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**THE EFFECT OF VARIATIONS IN RELEVANCE
ASSESSMENTS IN COMPARATIVE EXPERIMENTAL
TESTS OF INDEX LANGUAGES**

by

Cyril W. Cleverdon

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SUMMARY

It was desired to check whether the unexpected test results obtained in Cranfield II had been influenced by the relevance decisions. Three new sets of relevance decisions were therefore obtained, and the Cranfield II results were re-calculated for nineteen index languages on the basis of the new relevance judgements. A rank order of the index languages was found; in no case did the correlation co-efficient of any of the three new rank orders fall below 0.921 when compared with the original Cranfield II results.

The findings of a similar type of test by Lesk and Salton are considered, and the conclusion is reached that the results of Cranfield II had showed that the superiority of the single term index languages were not significantly affected by relevance judgements.

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Introduction

The evaluation of experimental, as opposed to operational, information retrieval systems first requires the establishment of an environment. In real life the minimum requirement for an IR system is a set of documents and one or more users, that is individuals for whom the document set can meet an information requirement. While it is relatively easy to obtain a set of documents that can be used in an experimental system, it is in practice, if not in theory, impossible to obtain a genuine group of users. There are obvious reasons for this; economically it is not possible to have a large and comprehensive set of documents, therefore potential users cannot be expected to become genuine users. The best that can be expected is to obtain a set of potential users who will simulate as closely as possible the actions which they would carry out in an operational system. These actions mainly consist of the formulating and stating of search questions, and judgements concerning the relevance of documents presented to them.

The simplest method of obtaining questions and relevance judgements is the "source - document question" technique originally used at Cranfield in 1953 (Ref. 1), but best known as the result of its use in Cranfield I (Ref. 2). The main developments and variations of this technique can be set out as follows:

Types of search questions

1. An actual question that is put to an information retrieval system and searched at the time it is required.
2. An actual question that has been put to an IR system. In other words, questions that have been used previously, either with the system being tested or some other system.
3. A prepared question, that is a question which has been composed specifically for the purpose of the test and is not a question which meets an actual need of the questioner. Such prepared questions may or may not be based on a particular document or documents.

Method of Relevance Assessment

- I By the questioner
- II By the consensus of opinion of a group of people
- III By an individual, not the questioner
- IV By matching the indexing with the search programme.

Type of Individual(s) Involved

- A User of a system
- B Scientific or technical staff, not users of the system
- C Librarians or other information staff.

If Type of Question is put against Method of Relevance Assessment, the various possibilities can be shown.

Method of Relevance Assessment

<u>Type of Question</u>		I	II	III	IV
	1	A A	A BC	A BC	A -
	2	AB AB	AB BC	AB BC	AB -
	3	ABC ABC	ABC ABC	ABC ABC	ABC -

In the chart, the upper half of each box represents the type of person asking the question, the lower half represents the type of person making the relevance assessment.

In Cranfield II (Ref. 3) the test set of questions was obtained by asking scientists to state questions which had been put to an IR system and to state which documents had been found to be relevant to these questions. From the table given above the question and assessment would be graded at (2B) (IB), which was considered to be as close as it was possible to get to the situation which exists in an operational environment, namely (1A)(1A). The test set of documents was largely made up of the documents which had been stated to be relevant to the set of test questions.

When the environment has been fixed, experimental tests must be so controlled that the effect can be measured of changing a single variable. Conversely, there is no point in carrying out a test in an artificial environment in which none of the variables is changed. In Cranfield II the main variable being investigated was the index language and 33 index languages were tested. For this to be done, all other variables had to be held constant; one set of indexing decisions was used throughout and the different index languages were applied to this basic set of indexing decisions. However, the test was so designed that it was possible to investigate other variables such as the level of the exhaustivity of indexing, but it was index

languages which were the main consideration.

The use of the measure "normalised recall" based on an adaptation of the measure originally used by Professor Salton (Ref. 4), permitted an order of merit to be established for the 33 index languages, and this is given in Figure I. Based on this measure, the results appeared to show that single terms in natural language, with only the minimum of control, performed better than any other method. Because this was completely unexpected, in fact the contrary of the original hypothesis, considerable effort was put into establishing whether the results could have been distorted by any factor or factors of the environment or by the measures used. In most areas it was possible to advance reasoned arguments, supported by results from other tests, to show that the environment could not have been responsible for the unexpected results; the only area for which at that time no experimental evidence existed was in relation to the relevance decisions. With Cranfield I it was difficult to argue that the use of source document questions had not affected the comparative results, but the increased control which had been introduced into Cranfield II made it seem improbable that the relevance decisions had played a significant part in determining the order of merit of the index languages. However, a suspicion remained that this might be the cause, so a proposal was made to investigate this matter; this report is an account of the resulting project which was supported by a grant from the Office of Scientific and Technical Information of the Department of Science.

Design of the Test

In Cranfield II, the main series of tests had been carried out on subsets of the original sets of documents and questions; these subsets, consisting of 200 documents and 42 questions (as given in Appendix I) were used in the present test. For each question there was a known group of relevant documents, varying in number from a minimum of 1 to a maximum of 12, with an average of 4.7 per question. The relevance of the documents had been determined in scale of 1 - 5 which was interpreted as follows:

- (1) References which are a complete answer to the question. Presumably this would only apply for supplementary questions, since if they applied to the main question there would have been no necessity for the research to be done.
- (2) References of a high degree of relevance, the lack of which either would have made the research impracticable or would have resulted in a considerable amount of extra work.
- (3) References which were useful, either as general background to the work or as suggesting methods of tackling certain aspects of the work
- (4) References of minimum interest, for example, those that have been included from an historical viewpoint.
- (5) References of no interest.

<u>ORDER</u>	<u>NORMALISED RECALL</u>	<u>INDEXING LANGUAGE</u>
1	65.82	I-3 Single terms. Word forms
X 2	65.23	I-2 Single terms. Synonyms
X 3	65.00	I-1 Single terms. Natural Language
X 4	64.47	I-6 Single terms. Synonyms, word forms, quasi-synonyms
X 5	64.41	I-8 Single terms. Hierarchy second stage
X 6	64.05	I-7 Single terms. Hierarchy first stage
7=	63.05	I-5 Single terms. Synonyms. Quasi-synonyms
7=	63.05	II-11 Simple concepts. Hierarchical and alphabetical selection
9	62.88	II-10 Simple concepts. Alphabetical second stage selection
X 10=	61.76	III-1 Controlled terms. Basic terms
X 10=	61.76	III-2 Controlled terms. Narrower terms
12	61.17	I-9 Single terms. Hierarchy third stage
X 13	60.94	IV-3 Abstracts. Natural language
X 14	60.82	IV-4 Abstracts. Word forms
X 15	60.11	III-3 Controlled terms. Broader terms
X 16	59.76	IV-2 Titles. Word forms
X 17	59.70	III-4 Controlled terms. Related terms
X 18	59.58	III-5 Controlled terms. Narrower and broader terms
X 19	59.17	III-6 Controlled terms. Narrower, broader and related terms
X 20	58.94	IV-1 Titles. Natural language
X 21	57.41	II-15 Simple concepts. Complete combination
22	57.11	II-9 Simple concepts. Alphabetical first stage selection
X 23	55.88	II-13 Simple concepts. Complete species and superordinate
24	55.76	II-8 Simple concepts. Hierarchical selection
X 25	55.41	II-12 Simple concepts. Complete species
26	55.05	II-5 Simple concepts. Selected species and superordinate
27	53.88	II-7 Simple concepts. Selected coordinate and collateral
28	53.52	II-3 Simple concepts. Selected species
X 29	52.47	II-14 Simple concepts. Complete collateral
30	52.05	II-4 Simple concepts. Superordinate
31	51.82	II-6 Simple concepts. Selected coordinate
32	47.41	II-2 Simple concepts. Synonyms
33	44.64	II-1 Simple concepts. Natural language

FIGURE 1. Order of Effectiveness based on normalised recall for 33 Cranfield Index Languages
(^XIndex languages used in present test)

In the project it was proposed to have relevance decisions made by three other people. It being a well-established fact that there is a significant variation (up to 10%) in relevance decisions when these are based on titles rather than on full text, it was considered essential that full text should be used. This decision affected the scale of the test, for it was impracticable to contemplate having staff working on this project full-time. Part-time staff might be expected to do, on a regular basis, about four hours each week, and preliminary tests showed that in this time it was possible to reach studied decisions of some 20 fringe documents. By the description "fringe documents" is implied documents which are at least on the border line of relevance. Clearly to reject as non-relevant, in relation to a question on aerodynamics, 20 documents dealing with Chinese vases would take only a minute; although in the main project all the documents in the test collection dealt with aerodynamics, yet for the trained aerodynamicist many could immediately have been rejected as non-relevant in relation to a specific question.

Two methods of obtaining a sub-set of 200 or so documents were considered; one method was to take all the documents judged relevant by the original questioners, add a number of non-relevant documents retrieved at high coordination levels and also non-relevant documents having a relatively high bibliographic coupling with known relevant documents. The alternative method would be for the relevance judge to read through the titles of the 200 documents in the test collection in relation to a given question and select about 20 that looked as though they might be relevant. This latter method was tried in preliminary tests, but not unexpectedly it was found that on the basis of titles, the assessors were rejecting documents that were relevant and which they would have accepted as relevant on the basis of the complete document. For this reason, the decision was taken to use the former method.

With 42 questions to be used, it was hoped that the first phase of the work would be completed within a year. The three persons who agreed to take part in the tests were Mr. T. Bateman, Senior Aerodynamicist at the Aircraft Research Association, Mr. E. J. MacAdam, formerly Librarian of the Aircraft Research Association, and Mr. G. Scott, a Research Fellow in the Department of Aerodynamics, at the College of Aeronautics.

Test Procedure

The first requirement was to prepare sets of documents to be assessed for relevance for each of the questions. This was done on the basis already mentioned, except that for each question two or three additional documents, taken at random from the complete collection, were added to the set. Over the range of 42 questions, the number of documents originally considered relevant varied from one to twelve for different questions; this variation was reflected in the test sets, which ranged from thirteen to twenty-nine, with an average of 19 documents per question. The document sets are given in Appendix II.

To Mr. Scott.

Date 26-3-68

Please find enclosed herewith the documents relating to question 118

Do the discrepancies among current analysis of the cavity effect on stagnation-point heat transfer result primarily from the differences in the viscosity

The following documents are included in this set

temperature law assumed

1324- 1378 - 1436 - 1437 - 1509 - 1575 - 1576 - 1666 -
1667 - 1670 - 1695 - 1707 - 1779 - 1880 - 1964 - 1978 - 2099
2100 - 2274 - 2319 - 2391

The relevance decisions should be made in accordance with the following definitions:

1. Documents which are a complete answer to the question.
2. Documents of a high degree of relevance.
3. Documents which might be useful, either as general background, work or as suggesting methods of tackling certain aspects of the work.
4. Documents of minimum relevance.
5. Documents of no relevance.

FIGURE 2. Question sheet for Q.118 for Scott.

Copies of the documents for a given question set were collected and a relevance assessment sheet attached to each document (Fig. 2); these were then sent to the assessor with a question sheet (Fig. 3), giving particulars of the search question and the documents. The assessors made their relevance judgements and in some cases added comments before returning the documents and assessment sheets. From these sheets the relevance decisions were extracted and recorded as in Fig. 4. (see also Appendix III).

Although in Cranfield II 29 index languages had been tested, it was not considered necessary to check every language in this test, and 15 index languages were selected. In addition to the above group of index languages, all of which were based on the same set of indexing decisions, Cranfield II had also tested the effect of substituting for the index entries the terms in titles or abstracts; these variations in indexing had been tested with single term natural language, and single term word forms, and provided a further four sets of results. In total, therefore, there were nineteen index languages or indexing variations to be considered as indicated in Figure 1.

As all the test data from Cranfield II was still available, it was a relatively straightforward, although somewhat tedious process, to estimate the results based on the new relevance decisions. As an example, we show the results for Question 118, using the new set of relevance decisions as made by Scott and MacAdam (Fig. 5). In Cranfield II, five documents (1324, 1378, 1666, 1667, and 1670) were considered relevant, and the coordination levels at which these documents were retrieved is shown in the first column, together with the number of non-relevant documents retrieved. Scott was in agreement concerning the relevance of four of these documents, but rejected 1378 as non-relevant. Whatever documents are judged relevant or non-relevant, the total number of documents retrieved at any coordination level must be the same, and therefore the only difference will lie in the proportion of relevant and non-relevant. With index language I.1, document 1378 was retrieved at a coordination level of 3, so at this stage there is a change as compared to the figures in the first column, and this continues at the lower coordination level. On the other hand, MacAdam accepted as relevant not only the original set, but a further ten documents, and the effect of this on the scoring can be seen in the third column.

This exercise was repeated for all 42 questions, for the 19 index languages, and for each of the three assessors; part of an index language result sheet is shown in Fig. 6 for index language I.1 in relation to the decisions by Scott. From such sheets, using the method considered at length in Chapter 6 of Ref. 3 the normalised recall ratio was obtained for each of the 57 cases. Briefly, the measure is a simplification of the computer-calculated measure originally devised by Salton. A simulated ranking is given to all the documents and 17 cut-off points for document

CRANFIELD PROJECT ON RELEVANCE DECISIONS

QUESTION No. 118

DOCUMENT No. 1670

RELEVANCE DECISION

1	2	3	4	5
	✓			

COMMENTS

This document is considered highly relevant because it deals specifically with the discrepancies referred to in the question.

FIGURE. 3. Example of document assessment sheet.

<u>Question 118</u>	<u>Cranfield</u>	<u>Scott</u>	<u>MacAdam</u>	<u>Bateman</u>
<u>Document</u>				
1324	3	3	2-3	3
1378	3	5	3	3
1436	5	5	4	2
1437	5	5	4	3
1509	5	5	4	4
1575	5	5	5	5
1576	5	5	4	3
1666	3	3	3	2
1667	2	3	3	2
1670	3	2	2	1
1695	5	5	5	5
1707	5	5	4	4
1779	5	5	5	5
1880	5	5	5	5
1964	5	5	5	5
1978	5	5	4	4
2099	5	5	4	4
2100	5	5	4	4
2274	5	5	4	4
2319	5	5	4	4
2391	5	5	2-3	2

FIGURE 4. Relevance decision for Question 118 by the three judges.

Coordination Level	Cranfield II		Scott		MacAdam	
	Rel.	N. R.	Rel.	N. R.	Rel.	N. R.
6+	0	1	0	1	1	0
5+	3	10	3	10	9	4
4+	3	17	3	17	12	8
3+	5	29	4	30	14	20
2+	5	49	4	50	15	39
1+	5	123	4	124	15	113

FIGURE 5 Comparative results for Q118 with Index Language I. 1.

Question	No. of Relevant Document	Co-ordination Level															
		1+		2+		3+		4+		5+		6+		7+			
		R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR		
170	1	1	110	1	45	1	18	1	6	1	1						
181	2	2	90	2	42	1	7										
182	3	3	163	1	47	1	5										
189	6	1	65	1	11	0	1										
190	6	5	164	5	46	4	11	3	0								
223	2	2	148	2	75	2	38	2	19	2	3	2	1	2	0		
224	2	2	50	2	67	0	29	0	3								
225	4	4	160	4	91	4	43	2	17	0	5						
226	9	9	58	6	17	5	1	4	1	2	0						
227	2	2	83	2	35	2	8	2	3	1	0	1	0				
239	5	5	44	2	0	1	0										
250	8	8	162	8	54	8	25	8	7	5	4	3					
261	3	3	132	3	35	3	14	3	6	3	1	3	1	2	1		
264	2	2	104	2	29	2	5	2	1	1	0	1	0	1	0		

FIGURE 6. Results sheet for Index Language I.1 based on relevance decisions by Scott.

output are selected. The recall ratio is calculated for each of these points, these are then summed, and when divided by 17 produce the normalised recall. Fig. 7 is an illustration of this in relation to index language I.1 for the three assessors. It will be noted that, in every case, the resulting final figure varies; this is due to the differing numbers of relevant documents and is in no way indicative of better or worse performance. The comparison that has to be made is not between the figures obtained for different sets of relevant documents, but between the different index languages for the same set of relevant documents.

Main Results

The normalised recall obtained for each assessor for all nineteen index languages is given in Fig. 8, together with the original results obtained in Cranfield II. The purpose of this test was to find whether these new sets of relevance decisions made any significant difference in the order of merit, as determined by the normalised recall, of the index languages. The rank order of each language is given in Figure 9, and in Figure 10 the index languages are rearranged in order of their ranking. Visually it can be seen that there is a strong correlation between the original ranking and each new set of rankings, but to determine the significance of these results, the Spearman rank-correlation coefficient is used. This is a function of the sum of the squares of the differences of the two rankings for each observation and the number of observations, so that

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where r_s = Spearman rank-correlation coefficient

d_i = difference between the rankings of the i th observation

n = number of observations.

The maximum value of r_s that would be expected by chance at the level of 0.01 with 19 observations is 0.538.

The rank-correlation between the various sets of relevance decisions is calculated from Figure 10 and is presented in Figure 11.

The figures appear to confirm the original hypothesis, namely that the relevance decisions did not significantly affect the comparative results of Cranfield II. The rank correlation never falls below 0.92; where there are comparatively large changes in the ranking, as with index language III.5 which rises from rank 13 with the original results to rank 8 for Scott, the actual difference in the normalised recall is small and an increase of 1.4% would have raised it to the eighth position in the original test. In Ref. 3 we suggested that it might be unwise to consider as

<u>Document Output Cut off</u>	<u>Scott</u>	<u>Bateman</u>	<u>MacAdam</u>
	<u>% Recall</u>	<u>% Recall</u>	<u>% Recall</u>
1	12.22	6.53	6.62
2	21.10	12.65	12.65
3	31.10	16.73	17.26
4	37.77	22.04	22.69
5	40.54	27.14	27.10
6-7	48.32	33.67	34.93
8-10	57.21	42.24	45.27
11-15	64.44	52.85	53.01
16-20	68.32	59.18	61.44
21-30	76.10	69.18	71.28
31-50	83.88	77.75	79.51
51-75	86.66	82.24	83.53
76-100	90.54	88.30	86.34
101-125	93.87	89.38	90.16
126-150	96.66	93.67	93.97
151-175	100.00	98.36	98.79
176-200	100.00	100.00	100.00
Normalised Recall	65.21	56.99	57.75

FIGURE 7 Normalised recall for three sets of relevance decisions
for Index Language I.1

	<u>Cranfield II</u>	<u>Scott</u>	<u>Bateman</u>	<u>MacAdam</u>
I. 1	65.00	65.21	56.99	57.75
I. 2	65.23	65.46	57.28	58.16
I. 6	64.47	65.91	57.78	57.98
I. 7	64.45	65.52	57.70	57.99
I. 8	64.41	63.12	55.48	55.79
II. 12	55.41	56.39	40.82	40.20
II. 13	55.88	55.74	43.75	42.56
II. 14	52.47	52.50	44.66	43.50
II. 15	57.41	58.06	49.13	49.10
III. 1	61.76	61.52	49.52	50.49
III. 2	61.76	61.49	49.24	50.50
III. 3	60.11	59.89	48.57	49.74
III. 4	59.70	59.66	48.78	49.52
III. 5	59.58	61.72	48.71	49.58
III. 6	59.17	60.96	48.99	49.66
IV. 1	58.94	60.22	44.92	45.14
IV. 2	59.76	61.23	45.57	45.40
IV. 3	60.94	62.96	52.38	52.96
IV. 4	60.82	62.40	52.15	52.71

FIGURE 8 Normalised recall ratios for four sets of relevance decisions

	<u>Cranfield II</u>	<u>Scott</u>	<u>Bateman</u>	<u>MacAdam</u>
I. 1	2	4	4	4
I. 2	1	3	3	1
I. 6	3	1	1	3
I. 7	4	2	2	2
I. 8	5	5	5	5
II. 12	18	17	19	19
II. 13	17	18	18	18
II. 14	19	19	17	17
II. 15	16	16	14	14
III. 1	6	9	8	9
III. 2	7	10	9	8
III. 3	10	14	13	10
III. 4	12	15	11	13
III. 5	13	8	12	12
III. 6	14	12	10	11
IV. 1	15	13	16	16
IV. 2	11	11	15	15
IV. 3	8	6	6	6
IV. 4	9	7	7	7

FIGURE 9 Rank order of index languages

Rank	<u>Cranfield II</u>	<u>Scott</u>	<u>Bateman</u>	<u>MacAdam</u>
1	I. 2	I. 6	I. 6	I. 2
2	I. 1	I. 7	I. 7	I. 7
3	I. 6	I. 2	I. 2	I. 6
4	I. 7	I. 1	I. 1	I. 1
5	I. 8	I. 8	I. 8	I. 5
6	III. 1	IV. 3	IV. 3	IV. 3
7	III. 2	IV. 4	IV. 4	IV. 4
8	IV. 3	III. 5	III. 1	III. 2
9	IV. 4	III. 1	III. 2	III. 1
10	III. 3	III. 2	III. 6	III. 3
11	IV. 2	IV. 2	III. 4	III. 6
12	III. 4	III. 6	III. 5	III. 5
13	III. 5	IV. 1	III. 3	III. 4
14	III. 6	III. 3	II. 15	II. 15
15	IV. 1	III. 4	IV. 2	IV. 2
16	II. 15	II. 15	IV. 1	IV. 1
17	II. 13	II. 12	II. 14	II. 14
18	II. 12	II. 13	II. 13	II. 13
19	II. 14	II. 14	II. 12	II. 12

FIGURE 10 Comparison of rank order for four sets of relevance decisions

	<u>Cranfield</u>	<u>Scott</u>	<u>Bateman</u>	<u>MacAdam</u>
Cranfield	-	0.921	0.925	0.944
Scott	0.921	-	0.933	0.925
Bateman	0.925	0.933	-	0.977
MacAdam	0.944	0.925	0.977	-

FIGURE 11 Rank-correlation coefficients.

significant a difference in the normalised recall ratio of less than 3%, but in that the greatest difference between any two sets of figures as shown by this test is 1.4%, it would be reasonable to suggest that 2% could be considered significant.

The results obtained in this test have, in fact, been supported by a similar test undertaken by Lesk and Salton (Ref. 4) in connection with the Smart project. In this work, a collection of 1268 abstracts in the field of documentation was used. Eight different persons (librarians or library students) were asked to generate six requests that might actually be put to such a collection. When these had been received, each person was sent a copy of the complete set of abstracts, and working to definite instructions, was asked to assess the relevance of each document with respect to each of his six queries. Then a second set of independent relevance judgements was obtained by asking each person in the test group to judge for relevance six additional queries originated by other people.

The most interesting aspect of the Smart test was that the relevance judges only had an average consistency of 30%. While the authors of the questions selected 853 documents as relevant to their own questions, only 713 documents were judged relevant when the assessment was of questions originated by other people. In total, 1260 documents were considered relevant, but only 366 were common to the two groups. This consistency of 30% is very similar to the consistency found in tests of indexers (Ref. 5), and compares, for instance, with the very high consistency of 79% achieved in the Cranfield test by Scott with the original decisions of the questioners. This high consistency may be partly due to the use of full text documents rather than abstracts.

Lesk and Salton tested three index languages, and consistently found that the thesaurus was better than word stems, which was in turn better than word forms. Although the test was on a smaller scale than the Cranfield work, there seem no grounds for arguing against their conclusion that "there appears to be no reason to reject previously published evaluation results for manual or automatic searches because of uncertainties in the computation of the performance measures".

The results of this test can only lead to the same conclusion. In the light of the considerable amount of criticism concerning relevance decisions which has been made over the past decade, it is desirable to make an attempt to explain the results. Some of the earliest criticisms came from Fairthorne who suggested that relevance refers to a group or type of request, rather than to an individual user, and that therefore individual judgements should give way to the views of a group of users. Taube (Ref. 6) attacked the whole idea of relevance and expressed the view that recall and precision could not be accepted as valid measures of I.R. systems. O'Connor, in a continuing series of papers (Ref. 7) has argued that relevance can mean many different things to the same person at different times, or in different situations; because of this, it is not possible to speak of relevance without defining in detail the particular circumstances.

These and other comments led to the setting-up of two investigations into relevance, supported by grants from the National Science Foundation. Cuadra and Katter (Ref. 8) and Rees and Schultz (Ref. 9) both attempted to analyse the effect of the variables involved in relevance judgements. While both these tests were, in their ways, of interest, neither had any real connection with the problems of relevance decisions. The fault was that the attempts to find how people arrived at relevance decisions in real life were carried out in a completely artificial environment. For example, in the S.D.C. test (Ref. 8) the subjects (psychology students) were presented with nine abstracts and eight question statements. They were then given the following instruction:

"You are to imagine that you are acting as judging agent for a person who is strongly concerned about the problem of increasing the precision of use of terminology in science. You are aware that in making each relevance rating you are demonstrating exactly what each term in your requirement statement means to you (or does not mean to you). You appreciate the fact that all terminology is arbitrary, and that therefore the important thing is not 'picking the right term', but rather, the important thing is that everyone should try to use the same term. You will try to judge the relevance of articles accordingly".

This exercise was repeated 14 times with different sets of instructions, each of which required the relevance judgement to be biased by a particular viewpoint, each of which tried to simulate a real-life situation, but all baulked by the fact that it was a simulation. In the final report the authors do not appear to have appreciated the artificiality of the test-environment and the report contains many statements that could only apply to a real-life situation, and for which the project produced absolutely no evidence. However, in the matter of artificial relevance judgements, they make the claim that relevance scores are likely to be artefacts of particular experimental instructions and conditions, and that therefore while "this conclusion does not invalidate experiments in which a given group of judges makes relevance appraisals for a specific system, it does call into question any comparative evaluations (between systems and sub-systems) in which the attitude of the judges about the intended use of the materials was not considered and controlled, either experimentally or statistically".

This statement, which is clearly directed to the Cranfield and Smart projects, draws false conclusions from the test results, and shows a complete misunderstanding of operational situations. From their statements, the authors appear to think that scientists are significantly influenced by subconscious motives in making a decision as to whether a given document is or is not relevant to the problems with which they are concerned. One can consider that if every user of a given system approached the analysis of his output in one specific way, as for instance,

a concern with terminology as in the example above, one would expect different relevance judgements than if everybody approached it from another fixed viewpoint of, say, methodological interest. However, anyone with practical experience of operational systems will know that users do not fall into any one such category and, in general, information retrieval systems are not designed to serve only people having one particular quirk or bias. This is one reason why in the Cranfield projects we have deliberately been vague in our instructions to the relevance judges; apart from interpreting the different levels of relevance, we have left it to the scientists involved in the decisions to make these based on their normal approach. Had we tried to introduce the strict controls advocated by Cuadra and Katter, the relevance decisions might have been completely distorted from what one would reasonably expect to find in a real-life situation. No doubt, amongst the 200 relevance judges in Cranfield II there were some who were more concerned than the average with a particular aspect, such as methodology or terminology, but taken together, we would argue that they were representative of the user group of an operational service covering aerodynamics, and for the large majority, their interest in the subject content of the documents would be sufficient to outweigh their personal idiosyncracies concerning presentation.

A major reason for undertaking the investigation covered in this report was that the results of Cranfield II were so unexpected that it was essential to check every possible source of error. However, other tests, such as that by Aitchison, (Ref.11) largely confirmed the results of Cranfield II, and with greater understanding of the workings of information retrieval systems, it is quite obvious that a system using the natural language of the documents in the collection and the natural language of question statements can never - other things being equal - have a worse performance than a system using any form of controlled language. It may not be significantly better, nor may it economically be so efficient, but in relation to performance, it can never be improved.

We can therefore claim that, quite apart from the results of this test and that by Salton, the mere fact that Cranfield II gave the correct results can be taken as positive proof that the methodology - including in particular the relevance decisions - as used in Cranfield II was also correct.

The Effect of Random Relevance

As an exercise, it was decided that an attempt would be made to find the effect of random changes in the sets of relevance documents. For this test, twenty questions, each of which had a minimum of four and a maximum of eight relevant documents

were selected, the question numbers being as follows:

<u>Question No.</u>	<u>No. of relevant documents</u>
100	4
116	6
118	5
119	6
122	5
123	4
130	4
132	4
136	6
137	6
147	5
148	4
167	4
224	5
250	8
261	4
266	5
268	5
274	5
323	5

It will be noted that there were exactly 100 relevant documents for this set of twenty questions.

The test was carried out on six index languages, namely I-1, I-7, III-2, IV-2, II-15, and II-12. The normalised recall ratios for the twenty questions as given above were calculated for these six index languages. The actual figures were lower in each case, indicating that this sub-set of twenty questions had not performed as well as the remaining twenty-two questions, but as is shown below, the rank order of the languages is not affected.

Index Language	Normalised recall on 20 questions	Original rank order (see Fig. 1)	Normalised recall on 42 questions (see Fig. 1)
I-1	61.47	1	65.00
I-7	60.76	6	64.05
III-2	58.54	10	61.76
IV-2	56.62	16	59.76
II-15	54.21	21	57.41
II-12	52.07	25	55.41

It will be seen that not only has the rank order remained the same, but also there is approximately the same difference in the normalised

recall ratios for any pair of index languages. The test required the addition of increasing numbers of randomly selected documents to the set of relevant documents for each question and then for the random selection of documents to form a new relevant document set which had the same number of documents as the original set. This can most simply be explained by illustrating the effect with a given question. Question 116 has six known relevant documents, namely 1317, 1574, 1575, 1576, 1578 and 1656. From the whole collection of 200 documents, one document was selected at random; it was, in fact, No. 1783. This document was added to the six relevant documents, from which six were taken at random to form the new set of relevant documents. The effect on this occasion was to substitute this presumably non-relevant document, No. 1783, for the known relevant document No. 1576. At the next stage two randomly selected non-relevant documents were added to the original six relevant documents and then a further random selection was made to obtain a new set of six relevant documents. This procedure was repeated adding four randomly-selected documents and finally adding five such documents. At this final stage the relevant document sets were being selected from the total of 200 documents, equally divided between known relevant documents and randomly-selected - therefore presumably non-relevant - documents.

The effect in relation to Question 116 was as follows: (The substituted documents are shown by an asterisk).

Original Relevant Documents	Amended Set 1	Amended Set 2	Amended Set 3	Amended Set 4
1317	1317	1317	1317	1317
1574	1574	1574	* 1615	* 1443
1575	1575	* 1972	1575	1575
1576	* 1783	1576	* 1705	1576
1578	1578	1578	1578	* 1620
1656	1656	1656	1656	* 2391

As can be seen, with Set 4 there is now the position where the set of 'relevant' documents is made up of three documents originally judged relevant, namely 1317, 1575 and 1576, and three documents which have been randomly selected and which are, in fact, not relevant, namely 1443, 1620 and 2391.

There were, of course, variations in this random selection. In one case, with Question 167, Set 4 was made up of four new documents, without a single known relevant document being included. There was no situation where the reverse happened, i.e. the relevant set remained as the original, but with Questions 122 and 268, four of the original documents were included. The total of original

relevant documents for the four sets, for all twenty questions is as shown below:

	Set 1	Set 2	Set 3	Set 4
Number of relevant documents	84	75	59	49
Number of presumably non-relevant documents	16	25	41	51

New sets of "relevant" documents having been thus obtained, the results were calculated for the twenty questions and six index languages for each of the four sets. This involved going back to the original records and finding whether the added relevant new documents have been retrieved in the course of the search, a procedure similar to that described earlier in this report. On the basis of the new calculations the rank orders of the six index languages were obtained. These are shown below together with the rank correlation.

Index Language	Original order	Set 1	Set 2	Set 3	Set 4
I-1	1	1	1	3	4
I-7	2	2	3	1	3
III-2	3	4	4	4	1
IV-2	4	3	2	6	6
II-15	5	5	5	2	2
II-12	6	6	6	5	5
Rank correlation		0.943	0.829	0.43	0.20

It will be noted that the rank order holds up reasonably well for Sets 1 and 2, but that by Set 3 there are major changes and with the final Set, the result is approaching zero correlation. To consider the position regarding this final set, there were 49 documents, common to both the original set and to Set 4, and 102 documents appeared in only one set. This gives an overlap between the two sets of approximately 30%, and corresponds closely to the overlap between different relevance judgements which was found in the tests reported by Lesk and Salton in Ref. 4. It is reasonable to ask why, in those circumstances they should have found no significant difference between the index languages which were tested whereas in this case the correlation is low. The reason can be appreciated by the quotation by Salton (Ref. 10).

"The shape of a typical recall precision graph averaged over many search requests is determined almost entirely by the first few documents retrieved (when the documents are retrieved in decreasing order of the correlation coefficient). Thus, by the time the top ten documents are retrieved, usually the precision will be very low and the recall will already be quite respectable. However, it is precisely for the first few documents, which exhibit the highest

correlation coefficient with the query, where the relevance judgements appear to be practically invariant among different judges. It is for this reason that the recall precision graphs stay the same. For documents retrieved late in the search which rank 100 or 200 or 300, etc. the judgements will be very different among the various assessors, but these different judgements will affect only the lower righthand corner of our recall-precision graph (where the recall is higher than .8 and the precision usually lower than .2)."

The overlap in the Lesk and Salton test was due to varying decisions concerning the documents of doubtful relevance which, being retrieved relatively late in the search, do not significantly change the results. However, in this test, the overlap was determined by a random substitution of documents, with the probability that a highly relevant document would be eliminated as would a document of minimum relevance.

Analysis showed that documents retrieved at a relatively high level were eliminated from the relevant documents set. The normalised recall at various stages shows this quite clearly; originally, for the twenty questions, the normalised recall for index language I-1 was 61.47%. The normalised recall for these questions when only the forty-nine remaining relevant documents are counted was 58.5%. This is a relatively small drop, but it shows that the proportion of documents retrieved at high coordination levels which were eliminated, was rather more than might have been expected, since if it had been exactly proportionate, the normalised recall would have remained the same. With Set 4, the normalised recall dropped sharply to 41.7%, showing the effect of complete randomness in the selection of additional documents, for the "relevant" set.

The results of this additional test make clear what might reasonably have been hypothesised, namely that if two sets of relevance judgements, having the same generality number, result in a similar level of performance for any given index language, then there will not be any significant difference in the comparison between different index languages using either set of relevance judgements.

REFERENCES

1. CLEVERDON, C.W. and THORNE, R.G. A brief experiment with the Uniterm system of coordinate indexing for cataloguing of structural data. R.A.E. Library Memo 7, 1954.
2. CLEVERDON, C.W. Report on the testing and analysis of an investigation into the comparative efficiency of indexing systems. Cranfield, 1962.
3. CLEVERDON, C.W., MILLS, J. and KEEN, E.M. Factors determining the performance of indexing system. 2 vols. Cranfield 1968.
4. LESK, M.E. and SALTON, G. Relevance assessments and retrieval system evaluation. Information Storage and Retrieval Report IRS-14, Cornell, 1968.
5. HOOPER, R.S. Indexer consistency tests. I.B.M. Corporation, Bethesda.
6. TAUBE, M. The pseudo-mathematics of relevance. American Documentation, Vol. 16, 1965, pp 69-72.
7. O'CONNOR, J. Some questions concerning information need. American Documentation, Vol. 19, 1968, pp 200-203.
8. CUADRA, C. and KATTER, R. Experimental studies of relevance judgements. 2 vols.
9. REES, A.M. and others. A field experimental approach to the study of relevance assessments in relation to document searching. 2 vols. Case Western Reserve University, 1967.
10. SALTON, G. Private communication.
11. AITCHISON, T.M. et al. Comparative evaluation of index languages. INSPEC Report 5, 1970.

APPENDIX I

QUESTIONS AND DOCUMENTS USED IN TEST

QUESTIONS

- Q79 What are the details of the rigorous kinetic theory of gases. (Chapman-Enskog Theory).
- Q100 How much is known about boundary layer flows along non-circular cylinders.
- Q116 How significant is the possible pressure of a dissociated free stream with respect to the realization of hypersonic simulation in high enthalpy wind tunnels
- Q118 Do the discrepancies among current analyses of the vorticity effect on stagnation-point heat transfer result primarily from the differences in the viscosity - temperature law assumed.
- Q119 How far can one trust the linear viscosity - temperature solution assumed in some of the analyses of hypersonic shock layer at low Reynolds number.
- Q121 Has anyone explained the kink in the surge line of a multi-stage axial compressor.
- Q122 Have any aerodynamic derivatives been measured at hypersonic Mach numbers and comparison been made with theoretical work.
- Q123 Are methods of measuring aerodynamic derivatives available which could be adopted for use in short running time facilities.
- Q126 What are wind-tunnel corrections for a two-dimensional aerofoil mounted off-centre in a tunnel
- Q130 What is the present state of the theory of quasi-conical flows
- Q132 What parameters can seriously influence natural transition from laminar to turbulent flow on a model in a wind tunnel.
- Q136 How does a satellite orbit contract under the action of air drag in an atmosphere in which the scale height varies with altitude.
- Q137 How is the flow at transonic speeds about a delta wing different from that on a closely-related tapered sweptback wing.
- Q141 Can methane-air combustion product be used as a hypersonic test medium and predict, within experimental accuracies, the results obtained in air.
- Q145 Has anyone investigated the unsteady lift distributions on finite wings in subsonic flow.
- Q146 What information is available for dynamic response of airplanes to gusts or blasts in the subsonic regime.

QUESTIONS

- Q147 Will forward or apex located controls be effective at low subsonic speeds and how do they compare with conventional trailing-edge flaps.
- Q148 Given that an uncontrolled vehicle will tumble as it enters an atmosphere, is it possible to predict when and how it will stop tumbling and its subsequent motion.
- Q167 It is not likely that the airforces on a wing of general planform oscillating in transonic flow can be determined by purely analytical methods. Is it possible to determine the airforces on a single particular planform, such as the rectangular one by such method.
- Q170 Is there any information on how the addition of a "boat-tail" affects the normal force on the body of various angles of incidence.
- Q181 Has any work been done on determining the nature of compressible viscous flow in a straight channel.
- Q182 In what areas, other than low density wind tunnel flows, is viscous compressible flow in slender channels a problem.
- Q189 Has anyone programmed a pump design method for a high-speed digital computer.
- Q190 Has anyone derived simplified pump design equation from the fundamental three-dimensional equations for incompressible nonviscous flow.
- Q223 What is the magnitude of second-order wing-body interference at high supersonic Mach number.
- Q224 What is the best theoretical method for calculating pressure on the surface of a wing alone.
- Q225 How can the effect of the boundary-layer on wing pressure be calculated, and what is its magnitude.
- Q226 How should the Navier-Stokes difference equations be solved.
- Q227 Which iterative method for solving linear elliptic difference equations is most rapidly convergent.
- Q230 Technical report on measurement of ablation during flight.
- Q250 What determines the onset of shock-induced boundary-layer separation.
- Q261 Solution of the Blasius problem with three-point boundary conditions.
- Q264 References on Lyapunov's method on the stability of linear differential equations with periodic coefficients.
- Q266 Work on flow in channels at low Reynolds numbers.

QUESTIONS

- Q268 What mode of stalling can be expected for each stage of an axial compressor.
- Q269 Has a criterion been established for determining the axial compressor choking line.
- Q272 Has a theory of quasi-conical flows been developed, in supersonic linearised theory, for which the upwash distribution on the lifting surface, apart from being a homogeneous function in the co-ordinate, is permitted to have a quite general functional form.
- Q273 How does scale height vary with altitude in an atmosphere.
- Q274 Jet interference with supersonic flows - theoretical papers.
- Q317 Has anyone investigated theoretically whether surface flexibility can stabilize a laminar boundary layer.
- Q323 How do large changes in new mass ratio quantitatively affect wing-flutter boundaries.
- Q360 In practice, how close to reality are the assumptions that the flow in a hypersonic shock tube using nitrogen is non-viscous and in thermodynamic equilibrium.

DOCUMENTS

- 1302 HANSEN, C. F. Approximations to the thermodynamic and transport properties of high temperature air. NASA R50, 1959.
- 1311 PEARCEY, H. H. A method for predicting the onset of buffeting and other separation effects from wind tunnel tests on rigid models NPL Aero, 358, 1958.
- 1316 PEARCEY, H. H. The occurrence and development of boundary layer separation at high incidence and high speeds. ARC R & M 3109, 1955.
- 1317 FREEMAN, N. C. Dynamics of a dissociating gas, III. Non-equilibrium theory. J. Fluid Mech. 4, 1958.
- 1320 LEIGH, D. C. Comment on improved numerical solution of the Blasius problems with three-point boundary conditions. J. Ae. Scs. 29, 1962.
- 1320 CHRISTIAN, W. J. Improved numerical solution of the Blasius problem with three-point boundary conditions. J. Ae. Scs. 28, 1961.
- 1322 TOBA, K. On the numerical solution of the Blasius problem with three-point boundary conditions. J. Ae. Scs. 29, 1962, 480.
- 1324 ROTT, N. and LENARD, M. Vorticity effect on the stagnation point flow of a viscous incompressible fluid. J. Ae. Scs. 26, 1959.
- 1335 LEIPMANN, H. W. The interaction between boundary layer and shock waves in transonic flow. J. Ae. Scs. 13, 1946.
- 1351 MILLSAPS, K. and POHLHAUSEN, K. Thermal distributions in Jeffrey-Hamel flows between nonparallel walls. J. Ae. Scs. 20, 1953, 187.
- 1360 GRIMMINGER, G., WILLIAMS, E. P. and YOUNG, G. Lift on inclined bodies of revolution in hypersonic flow. J. Ae. Scs. 17, 1950.
- 1367 KALMAN, R. E. and BERTRAM, J. E. Control system and analysis and design via the second method of Lyapunov. ASME Trans. 82, 1960.
- 1378 ECKERT, E. Survey on heat transfer at high speeds. WADC TR54-70, 1954.
- 1383 MEKSYN, D. Integration of the boundary layer equations for a plane in compressible flow with heat transfer. Proc. Roy. Soc. A, 231, 1955, 274.
- 1399 JAEGER, J. C. Composite slabs. Q. App. Math. 8, 1950.
- 1406 MONAGHAN, R. J. On the behaviour of boundary layers at supersonic speeds. 5th Int. Astro. Conf. 1955.
- 1409 CHOW, W. L. On the base pressure resulting from the interaction of a supersonic external stream with a sonic or subsonic jet. J. Ae. Scs. 1959 176.

DOCUMENTS

- 1415 PEARCEY, H. H. The aerodynamic design of section shapes for swept wings. 2nd Int. Cong. Aero. Sc. 1960.
- 1416 PEARCEY, H. H. and STUART, C. M. Methods of boundary layer control for postponing and alleviating buffeting and other effects of shock-induced separation. SMF Fund Paper FF22, 1959.
- 1420 JASZLICS, I. and TRILLING, L. An experimental study of the flow field about swept and delta wings with sharp leading edges. J. Ae. Scs. 1959, 487.
- 1436 HOSHIZAKI, H. Heat transfer in planetary atmospheres at supersonic speeds. ARS Prep. 2173-62, 1961.
- 1437 SCALA, S. M. and WARREN, W. R. Hypervelocity stagnation point heat transfer in dissociated air. ARS J. 1962.
- 1443 PINKERTON, R. M. Calculated and measured pressure distribution over the midspan section of the NACA 4412 airfoil. NACA R563, 1936.
- 1451 PARKS, P. C. The methods of Lyapunov in the theory of automatic control. Control, 1961.
- 1467 SPREITER, J. R. and ALKSNE, A. Y. Thin airfoil theory based on approximate solution of the transonic flow equations. NACA TN. 3970. 1957.
- 1476 NAPOLITANO, I. G. The Blasius equation with three-point boundary conditions. Q. App. Math. 16, 1958, 397.
- 1509 ADAMS, E. W. A graphical approximation for temperatures and sublimation rates at surfaces subjected to small net and large gross heat transfer rates. J. Ae. Scs. 29, 1962, 360.
- 1569 KENDALL, J. M. An experimental investigation of leading edge shock wave boundary layer interaction at Mach 5.8. J. Ae. Scs. 24, 1957, 47.
- 1572 CHENG, H. K., HALL, J. F., GOLIAN, T. C. and HERTZBERG, A. Boundary layer displacement and leading edge bluntness effects in high temperature hypersonic flow. J. Ae. Scs. 28, 1961, 353.
- 1574 BLOOM, M. H. and STEIGER, M. H. Inviscid flow with nonequilibrium molecular dissociation for pressure distribution encounter in hypersonic flight. J. Ae. Sc. 27, 1960, 821.
- 1575 BRAY, K. N. C. Atomic recombination in a hypersonic wind tunnel nozzle. J. Fluid Mech. 6, 1959, 1.
- 1576 INGER, G. R. Viscous and inviscid stagnation flow in a dissociated hyper-velocity free stream. Proc. 1962 Heat Transfer and Fluid Mech. Inst.

DOCUMENTS

- 1578 GIBSON, W.E. Dissociation scalling for nonequilibrium blunt nose flows. ARS J. 32, 1962, 285.
- 1588 BENSER, W. A. Aerodynamic design of axial flow compressors. Chapter XIII Compressor operation with one or more blade rows stalled. NACA RM E56B03b, 1956
- 1589 HUPPERT, M.C. and BENSER, W. A. Some stall and surge phenomena in axial flow compressors. J. Ae. Scs. 1953, 835.
- 1590 STONE, A. Effects of stage characteristics and matching on axial flow compressor performance. ASME Trans. 80, 1958, 1273.
- 1591 CSANADY, G. T. An approximate equation for the 'choke line' of a compressor. J. Ae. Scs. 1960, 637.
- 1592 HOWELL, A. R. Design of axial compressor. Proc. I. Mech. E. 153, 1945.
- 1594 BRATT, J. B. Wind tunnel techniques for the measurements of oscillatory derivatives. ARC 22, 146, 1960.
- 1596 WITTRICK, W.H. The relation between torque and rotation of a crossed flexure pivot. Aero. Quart. 2, 1950.
- 1597 PUGH, P.G. and WOODGATE, L. Measurement of pitching moment derivatives for blunt-nose aerofoils oscillating in two-dimensional supersonic flow. ARC 23, 012, 1961.
- 1598 STALMACH, C. J. and COOKSEY, J. M. New test techniques for a hyper-velocity wind tunnel. Aerospace Eng. 21, 1962.
- 1605 WOODLEY, J. G. Pressure measurements on a cone-cylinder-flare configuration at small incidence for M=6.8. RAE TN. Aero. 2739.
- 1606 MONAGHAN, R. J. Formulae and approximations for aerodynamic heating rates in high speed flight. RAE TN. Aero. 2407.
- 1608 LAUFER, J. Aerodynamic noise in supersonic wind tunnels. J. Ae. Scs. 28, 1961.
- 1613 KING-HELE, D. G., COOK, G. E. and WALKER, D. M. C. The contraction of satellite orbits under the influence of air drag. Part I. With spherically symmetrical atmosphere RAE TN. G. W. 533, 1959.
- 1614 KING-HELE, D. G., COOK, G. E. and WALKER, D. M. C. The contraction of satellite orbits under the influence of air drag. Part II, With oblate atmosphere. RAE TN. G. W. 565, 1960.
- 1615 KING-HELE, D. G. The contraction of satellite orbits under the influence of air drag. Part III. High eccentricity orbits. RAE TN. Space 1, 1962.

DOCUMENTS

- 1616 GROVES, G. V. Determination of upper atmosphere air density and scale height from satellite observations. Proc. Roy. Soc. A252, 1959, 16.
- 1617 GROVES, G. V. Determination of upper atmosphere air density profile from satellite observations. Proc. Roy. Soc. A252, 1959, 28.
- 1618 MICHIELSEN, H. F. Orbit decay and prediction of the motion of artificial satellites. Advances in Astro. Sc. 4, Plenum Press 1959, 255.
- 1619 KING-HELE, D. G. Density of the upper atmosphere from analysis of satellite orbits: further results. Nature, 184, 1959, 1267.
- 1620 PRIESTER, W., MARTIN, H. A. and KRAMP, K. Earth satellite observations and the upper atmosphere. Nature, 188, 1960, 200
- 1621 GROVES, G. V. Latitude and diurnal variations of air densities from 190 to 280 km as derived from the orbits of Discoverer satellites. Proc. Roy. Soc. A263, 1961, 212.
- 1622 KING-HELE, D. G., and HUGHES, K. M. Scale height in the upper atmosphere, derived from changes in satellite orbits. RAE TN. Space 4, 1962.
- 1655 BERTRAM, M. H. and HENDERSON, A. Effects of boundary layer displacement and leading edge bluntness on pressure distribution, skin friction and heat transfer of bodies at hypersonic speeds. NACA TN. 4301, 1958.
- 1656 BRAY, K. N. C. Departure from dissociation, equilibrium in a hypersonic nozzle. ARC 19, 983, 1958.
- 1666 FERRI, A., AZKKAY, V. and TING, L. Blunt body heat transfer at hypersonic speed and low Reynolds number. J. Ae. Scs. 28, 1961, 862.
- 1667 CHENG, H. K. Hypersonic shock layer theory of the stagnation region at low Reynolds number. Proc. 1961 Heat Trans. and Fluid Mech. Inst. Stanford Univ. Press, 1961, 161.
- 1670 FERRI, A., ZAKKAY, V. and TING, L. On blunt-body heat transfer at hypersonic speed and low Reynolds numbers. J. Ae. Scs. 29, 1962, 882.
- 1671 BREBNER, G. G. and BAGLEY, J. A. Pressure and boundary layer measurements on a two dimensional wing at low speed. ARC R & M. 2886 1962.
- 1672 PANKHURST, R. C. and HOLDER, D. W. Wind tunnel techniques. Chapt. 8, Tunnel interference effects. Pitman, 1962.

DOCUMENTS

- 1675 GARNER, H. C. and WALSHE, D. E. Pressure distribution and surface flow on 5% and 9% thick wings with curved tip and 60° sweepback. ARC R & M. 3244, 1959.
- 1676 KUCHEMANN, D. A simple method for calculating the span and chordwise loading on straight and swept wings of any aspect ratio at subsonic speeds. RAE R. Aero. 2476, 1962.
- 1677 MULTHOPP, H. Methods for calculating the lift distribution of wings (subsonic lifting surface theory). RAE R. Aero. 2353, 1950.
- 1680 LOMAX, H. and HEASLETT, M. A. Generalized conical flow fields in supersonic wing theory. NACA TN. 2497, 1951.
- 1681 LOMAX, H., HASLETT, M. A. and FULLER, F. B. Integrals and integral equations in linearized wing theory. NACA R. 1054, 1951.
- 1682 LANCE, G. N. The lift of twisted and cambered wings in supersonic flow. Aero. Quart. 6, 1955.
- 1683 SMITH, J. H. B. and MANGLER, K. W. The use of conical camber to produce flow attachment at the leading edge of a delta wing and to minimize the lift-dependent drag at sonic and supersonic speeds. RAE R. Aero. 2584, 1957.
- 1684 HEUMAN, C. Tables of complete elliptic integrals. J. Maths. Phys., 20, 1941, 127.
- 1687 LIGHTHILL, M. J. Oscillating airfoils at high Mach number. J. Ae. Scs. 20, 1953, 402
- 1688 WELLS, W. R. and ARMSTRONG, W. O. Tables of aerodynamic coefficients obtained from developed Newtonian expressions for complete and partial conic and spheric bodies at combined angles of attack and sideslip with some comparisons with hypersonic experimental data. NASA TR R127, 1962.
- 1691 LEYHE, E. W. and HOWELL, R. R. Calculation procedure of thermodynamic transport and flow properties of the combustion products of a hydro-carbon fuel mixture burned in air with results for ethylene-air and methane-air mixtures. NASA TN. D914, 1962.
- 1692 BRESSETTE, W. E. Investigation of the jet effects of a flat surface downstream of the exit of a simulated turbojet nacelle at the free-stream Mach number 2.02. NACA RM L54E05a, 1954.
- 1693 BRESSETTE, W. E. and LEISS, A. Investigation of jet effects on a flat surface downstream of the exit of a simulated turbojet nacelle at a free-stream Mach number of 1.39.
- 1695 BRESSETTE, W. E. Some experiments relating to the problem of simulation of hot jet engines in studies of jet effects on adjacent surfaces at a free stream Mach number of 1.80. NACA RM L56E07, 1956.

DOCUMENTS

- 1696 FALANGAN, R. A. and JANOS, J. J. Pressure loads produced on a flat plate wing by rocket jets exhausting in a spanwise direction below the wing and perpendicular to a free-stream flow of Mach number 2.0. NASA TN. D893, 1961.
- 1697 BRESSETTE, W.E. and LEISS, A. Effects on adjacent surfaces from the firing of rocket jets. NACA RM L57D19a, 1957.
- 1698 JONES, R. T. The unsteady lift of a wing of finite aspect ratio. NACA R. 681, 1940.
- 1699 DRISCHLER, J. A. Approximate indicial lift functions for several wings of finite span in incompressible flow as obtained from oscillatory lift coefficients. NACA TN. 3639, 1956.
- 1700 LOMAX et al. Two and three dimensional unsteady lift problems in high speed flight. NACA R. 1077, 1952.
- 1701 MAZELSKY, B. Numerical determination of indicial lift of a two dimensional sinking airfoil at subsonic Mach numbers from oscillatory lift coefficients with calculations for Mach number 0.7. NACA TN. 2562 1951.
- 1702 MAZELSKY, B. and DRISCHLER, J. A. Numerical determination of indicial lift and moment functions for a two dimensional sinking and pitching airfoil at Mach numbers 0.5 and 0.6. NACA TN. 2739, 1952.
- 1703 KUSSNER, H. G. General airfoil theory. NACA TM. 979, 1941.
- 1704 WATKINS, C.E. WOOLSTON, D.S. and CUNNINGHAM, H. J. A systematic kernel function procedure for determining aerodynamic forces on oscillating or steady finite wings at subsonic speeds. NASA TR. R48, 1959.
- 1705 WATKINS, C.E., RUNYAN, H. L. and WOOLSTON, D.S. On the kernel function of the integral equation relating the lift and downwash distributions of oscillating finite wings in subsonic flow. NACA R. 1234, 1955.
- 1706 GARRICK, I. E. On some reciprocal relations in the theory of nonstationary flows. NACA R. 629, 1938.
- 1707 HANAWALT, A. J. BLESSING, A. H. and SCHMIDT, C. M. Thermal analysis of stagnation regions with emphasis on heat-sustaining nose shapes at hypersonic speeds. J. Ae. Scs. 1959, 257.
- 1708 LADSON, C. L. and JOHNSTON, P. J. Aerodynamic characteristics of two winged re-entry vehicles at supersonic and hypersonic speeds. NASA TM. X346, 1961.

DOCUMENTS

- 1709 OLSTAD, W. B. Static longitudinal aerodynamic characteristics at transonic speeds and angles of attack up to 99° of a re-entry glider having folding wing-tip panels. NASA TM.X610, 1961.
- 1710 SMITH, M.O. and CLUTTER, D.W. The smallest height of roughness capable of affecting boundary layer transition. J. Ae.Scs. 1959, 229.
- 1711 SPENCER, B. An investigation at subsonic speeds of aerodynamic characteristics at angles of attack from -4° to 100° of a delta-wing re-entry configuration having folding wingtip panels. NASA TM.X288, 1960.
- 1712 SPENCER, B. and HAMMOND, A.D. Low-speed longitudinal aerodynamic characteristics associated with a series of low-aspect ratio wings having variations in leading-edge contour. NASA TN.D1374, 1962.
- 1713 MAYO, E.E. Static longitudinal stability characteristics of a blunted glider re-entry configuration having 79.5° sweepback and 45° dihedral at a Mach number of 6.2 and angles of attack up to 20° . NASA TM.X222, 1959.
- 1717 PETERSON, V. L. Motions of a short 10° blunted cone entering a Martian atmosphere at arbitrary angles of attack and arbitrary pitching rates. NASA TN.D1326.
- 1719 REMMLER, K. L. Tumbling bodies entering the atmosphere. ARS. Jnl. 32, 1962, 92.
- 1728 LIN, Y.K. Free vibrations of continuous skin stringer panels. J. App. Mech. 1960.
- 1729 LIN, Y.K. Stresses in continuous skin stiffener panels under random loading. J. Ae.Scs. 1962.
- 1748 MINHINNICK, I. T. Subsonic aerodynamic flutter derivatives for wings and control surfaces. RAE R. Struct. 87. 1950.
- 1772 CLARK, E. L. and ORDWAY, D. E. An experimental study of jet flap compressor blades. J. Ae. Scs. 1959, 698.
- 1779 DRISCHLER, J. A. Calculation and compilation of the unsteady lift functions for a rigid wing subjected to sinusoidal gusts and to sinusoidal sinking oscillations. NACA TN. 3748, 1956.
- 1782 QUEIJO, M. J. and RILEY, D. R. Calculated subsonic span loads and resulting stability derivatives of unswept and 45° sweptback tail surfaces in side-slip and steady roll. NACA TN. 3245, 1954.
- 1783 GRAY, W. L. A method for calculating the steady-state loading on an airplane with a wing of arbitrary planform and stiffness. NACA TN. 3030, 1953.

- 34 -
DOCUMENTS

- 1785 COOKE, J. C. The flow of fluid along cylinders. Q. J. Mech. App. Math. 10, 1957, 312.
- 1786 BATCHELOR, G. K. The skin friction of infinite cylinders moving parallel to their length. Q. J. Mech. App. Math. 7, 1954, 179.
- 1787 HASIMOTO, H. Rayleigh's problem for a cylinder of arbitrary shape. J. Phys. Soc. Japan, 9, 1954, 611.
- 1788 VARLEY, E. An approximate boundary layer theory for semi-infinite cylinders of arbitrary cross-section. J. Fluid Mech. 3, 1958, 601.
- 1792 SPENCE, A. and LEAN, D. Some low speed problems of high speed aircraft. J. Roy. Aero. Soc. 66, 1962, 211.
- 1793 HALL, I. M. and ROGERS, E. W. E. The flow pattern on a tapered sweptback wing at Mach numbers between 0.6 and 1.6. ARC R & M 3271, 1960.
- 1794 HALL, I. M. and ROGERS, E. W. E. Experiments with a tapered swept-back wing of Warren 12 planform at Mach numbers between 0.6 and 1.6. ARC R & M 3271, 1960.
- 1795 HALL, I. M. The operation of the NPL 18in x 14in. wind tunnel in the transonic speed range. ARC CP. 338, 1957.
- 1796 ROGERS, E. W. E. and HALL, I. M. An investigation at transonic speeds of the performance of various distributed roughness bands used to cause boundary layer transition near the leading edge of a cropped delta half-wing. ARC CP. 481, 1959.
- 1797 ROGERS, E. W. E., TOWNSEND, J. E. G. and BERRY, C. J. A study of the effect of leading edge modifications on the flow over a 50° sweptback wing at transonic speeds. ARC R & M 3270, 1960.
- 1798 HOLDER, D. W. PEARCEY, H. H. and GDDDD, G. E. Interaction between shock waves and boundary layers. With a note on the effects of the interaction on the performance of supersonic intakes, by J. Seddon. ARC CP. 180, 1954.
- 1799 PEARCEY, H. H., SINNOTT, C. S. and OSBORNE, J. Some effects of wind tunnel interference observed in tests on two dimensional aerofoils at high subsonic and transonic speeds. NPL. Aero, 373, 1959.
- 1800 ROGERS, E. W. E. and HALL, I. M. Wall interference at transonic speeds on a hemisphere cylinder model. ARC CP. 510, 1959.
- 1836 SPRAGUE, G. H. and HUANG, P. C. Analytical and experimental investigation of stress distributions in long plates subjected to longitudinal loads and transverse temperature gradients. WADC TR 55-350, 1955.
- 1874 DUNCAN, W. J. The use of models for the determination of critical flutter speeds. ARC R & M, 1425, 1931.

DOCUMENTS

- 1879 TARGOFF, W. P. and WHITE, R. P. Flutter model testing at transonic speeds. Inst. Aero. Sc. Perp. 706, 1957.
- 1880 McCARTHY, J. F. and HALFMAN, R. L. The design and testing of supersonic flutter models. J. Ae. Scs. 1956.
- 1916 LANDAHL, M. T. The flow around oscillating low aspect ratio wings at transonic speeds. KTH AERO. TN. 40, 1954.
- 1919 LANDAHL, M. T. Theoretical studies of unsteady transonic flow. Part III, The oscillating low aspect ratio rectangular wing. Aero. Res. Inst. of Sweden (FFA) R. 79, 1958.
- 1920 STEWARTSON, K. Supersonic flow over an inclined wing of zero aspect ratio. Proc. Cam. Phil. Soc. 46, 1950, 307.
- 1921 ADAMS, M. C. and SEARS, W. R. Slender body theory review and extension. J. Ae. Scs. 29, 1953.
- 1963 AGRAWAL, H. C. A variational principle for convection of heat II. J. Math. Mech. 9, 1960.
- 1964 RIVAS, M. A. and SHAPIRO, A. H. On the theory of discharge coefficients for round entrance flowmeters and venturis. ASME Trans. 78, 1956. 489.
- 1965 SIMMONS, F. S. Analytical determination of discharge coefficients for flow nozzles. NACA TN. 3499, 1955.
- 1966 MASLEN, S. H. On fully developed channel flows: some solutions and limitations, and effects of compressibility, variable properties, and body forces. NASA TR. R34, 1959.
- 1967 MARTIN, D. E. A study of laminar compressible viscous pipe flow accelerated by a body force, with application to magnetogas-dynamics. NASA TN. D855, 1961.
- 1968 SUTTON, G. P. Rocket propulsion systems for interplanetary flight. J. Ae. Scs. 26, 1959.
- 1970 JANOS, J. J. Loads induced on a flat plate wing by an air jet exhausting perpendicularly through the wing and normal to a free-stream flow of Mach number 2.0. NASA TN. D649, 1961.
- 1971 CUBBISON, R. W. ANDERSON, B. H. and WARD, J. J. Surface pressure distributions with a sonic jet normal to adjacent flat surfaces at Mach 2.92 to 6.4. NASA TN. D580, 1961.
- 1972 ROMEO, D. J. and STERRETT, J. R. Aerodynamic interaction effects ahead of a sonic jet exhausting perpendicularly from a flat plate into a Mach number 6 free stream. NASA TN. D743, 1961.

DOCUMENTS

- 1973 VINSON, P.W., AMIC, J. L. and LIEPMAN, H. P. Interaction effects produced by jet exhausting laterally near base of agive-cylinder model in supersonic main stream. NASA Memo 12-5-58W, 1959.
- 1974 WU, J. M., CHAPKIS, R. L. and MAGER, A. An approximate analysis of thrust vector control by fluid injection. ARS Jnl. 1677-1685, 1961.
- 1978 DEWEY, C. F., SCHLESINGER, S. I. and SAHSKIN, L. Temperature profiles in a finite solid with moving boundary. J. Ae. Scs. 27, 1960.
- 1980 HILLS, P. R. A method of computing the transient temperatures of thick walls from arbitrary variation of adiabatic wall temperature and heat transfer coefficient. NACA R. 1372, 1958.
- 1981 BERGLES, A. E. and KAYE, J. Solutions to the heat conduction equation with time-dependent boundary conditions. J. Ae. Scs. 28, 1961, 251.
- 1982 SUTTON, G. W. The temperature history in a thick skin subjected to laminar heating during entry into the atmosphere. Jet. Prop. 28, 1959. 40.
- 1983 DETRA, R. W., KEMP, N. H. and RIDDELL, F. R. Addendum to 'Heat transfer to satellite vehicles re-entering the atmosphere'. Jet. Prop. 27 1957, 1256.
- 1984 HAMRICK, J. T. Method of analysis for compressible flow through mixed-flow centrifugal impellers of arbitrary design. NACA R. 1082, 1952.
- 1985 SMITH, K. J. and HAMRICK, J. T. A rapid approximate method for the design of hub shroud profiles of centrifugal impellers of given blades shapes. NACA TN. 3399, 1955.
- 1986 OSBORN, W. M. Design and test of mixed-flow impellers. VIII - Comparison of experimental results for three impellers with shroud redesigned by rapid approximate method. NACA RM E56L07, 1957.
- 1987 WU, C. A general theory of three dimensional flow in subsonic and supersonic turbo-machines of axial-radial and mixed-flow types. NACA TN. 2604, 1952.
- 1988 KRAMER, J. J. Non-viscous flow through a pump impeller on a blade-to-blade surface of revolution. NASA TN. D1108, 1962.
- 1989 KRAMER, J. J. Incompressible nonviscous flow through a pump rotor with splitter vanes. NASA. TN. D1186, 1962.
- 1990 STANITZ, J. D. and PRIAN, V. D. A rapid approximate method for determining velocity distribution on impeller blades of centrifugal compressors. NACA TN. 2421, 1951.
- 1991 LOPATOFF, M. Wing-flow study of pressure drag reduction at transonic speed of projecting a jet of air from the nose of a prolate spheroid of fineness ratio 6. NACA RM L51E09, 1951.

DOCUMENTS

- 1992 LOVE, E.S. The effects of a small jet of air exhausting from the nose of a body of revolution in supersonic flow. NACA RM L52119a, 1952.
- 1993 HAYMAN, L.O. and McDEARMON, R.W. Jet effects on cylindrical afterbodies housing sonic and supersonic nozzles which exhaust against a supersonic stream at angles of attack from 90° to 180° . NASA TN.D1016, 1962.
- 1994 CHARCZENKO, N. and HENNESSY, K.W. Investigation of a retrocket exhausting from the nose of a blunt body into a supersonic free stream. NASA TN.D751, 1961.
- 1995 PETERSON, V.L. and McKENZIE, R.L. Effects of simulated retrockets on the aerodynamic characteristics of a body of revolution at Mach numbers from 0.25 to 1.90. NASA TN.D 1300.
- 1997 LOVE, E.S. Experimental and theoretical studies of axisymmetric free jets. NASA TR.R6, 1959.
- 2001 WEHREND, W.R. Wind tunnel investigation of the static and dynamic stability characteristics of a 10° semivertex angle blunted cone. NASA TN. D1202, 1962.
- 2002 BOGDONOFF, S.M. and VAS, I.E. Preliminary investigations of spiked bodies at hypersonic speeds. J. Ae. Scs. 1959, 65.
- 2061 VASILU, J. Turbulent mixing of a rocket exhaust jet with a supersonic stream including chemical reactions. J. Ae. Scs. 29, 1962, 19.
- 2074 LANDAHL M. DROUGGE, G. and BEANE, B.J. Theoretical and experimental investigation of second-order supersonic wing-body interference. J. Ae. Scs. 27, 1960, 694.
- 2075 WILBY, P.G. An experimental and theoretical investigation of second-order supersonic wing-body interference, for a non-lifting body with wings at incidence. Aero. Res. Inst. of Sweden, FFA R.87. 1960.
- 2076 BERTRAM, M.H. An approximate method for determining the displacement effects and viscous drag of laminar boundary layers in two dimensional hypersonic flow. NACA TN. 2773, 1952.
- 2077 TRIMPI, R.L. and JONES, R.A. A method of solution with tabulated results for the attached oblique shock wave system for surface at various angles of attack, sweep, and dihedral in an equilibrium real gas including the atmosphere. NASA TR.R63, 1960.
- 2078 APPELT, C.J. The steady flow of a viscous fluid past a circular cylinder at Reynolds numbers 40 and 44 ARC R & M. 3175.
- 2080 JENSON, V.G. Viscous flow round a sphere at low Reynolds numbers Proc. Roy. Soc. A, 249, 1959, 346.

DOCUMENTS

- 2081 KAWUGUTI, M. Numerical solution of the Navier-Stokes equations for the flow around a circular cylinder at Reynolds number 40, J. Phys. Soc. Japan, 8, 1953, 747.
- 2082 LESTER, W.G.S. The flow past a pitot tube at low Reynolds numbers. Pt. 1, The numerical solution of the Navier-Stokes equations for steady viscous exisymmetric flow. Pt. 2, The effects of viscosity and orifice size on a pitot tube at low Reynolds numbers. ARC. 22,070.
- 2083 THOM, A. An investigation of fluid flow in two dimensions. ARC R & M 1194, 1928.
- 2084 THOM, A. The flow past circular cylinders at low speeds. Proc. Roy. Soc. A. 141, 1933, 651.
- 2085 THOM, A. and APELT, C.J. Note on the convergence of numerical solutions of the Navier-Stokes equations. ARC R & M 3061, 1956.
- 2087 FRANKEL, S. P. Convergence rates of iterative treatments of partial differential equations. Math. Tables Aids Comp. 4, 1950, 65.
- 2088 YOUNG, D. Iterative treatments for solving partial difference equations of elliptic type. Trans. Amer. Math. Soc. 76 1954. 92.
- 2099 ROBERTS, L. A theoretical study of stagnation point ablation. NASA TR. R9, 1959.
- 2100 RASHIS, B. and HOPKO, R. N. An analytical investigation of ablation. NASA TM. X-300, 1960.
- 2101 WINTERS, C.W. and BRACALENTE, E.M. A sensor for obtaining ablation rates. NASA TN. D800, 1961.
- 2102 SWANSON, A.G. A five-stage solid fuel sounding rocket system. NASA Memo 3-6-59L, 1959.
- 2103 The Rocket Panel: pressures, densities and temperatures in the upper atmosphere. Phys. Rev. 88, 1952, 1027.
- 2104 STONEY, W.E. Aerodynamic heating of blunt nose shapes at Mach numbers up to 14. NACA RM. L58E05a, 1958.
- 2111 GARRICK, I.E. Some research on high speed flutter. 3rd A. A. Aero. Conf. 1951, 419.
- 2150 McISAAC, J. POND, H. and STERGIS, G. Preliminary results of density measurements from an Air Force satellite. Air Force, Cam. Lab., 63-24, 1963.
- 2153 SPREITER, J. R., SMITH, D. W. and HYETT, B. J. A study of simulation of flow with free stream Mach number one in a choked wind tunnel. NASA TR. R73, 1960.

DOCUMENTS

- 2154 BERNDT, S. B. On the influence of wall boundary layers in closed transonic test section. FFA R. 71, Stockholm, 1957.
- 2155 PETERSOHN, E. G. M. Some experimental investigations on the influence of wall boundary layers upon wind tunnel measurements at high subsonic speeds. FFA R. 44, Stockholm, 1952.
- 2157 NAGAMATSU, H. T. Hypersonic shock tunnel, ARS J. 29, 1959, 332.
- 2187 ARENS, M. and SPIEGLER, E. Shock-induced boundary layer separation in overexpanded conical exhaust nozzles. AIAA Jnl. 1963, 578.
- 2274 NAGAMATSU, H. T. GEIGER, R. E. and SHEER, R. E. Real gas effects in flow over blunt bodies at hypersonic speeds. J. Ae. Scs. 1960, 241.
- 2313 HOLDER, D. W. and SCHULTZ, D. L. On the flow in a reflected shock tunnel. ARC R & M 3265, 1960.
- 2316 CLOUSTON, J. G. GAYDON, A. G. and HURLE, I. R. Temperature measurements of shock-waves by spectrum-line reversal. II, A double beam method. Proc. Roy. Soc. A252, 1959, 143.
- 2317 ANDERSON, G. Shock-tube testing time. J. Ae. Scs. 26, 1959, 184
- 2318 STOLLERY, J. L. Stagnation temperature measurements in a hypersonic gun tunnel using the Sodium-line reversal method. ARC 22, 854, 1961.
- 2321 BENJAMIN, T. B. Effects of a flexible boundary on hydrodynamic stability J. Fluid Mech. 9, 1960, 513.
- 2322 NONWEILER, T. R. F. Qualitative solutions of the stability equation for a boundary layer in contact with various forms of flexible surface. ARC 22, 670, 1961.
- 2338 JONES, G. W. and UNANGST, J. R. Investigation to determine effects of center-of-gravity location on transonic flutter characteristics of a 45° sweptback wing. NACA RM. L55K30, 1956.
- 2339 YATES, E. C. Calculation of flutter characteristics of finite-span swept or unswept wings at subsonic and supersonic speeds by a modified strip analysis. NACA RM. L57L10, 1958.
- 2340 LAND, N. S. and ABBOTT, F. T. Method of controlling stiffness properties of a solid-construction model wing. NACA TN. 3423. 1955.
- 2341 JONES, G. W. and DuBOSE, H. C. Investigation of wing flutter at transonic speeds for six systematically varied plan forms. NACA RM. L53G10a, 1953.
- 2342 FALKNER, V. M. The calculation of aerodynamic loading on surfaces of any shape. ARC R & M. 1910, 1943.

DOCUMENTS

- 2364 GADD, G. E. , HOLDER, D. W. and REGAN, J. D. An experimental investigation of the interaction between shock waves and boundary layers Proc. Roy. Soc. A. 226, 1954, 227
- 2367 GADD, G. E. A theoretical investigation of the effects of Mach number, Reynolds number, wall temperature and surface curvature on laminar separation in supersonic flow. ARC 18,494, 1956.
- 2379 ALLEN, H. J. Hypersonic flight and the re-entry problem. J. Ae. Scs. 25 1958, 217.
- 2391 PROBSTEIN, R. F. Shock wave and flow field development in hypersonic re-entry. ARS. Jnl. 31, 1961, 185.
- 1694 LEISSE & BRESSETTE Pressure distribution induced in a flat plate by a supersonic and sonic jet at a free-stream Mach number of 1.80. NACA RM L56I06, 1957.

APPENDIX II

SETS OF DOCUMENTS SUBMITTED FOR
RELEVANCE DECISIONS

<u>Question</u>	<u>Documents</u>
79	1302, 1317, 1436, 1437, 1572, 1575, 1672, 1967, 2111, 2313, 2319, 2379, 2391.
100	1321, 1324, 1335, 1378, 1383, 1569, 1572, 1608, 1655, 1671, 1785, 1786, 1787, 1788, 2076, 2155, 2364, 2367.
116	1317, 1435, 1569, 1574, 1575, 1576, 1578, 1605, 1608, 1656, 1666, 1972, 1993, 2002, 2153, 2155, 2391.
118	1324, 1378, 1436, 1437, 1509, 1575, 1576, 1666, 1667, 1670, 1695, 1707, 1779, 1880, 1964, 1978, 2099, 2100, 2274, 2319, 2391.
119	1302, 1324, 1378, 1383, 1406, 1437, 1476, 1569, 1572, 1576, 1606, 1618, 1666, 1667, 1670, 1798, 1916, 2076, 2082, 2084, 2274, 2318, 2391.
121	1311, 1406, 1416, 1588, 1589, 1590, 1681, 1772, 1788, 1836, 1994, 1988, 2076, 2111, 2321, 2322.
122	1360, 1572, 1597, 1598, 1605, 1688, 1708, 1713, 1748, 1783, 1792, 1972, 1995, 1997, 2319, 2339, 2342, 2391, 1619, 1508.
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126	1311, 1415, 1416, 1443, 1597, 1671, 1672, 1676, 1687, 1710, 1794, 1799, 1972, 1995, 2076, 2150, 2153, 2154, 2338, 2341.
130	1316, 1317, 1467, 1569, 1572, 1605, 1667, 1676, 1680, 1681, 1682, 1683, 1700, 1703, 1706, 1920, 1921, 1967, 1985, 2075, 2111.
132	1335, 1378, 1406, 1443, 1569, 1572, 1606, 1608, 1620, 1697, 1710, 1783, 1799, 1874, 1880, 1972, 1973, 2144.
136	1311, 1317, 1436, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1622, 1966, 1991, 1997, 2153.
137	1311, 1316, 1415, 1420, 1572, 1621, 1675, 1682, 1683, 1699, 1709, 1711, 1793, 1794, 1795, 1796, 1797, 1799, 1916, 2338, 2341.

<u>Question</u>	<u>Documents</u>
141	1360, 1666, 1691, 1698, 1785, 1967, 1982, 1983, 2077, 2100, 2150, 2274, 2340.
145	1316, 1415, 1671, 1675, 1676, 1677, 1682, 1683, 1692, 1693, 1694, 1698, 1699, 1700, 1701, 1702, 1703, 1704, 1705, 1706, 1748, 1779, 1792, 1794, 1796, 1919, 1921, 2339, 2342
146	1576, 1681, 1688, 1699, 1700, 1701, 1702, 1703, 1705, 1706, 1779, 1792, 1921, 2001, 2077, 2154, 2157, 2274, 2319, 2339.
147	1311, 1316, 1320, 1415, 1574, 1622, 1681, 1683, 1700, 1701, 1708, 1709, 1711, 1712, 1713, 1792, 1797, 2339.
148	1436, 1509, 1618, 1688, 1699, 1717, 1719, 1786, 1968, 1982, 2001, 2002, 2379.
167	1321, 1415, 1416, 1575, 1589, 1676, 1681, 1688, 1699, 1700, 1792, 1798, 1800, 1916, 1919, 1920, 1921, 2155, 2342.
170	1320, 1420, 1572, 1605, 1655, 1675, 1688, 1693, 1694, 1695, 1700, 1717, 1787, 1794, 1971, 2075.
181	1302, 1576, 1671, 1688, 1691, 1710, 1798, 1966, 1967, 1970, 1972, 2061, 2083, 2157, 2364, 2391
182	1322, 1383, 1420, 1569, 1572, 1578, 1605, 1656, 1667, 1676, 1681, 1683, 1701, 1920, 1964, 1965, 1967, 1968.
189	1416, 1575, 1588, 1590, 1592, 1710, 1788, 1968, 1971, 1985, 1986, 1988, 1989, 1990, 2157.
190	1591, 1680, 1681, 1682, 1688, 1700, 1704, 1705, 1916, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 2074, 2078, 2082, 2187.
223	1324, 1360, 1572, 1578, 1666, 1692, 1693, 1694, 1695, 1696, 1697, 1702, 1971, 2074, 2075
224	1383, 1405, 1572, 1675, 1677, 1687, 1692, 1693, 1694, 1695, 1792, 1794, 1971, 1972, 2074, 2075, 2076, 2077, 2274, 2342
225	1311, 1335, 1360, 1383, 1406, 1436, 1569, 1572, 1588, 1655, 1671, 1687, 1688, 1796, 1971, 2075, 2076, 2077, 2155, 2187.
226	1451, 1666, 1667, 1680, 1681, 1703, 1916, 2078, 2080, 2081, 2082, 2083, 2084, 2085, 2087, 2088, 2100, 2111

<u>Question</u>	<u>Document</u>								
227	1451,	1575,	1672,	1677,	1680,	1681,	1719,	1785,	1793,
	1916,	2076,	2081,	2082,	2085,	2087,	2088,	2111.	
230	1311,	1351,	1589,	1670,	1704,	1707,	1792,	1968,	1983,
	2099,	2100,	2101,	2103,	2104,	2157,	2274,	2313,	2319.
250	1311,	1316,	1335,	1415,	1415,	1569,	1575,	1675,	1793,
	1794,	1797,	1798,	1799,	1966,	1974,	2077,	2154,	2157,
	2187,	2274,	2313,	2319,	2364,	2367.			
261	1320,	1321,	1322,	1476,	1672,	1787,	1794,	1974,	1978,
	1981,	2081,	2082,	2083,	2087,	2088,	2099,	2274,	2319.
264	1360,	1367,	1451,	1590,	1671,	1672,	1677,	1680,	1681,
	1719,	1916,	2081,	2082,	2087,	2088,	2111,	2316.	
266	1351,	1575,	1667,	1670,	1705,	1710,	1712,	1795,	1916,
	1919,	1964,	1965,	1967,	1972,	2078,	2080,	2082,	2084,
	2364.								
268	1588,	1589,	1590,	1592,	1619,	1680,	1772,	1786,	1787,
	1788,	1967,	1978,	1985,	1986,	1987,	1988,	1990,	2078,
	2318,	2322.							
269	1311,	1367,	1476,	1588,	1589,	1590,	1591,	1592,	1596,
	1672,	1710,	1772,	1787,	1987,	1988,	2088,	2100,	2187,
	2317.								
272	1415,	1676,	1677,	1680,	1681,	1682,	1683,	1692,	1693,
	1694,	1700,	1706,	1794,	1796,	1920,	1921,	2080,	2111,
	2339,	2367.							
273	1302,	1378,	1578,	1606,	1613,	1614,	1615,	1616,	1617,
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	2150,	2274,	2318,	2379,	2391.				
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RELEVANCE JUDGEMENTS

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IIIb Judgements by Scott

IIIc Judgements by ~~Boolean~~ *Bateman?*

IIId Judgements by MacAdam

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119	1324, 1329, 1378, 1666, 1667, 1670, 2391
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145	1698, 1699, 1700, 1701, 1702, 1703, 1704, 1705, 1706, 1779, 1792, 2289, 2339
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272	1680, 1681, 1682, 1683
273	1617, 1616, 1619, 1620, 1621, 1622, 2150
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226	2078, 2080, 2081, 2082, 2083, 2084, 2085, 2087, 2088
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230	1351, 1670, 1707, 1968, 1983, 2099, 2100, 2101, 2103, 2104, 2157, 2274, 2319.
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