review, 1969, Feb. 28th, p. 312

42 The ACE thyristor
Electrical Review, 1969, Feb., 28, p. 305

43 High precision lens construction Symposium
SIRA Review, 1969, Feb., p. 33

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SIRA Review, 1969, Feb. p 18

45 An automatic test set for instrument evaluation
SIRA Review, 1969, Feb., p 5

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Cryogenics, 1969, Feb., p. 58

47 Superconducting manometers for high pressure measurement at low temperature
Cryogenics, 1969, Feb., p. 53

48 Cryostats for measuring electrical, thermoelectric galvana and thermomagnetic properties
Cryogenics, 1969, Feb., p 51

49 A wide-range sub-millimetre radiospectrometer for studying absorption in solids at liquid helium temperature
Cryogenics, 1969, Feb., p. 39

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Cryogenics, 1969, Feb., p. 32

51 Cryoelectronics
Cryogenics, 1969, Feb. p. 20

52 The control of flow
Engineering, 1969, Feb. 21. p. 326

53 Engine for any fuel - will it work?
Engineering, 1969, Feb. 21, p. 313

54 Close look at the sun
Engineering, 1969, Feb. 21, p. 309

55 Silencing induction motors
Electrical Review, 1969, Feb. 21, p. 269

56 Noise measurement techniques inadequate at design stage
Electrical Review, 1969, Feb. 21, p. 273

57 Developments in transducers
Electrical Review, 1969, Feb. 21, p. 267

58 Electronic metronome using a novel frequency divider
Electronic Engineering, 1969, Feb., p. 224

59 Pulse delay circuit suitable for triggering thyristors
Electronic Engineering, 1969, Feb., p. 211

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Electronic Engineering, 1969, Feb , p 209

61 Simple temperature compensation of large rectangular waveguide resonant cavities
Electronic Engineering, 1969, Feb., p. 198-199

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Engineer, 1969, Feb. 14, p. 252

63 Automobile engineers discuss transport and engines
Engineer, 1969, Feb. 14, p. 244

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Brown Boveri Review, 1968, Sept., p. 496

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Brown Boveri Review, 1968, Sept, p. 491

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Brown Boveri Review, 1968, Sept., p. 478

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Brown Boveri Review, 1968, Sept., p. 469

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Machine-Tool Review, 1968, Nov/Dec. p. 304-307

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Machine-Tool Review, 1968, Nov./Dec. p. 290-293

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Machine-Tool Review, 1968, Nov./Dec. p. 270

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Plastics, 1969, Feb., p. 186-188

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J. Sound & Vib. 1969, Jan., p. 65-79

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J. Sound & Vib. 1969, Jan., p. 59-64

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J. Sound & Vib. 1969, p. 53-58

76 On the study of a third-order mechanical oscillator
J. Sound & Vib., 1969, Jan., p. 49-52

77 The response of a supersonic transport fuselage to boundary layer and to reuerberant noise
J. Sound & Vib. 1969, Jan., p. 6-20

78 A note on the radiation froma circular piston in a plane wall
J. Sound & Vib., 1969, Jan., p. 1-5

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Inst. J. Mech, Sic., 1969, Feb., p. 209-215

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Inst. J. Mech. Sci., 1969, Feb., p. 199-207

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International Journal of Mech. Sci. 1969, Feb., p. 175-186

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Metalworking Production, 1969, Feb. 12, p. 39

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Metalworking Production, 1969, Feb. 12, p. 51

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Metalworking Production, 1969, Feb. 12, p. 46

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Metalworking Production, 1969, Feb. 12, p. 43-45

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Instrument & Control Engineering, 1969, Feb., p. 36-39

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Advances M.T.D.R., 1966, 7, p. 369

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Advances M.T.D.R., 1966, 7, p. 351

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Advances M.T.D.R., 1966, 7, p. 335

93 The investigation of linear rolling slides by means of digital computation
Advances M.T.D.R., 1966, 7, p. 299

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Advances M.T.D.R., 1966, 7, p. 273

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Electronics Letters, 1969, Feb. 6, p. 57

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Machinery (Production Engineering), 1969, Feb. 12, p. 267

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Machinery (& Production Engineering), 1969, Feb. 12, p. 264

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International Journal Control, 1969, March 9, (3) p. 267-279

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Automation & Remote Control, 1968, March, p. 520

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Automation & Remote Control, 1968, March, p. 516

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Automation & Remote Control, 1968, March, p. 511

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Electronics, 1969, Jan. 20, p. 91-96

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J. Scientific Instruments, 1969, Feb., p. 191

109 Semiconductor nuclear particle detectors
Instrument Practice, 1969, Feb., p. 113

110 Detection of faint luminous flux by means of electron photomultipliers
Microtecnic, 1967, (4) p. 411 (5) (6) p. 591

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Sheet Metal Industries, 1969, Jan. p. 41 1969, Feb. p 131

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Sheet Metal Industries, 1969, Feb., p 119

113 Development and use of an abrasion test for cast-irons and steels
Iron & Steel, 1969, Feb., p 57

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Production Engineer, 1969, Feb , p 69-82

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Production Engineer, 1969, Feb., p. 55

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Electronics & Power, 1969, Feb., p. 59

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Electronics & Power, 1969, p. 56-58

118 Dry reed uniselector with retentive memory
Instrument Practice, 1969, Feb., p. 131

119 Tiltmeter goes to the field
Electronics, 1969, Feb. 3, p. 147

120 The pots are not driftless, but they drift less
Electronics, 1969, Feb. 3, p. 141

121 Integrated solid state display needs no complex circuitry
Electronics, 1969, Feb. 3, p. 100

122 Bulk-effect modules pave way for sophisticated use
Electronics, 1969, Feb. 3, p. 94

123 Electron-beam testing: gentle and fast
Electronics, 1969, Feb. 3, p. 92

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Engineering, 1967, Feb. 7, p 236-238

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Engineering, 1969, Feb. 7, p. 217

128 Developing the d.c. linear motor
Engineer, 1969, Feb. 7, p. 197

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Engineer, 1969, Feb. 7, p. 207

130 Hoffman develops steel-ball assessor
Engineer, 1969, Feb. 7, p. 201

131 Asbestos as used in Engineering
Chartered Mechanical Engineer, 1969, Feb , p. 62

132 An apparatus for cutting large soluble crystals
J. Scientific Instruments, 1969, Feb., p. 210-211

133 Articulated vacuum line
J. Scientific Instruments, 1969, Feb., p. 215

134 A spherical cavity calorimeter for measuring absolute laser energies
J. Scientific Instruments, 1969, Feb., p. 215

135 A pressure transducer of the strain-gauged diaphragm type
J. Scientific Instruments, 1969, Feb., p. 218

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J. Scientific Instruments, 1969, Feb., p. 203

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J. Scientific Instruments, 1969, Feb., p. 143-145

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J. Scientific Instruments, 1969, Feb., p. 198

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J. Scientific Instruments, 1969, Feb., p 197

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J. Scientific Instruments, 1969, Feb. 1, p. 183-186

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J. Scientific Instruments, 1969, Feb., p. 178

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J. Scientific Instruments, 1969, Feb., p. 170

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Metalworking Production, 1969, Feb. 5, p. 55-58

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Metalworking Production, 1969, Feb. 5, p. 48, 50, 52, 53

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Electrical Review, 1969, Jan. 31, p. 161

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Electrical Review, 1969, Jan., 31, p. 159

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The Engineer, 1969, Jan. 31, p. 171

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Engineering, 1969, Jan. 31, p. 186

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Engineering, 1969, Jan 31, p. 170

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Metalworking Production, 1969, Jan. 29

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Metalworking Production, 1969, Jan. 19, p. 39

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Automobile Engineer, 1969, Feb., p. 50

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Automobile Engineer, 1969, Feb. p. 70

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Advances M.T.D.R., 1966, 7, p. 5-24

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Machinery (& Production Engineering), 1969, Jan. 29, p. 190-192

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Machinery, 1969, Jan. 8, p. 42-46, and 1969, Jan. 29, p. 162

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Control, 1969, Jan., p. 32

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Machinery (& Production Engineering), 1968, November, 13. p. 995

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Machinery (& Production Engineering), 1968, Dec. 25, p. 1284

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Industrial Electronics, 1968, Jan. p. 11

211 The readout revolution
American Machinist, 1968, April 22, p. 158

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J. Mech. Eng. Sc., 1968, October, p. 360-362

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J. Mechanism, 1968, 3 (2), p. 73-78

APPENDIX J

QUESTIONNAIRE SENT TO ALL USERS OF C.R.I.S.P.E. JUNE, 1970.

SECTION A

Your views of the service may be influenced by the other information services that are available to you. This first set of questions will help us to make any necessary allowances for this.

A1. Do you have access within your organisation to a library or information service which covers your particular subject interests.

( ) YES If "yes" please answer questions 2 and 3.
( ) NO If "no" please answer question 4.

A2. Is the information service located

( ) In the same building as your office.
( ) In a separate building within 100 yards
( ) In a separate building within 100-400 yards
( ) In a separate building more than 400 yards

A3. Does the information service issue and send to you any form of current-awareness service in your field (e.g. accession list or abstract bulletin)

( ) YES ( ) NO

A4. If you do not have an information service available to you within your organisation, from where would you obtain copies of relevant articles of interest to you.

_____
_____
_____
_____
_____

SECTION B

This set of questions ask for comments on the service which you have been receiving from us. If some questions raise the difficulty of whether you should be candid or polite, we would prefer that you should be candid.

B1. How useful has the service been to you?

( ) Most useful ( ) Useful ( ) Little use ( ) No use

B2. Regarding the references you have been receiving

( ) was the number reasonably satisfactory
( ) were too many references not relevant to your interest
( ) did you feel that important relevant references have not been sent to you.

B3. Has the receipt of the service brought to your attention periodicals of which you were previously unaware

( ) 5 or more ( ) 1-5 ( ) None

B4. Has the receipt of the service brought to your attention articles which proved to be of real value in your current work

( ) 5 or more ( ) 1-5 ( ) None

If "yes" could you give an example

B5. Have you passed on information from the service to any of your colleagues

( ) REGULARLY ( ) OCCASIONALLY ( ) NEVER

SECTION C

These questions relate to the setting up of an operational service which would be more comprehensive and in some respects better organised than the experimental service. If your answer to the first question is "no", there is no point in continuing with the other questions. If "yes", the following questions are intended to elicit the improvements you think would be helpful. The real crunch comes with the penultimate question.

C1. Assuming it was free, and improvements were made, would you wish to continue to receive the service

( ) YES ( ) NO

C2. The articles indexed have been restricted to English language journals. How important is it that the following additional types of literature should be included. (indicate in range: 1. very important 2. important 3. minor importance 4. not required)

( ) German language periodicals
( ) French language periodicals
( ) Russian language periodicals
( ) Other foreign language periodicals
( ) Patents
( ) Manufacturers' literature
( ) Conference papers
( ) Standards and Specifications

C3. With many articles the title gives little idea of the content (e.g. an article on Visual contour grinding called "kick the habit"). Such titles must at least be expanded as has been done with the current output that accompanies this questionnaire. Is this sufficient, or should there also be a brief abstract.

( ) Abstract required
( ) Abstract not required

C4. Assuming titles or abstracts are issued, would you prefer to receive them on separate cards, or listed on a sheet of paper?

( ) Cards ( ) List ( ) No preference

C5. What would be the maximum interval in sending output that you would consider acceptable?

( ) 4 weeks
( ) 3 weeks
( ) 2 weeks
( ) 1 week

C.6 If an operational service were established it would be on a cost-recovery basis. The cost would be related to the number of users, and you are therefore asked to say, for three possible types of service, the maximum figure for which you would be

prepared to recommend your organisation to place a subscription.

In all cases it is assumed that there would be a fortnightly service sending about 20 notifications each time. Please indicate the maximum price that would be acceptable for each type of service. This will, of course, in no way commit you, but will give us a lead on what cost figure is likely to be acceptable.

(a) A service issuing cards or lists of references having expanded titles.

( ) £0 ( ) £10 ( ) £15 ( ) £20 ( ) £25 ( ) £30

(b) A service issuing cards or lists of references with abstracts

( ) £0 ( ) £15 ( ) £20 ( ) £25 ( ) £30 ( ) £35

(c) A service issuing complete copies of all the articles

( ) £0 ( ) £20 ( ) £25 ( ) £30 ( ) £35 ( ) £40 ( ) £45

C.7 Do you dislike answering questionnaires? The presumed answer is yes, but if you have reached this far, please accept our most sincere thanks for your cooperation.

Any additional comments will be welcome.

K.1

COMPUTER TIME

Creation of Master File of Questions and Documents

A typical run time for the DEVIL system file update was 24 minutes for 240 documents, and 17 minutes for 10 documents (i.e. corrections). Typical times for each program are given below.

Program	CPU Time (mins)		Program loading and operator time (mins)	Total Run Time (mins)	
	240 documents	10 documents		240 documents	10 documents
DEV1 (Read data tape and partial validation)	2.3	1.0	2.0	4.3	3.0
INS1 (Sort)	2.5	1.5	4.5	7.0	6.0
INMX (Merge new records with master file)	2.8	2.7	2.0	4.8	4.7
DEVP (Print out)	5.7	1.0	2.0	7.7	3.0
				23.8	16.7

INS1 is particularly dependent on the operator as it involves a number of magnetic tape unloading and loading operations.

Validate and Edit

A typical run-time for DEV2 is 4.5 mins (3.0 min. CPU time plus 1.5 mins. program loading and operator time).

DEV2 validates and edits all the questions and documents on the master file, and the time quoted is for 50 questions and 1700 documents.

Document Search

A typical search of 50 questions (2500 profile terms) and 200 documents takes 40 minutes. This time is made up of 30 mins. CPU time, 9 mins.

program loading and operator time, and 1 min. set-up time.

Details of Timed Document Searches

Number of Documents D	Number of Profile Terms T	Number of Questions	Number of single descriptor matches	Number of extended matches	Number of Print Records	Total Search time (mins.)
226	133	3	1,232	1,575	428	18
1,460	133	3	7,246	9,367	2,692	25
226	2,189	43	4,004	21,270	7,083	39
238	2,368	48	4,072	21,674	7,797	40

Timing of Each Program

Program	CPU Time (Mins.)			
	T = 133 D = 226	T = 133 D = 1,460	T = 2,189 D = 226	T = 2,368 D = 238
DEV3 (Decide single descriptor matches)	1.85	2.15	6.0	6.90
INS2 (Sort matches)	1.52	2.50	1.9	2.00
DEV4 (Eliminate duplicate descriptors)	0.17	0.2	0.85	1.00
INS3 (sort descriptors)	1.30	1.26	1.63	1.60
DEV5 (Extend matches)	0.35	0.90	1.20	1.28
INS4 (Sort extended matches)	1.50	3.17	5.90	6.40
DEV6 (Decide Boolean matches)	0.38	0.76	1.77	1.96
INS5 (Sort print records)	1.33	1.83	2.65	2.67
DEV7 (Print results)	0.92	1.23	6.9	6.95

ESTIMATE OF SEARCH TIME FOR RETROSPECTIVE SEARCHING

(a) For search of 5,000 documents

Number of Questions	Total search time (mins.)	Cost per question (at £22.10.0d per hour)
1 (T = 50)	31	£11.12. 6d
3 (T = 150)	40	£5. 0. 0d
10 (T = 500)	68	£2.12. 6d

(b) For search of 10,000 documents

1 (T = 50)	46	£17. 0. 0d
3 (T = 150)	61	£7.12. 6d
10 (T = 500)	117	£4. 7. 6d

K4

COST OF INPUTTING ONE DOCUMENT READY FOR SEARCH

Indexing time	=	15 minutes Cost at 20/-d per hour	= 5/-d
Punching time	=	2.4 minutes Cost at 12/6d per hour	= 6d
Time for checking and amending flexowriter and computer printouts	=	0.5 minutes Cost at 20/-d per hour	= 2d
Computer time (if document is batched with 240 others, and allowing for one amendment run)	=	0.187 minutes Cost at £22.10.0d per hour	= 1/5d
		Total Cost	= 7/1d.

If no amendments are necessary, the computer time is reduced to 0.121 minute, and the cost becomes 11d per document.

There is a dramatic increase in computer time per document for a small batch of documents. Thus for a batch of 10 documents, the computer time per document $\simeq$ 2.2 minutes, and the cost becomes 16/6d per document.

The indexing time of 15 minutes per document is based on the fact that about 60% of all the articles scanned for possible inclusion (i.e. concerned with Precision Engineering) are rejected and not indexed, the average number of articles indexed per day being about 28.

K5

COST OF AN AVERAGE SEARCH PROFILE (approx 50 terms)

Time to write profile = 3 hours
Cost at 20/-d per hour = £3. 0. 0d

An analysis (based on the relevance decisions of 20 documents) and subsequent modification of the profile takes about $3\frac{1}{2}$ hours

* Assuming two analyses and modifications of the profile,
time = 7 hours
Cost at 20/-d per hour = £7. 0. 0d

Time for punching = 15 minutes
Cost at 12/6d per hour = 3. 1d

Computer time $\simeq$ 1 minute each time profile is read in, i.e. total time = 3 minutes
Cost at £22.10.0d per hr. = £1. 2. 6d.

Total Cost = £11. 5. 7d.

The computer time assumes that the profile is read in at the same time as 240 other documents. If one profile was read in on its own, it would take about 20 minutes before a search could be carried out, and the cost at £22.10. 0d per hour, would be £7.10. 0d.

* The time is based on clerical analysis.

Rank order by articles indexed	Periodical	No of articles indexed	No of relevant articles	Rank by relevant articles
1	Machinery & Production Engineering	164	148	1
2	Machines & Tooling	104	71	4=
3	Metalworking Production	97	94	2
4	American Machinist	59	75	3
	Russian Engineering J.	59	15	28=
6	Product Engineering	58	26	16=
7	Tooling and Production	57	71	4=
	Review of Scientific Instruments	57	10	36=
9	J. Physics E - Scientific Instruments	52	26	16=
10	Engineering	49	23	23=
11	Engineer	41	23	23=
12	Trans. ASME - J. Engineering for Industry	37	26	16=
13	Instrument and Control Systems	36	11	34=
14	Machine Design	33	24	22
15	Engineers' Digest	30	36	8=
16	Mass Production	28	25	19=
17	Instrument Practice	27	8	40=
	Experimental Mechanics	27	17	27
19	Industrial Diamond Review	25	32	11=
	Electronics	25	1	65=
	Hydraulics/Pneumatics	25	9	39
22	Electrical Review	24	11	34=
	Precision Metal	24	6	45=
24	Advances M.T.D.R.	23	32	11=
	Int. J. Mech. Sci.	23	8	40=
	Iron Age	23	31	14
	Int. J. of Control	23	6	45=
	Instrument and Control Engineering	23	21	25
	J. Mechanisms	23	37	7
30	Wear	22	10	36=
31	Machine and Tool Blue Book	21	15	28=
	Machine Tool Review	21	13	31=
	Canadian Machinery and Metalworking	21	12	33
34	Microtecnic	20	47	6
	Bulletin J.S.M.E.	20	3	54=
	Jena Review	20	36	8=
37	Electronic Engineering	19	1	65=
38	Machinery	18	12	33=
	Control Engineering	18	19	26
40	Control and Instrumentation	17	2	59=
	Metal Progress	17	1	65=
	Trans. ASME - J. Lubrication Technology	17	36	8=
43	Tribology	16	32	11=
44	Fluid Power International	15	4	53
	Quality Engineer	15	25	19=

Rank order by articles indexed		Periodical	No of articles indexed	No. of relevant articles	Rank by relevant articles
46	46	Instrumentation Technology	14	1	65=
		Lubrication Engineering	14	25	19=
		Welding and Metal Fabrication	14	6	45=
	49	Annals C.I.R.P.	13	8	40=
		Aeronautical J.	13	1	65=
		Automation	13	8	40=
		Automation and Remote Control	13	8	40=
		E.M. & D.	13	1	65=
		J. Sound and Vibration	13	0	77=
		Production Engineer	13	13	31=
	56	J. Mech. Eng. Sci.	12	6	45=
		Machinery Market	12	10	36=
	58	Electronics Letters	11	*	
		Int. J. Mach. Tool Des. Res	11	2	59=
	60	Metrology and Inspection	10	27	15
		E.D.N.	10	1	65=
		Mechanical Engineering	10	25	19=
		Metallurgia	10	3	54=
	64	Cryogenics	9	*	
	65	A.I.A.A. Jnl.	8	3	54
		Brown Boveri Review	8	*	
		Electro-Technology	8	2	59=
		Quality Progress	8	0	77=
	69	British Plastics	7	6	45=
		Electronic Design	7	1	65=
		J. Strain Analysis	7	*	
		Trans. ASME - J. Applied Mechanics	7	6	45=
		Trans. ASME - J. Basic Engineering	7	1	65=
		Modern Plastics	7	1	65=
	75	Iron and Steel	6	0	77=
		Metal Construction	6	*	
		Fluidics Quarterly	6	2	59=
	78	Environmental Engineering	5	*	
		SIRA Review	5	14	30
		Tool and Manufact. Engineer	5	7	44
	81	Czechoslovak Foreign Trade	4	5	51
		Electronics and Power	4	2	59=
		Int. J. Prod. Res.	4	*	
		J. Metals	4	1	65=
		Sheet Metal Industries	4	*	
		SAE Jnl.	4	0	77=
	87	Chartered Mechanical Engineer	3	2	59=
		J. Astronautical Sci.	3	*	
		J. Spacecraft and Rockets	3	*	
		Microelectronics and Reliability	3	*	
		Systems Technology	3	*	

Rank order by articles indexed	Periodical	No of articles indexed	No of relevant articles	Rank by relevant articles
87	Tooling	3	*	
93	Automobile Engineer	2	3	54=
	Design Engineering	2	*	
	DISA Information	2	*	
	Escher Wyss News	2	*	
	Engineering Fracture Mechanics	2	*	
	Fluidics International	2	*	
	Industry Week	2	3	54=
	IBM Jnl. Res. Dev.	2	*	
	Measurement and Control	2	*	
	Spaceflight	2	*	
	Sperry Rand Engineering Review	2	*	
	Steel	2	*	
	Welding Engineer	2	*	
	Soviet Jnl. Instrumentation and Control	2	*	
	Trans. A.S.L.E.	2	*	
108	Astronautics and Aeronautics	1	*	
	New Technology	1	*	
	Plastics	1	0	77=

* No articles from these journals were sent to the users in the sets from which this data is taken

APPENDIX M

PRECISION PERFORMANCE FOR INITIAL AND FINAL RUNS

Request Profile	INITIAL RUN Documents sent	Major relevance	Major & Minor relevance	FINAL RUN Documents sent	Major relevance	Major & Minor relevance
R1	16	3 (19%)	13 (81%)	20	5 (20%)	20 (100%)
R5	14	5 (36%)	8 (57%)	17	3 (18%)	8 (47%)
R6	16	1 (6%)	3 (19%)	20	3 (15%)	8 (40%)
R7	40	9 (23%)	28 (70%)	23	18 (78%)	23 (100%)
R10	7	2 (28%)	5 (71%)	18	4 (22%)	14 (78%)
R11	18	5 (28%)	10 (56%)	18	5 (28%)	9 (50%)
R12	28	17 (61%)	25 (89%)	21	6 (29%)	19 (91%)
R14	11	0 (0%)	4 (36%)	16	3 (19%)	10 (63%)
R16	13	2 (16%)	9 (69%)	16	3 (19%)	10 (63%)
R17	15	11 (73%)	14 (93%)	16	9 (56%)	16 (100%)
R18	14	2 (14%)	12 (86%)	21	0 (0%)	7 (33%)
R20	29	6 (21%)	23 (79%)	23	2 (9%)	16 (70%)
R21	17	13 (72%)	17 (100%)	24	23 (96%)	24 (100%)
R23	10	0 (0%)	6 (60%)	20	0 (0%)	5 (25%)
R24	11	2 (18%)	10 (91%)	17	6 (35%)	12 (71%)
R25	17	3 (18%)	8 (47%)	23	4 (17%)	12 (52%)
R26	11	3 (27%)	7 (63%)	17	3 (18%)	7 (41%)
R27	13	5 (38%)	13 (100%)	20	3 (15%)	9 (45%)
R28	32	5 (16%)	24 (75%)	20	2 (10%)	8 (40%)
R29	23	14 (60%)	20 (87%)	23	2 (9%)	15 (65%)
R30	16	13 (81%)	15 (94%)	19	16 (84%)	19 (100%)
R32	15	10 (67%)	13 (87%)	15	10 (67%)	13 (87%)
R33	21	14 (67%)	19 (90%)	21	16 (76%)	21 (100%)
R34	11	3 (27%)	7 (64%)	14	4 (29%)	10 (71%)
R36	23	10 (43%)	13 (57%)	20	8 (40%)	14 (70%)
R37	17	5 (29%)	10 (69%)	16	15 (94%)	16 (100%)
R38	20	5 (25%)	11 (55%)	18	17 (95%)	18 (100%)
R39	12	6 (50%)	12 (100%)	17	3 (18%)	15 (88%
R40	10	4 (40%)	9 (90%)	15	3 (20%)	12 (80%
R41	15	3 (20%)	11 (73%)	23	4 (17%)	14 (61%)
R42	18	8 (44%)	17 (94%)	19	6 (32%)	17 (90%)
R43	17	7 (41%)	17 (100%)	19	13 (68%)	18 (95%)
R44	13	6 (46%)	13 (100%)	23	13 (57%)	23 (100%)

APPENDIX N

Replies to Questionnaire
(see Appendix J)

QUESTIONNAIRE REPLIES

SECTION A

	A1		A2				A3		A4
	YES	NO	Same building	100 yds	100-400 yds.	more 400 yds	YES	NO	
R1	x				x			x	
R2	x		x				x		
R5	x		x					x	
R6	x		x				x		
R7	x				x		x		
R8	x			x			x		
R10	x			x			x		
R11	x		x					x	
R12	x				x		x		
R14	x				x			x	
R15	x					x	x		
R16	x		x		x		x		
R18		x							PERA
R19	x				x			x	
R20	x			x			x		
R21	x				x		x		
R23	x		x				x		
R24	x				x			x	
R25	x				x		x		
R26	x				x		x		
R28	x					x		x	
R29	x		x					x	
R30	x		x				x		
R31	x		x		x			x	
R32	x				x		x		
R33	x				x			x	
R34	x				x			x	
R36		x							MTIRA and PERA
R38	x		x				x		
R39	x		x				x		
R40	x		x				x		
R41	x		x			x		x	
R42	x			x				x	
R43	x				x		x		
R44	x					x	x		

SECTION B

	B1				B2			B3			B4			B5		
	Most useful	Useful	Little use	No use	No. Satisf.	Not Relev.	Relev. missed	5 or more	1 - 5	None	5 or more	1 - 5	None	Regul.	Occas.	Never
R1	x				x				x			x		x		
R2		x			x				x				x		x	
R5		x				x				x			x			x
R6			x			x				x		x		x		
R7		x			x				x				x		x	
R8	x				x			x			x			x		
R10		x			x		x		x			x		x		
R11			x		x				x						x	
R12			x		x					x			x			x
R14			x			x	x			x			x	x		
R15			x		x		x		x						x	
R16		x			x				x		x				x	
R18			x			x							x		x	
R19		x				x			x				x		x	
R20		x				x			x			x			x	
R21	x				x			x			x			x		
R23			x			x	x		x			x			x	
R24		x			x	x				x		x				x
R25		x			x					x	x				x	
R26		x			x	x			x				x	x		
R28			x			x		x					x		x	
R29	x				x				x				x		x	
R30		x			x		x			x		x			x	
R31			x			x	x			x	x				x	
R32		x				x			x				x		x	
R33		x			x					x	x				x	
R34			x		x			x				x			x	
R36			x		x					x		x			x	
R38		x					x		x				x			
R39		x				x	x			x		x		x		
R40		x			x					x	x				x	
R41		x			x				x				x	x		
R42			x		x				x			x				x
R43		x					x		x		x				x	
R44		x					x		x			x			x	
	4	19	12	0	21	13	10	4	18	12	8	12	13	9	21	4

SECTION C (1 - 5)

	C1		C2								C3		C4			C5			
	Yes	No	German	French	Russian	Other	Patent	Manuf.	Conf.	Stand.	Abstract	Not Abstract	Card	List	No Pref.	4 weeks	3 weeks	2 weeks	1 week
R1	x		3	3	2	3	4	4	2	4	x		x			x			
R2	x		11	4	1	3	4	4	1	4		x	x			x			
R5		x																	
R6	x		4	4	4	4	2	2	1	2	x		x			x			
R7	x		1	4	2	4	4	4	4	4		x			x		x		
R8	x		4	4	4	4	4	4	1	4		x	x			x			
R10	x		4	4	4	4	2	2	1	2	x		x			x			
R11	x		4	4	4	4	4	4	4	4		x	x			x			
R12		x																	
R14	x		1	2	1	3	4	4	1	4	x		x			x			
R15	x		2	3	3	3	2	4	1	2	x				x	x			
R16	x		2	2	3	3	4	4	3	4		x	x			x			
R18		x																	
R19	x		4	4	4	4	4	4	4	4		x		x		x			
R20	x		4	4	4	4	4	3	2	4	x				x	x			
R21	x		2	2	2	2	3	2	2	3		x	x			x			
R23	x		4	4	4	4	4	3	2	3	x				x	x			
R24	x		4	4	4	4	2	3	1	4	x		x			x			
R25	x		1	3	1	3	3	4	1	4		x	x			x			
R26	x		1	2	2	2	2	3	1	3	x		x				x		
R27	x		3	3	3	3	4	2	4	2	x				x	x			
R29	x		3	3	3	3	3	2	1	3		x	x			x			
R30	x		1	3	2	3	4	4	1	3	x				x	x			
R31	x		1	4	1	4	1	4	1	4		x	x			x			
R32	x		4	4	4	4	4	1	4	4	x			x		x			
R33	x		2	3	2	2	2	4	1	2		x				x			
R34	x		4	4	4	4	3	1	1	3		x		x		x			
R36	x		3	3	4	4	4	3	2	3	x			x		x			
R38	x		1	3	2	2	2	3	1	3		x			x	x			
R39	x		2	2	2	2	3	3	2	3	x		x			x			
R40	x		3	3	3	3	2	2	3	2	x		x			x			
R41	x		1	2	1	1	1	3	1	4	x		x					x	
R42	x		4	4	4	4	4	3	3	4		x			x	x			
R43	x		4	4	4	4	3	3	2	2	x		x				x		
R44	x		1	1	11	4	4	1	1	1		x		x		x			
	32	3	10-1 5-2 5-3 12-3	1-1 6-2 10-3 14-4	6-1 8-2 5-3 13-4	1-1 5-2 10-3 16-4	2-1 8-2 6-3 16-4	3-1 6-2 10-3 13-4	17-1 7-2 3-3 5-4	1-1 7-2 9-3 15-4	17	15	19	5	8	28	3	1	-

SECTION C6

	(a)						(b)						(c)						
	£0	£10	£15	£20	£25	£30	£0	£15	£20	£25	£30	£35	£0	£20	£25	£30	£35	£40	£45
R1			x							x								x	
R2					x					x			x						
R5	x						x						x						
R6	x						x						x						
R7		x						x								x			
R8			x				x								x				
R10		x							x				x						
R11				x			x						x						
R12	x						x						x						
R14	x						x						x						
R15	x							x					x						
R16					x		x						x						
R18	x						x						x						
R19		x								x									x
R20	x						x						x						
R21			x					x							x				
R23		x						x					x						
R24		x									x								x
R25						x					x					x			
R26		x							x					x					
R28	x								x									x	
R29		x					x						x						
R31	x						x						x						
R32	x						x							x					
R33	x						x						x						
R34		x						x							x				
R36	x						x						x						
R38		x					x							x					
R39	x											x	x						
R40		x							x									x	
R41	x							x						x					
R42			x						x				x						
R43		x						x							x				
R44		x						x							x				
R30	x						x						x						
	15	12	4	1	2	1	16	8	5	3	2	1	19	4	5	2	0	3	2

APPENDIX P

ADDITIONAL COMMENTS BY USERS

In my case I feel that my subjects of interest would have to be further refined to get real value from this service. A good approach to the problem of absorbing what is new is provided by this service.

20 abstracts every 2 weeks could become a nuisance. A more restricted 4 week service could be useful.

Question C6 of the enclosed questionnaire refers to the maximum price a user might consider acceptable for various grades of service. Unfortunately, at the present time, this is zero, though I hasten to add that this in no way reflects on the type of service you offer, but rather on the current financial climate.

I think that in a highly specialised field such as ours, it is to be expected that very little published material will contain information that has a striking effect - fortunately! Much of our reading will be for background, including information about the industries that furnish our customers.

It follows that a service such as you have in mind produces a higher number of interesting references than even regular reading of a limited group of journals, but the effect on our business efficiency can never be obvious.

Clearly references we have not seen will be mainly in journals we do not take, and I think that abstracts at least are necessary. Even an expanded title is likely to miss the elements of real interest in an article, and a copy service is a necessary adjunct of an abstracting service.

I have had to tick the 'no cost £0' service. I do not think that the Directors would agree to paying another source of information when these are already covered fairly efficiently by the services from our Trade Organisations.

The system as set up at present is quick and seems efficient, but I suspect a lot depends on the initial 'Profile' accuracy The scanning, not to mention the purchase of magazines and other literature has been reduced considerably by the use of this pilot scheme service

I trust it will be able to continue Thank you

Copies of articles are of far greater value than lists of titles, although copies on one side of a sheet do become very bulky

As I explained at the beginning of the exercise, my interests are not primarily in precision engineering Nevertheless I have found the service of value

I have found the service to be useful in saving me time in browsing literature for relevant articles In fact, I do not have the time and facilities to browse through all the periodicals of interest To be fair to the retrieval system, I think my interest 'profile' is not static This makes a problem which is most easily solved by your computer solution than a manual one

The main fault I have found is that the field of search seems too wide, i e a better interest-profile definition seems necessary There are far too many articles of negligible or no interest This did, however, seem to vary considerably from batch to batch, e g the present batch is quite good, one previous batch might have been aimed at another person' I would prefer fewer more relevant references

I feel this to be potentially a very useful service and would like to thank you for including me in the pilot stage

You will note that my answer to question B2 was that I felt that some relevant references had not been sent, and I feel that some explanation may be useful By this I mean that many of the references received were very relevant, but on reading the original article I tended to find equally important pieces in the same journal

My personal conviction, based on experience of several discoveries from literature, is that it would be better to spend an even higher amount on a current awareness service operating in close proximity to the staff using it. But I cannot find a convincing way of proving this - in fsd term!

I am not convinced that a general service can be adequately tailored to an individuals needs - needs which are changing continuously and fairly rapidly!

A college could not possibly afford a service like this for a number of people, however desirable!

In my opinion your service is very useful, however, I felt that the definition of the profile which you have been attaching to my interests is not as comprehensive as I would wish. Examining your cards and my own information retrieval system for papers, I noticed that I missed some vital announcements in your card service.

It might be desirable to organise a discussion at Cranfield where the people who have been obtaining your information service could discuss the various points which might improve the efficiency and optimise this type of service which I think is of great importance.

Thank you very much for providing me with your information service. I will always be glad to help you in any way possible.

You are good enough to ask for comments which are candid rather than polite. I think the type of service you are trying to set up is inherently limited in its usefulness, because the 'customer' cannot convey his requirements at all exactly. I pick up information and ideas from publications by browsing through the library, and I don't know whether an article or book will be useful to me until I have had a fairly good look at it. This is often because authors use a badly chosen title, or publish in an unsuitable publication, but here, of course, key words in the text will pick up the article if it is relevant. This, however, is only a small part of the difficulty; I get useful ideas by analogy from publications in fields quite unrelated to my own. My answers to the relevance forms are also bound to be misleading, because some of the documents you have sent me, although totally unrelated to my formal activity as a mechanisms specialist, are in fact of major interest to me for some other reason - sometimes just idle, but intense, curiosity. I don't know whether these comments apply generally, or just to my own way of going about my work.

APPENDIX R

ANALYSIS OF RELEVANT DOCUMENTS SEEN BY USERS BEFORE RECEIVING NOTIFICATION FROM THE S D I SERVICE

User	Major Relevance	Previously seen	Minor Relevance	Previously seen
R1	4	0	16	0
R2	7	0	7	0
R3	4	3	6	0
R5	3	0	5	0
R6	3	0	5	0
R7	18	0	5	0
R10	4	1	10	2
R11	5	3	4	0
R12	6	1	13	3
R14	3	0	7	0
R16	3	0	7	0
R17	9	1	7	0
R18	0	0	7	1
R20	2	1	14	1
R21	23	1	1	0
R23	0	0	5	0
R24	6	6	6	0
R25	4	1	8	1
R26	3	0	4	0
R27	3	1	6	0
R28	2	2	6	0
R29	2	0	13	0
R30	16	1	3	0
R32	10	0	3	0
R33	16	1	5	0
R34	4	0	6	0
R36	8	4	6	0
R37	15	1	1	0
R38	17	8	1	0
R39	3	0	12	0
R40	3	1	9	0
R41	4	0	10	0
R42	6	2	11	0
R43	13	0	5	0
R44	13	0	10	0
TOTALS	242	39 (16%)	244	8 (3 3%