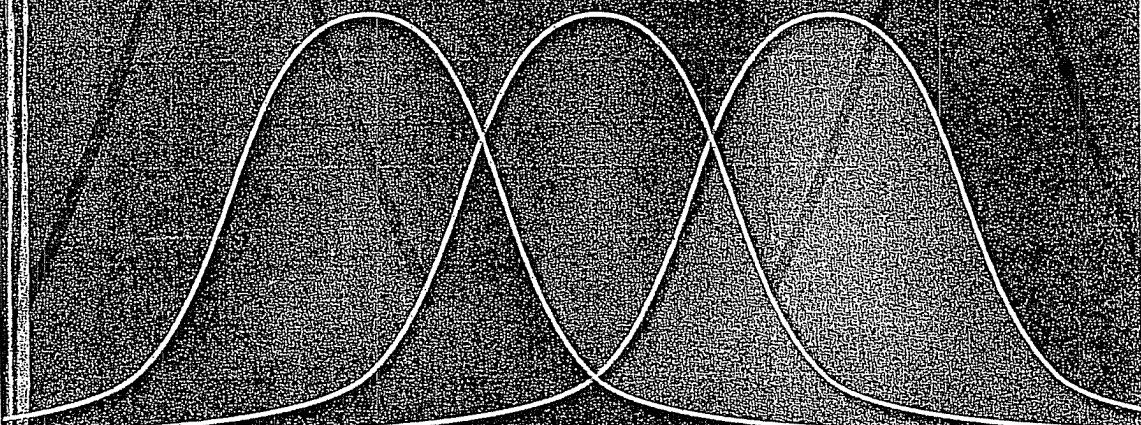


Introduction to  
**STATISTICAL  
QUALITY  
CONTROL**

5e



**Douglas C. Montgomery**

## SPC Calculations for Control Limits

Notation:	UCL—Upper Control Limit	$\bar{x}$ —Average of Measurements
	LCL—Lower Control Limit	$\bar{\bar{x}}$ —Average of Averages
	CL —Center Line	R —Range
	$n$ —Sample Size	$\bar{R}$ —Average of Ranges
	PCR—Process Capability Ratio	USL—Upper Specification Limit
	$\hat{\sigma}$ —Process Standard Deviation	LSL—Lower Specification Limit

### Variables Data ( $\bar{x}$ and R Control Charts)

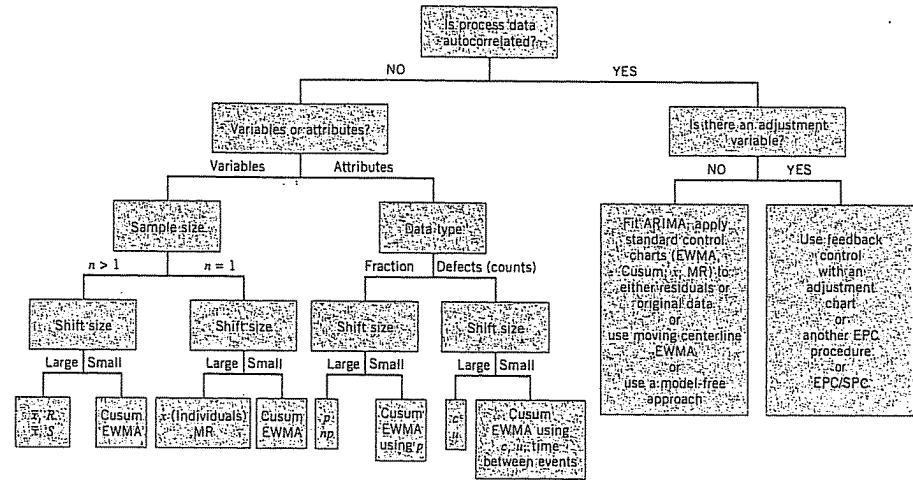
$\bar{x}$ Control Chart	$n$	$A_2$	$D_3$	$D_4$	$d_2$
UCL = $\bar{\bar{x}} + A_2 \bar{R}$	2	1.880	0.000	3.267	1.128
LCL = $\bar{\bar{x}} - A_2 \bar{R}$	3	1.023	0.000	2.574	1.693
CL = $\bar{\bar{x}}$	4	0.729	0.000	2.282	2.059
	5	0.577	0.000	2.114	2.326
R Control Chart	6	0.483	0.000	2.004	2.534
UCL = $\bar{R} D_4$	7	0.419	0.076	1.924	2.704
LCL = $\bar{R} D_3$	8	0.373	0.136	1.864	2.847
CL = $\bar{R}$	9	0.337	0.184	1.816	2.970
	10	0.308	0.223	1.777	3.078

Capability Study  
 $C_p = (USL - LSL)/(6\hat{\sigma})$ ; where  $\hat{\sigma} = \bar{R}/d_2$

### Attribute Data ( $p$ , $np$ , $c$ , and $u$ Control Charts)


	$p$ (fraction) <i>defective</i>	$np$ (number of nonconforming)	$c$ (count of nonconformances)	$u$ (count of nonconformances/unit) <i>nonconformities</i> <i>Defects</i>
CL	$\bar{p}$	$n\bar{p}$	$\bar{c}$	$\bar{u}$
UCL	$\bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	$n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$	$\bar{c} + 3\sqrt{\bar{c}}$	$\bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$
LCL	$\bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	$n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$	$\bar{c} - 3\sqrt{\bar{c}}$	$\bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$
Notes	If $n$ varies, use $\bar{n}$ or individual $n_i$	$n$ must be a constant	$n$ must be a constant	If $n$ varies, use $\bar{n}$ or individual $n_i$

### Guide to Univariate Process Monitoring and Control



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# Introduction to Statistical Quality Control

Fifth Edition

Douglas C. Montgomery

Arizona State University



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Douglas C. Montgomery is the Arizona State University Foundation Professor of Engineering and Professor of Statistics. He received his B.S., M.S., and Ph.D. degrees from Virginia Polytechnic Institute, all in engineering. From 1969 to 1984 he was a faculty member of the School of Industrial & Systems Engineering at the Georgia Institute of Technology; from 1984 to 1988 he was at the University of Washington, where he held the John M. Fluke Distinguished Chair of Manufacturing Engineering, was Professor of Mechanical Engineering, and was Director of the Program in Industrial Engineering.

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# Preface

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## INTRODUCTION

This book is about the use of modern statistical methods for quality control and improvement. It provides comprehensive coverage of the subject from basic principles to state-of-the-art concepts and applications. The objective is to give the reader a sound understanding of the principles and the basis for applying them in a variety of situations. Although statistical techniques are emphasized throughout, the book has a strong engineering and management orientation. Extensive knowledge of statistics is not a prerequisite for using this book. Readers whose background includes a basic course in statistical methods will find much of the material in this book easily accessible.

## AUDIENCE

The book is an outgrowth of over 30 years of teaching, research, and consulting in the application of statistical methods for industrial problems. It is designed as a textbook for students enrolled in colleges and universities, who are studying engineering, statistics, management, and related fields and are taking a first course in statistical quality control. The basic quality-control course is often taught at the junior or senior level. All of the standard topics for this course are covered in detail. Some more advanced material is also available in the book, and this could be used with advanced undergraduates who have had some previous exposure to the basics or in a course aimed at graduate students. I have also used the text materials extensively in programs for professional practitioners, including quality and reliability engineers, manufacturing and development engineers, product designers, managers, procurement specialists, marketing personnel, technicians and laboratory analysts, inspectors, and operators. Many professionals have also used the material for self-study.

## CHAPTER ORGANIZATION AND TOPICAL COVERAGE

Chapter 1 is an introduction to the philosophy and basic concepts of quality improvement. It notes that quality has become a major business strategy and that organizations that successfully improve quality can increase their productivity, enhance their market penetration, and achieve greater profitability and a strong competitive advantage. Some of the managerial and implementation aspects of quality improvement are included.

Following the introductory chapter, the book is divided into five parts. Part I is a description of statistical methods useful in quality improvement. Topics covered include sampling and descriptive statistics, the basic notions of probability and probability distributions, point and interval estimation of parameters, and statistical hypothesis testing. These topics are usually covered in a basic course in statistical methods; however, their presentation in this text is from the quality-engineering viewpoint. My experience has been that even readers with a strong statistical background will find the approach to this material useful and somewhat different from a standard statistics textbook.

Part II contains four chapters covering the basic methods of statistical process control (SPC) and methods for process capability analysis. Even though several SPC problem-solving tools are discussed (including Pareto charts, cause-and-effect diagrams, for example), the primary focus in this section is on the Shewhart control chart. The Shewhart control chart is certainly not new, but its use in modern-day business and industry is of tremendous value.

There are four chapters in Part III that present some more advanced SPC methods. Included are the cumulative sum and exponentially weighted moving average control charts (Chapter 8), several important univariate control charts such as procedures for short production runs, autocorrelated data, and multiple stream processes (Chapter 9), multivariate process monitoring and control (Chapter 10), and feedback adjustment techniques (Chapter 11). Some of this material is at a higher level than Part II, but much of it is accessible by advanced undergraduates or first-year graduate students. This material forms the basis of a second course in statistical quality control and improvement for this audience.

Part IV contains two chapters that show how statistically designed experiments can be used for process design, development, and improvement. Chapter 12 presents the fundamental concepts of designed experiments and introduces the reader to factorial and fractional factorial designs, with particular emphasis on the two-level system of designs. These designs are used extensively in industry for factor screening and process characterization. Although the treatment of the subject is not extensive and is no substitute for a formal course in experimental design, it will enable the reader to appreciate more sophisticated examples of experimental design. Chapter 13 introduces response surface methods and designs, illustrates evolutionary operation (EVOP) for process monitoring, and shows how statistically designed experiments can be used for process robustness studies. Chapters 12 and 13 emphasize the important interrelationship between statistical process control and experimental design for process improvement.

Two chapters deal with acceptance sampling in Part V. The focus is on lot-by-lot acceptance sampling, although there is some discussion of continuous sampling and MIL STD 1235C in Chapter 14. Other sampling topics presented include various aspects of the design of acceptance-sampling plans, a discussion of MIL STD 105E, MIL STD 414 (and their civilian counterparts, ANSI/ASQC Z1.4 and ANSI/ASQC Z1.9), and other techniques such as chain sampling and skip-lot sampling.

Throughout the book, guidelines are given for selecting the proper type of statistical technique to use in a wide variety of situations. Additionally extensive references to journal articles and other technical literature should assist the reader in applying the methods described.

## SUPPORTING TEXT MATERIALS

### Computer Software

The computer plays an important role in a modern quality-control course. This edition of the book uses Minitab as the primary illustrative software package. Instructors may order this book with a student version of Minitab included. I strongly recommend that the course have a meaningful computing component. To request this book with Minitab included, contact your local Wiley representative. You can find your local Wiley representative by going to [www.wiley.com](http://www.wiley.com) and clicking on the tab for "Who's My Rep?".

### Supplemental Text Material

I have written a set of supplemental material to augment many of the chapters in the book. The supplemental material contains topics that I could not easily fit into that chapter without seriously disrupting the flow. The topics are shown in the Table of Contents for the book and in the individual chapter outlines. Some of this material consists of proofs or derivations, new topics of a (sometimes) more advanced nature, supporting details concerning remarks or concepts presented in the text, and answers to frequently asked questions. The supplemental material provides an interesting set of accompanying readings for anyone curious about the field. It is available on the World Wide Web page that supports the book, located at [www.wiley.com/college/montgomery](http://www.wiley.com/college/montgomery).

### Student Resource Manual



The text contains answers to most of the odd-numbered exercises. A Student Resource Manual is available from John Wiley & Sons that presents comprehensive annotated solutions to these same odd-numbered problems. This is an excellent study aid that many text users will find extremely helpful. The Student Resource Manual may be ordered in a set with the text or purchased separately. Contact your local Wiley representative to request the set for your bookstore or purchase the Student Resource Manual from the Wiley website.

### Instructor's Materials

The instructor's section of the textbook website contains the following:

1. Solutions to the text problems
2. The supplemental text material described above
3. A set of Microsoft® PowerPoint slides for the basic SPC course
4. Data sets from the book, in electronic form

The instructor's section is for instructor use only and is password-protected. Visit the Instructor Companion Site portion of the website, located at [www.wiley.com/college/montgomery](http://www.wiley.com/college/montgomery), to register for a password.

## World Wide Web Page

The Web page for the book is accessible through the Wiley home page. It contains the supplemental text material and the data sets in electronic form. It will also be used to post items of interest to text users. The website address is [www.wiley.com/college/montgomery](http://www.wiley.com/college/montgomery). Click on the cover of the text you are using.

## KNOWLEDGMENTS

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Over the years since the first edition was published, I have received assistance and ideas from a great many other people. A complete list of colleagues with whom I have interacted would be impossible to enumerate. However, some of the major contributors and their professional affiliations are as follows: Dr. Mary R. Anderson-Rowland, Dr. Dwayne A. Rollier, and Dr. Norma F. Hubele, Arizona State University; Mr. Seymour M. Selig, formerly of the Office of Naval Research; Dr. Lynwood A. Johnson, Dr. Russell G. Heikes, Dr. David E. Fyffe, and Dr. H. M. Wadsworth, Jr., Georgia Institute of Technology; Dr. Sharad Prabhu and Dr. Robert Rodriguez, SAS Institute; Dr. Richard L. Storch and Dr. Christina M. Mastrangelo, University of Washington; Dr. Cynthia A. Lowry, formerly of Texas Christian University; Dr. Smiley Cheng, Dr. John Brewster, Dr. Brian Macpherson, and Dr. Fred Spiring, the University of Manitoba; Dr. Joseph D. Moder, University of Miami; Dr. Frank B. Alt, University of Maryland; Dr. Kenneth E. Case, Oklahoma State University; Dr. Daniel R. McCarville, Dr. Lisa Custer, Dr. Pat Spagon, and Mr. Robert Stuart, all formerly of Motorola; Dr. Richard Post, Intel Corporation; Dr. Dale Sevier, Hybritech; Mr. John A. Butora, Mr. Leon V. Mason, Mr. Lloyd K. Collins, Mr. Dana D. Leshner, Mr. Roy E. Dent, Mr. Mark Fazey, Ms. Kathy Schuster, Mr. Dan Fritze, Dr. J. S. Gardiner, Mr. Ariel Rosentrater, Mr. Lolly Marwah, Mr. Ed Schleicher, Mr. Amiin Weiner, and Ms. Elaine Baechtle, IBM; Mr. Thomas C. Bingham, Mr. K. Dick Vaughn, Mr. Robert LeDoux, Mr. John Black, Mr. Jack Wires, Dr. Julian Anderson, Mr. Richard Alkire, and Mr. Chase Nielsen, The Boeing Company; Ms. Karen Madison, Mr. Don Walton, and Mr. Mike Goza, Alcoa; Mr. Harry Peterson-Nedry, Ridgecrest Vineyards and The Chehalem Group; Dr. Russell A. Boyles, formerly of Precision Castparts Corporation; Dr. Sadre Khalessi and Mr. Franz Wagner, Signetics Corporation; Mr. Larry Newton and Mr. C. T. Howlett, Georgia Pacific Corporation; Mr. Robert V. Baxley, Monsanto Chemicals; Dr. Craig Fox, Dr. Thomas L. Sadosky, Mr. James F. Walker, and Mr. John Belvins, The Coca-Cola Company; Mr. Bill Wagner and Mr. Al Pariseau, Litton Industries; Mr. John M. Fluke, Jr., John Fluke Manufacturing Company; Dr. Paul Tobias, formerly of IBM and Semitech; Dr. William DuMouchel and Ms. Janet Olson, BBN Software Products Corporation. I would also like to acknowledge the many contributions of my late partner in Statistical

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I thank the various professional societies and publishers who have given permission to reproduce their materials in my text. Permission credit is acknowledged at appropriate places in this book.

I am also indebted to the many organizations that have sponsored my research and my graduate students for a number of years, including the member companies of the National Science Foundation/Industry/University Cooperative Research Center in Quality and Reliability Engineering at Arizona State University, the Office of Naval Research, the National Science Foundation, the Aluminum Company of America, and the IBM Corporation. Finally, I would like to thank the many users of the previous editions of this book, including students, practicing professionals, and my academic colleagues. Many of the changes and (hopefully) improvements in this edition of the book are the direct result of your feedback.

Douglas C. Montgomery  
Tempe, Arizona



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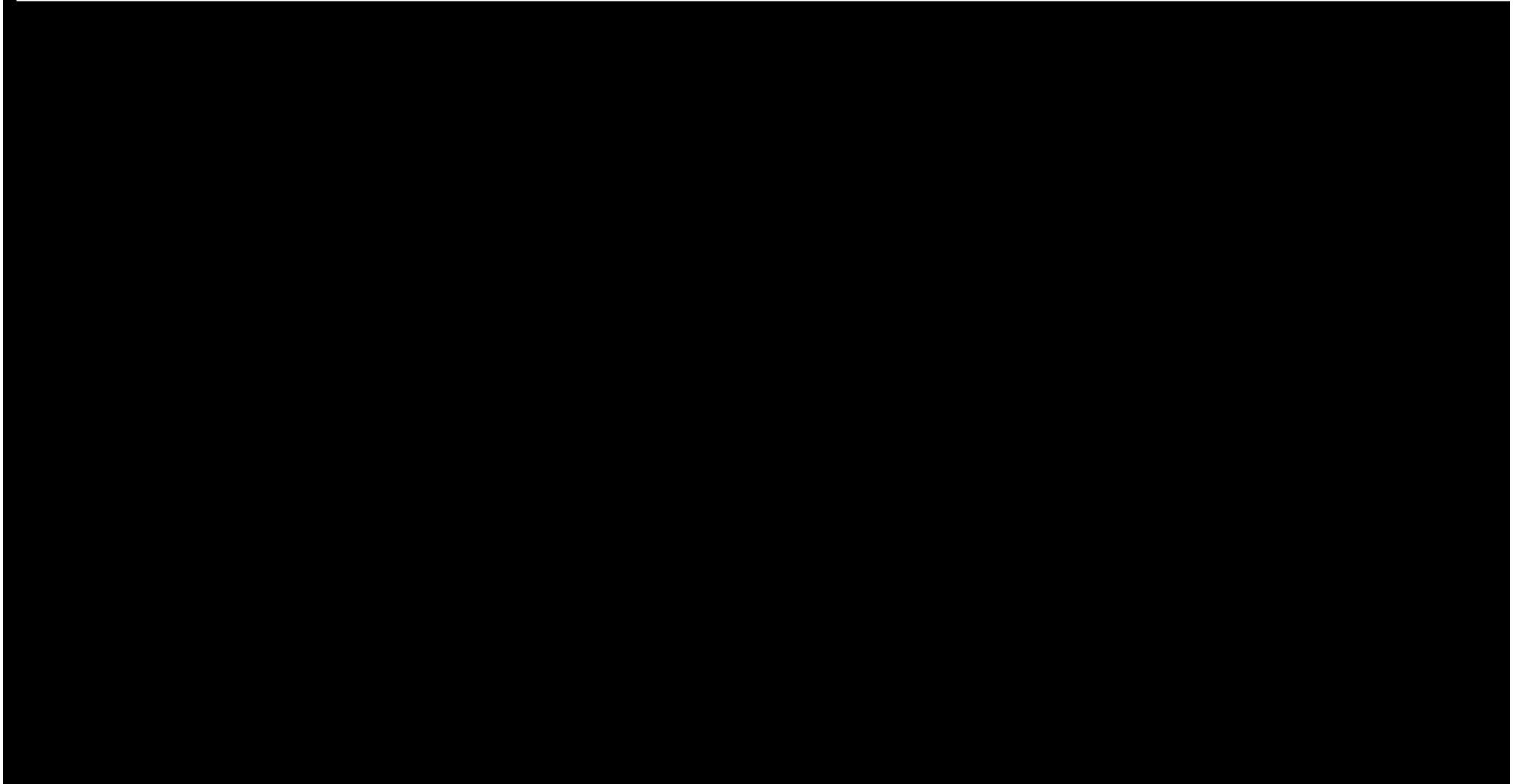
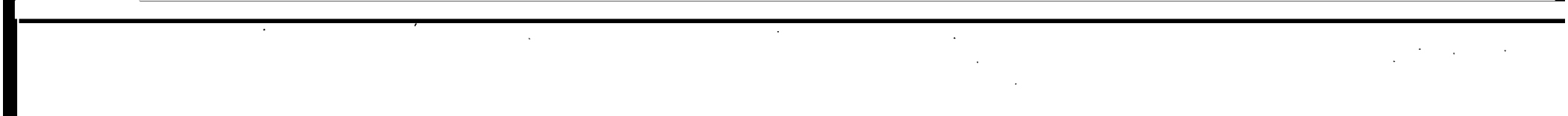
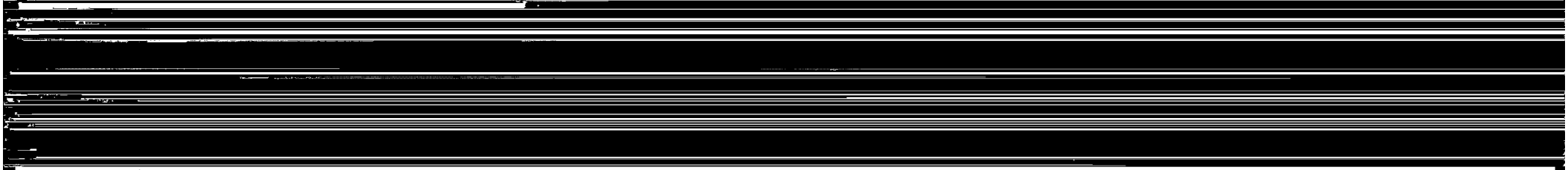
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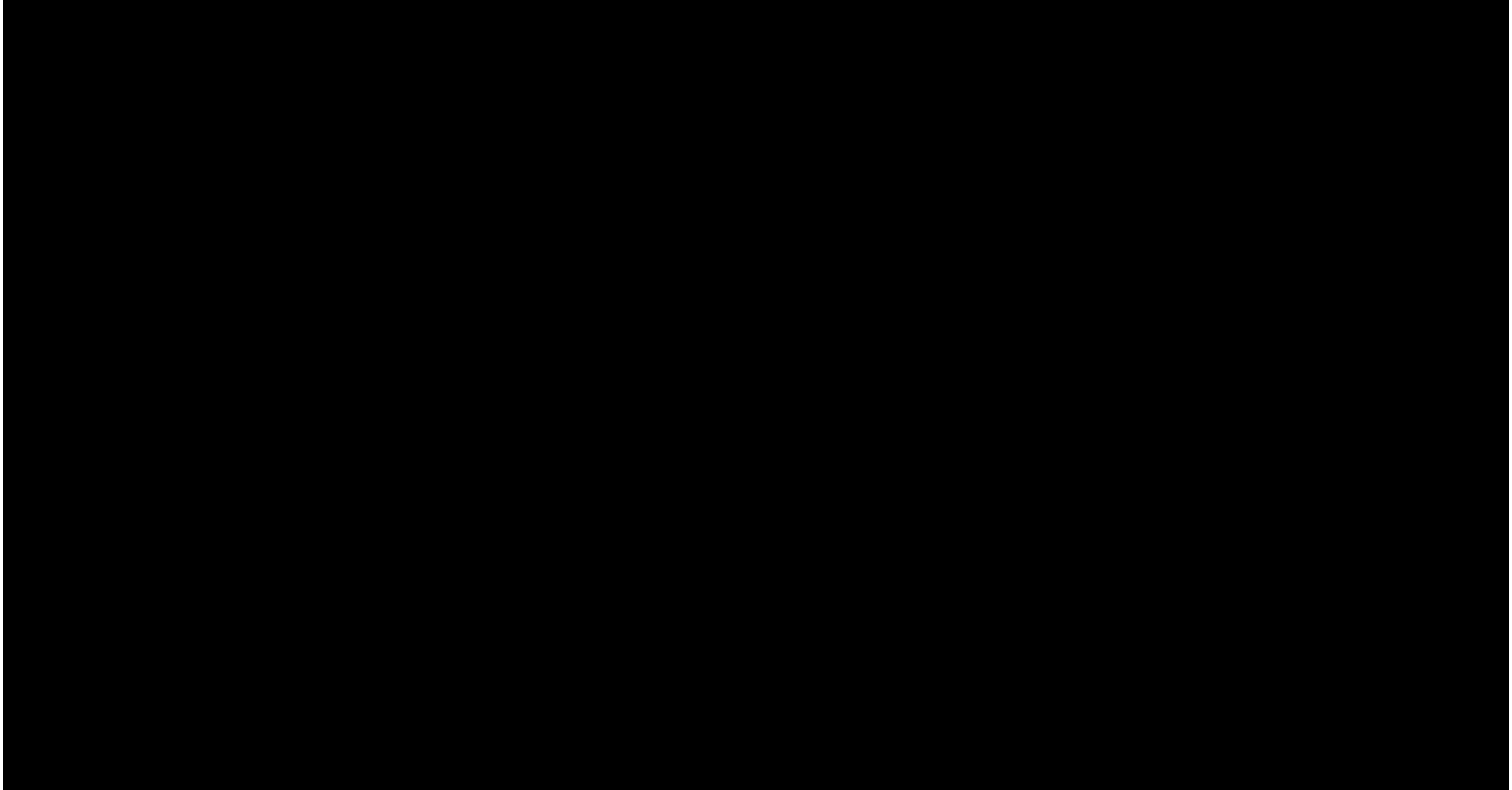
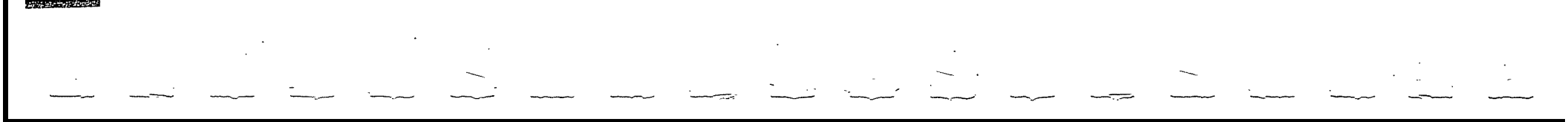
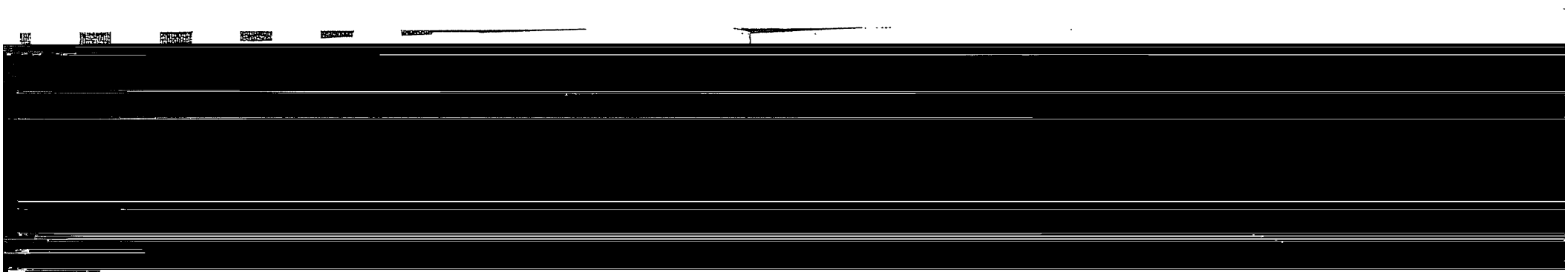
8-3 The Moving Average Control Chart 417

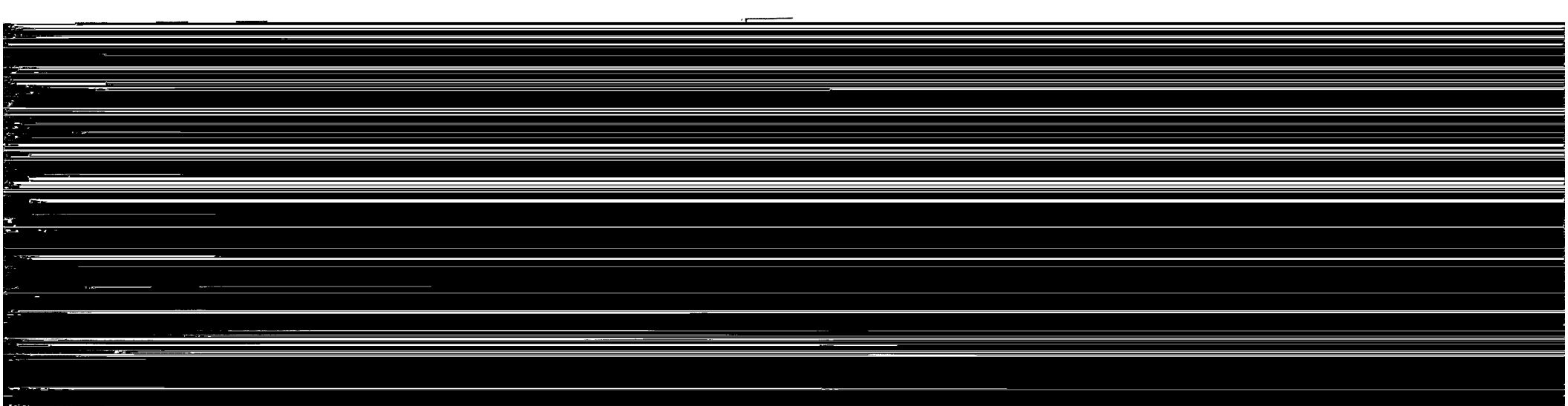
13.1.1. Designing a Single Sampling Plan with a

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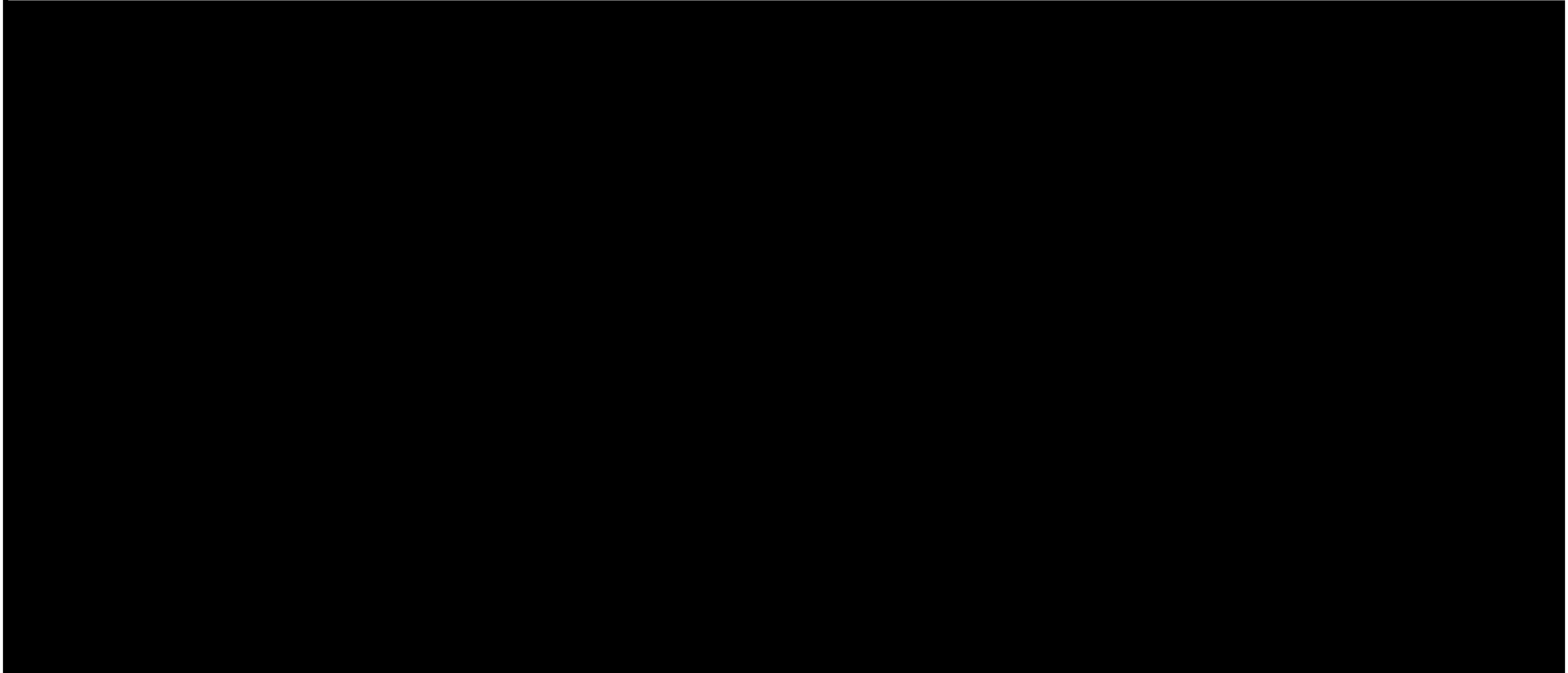
13.1.1. Designing a Single Sampling Plan with a

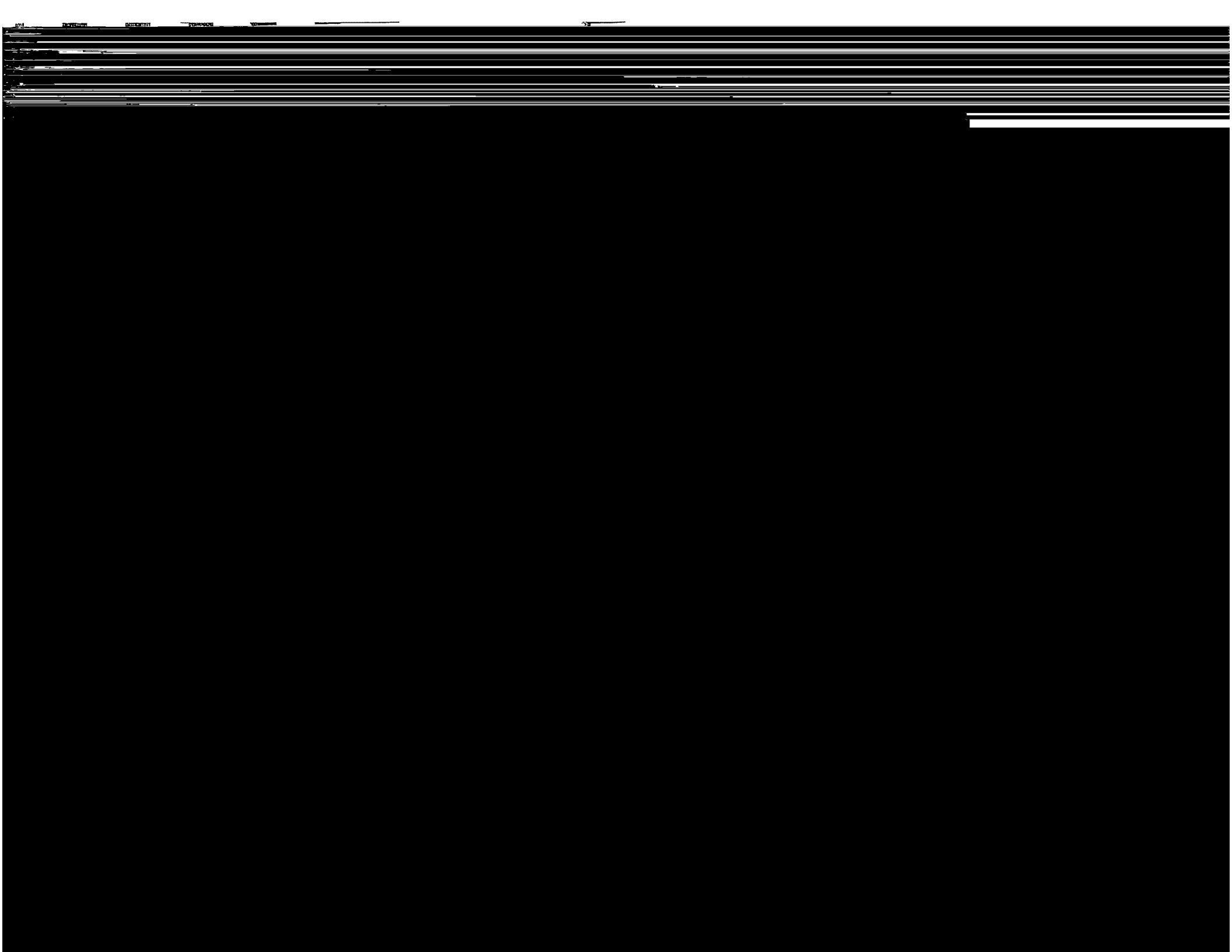


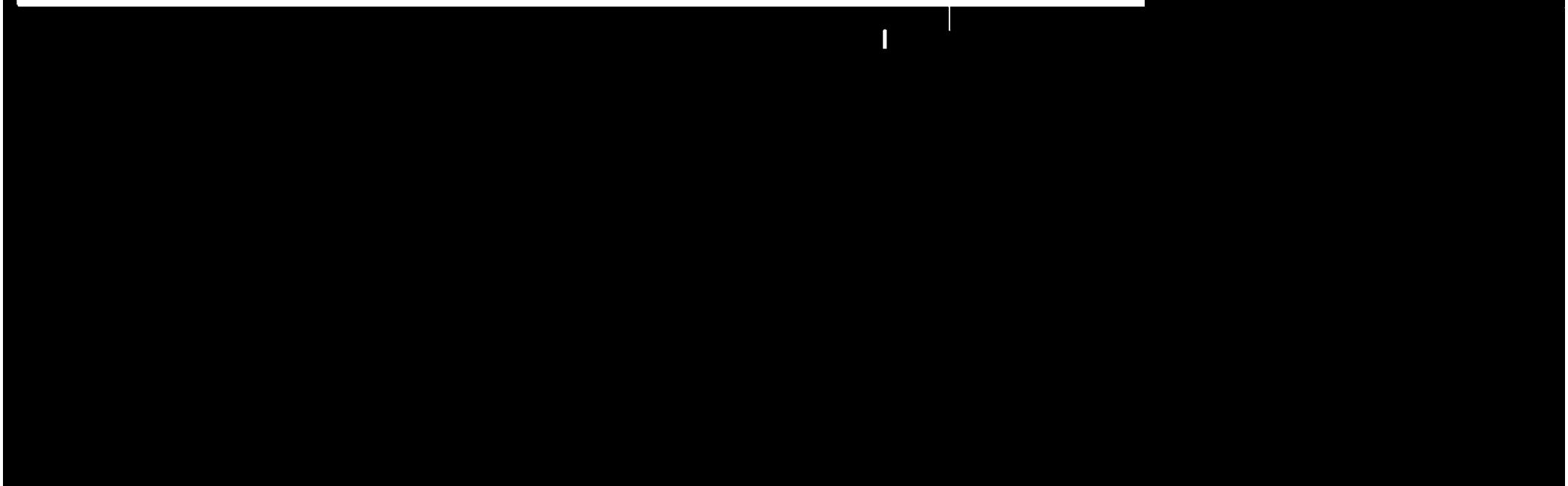


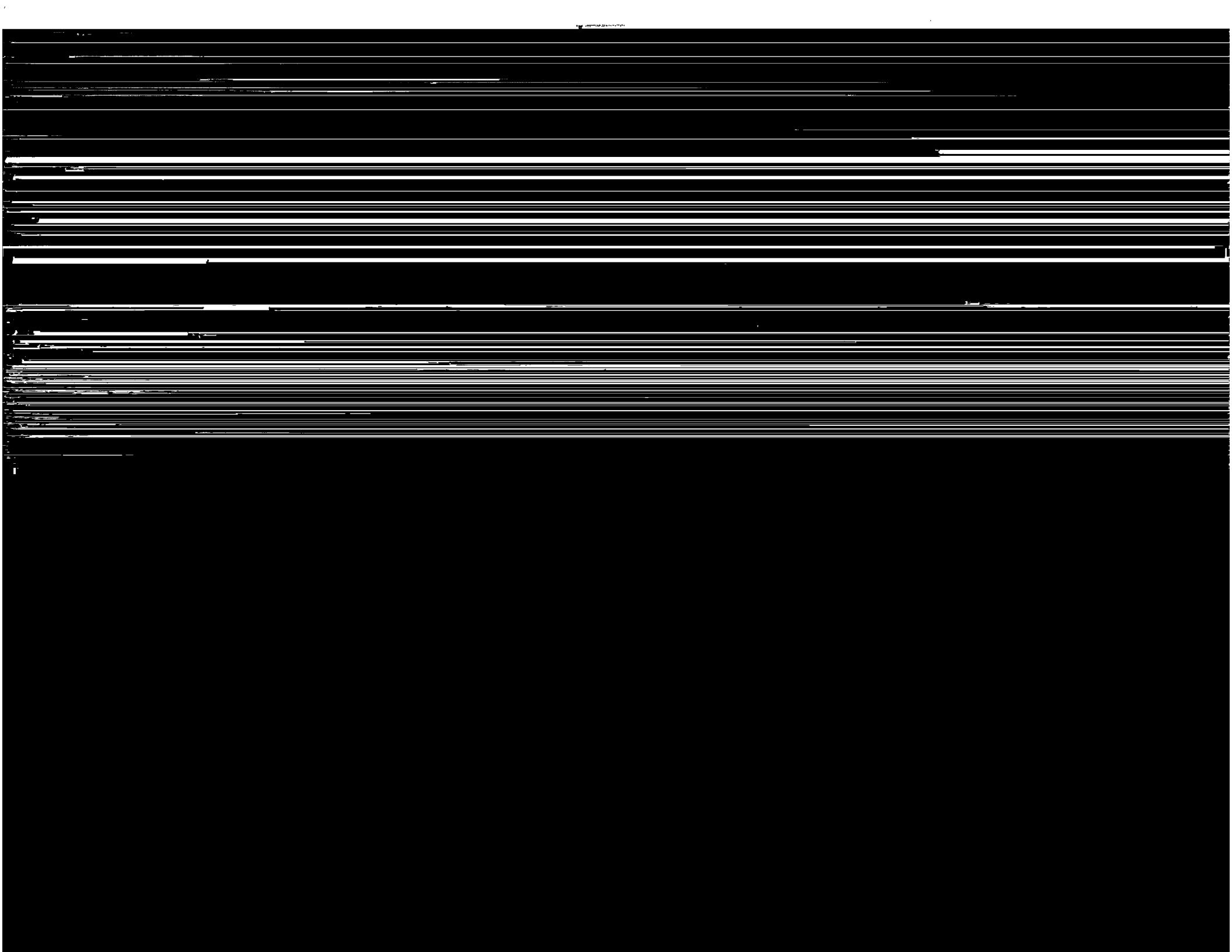


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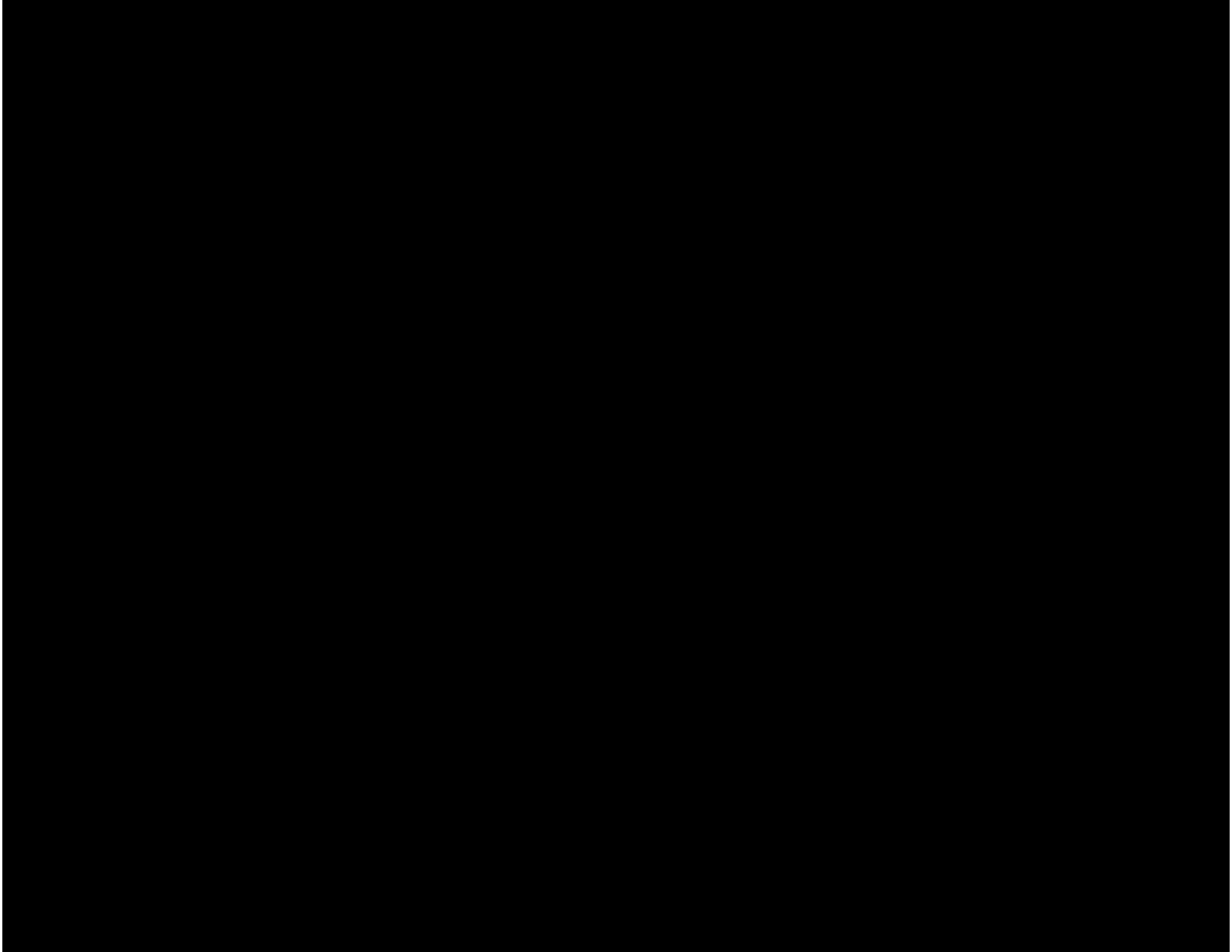












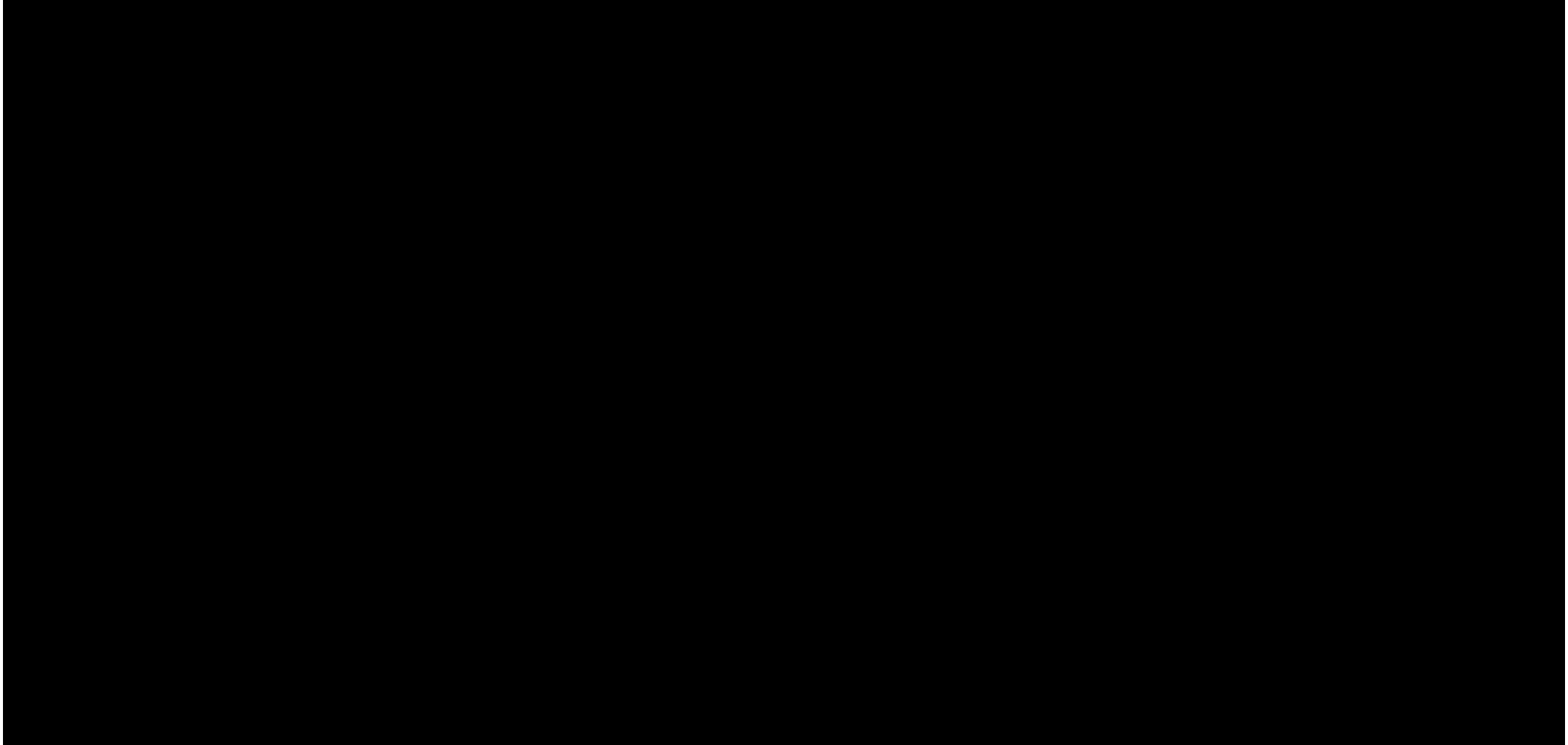
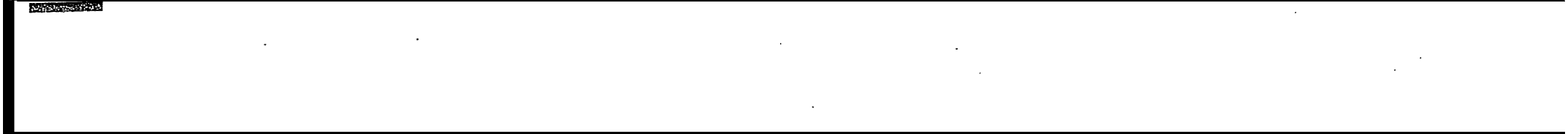
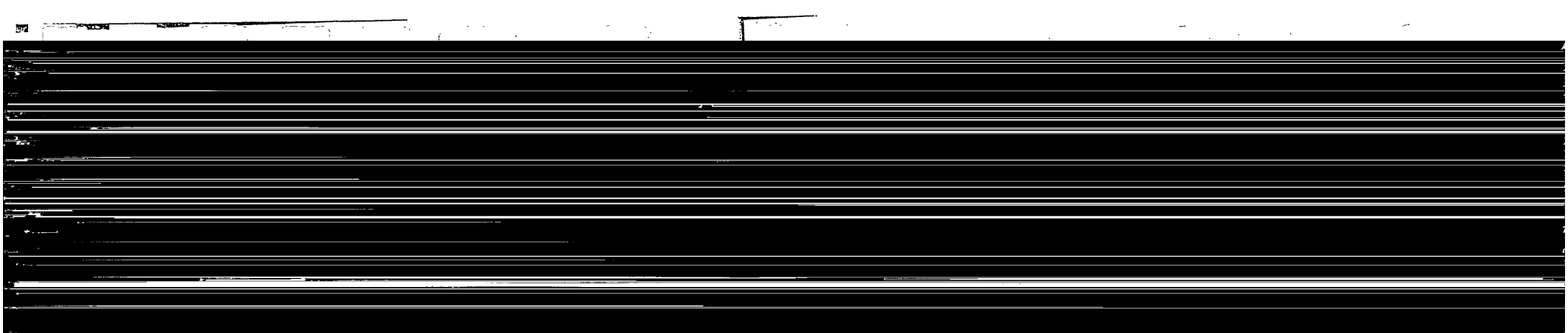
1. The first part of the document discusses the importance of maintaining accurate records of all transactions. This is essential for ensuring the integrity of the financial statements and for providing a clear audit trail. The records should be kept up-to-date and should be easily accessible to all relevant parties.

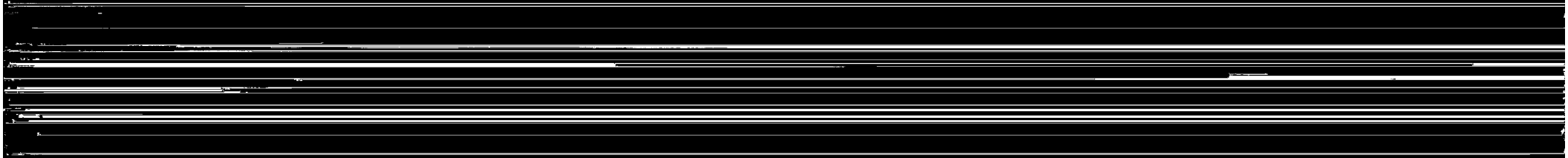
2. The second part of the document focuses on the need for transparency and accountability in financial reporting. This involves providing clear and concise information about the company's financial performance and the underlying transactions. It is important to disclose any potential risks and uncertainties that may affect the financial results.

3. The third part of the document addresses the issue of internal controls and risk management. This involves implementing a system of checks and balances to prevent errors and fraud. It also involves identifying and assessing the risks that the company faces and developing strategies to mitigate those risks.

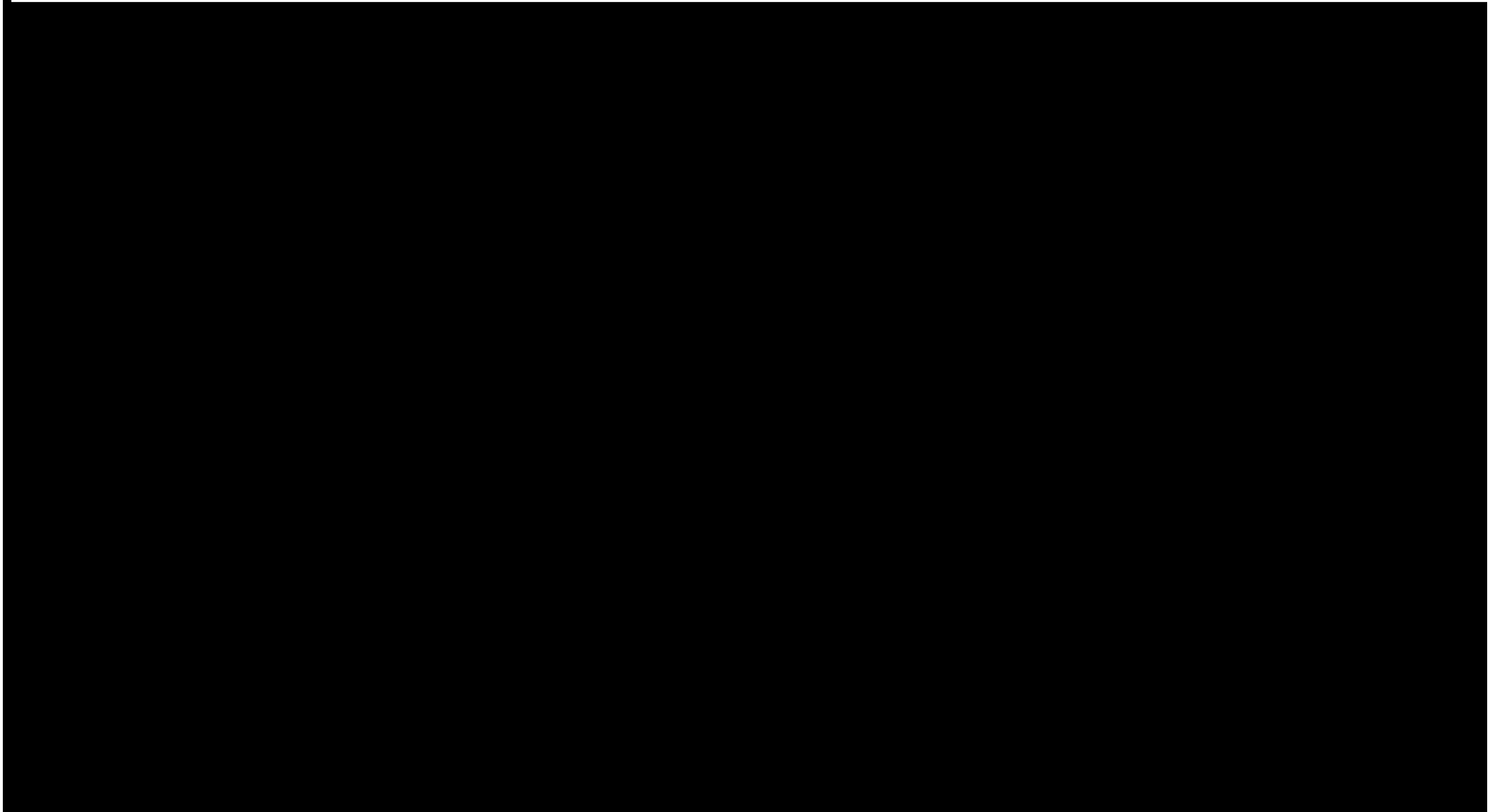
4. The fourth part of the document discusses the importance of communication and collaboration between different departments and stakeholders. This involves sharing information and working together to achieve the company's financial goals. It is important to have regular meetings and reports to ensure that everyone is on the same page.

5. The fifth part of the document concludes by emphasizing the need for continuous improvement and monitoring. This involves regularly reviewing the financial performance and the internal controls to identify areas for improvement. It is important to stay up-to-date with the latest financial reporting standards and regulations.



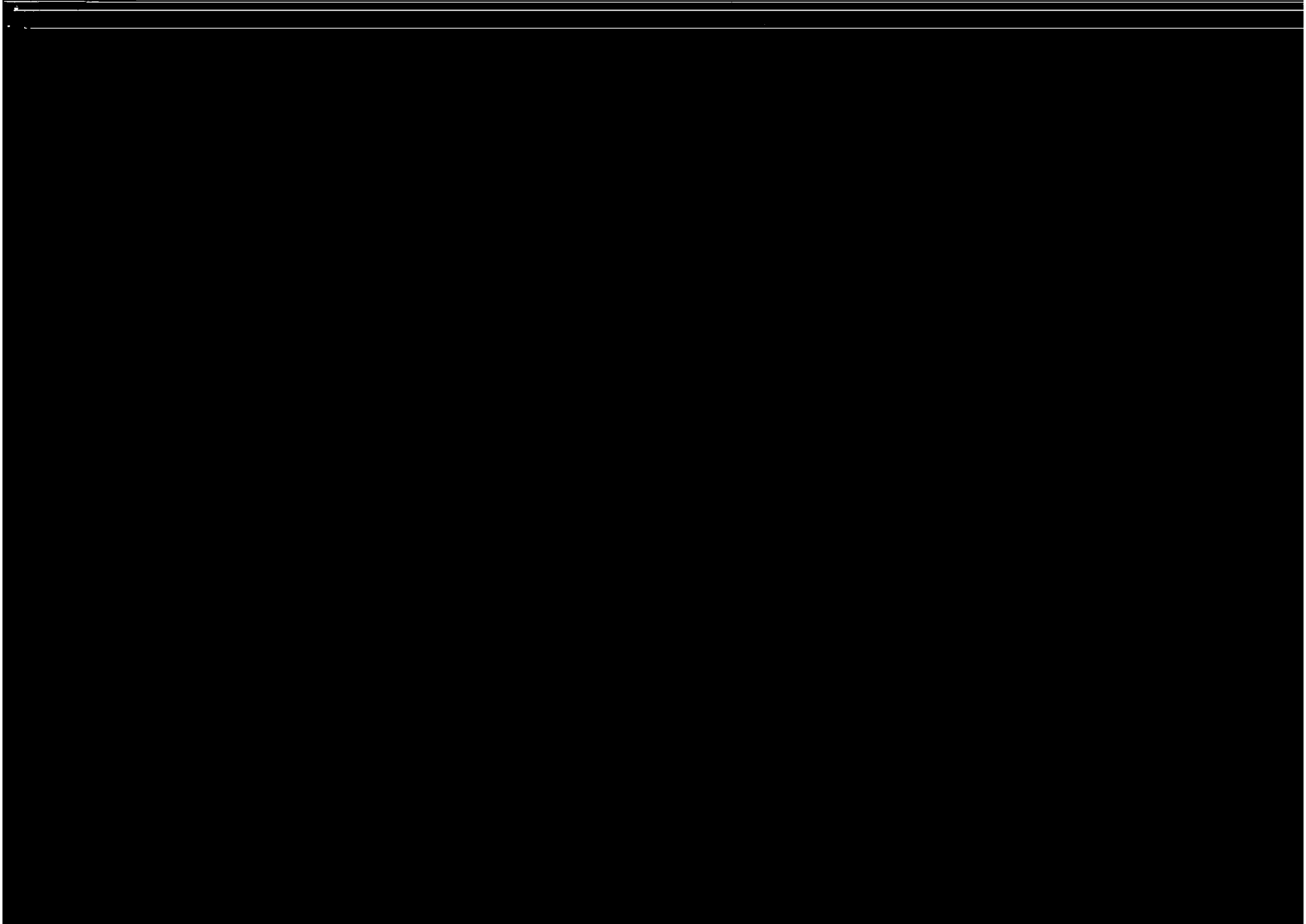


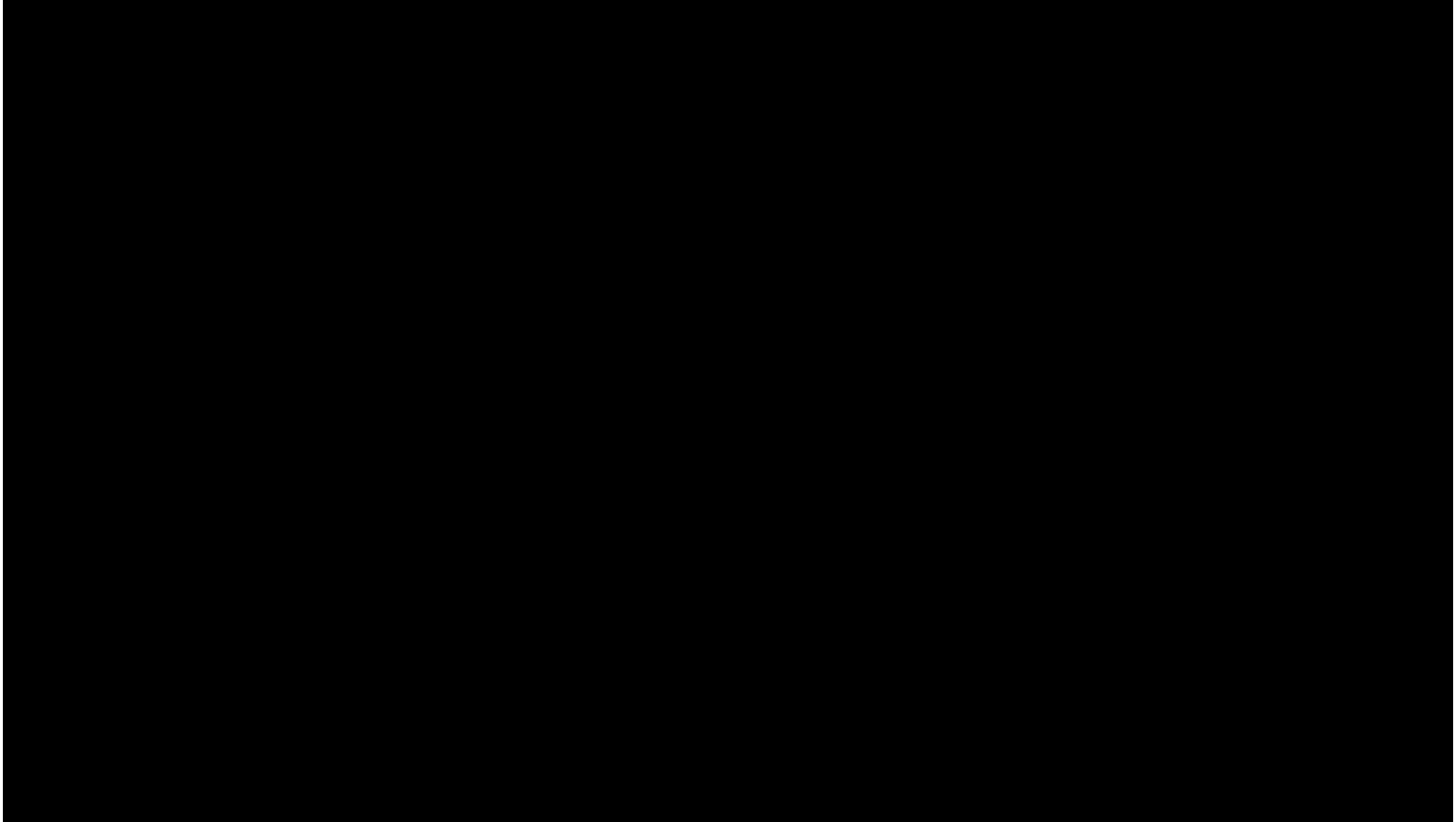
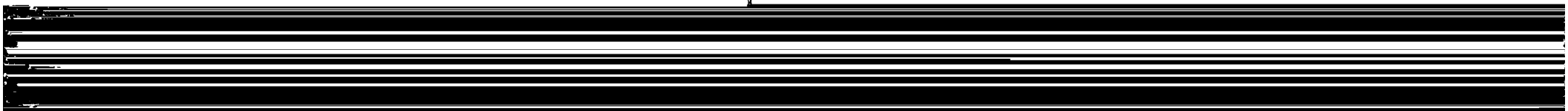
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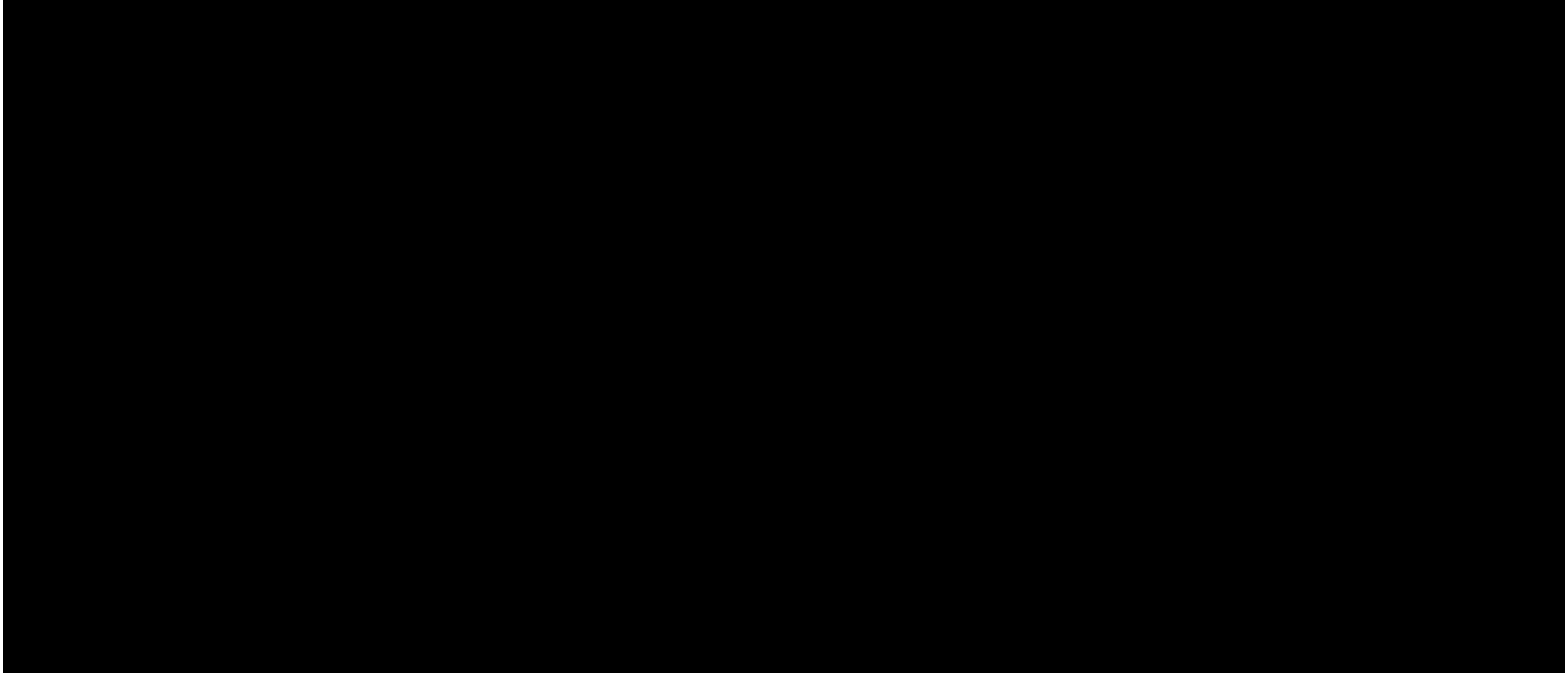
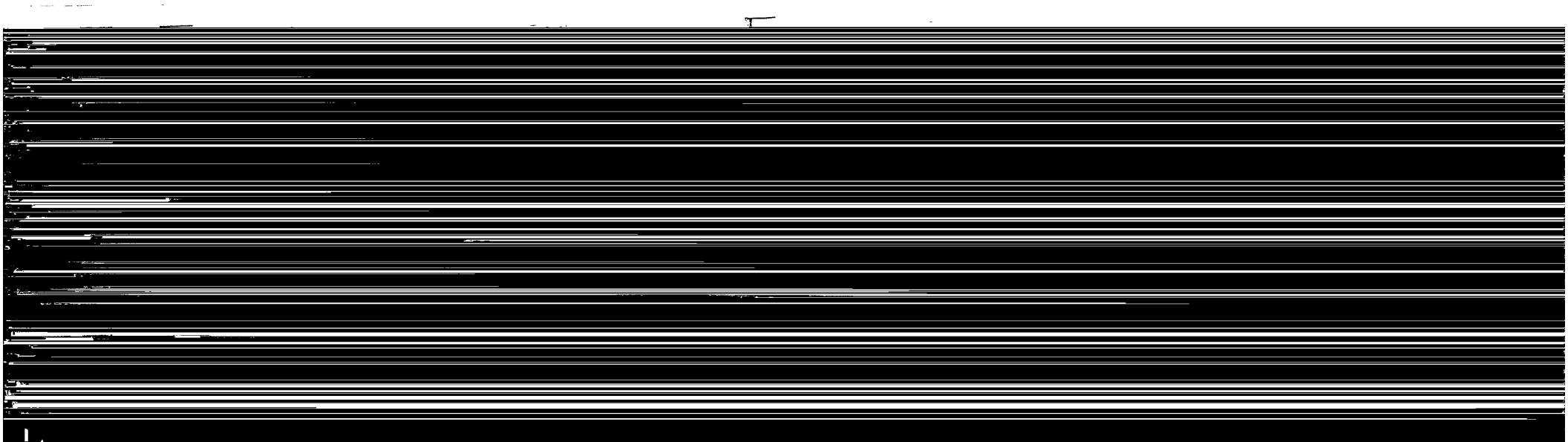
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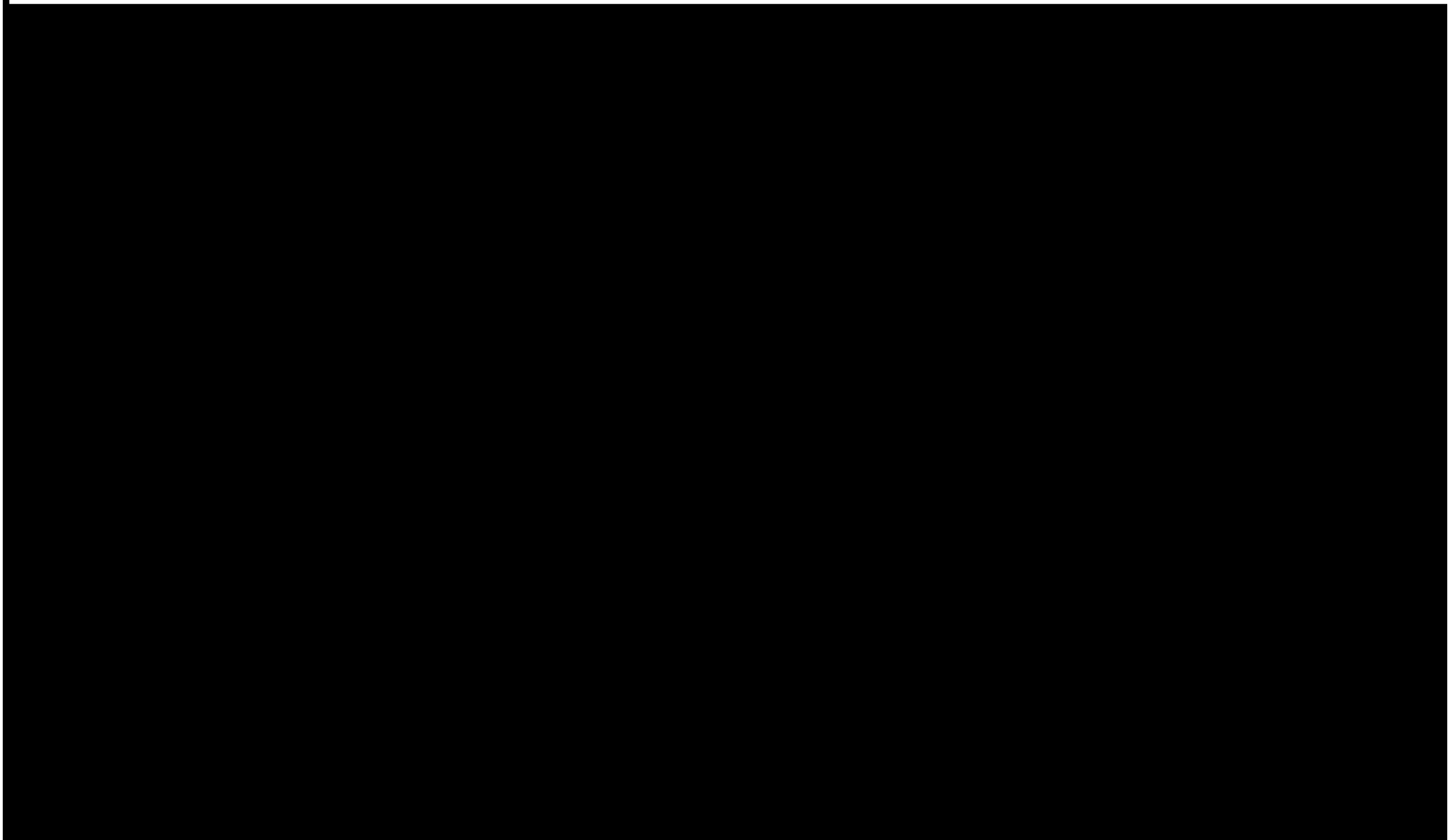
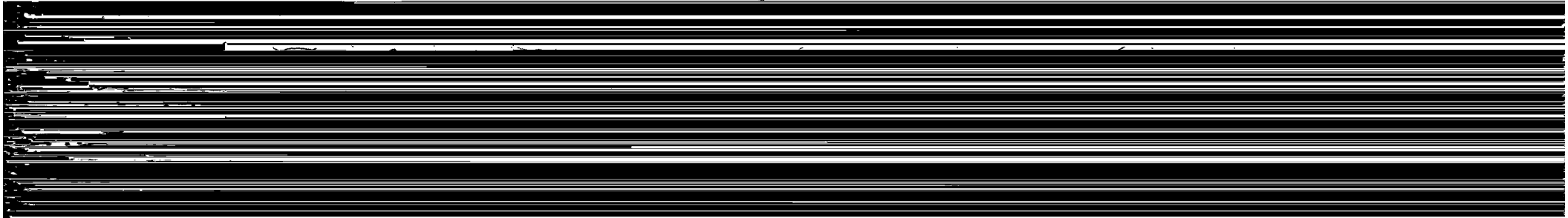


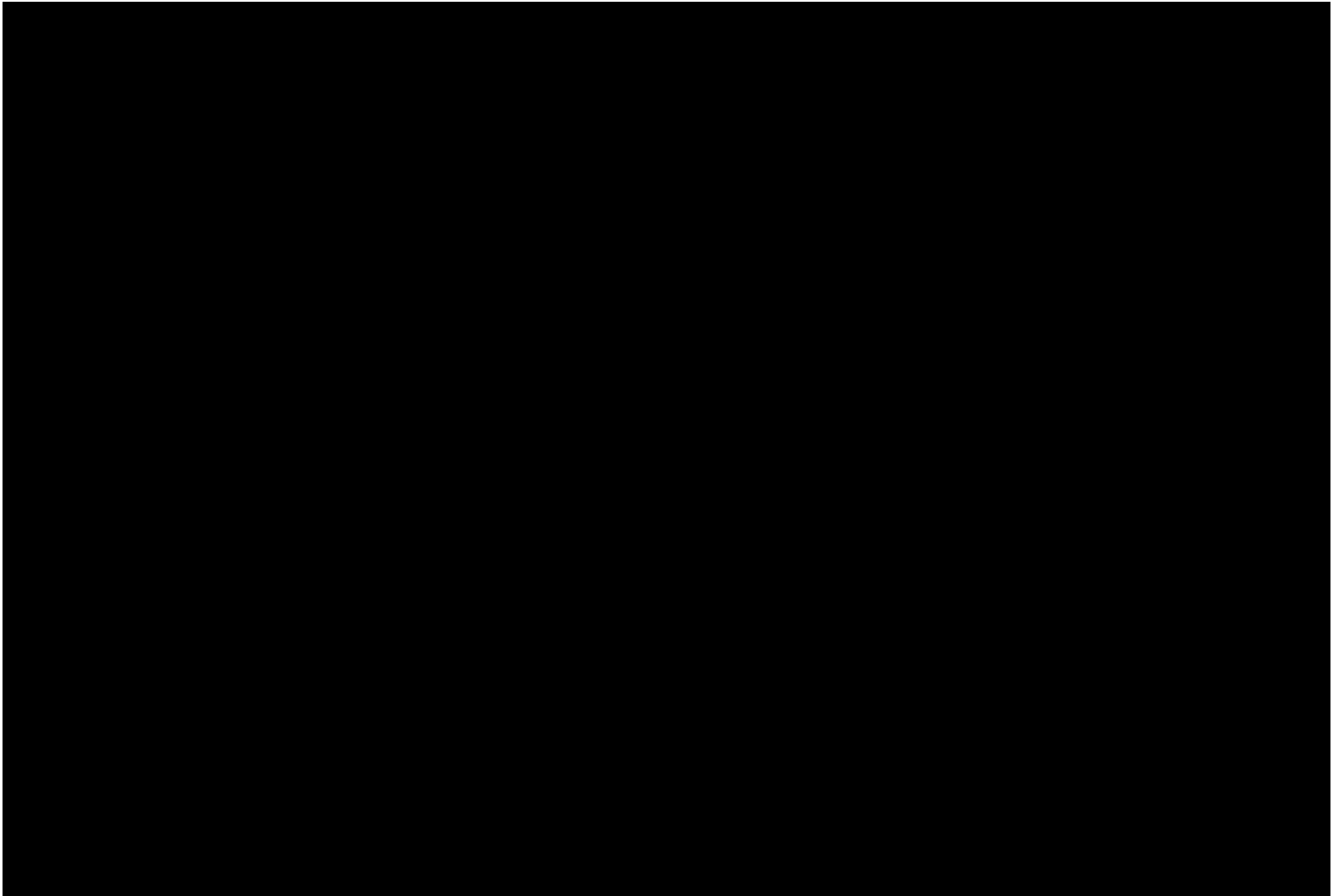


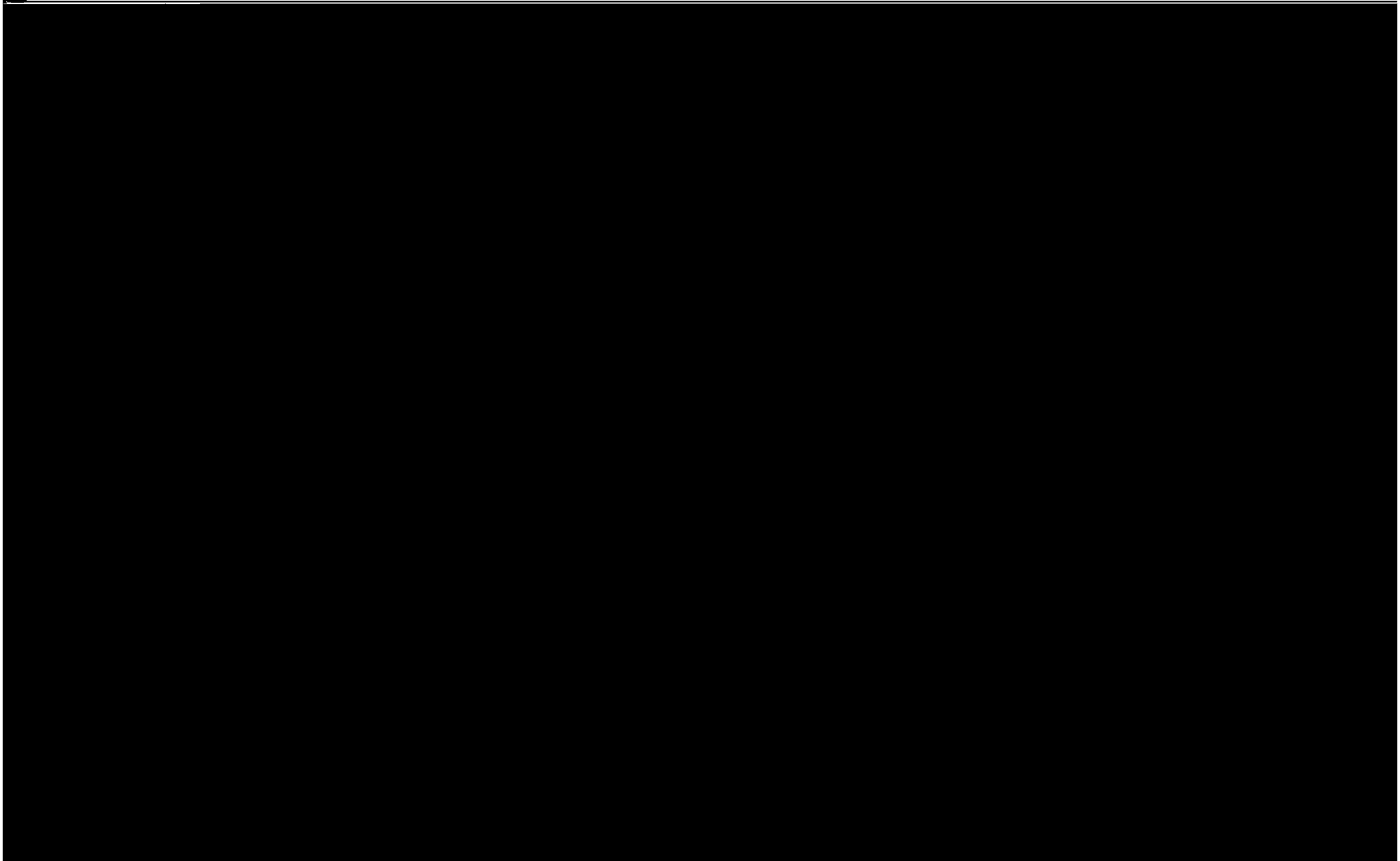
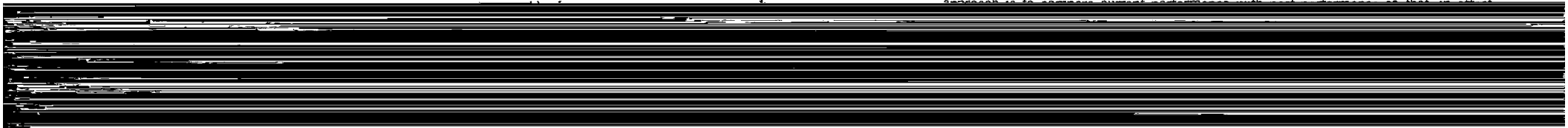






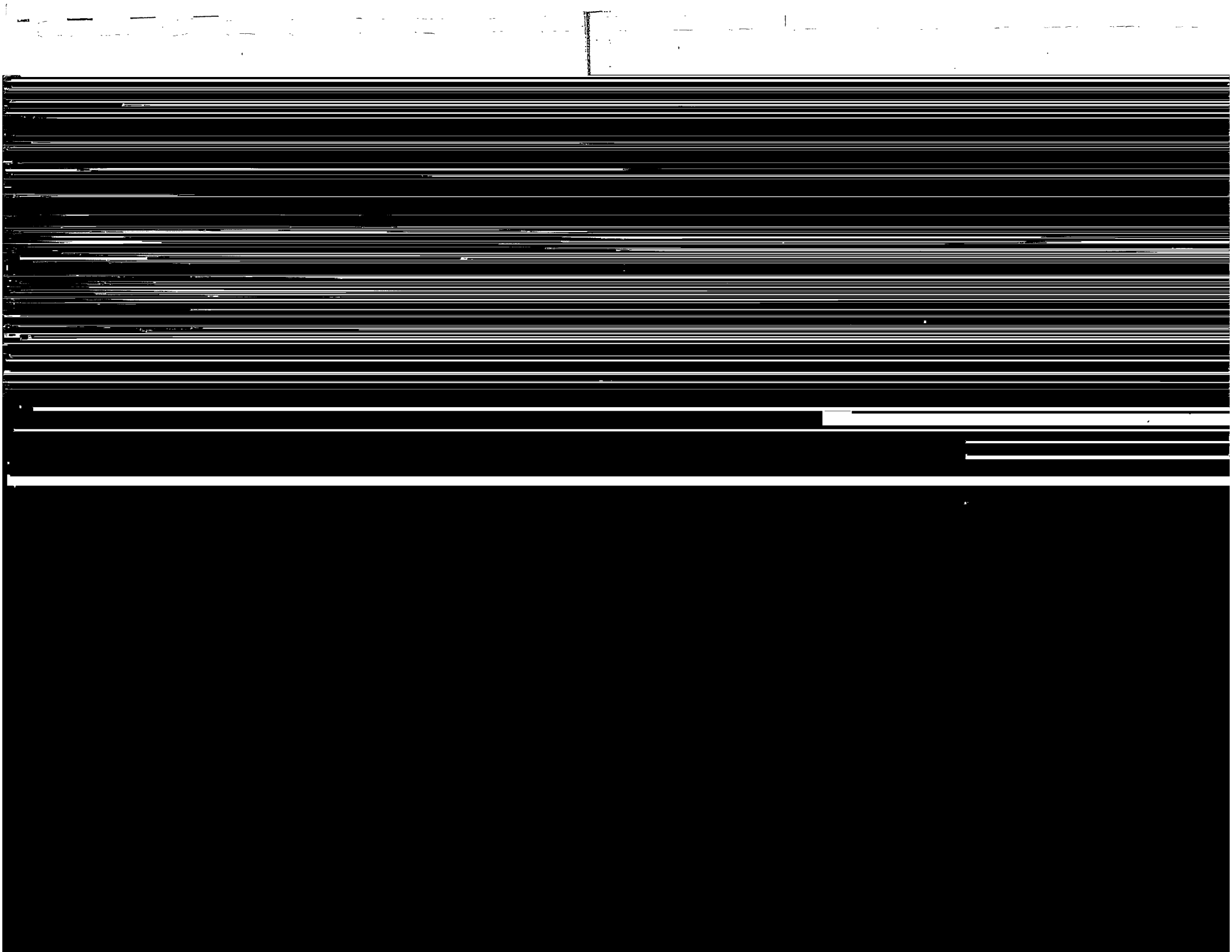






1.1.1.1

1. The first part of the text discusses the importance of the...  
2. The second part of the text discusses the importance of the...  
3. The third part of the text discusses the importance of the...  
4. The fourth part of the text discusses the importance of the...  
5. The fifth part of the text discusses the importance of the...  
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7. The seventh part of the text discusses the importance of the...  
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10. The tenth part of the text discusses the importance of the...



2

Modeling Process Quality

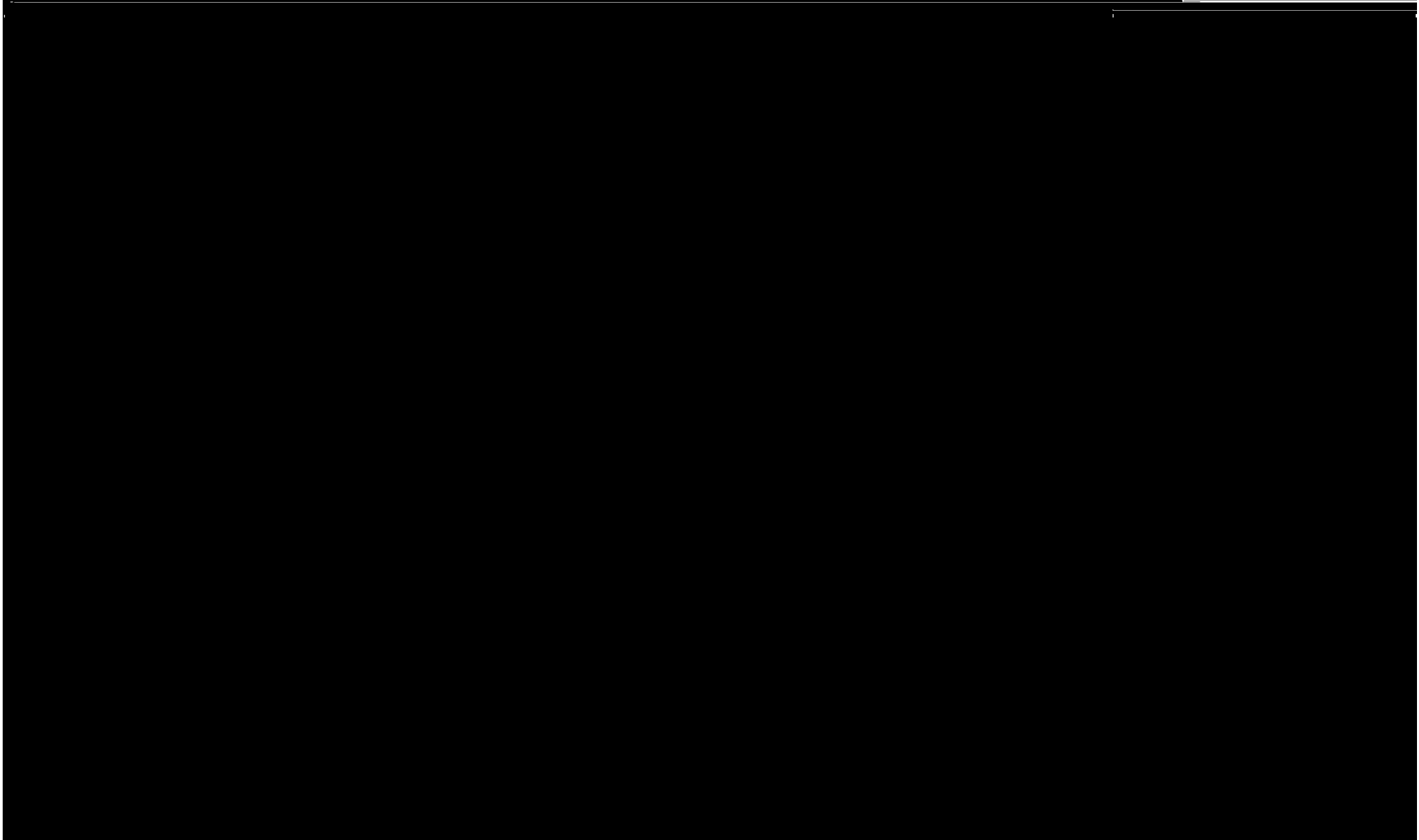


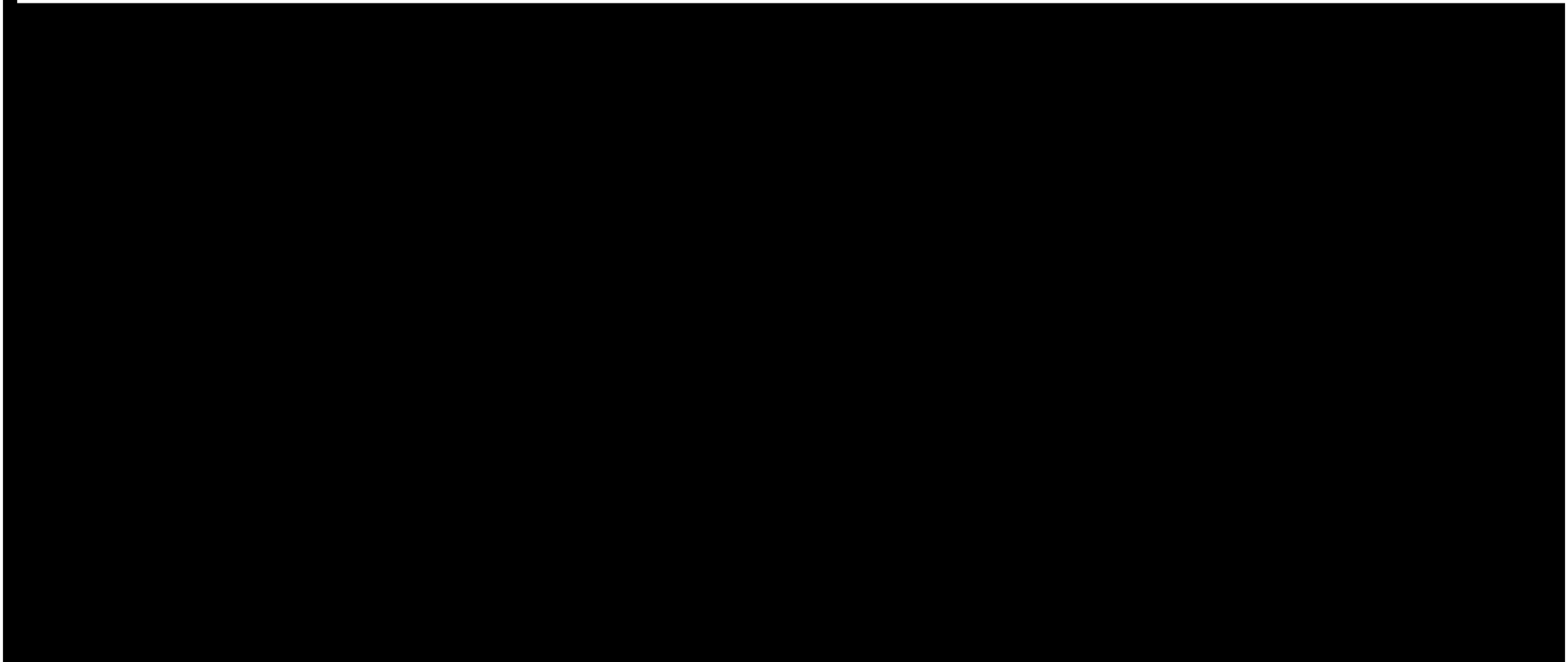
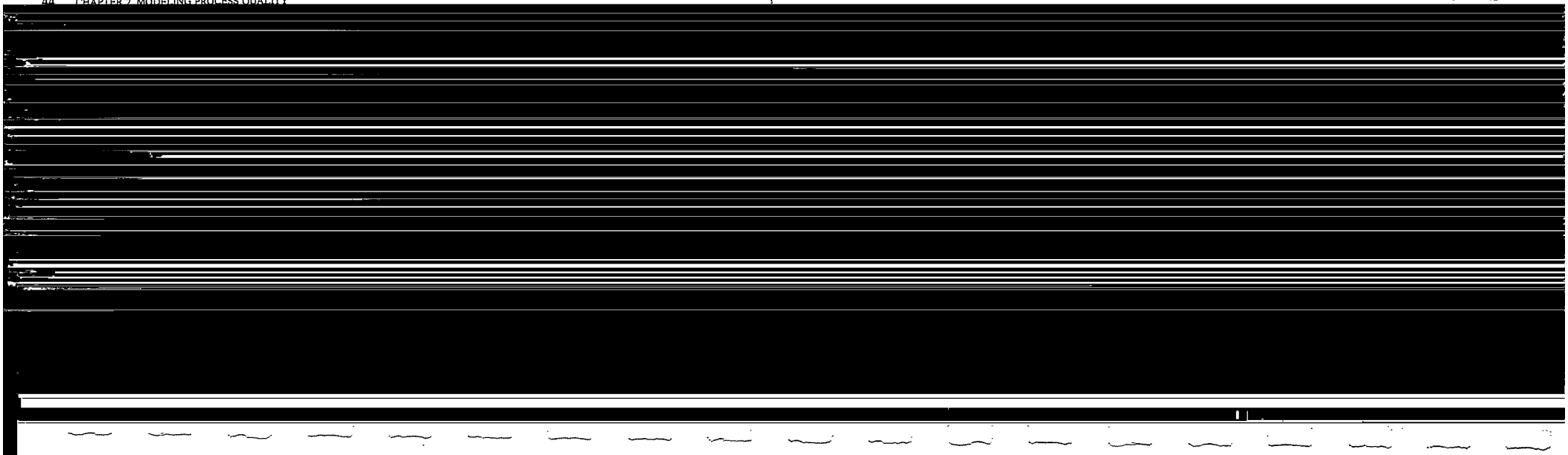


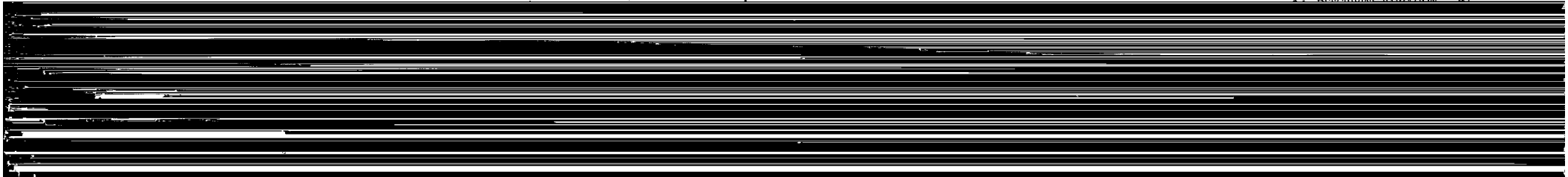
... probability distribution

Table 2.1 Days to Pay Employee Health Insurance Claims

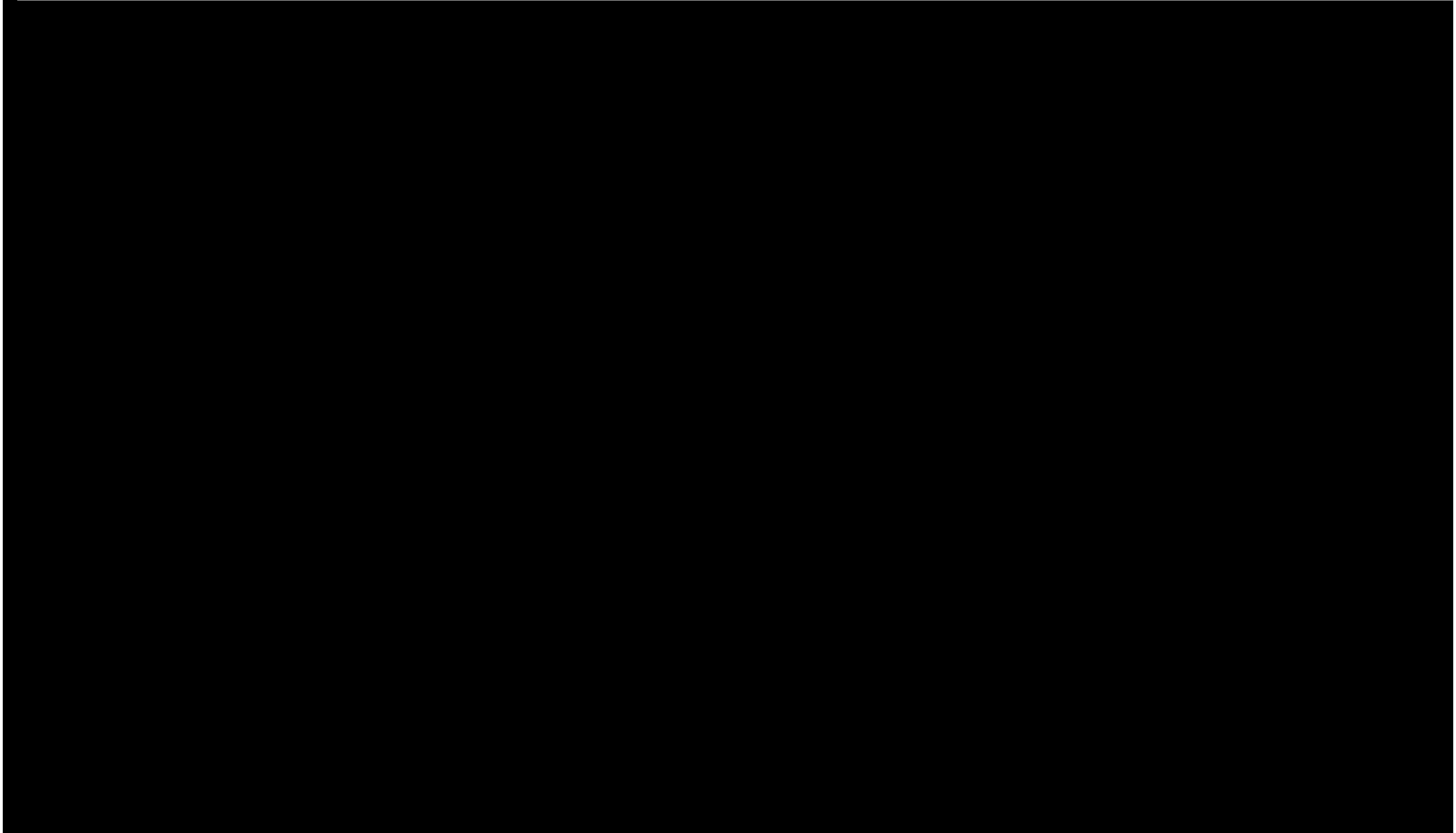
Source: U.S. Social Security Administration

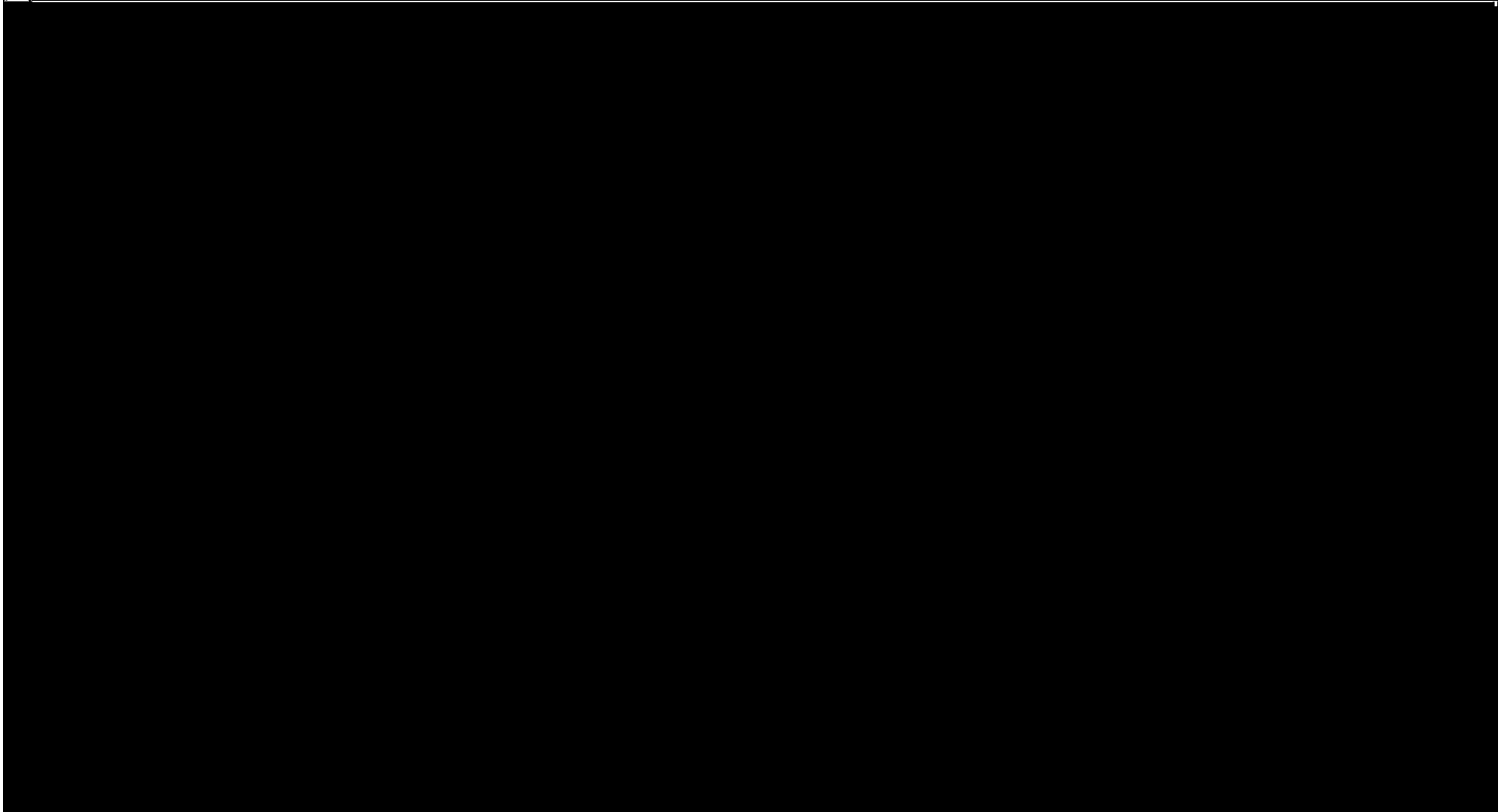






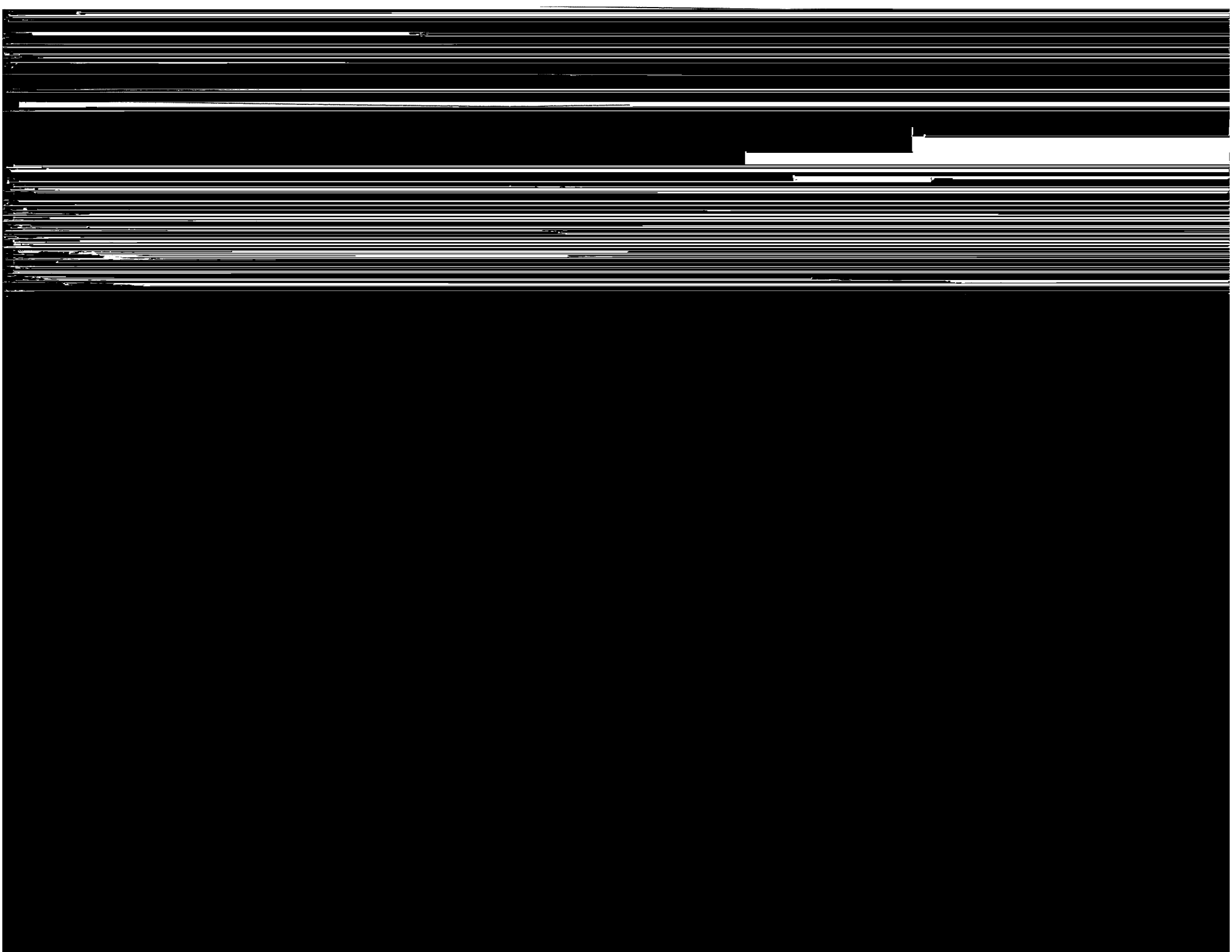
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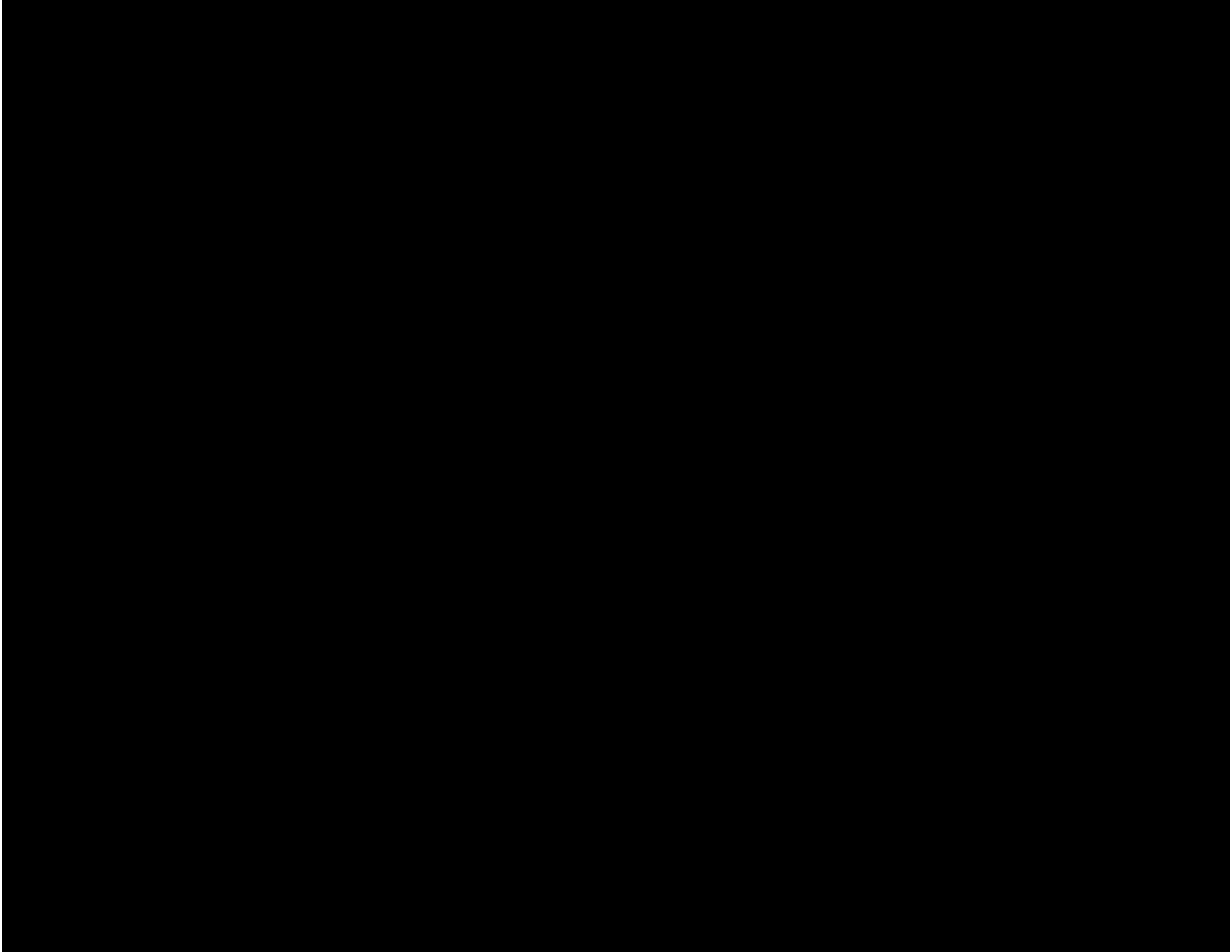


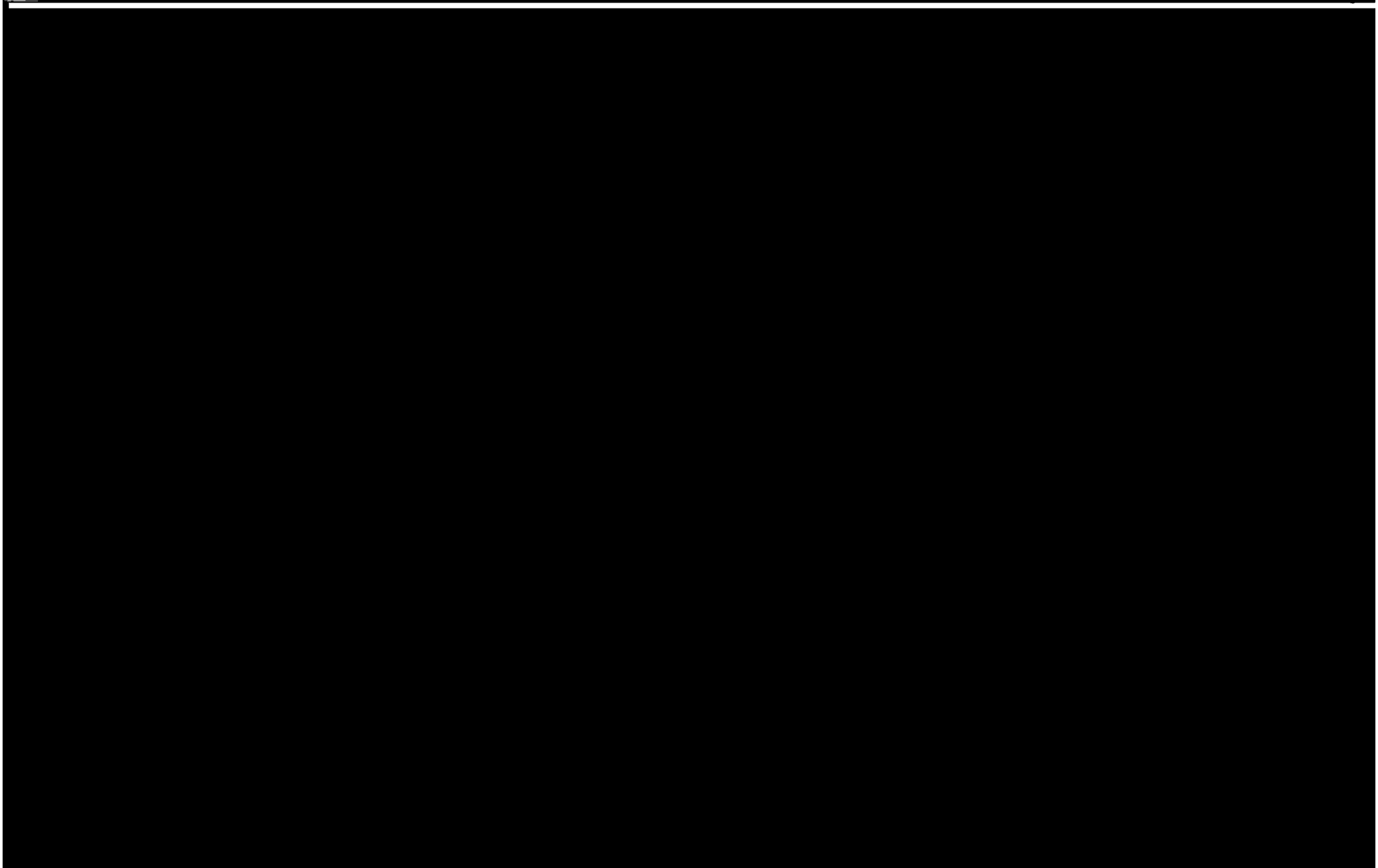
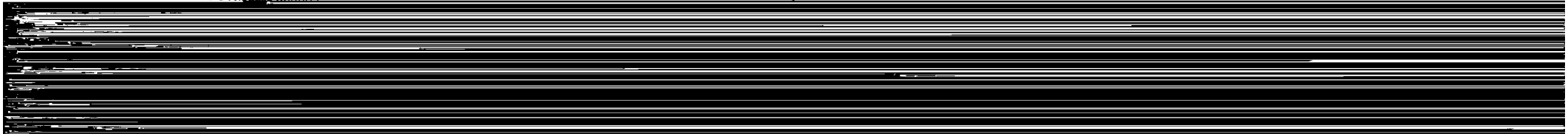




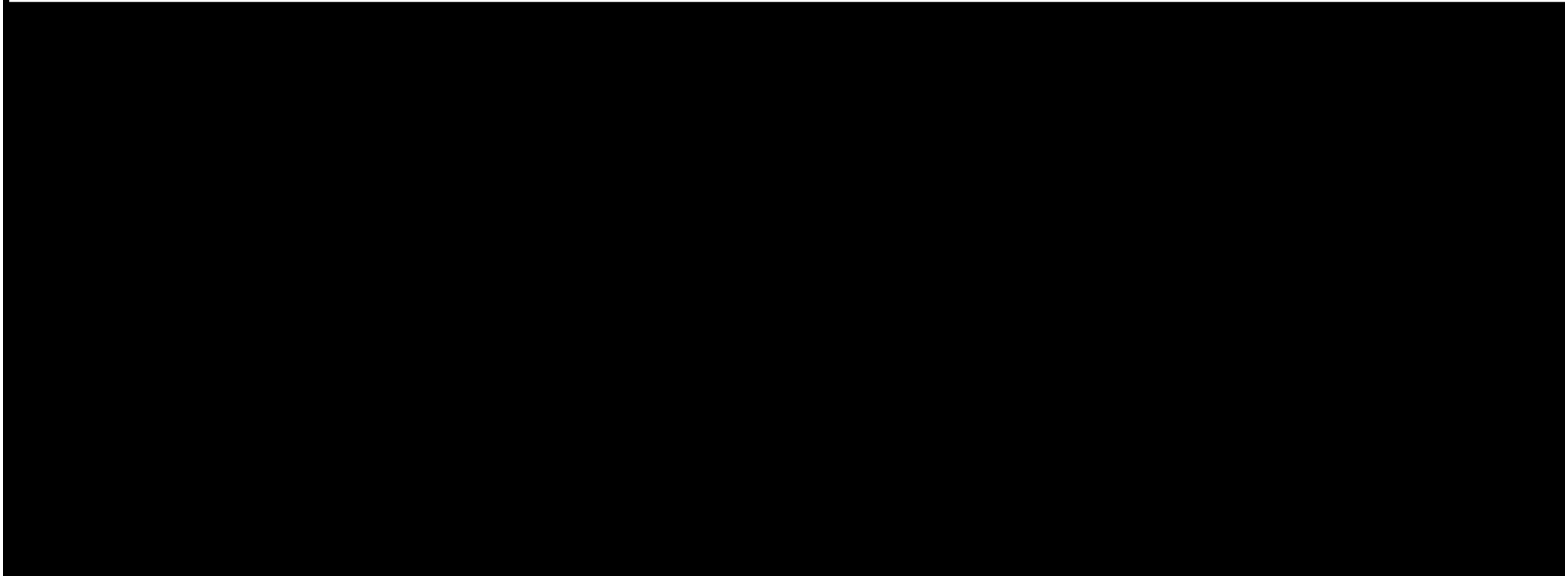
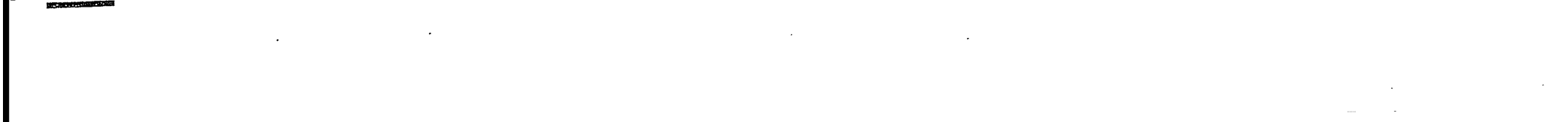
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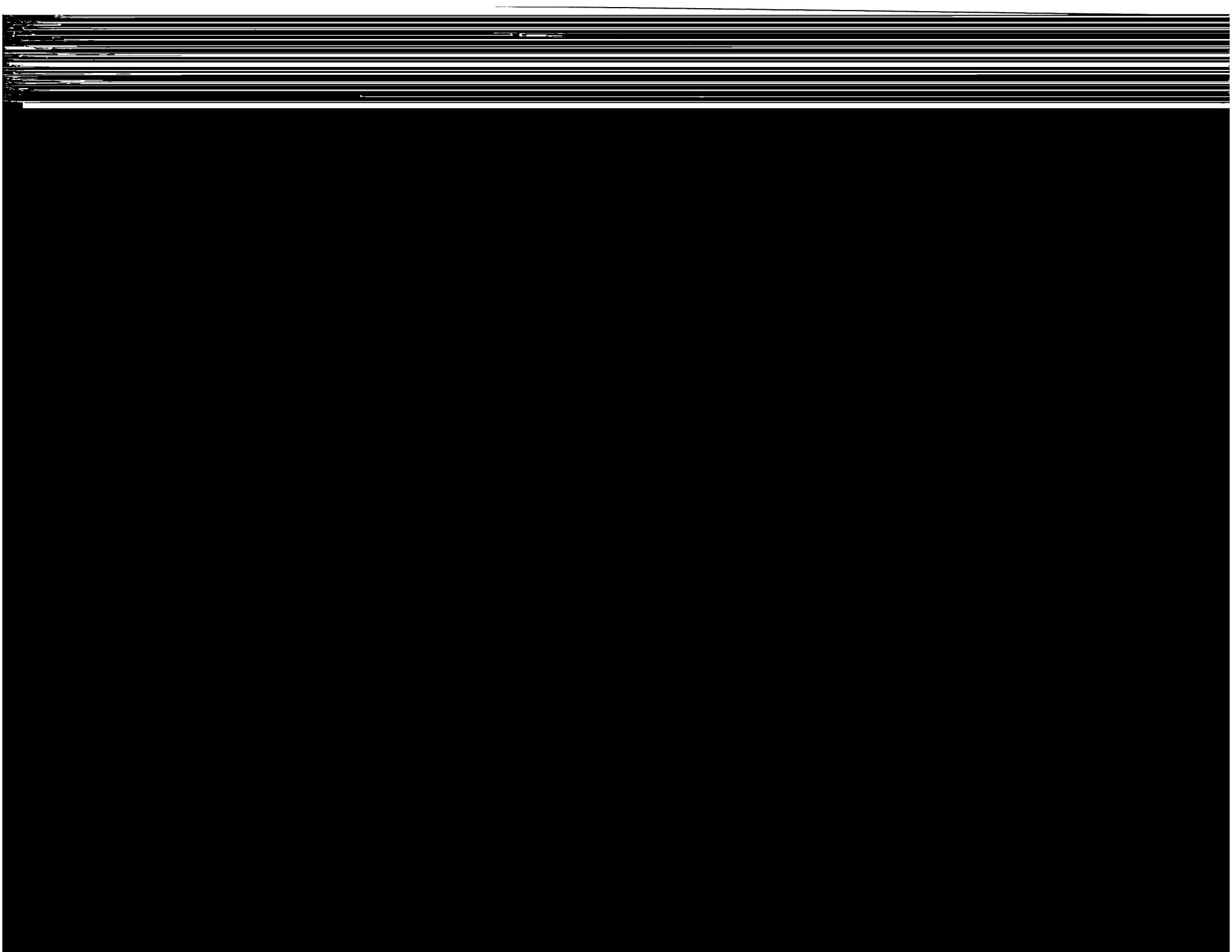






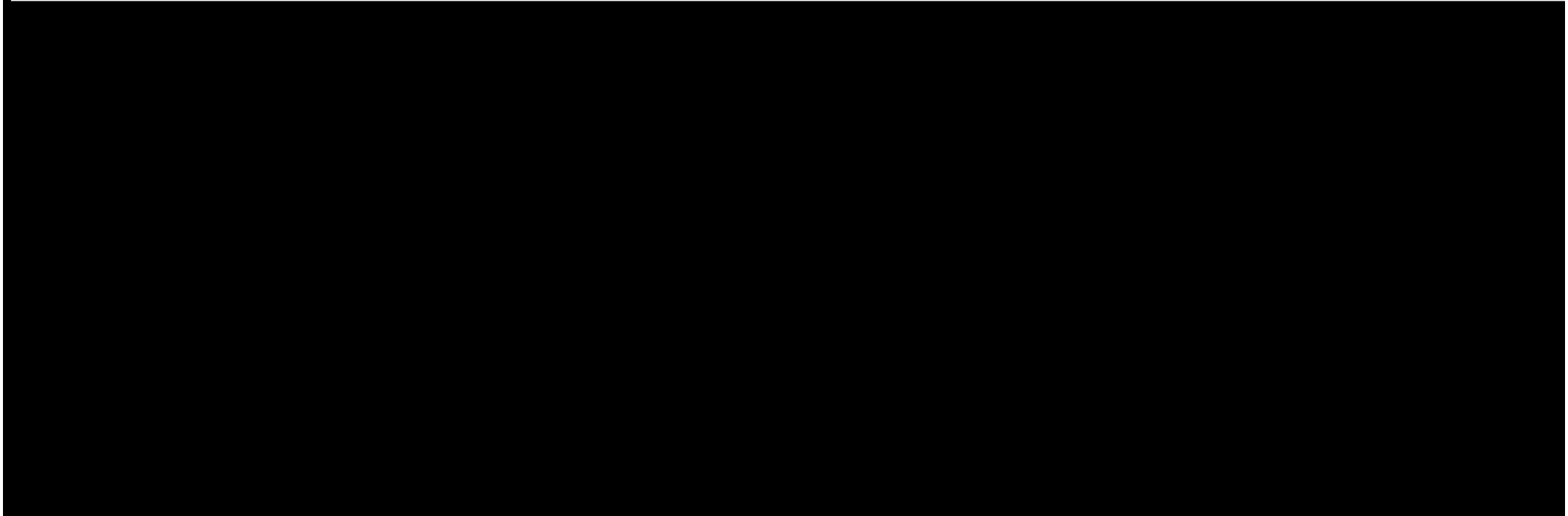


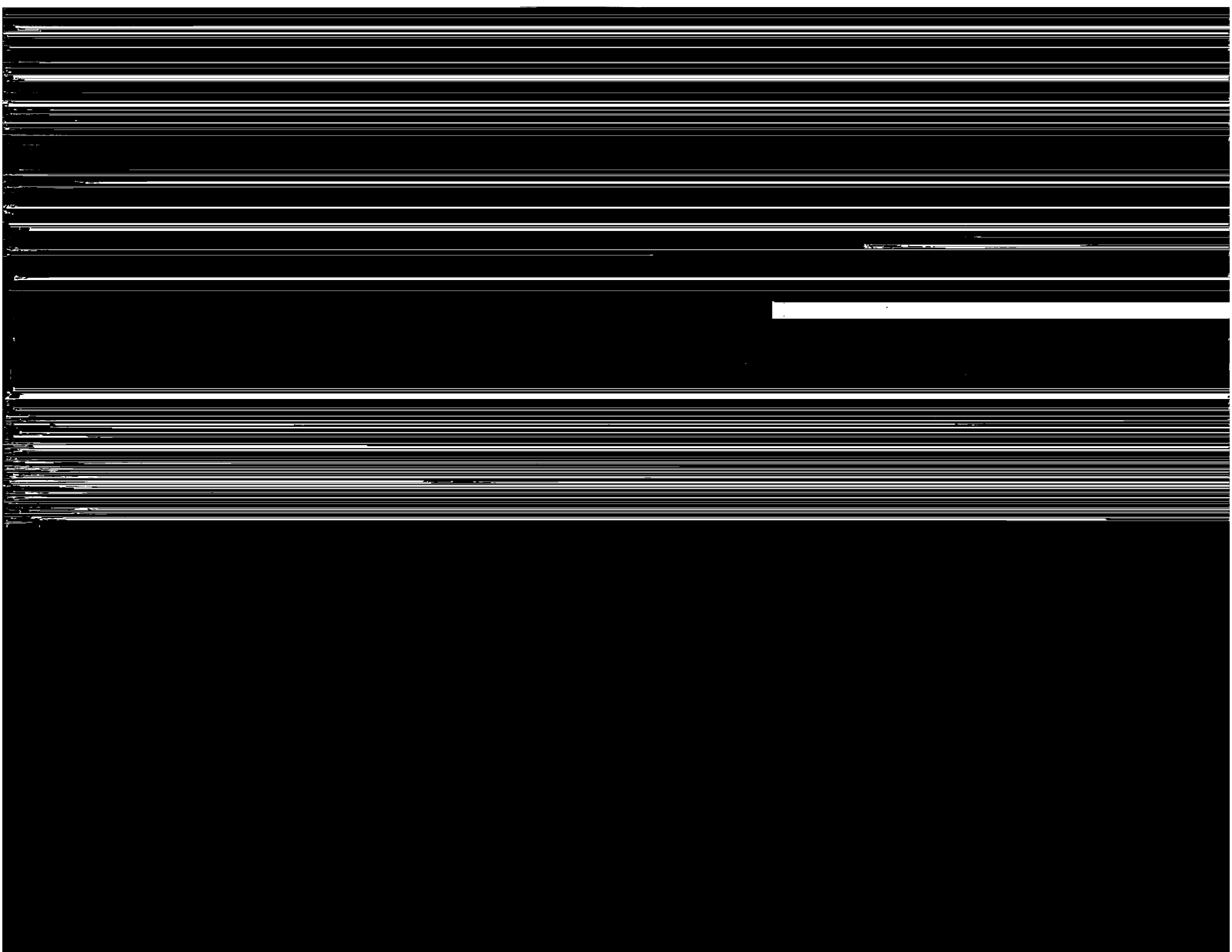


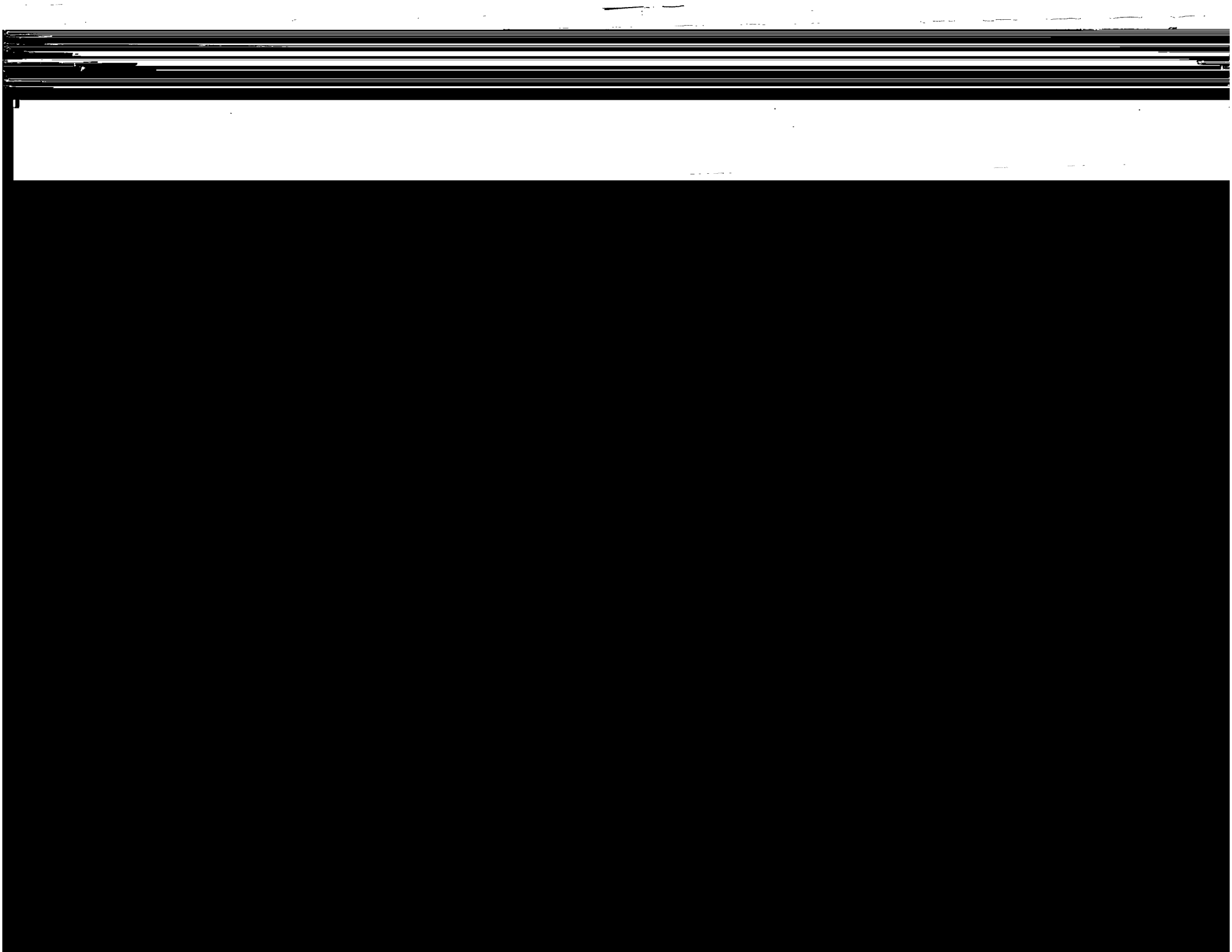


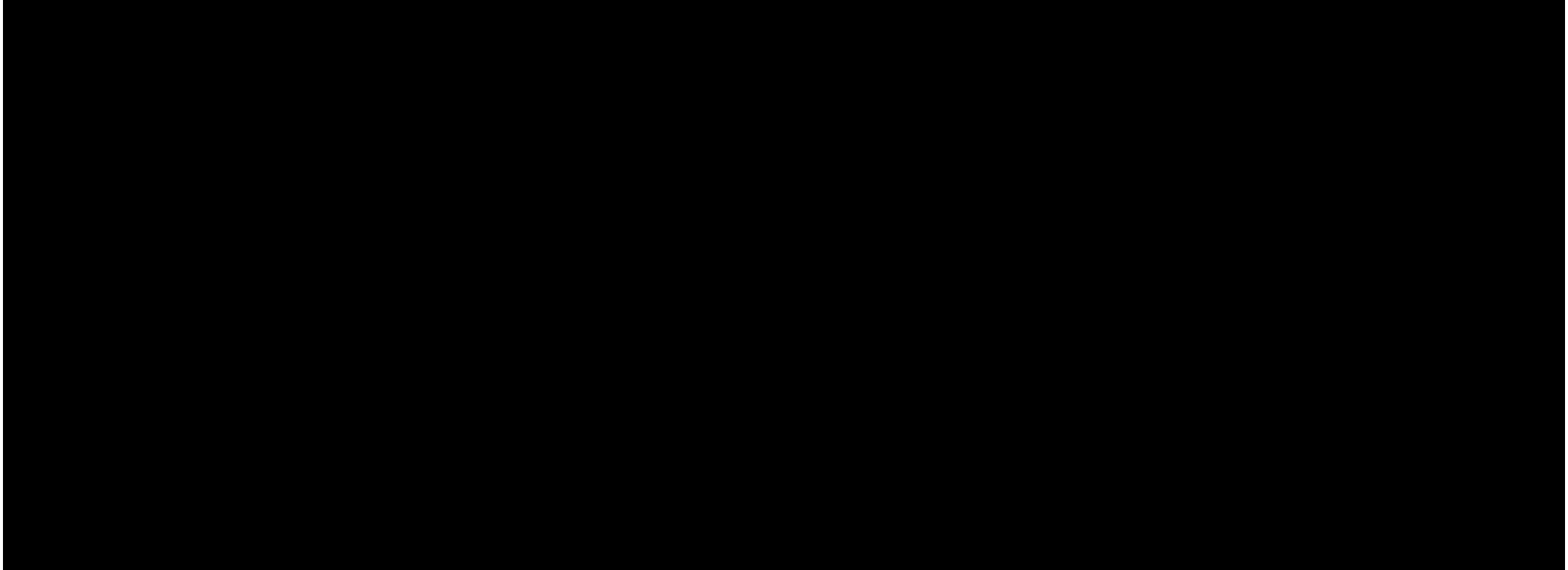
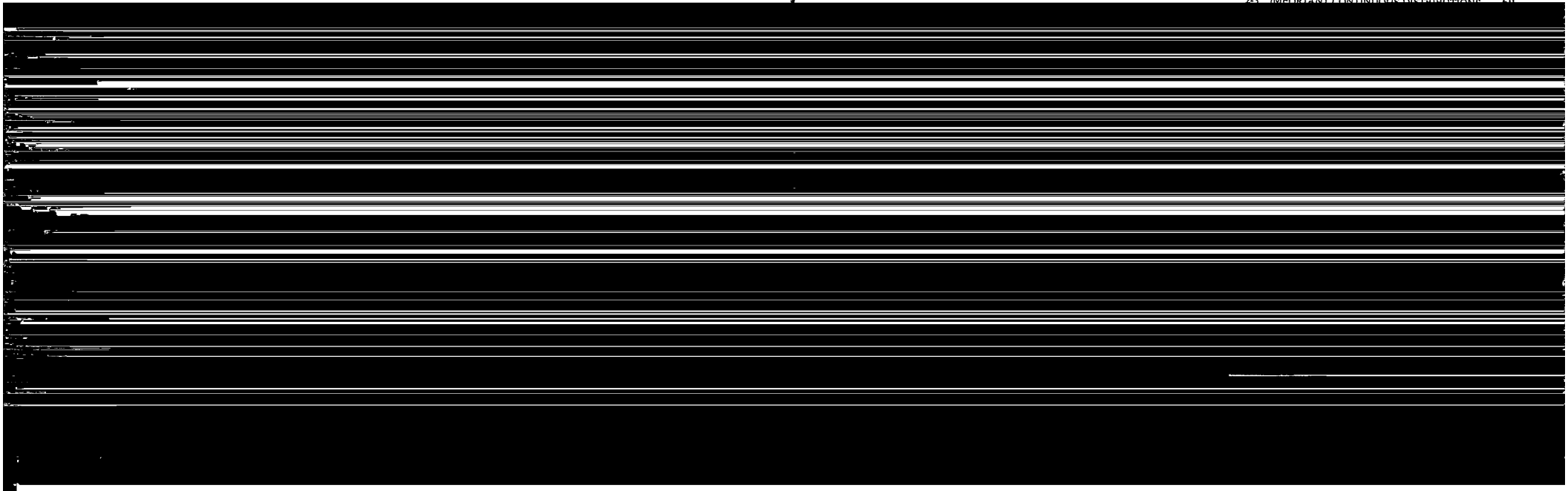


CHAPTER 2 MODELING PROCESS QUALITY

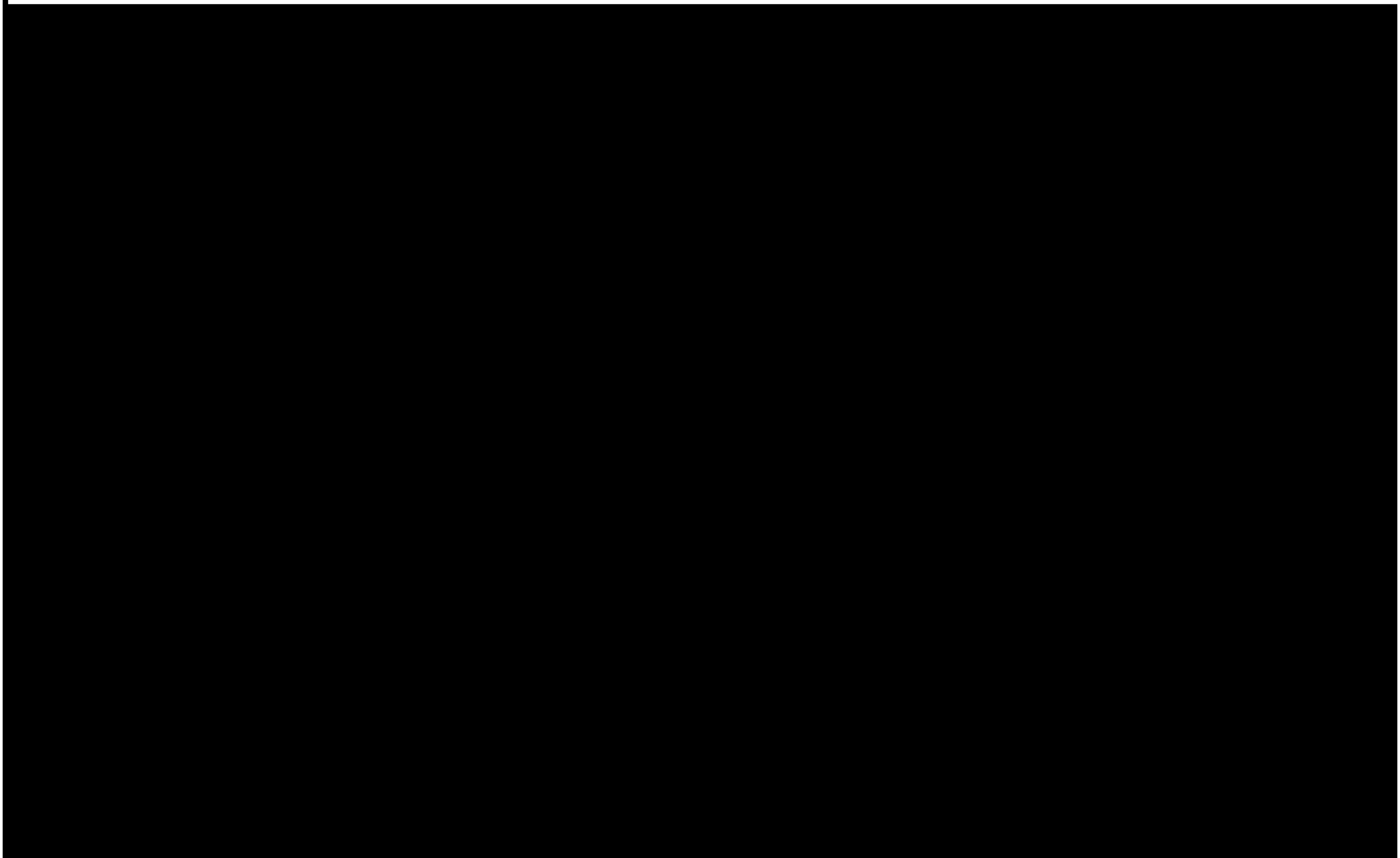


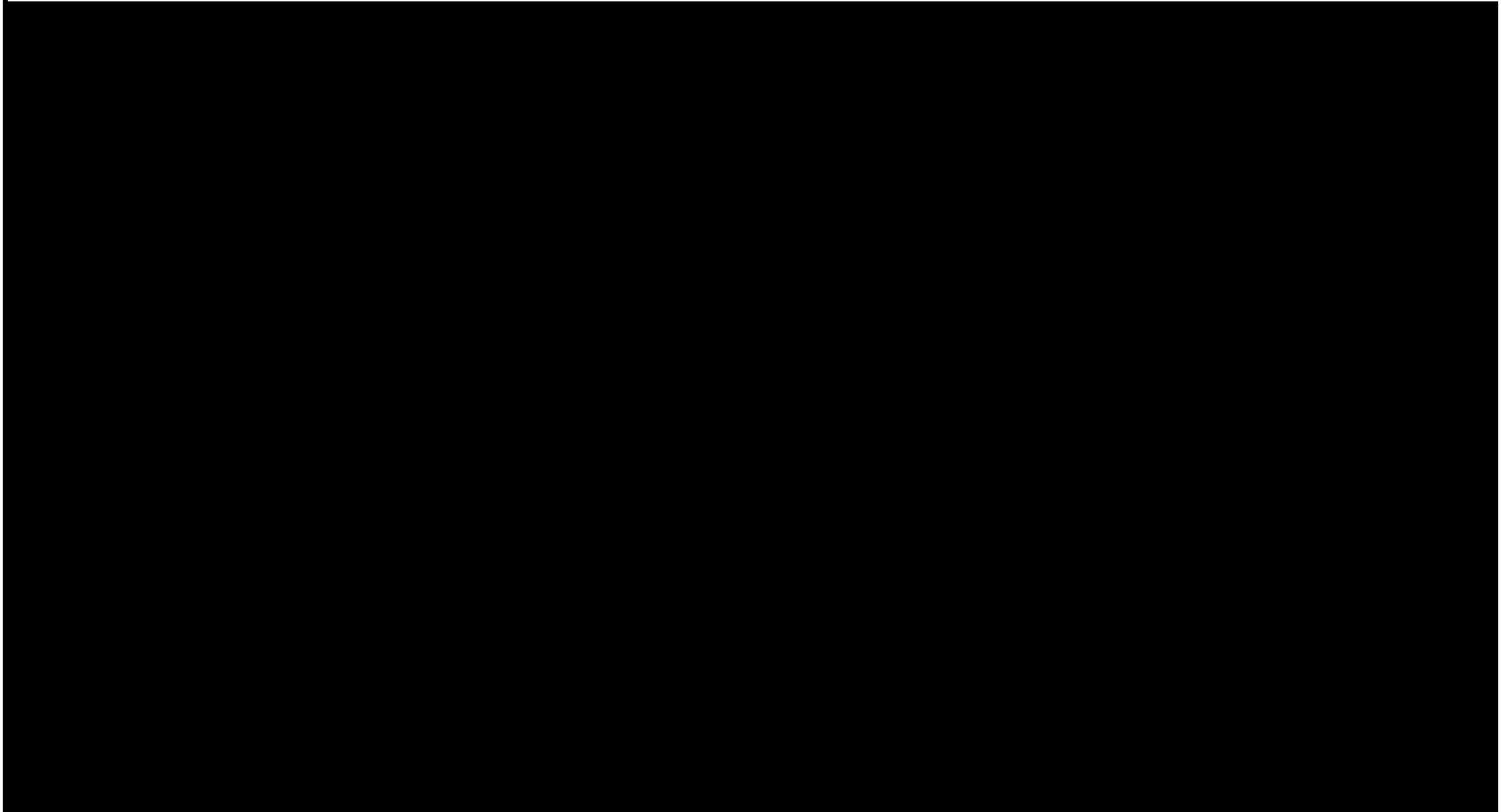
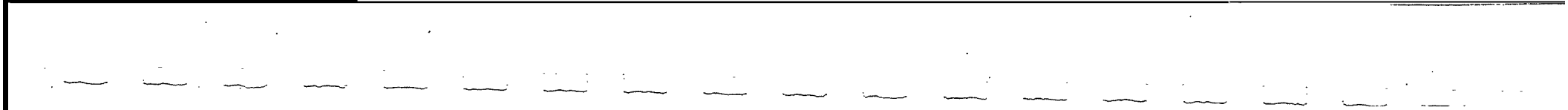
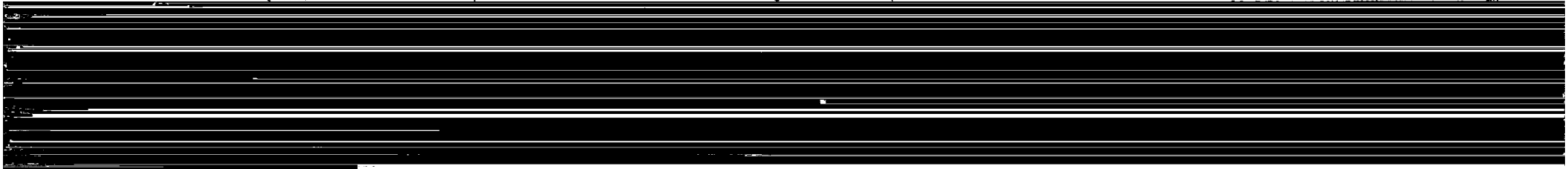




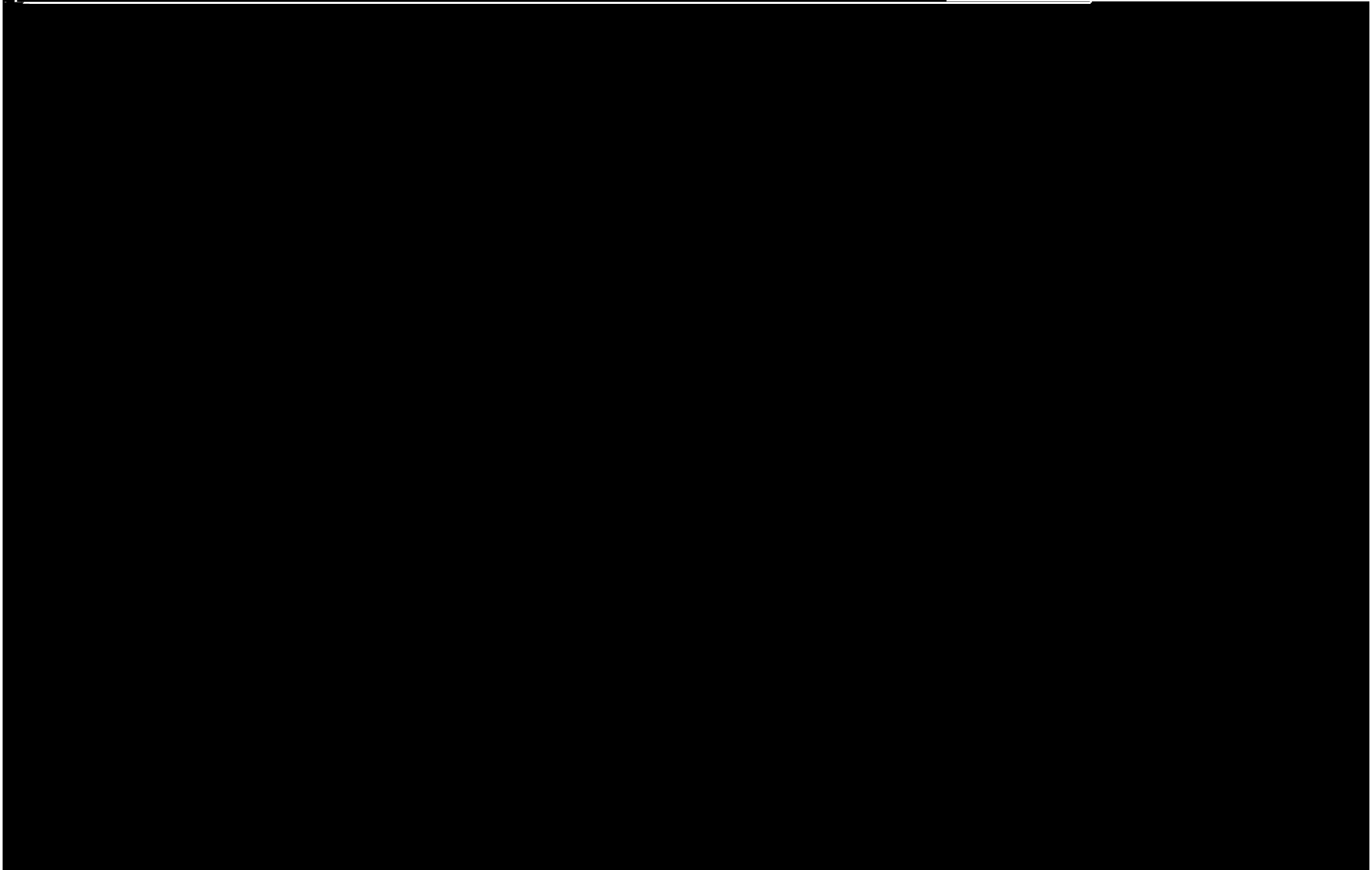
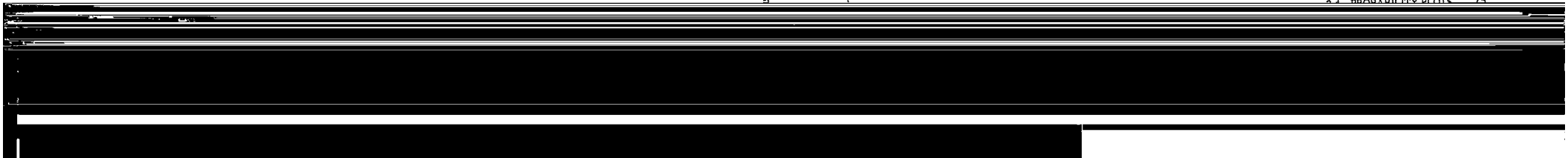


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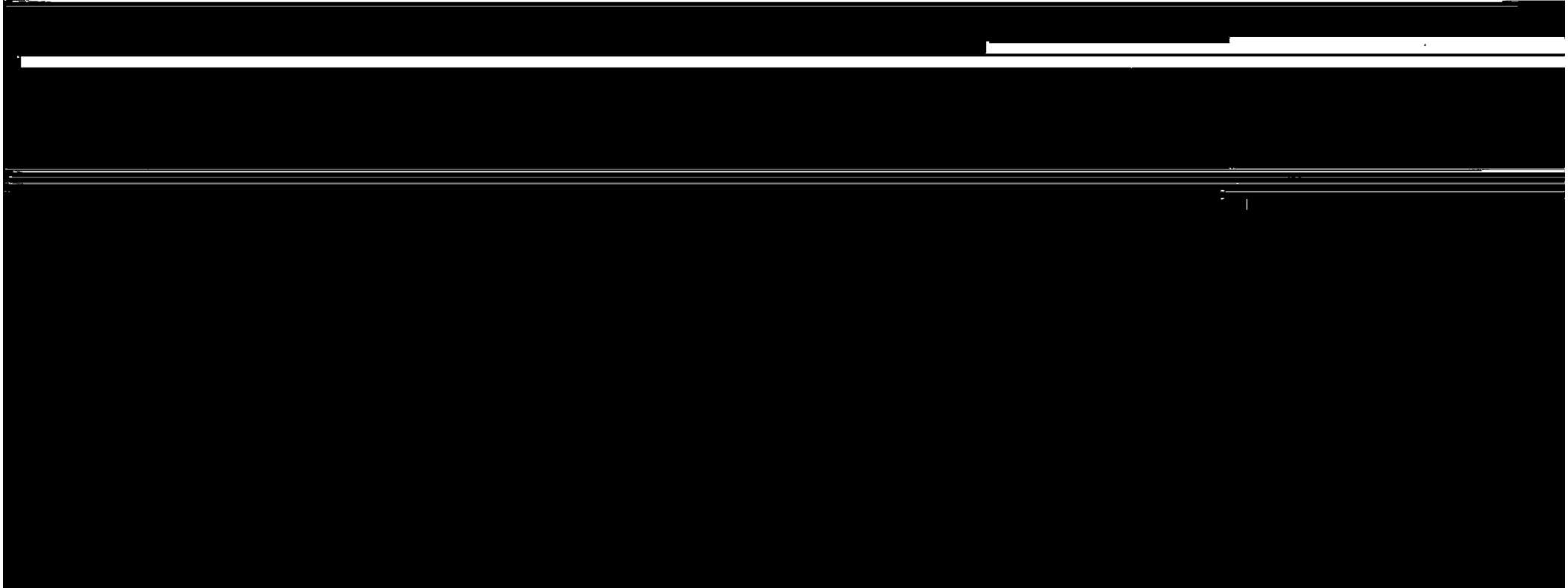




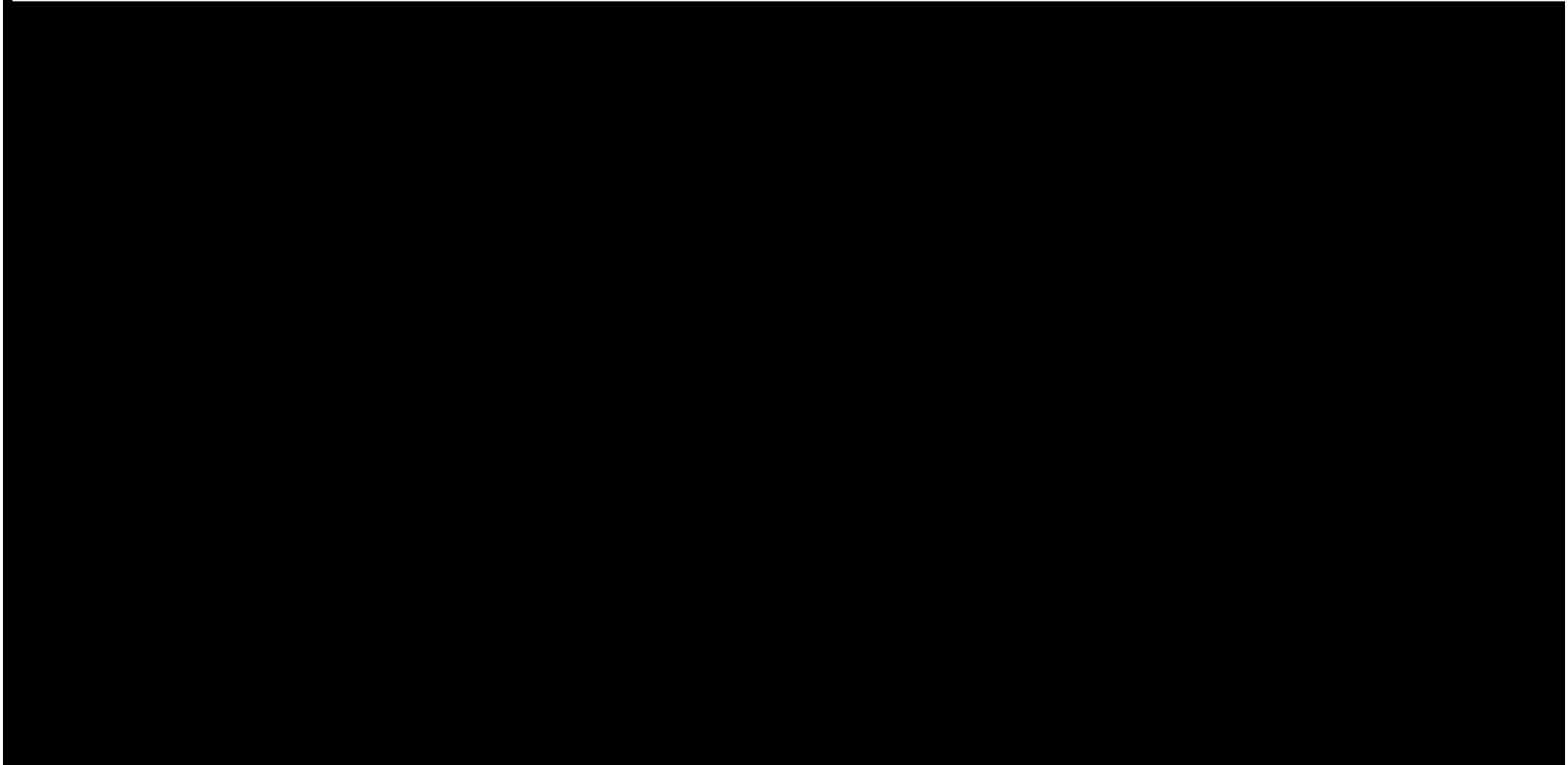
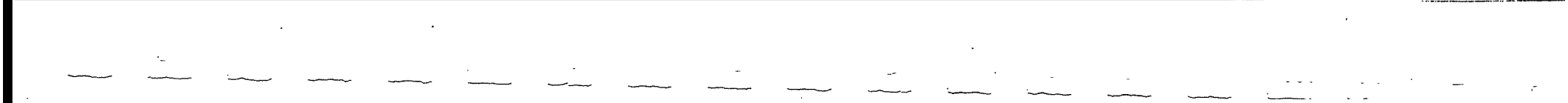
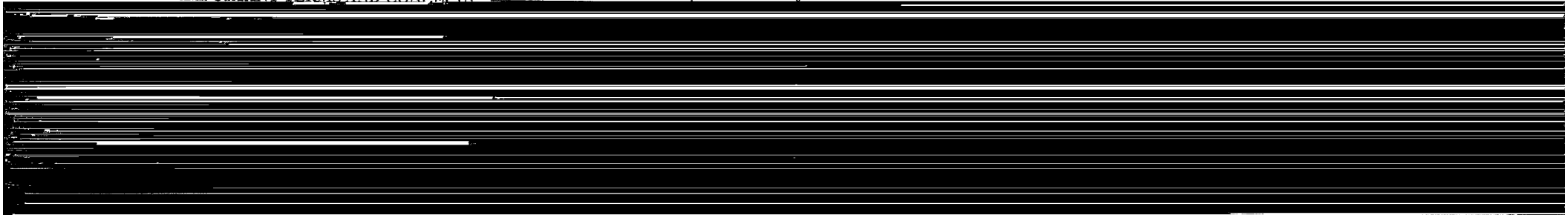


A very important collection of...

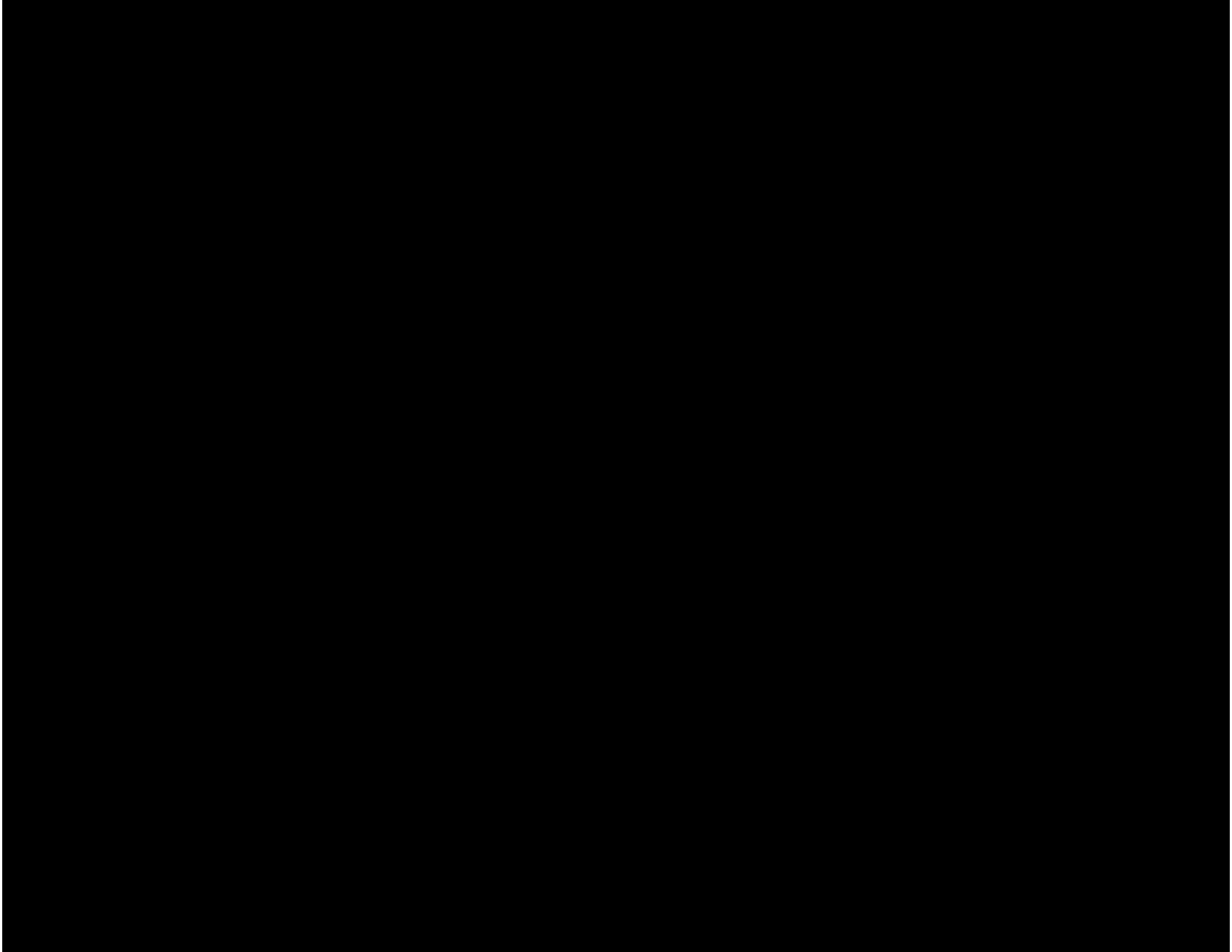




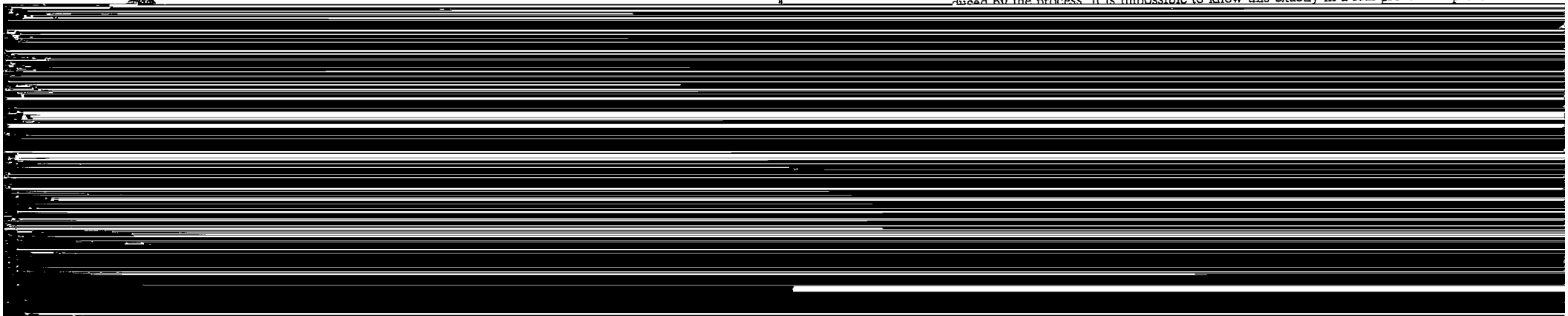
IMPORTANT TERMS AND CONCEPTS

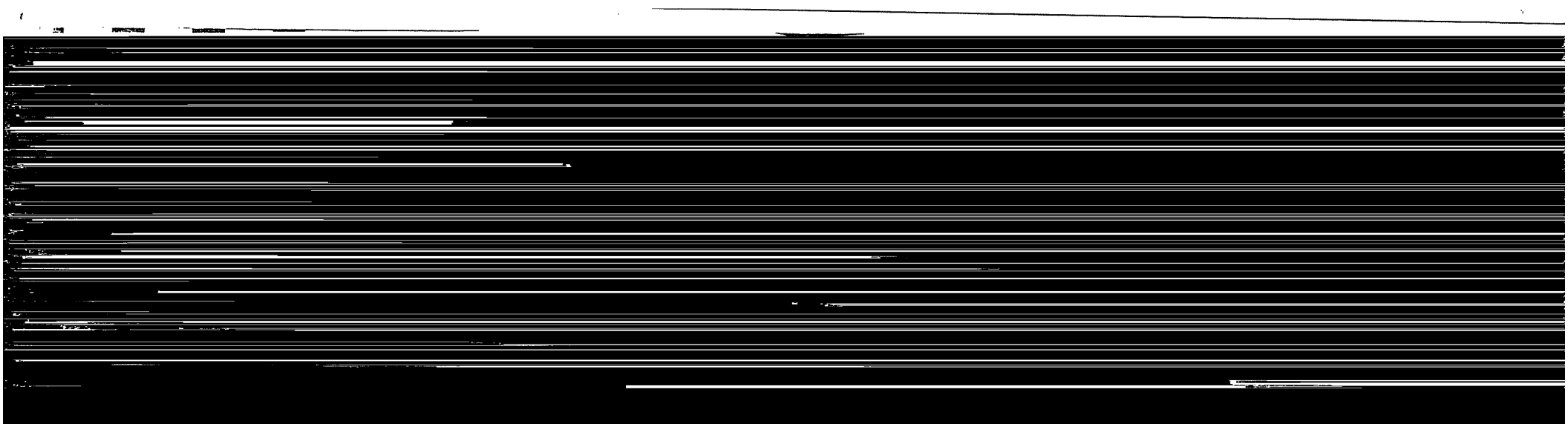




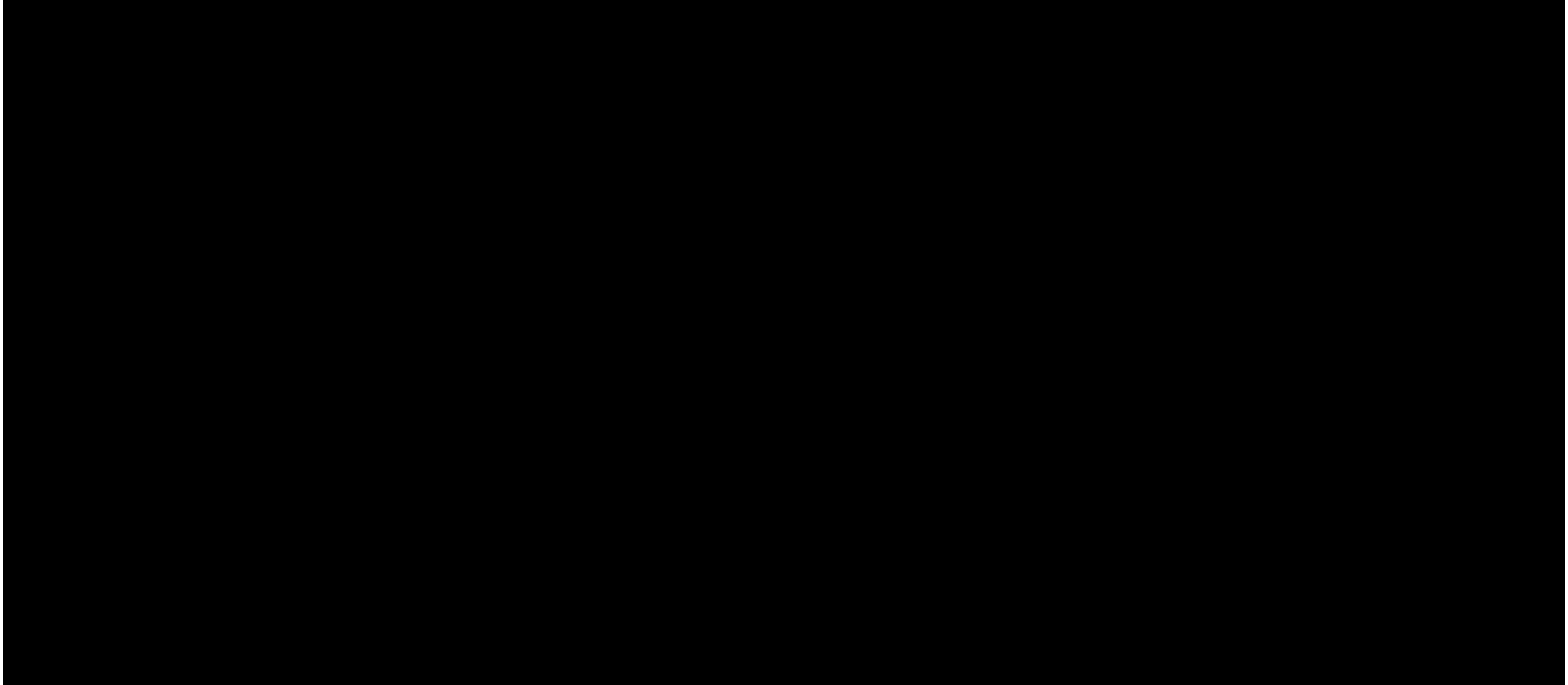


dictated by the process. It is impossible to know this exactly in a real production process.

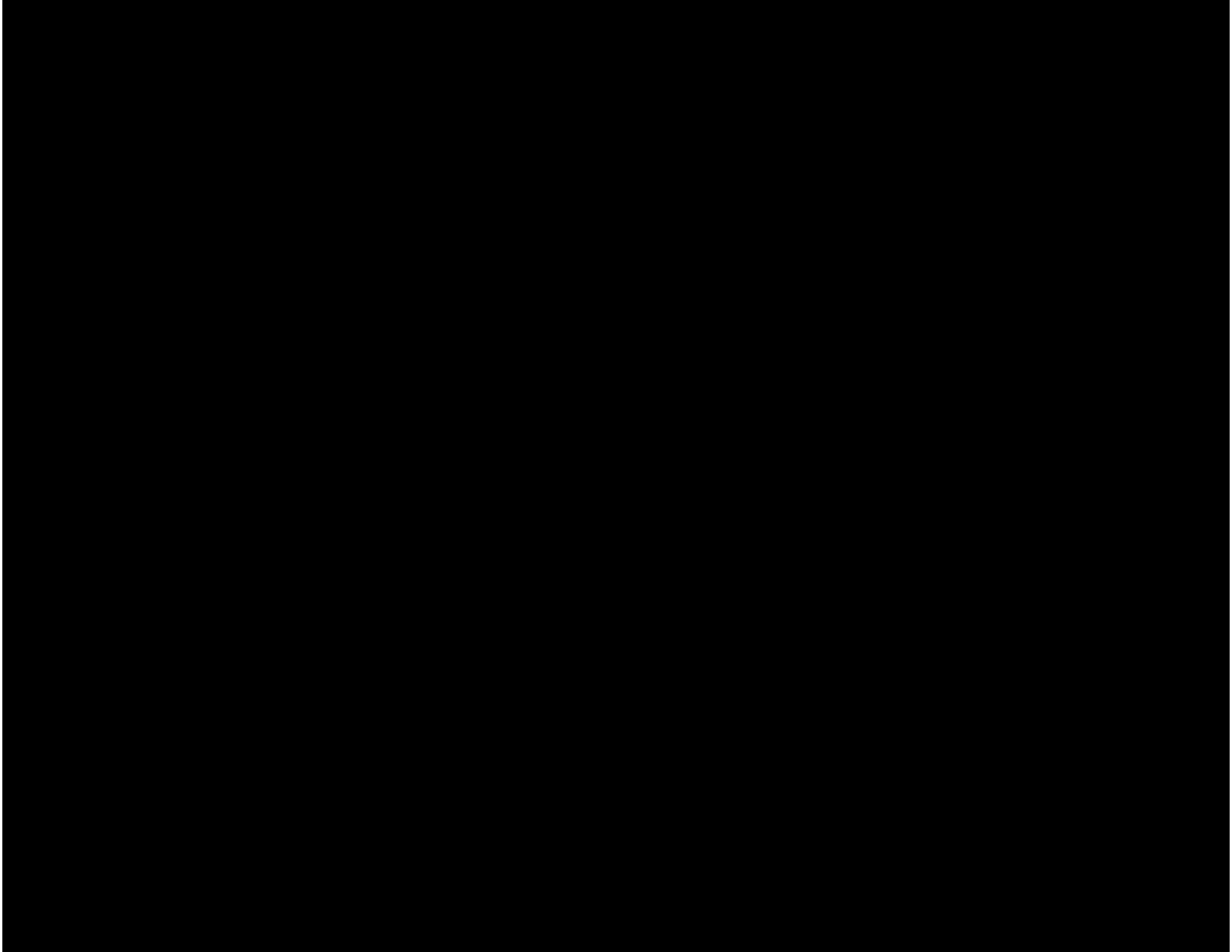




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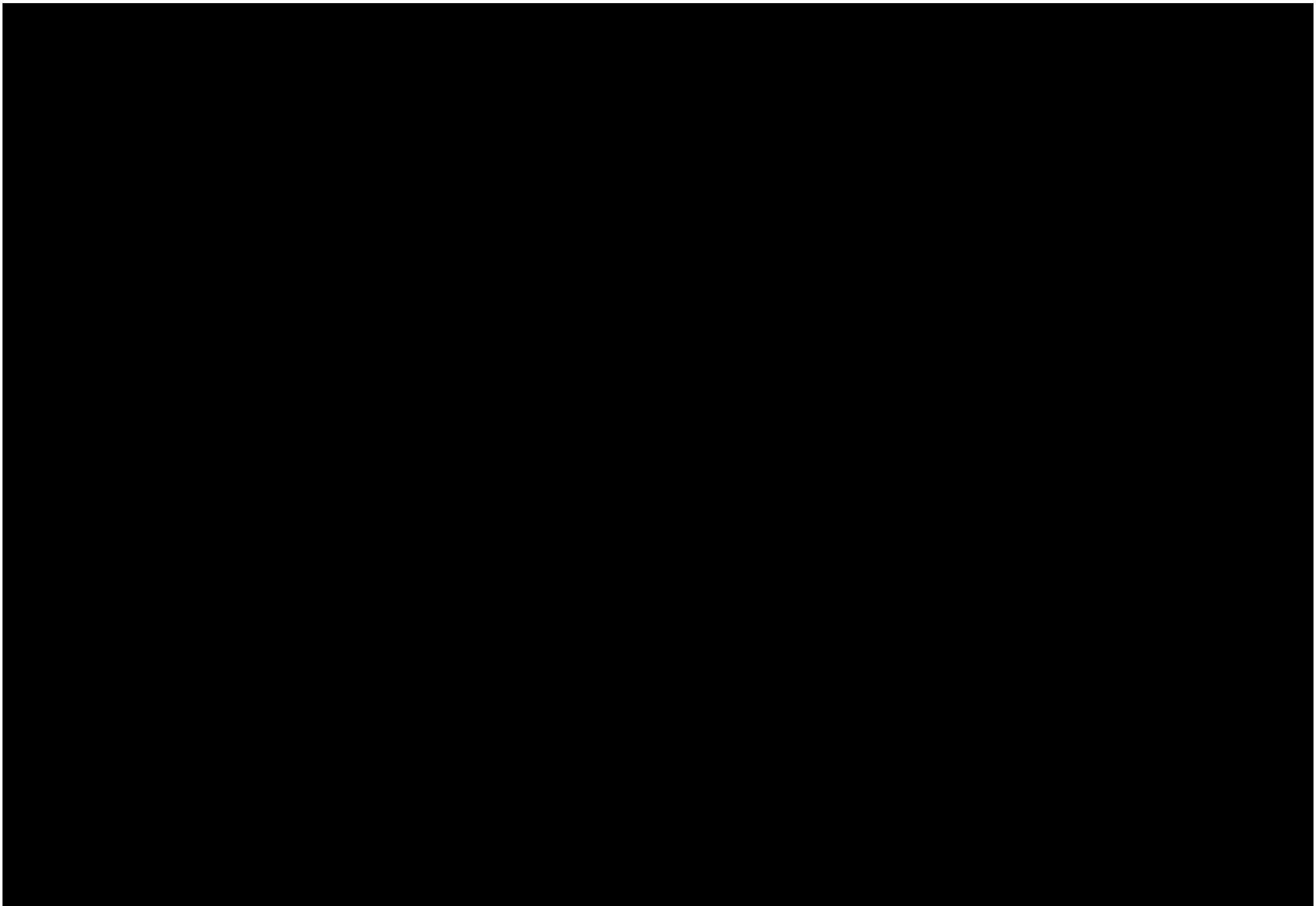




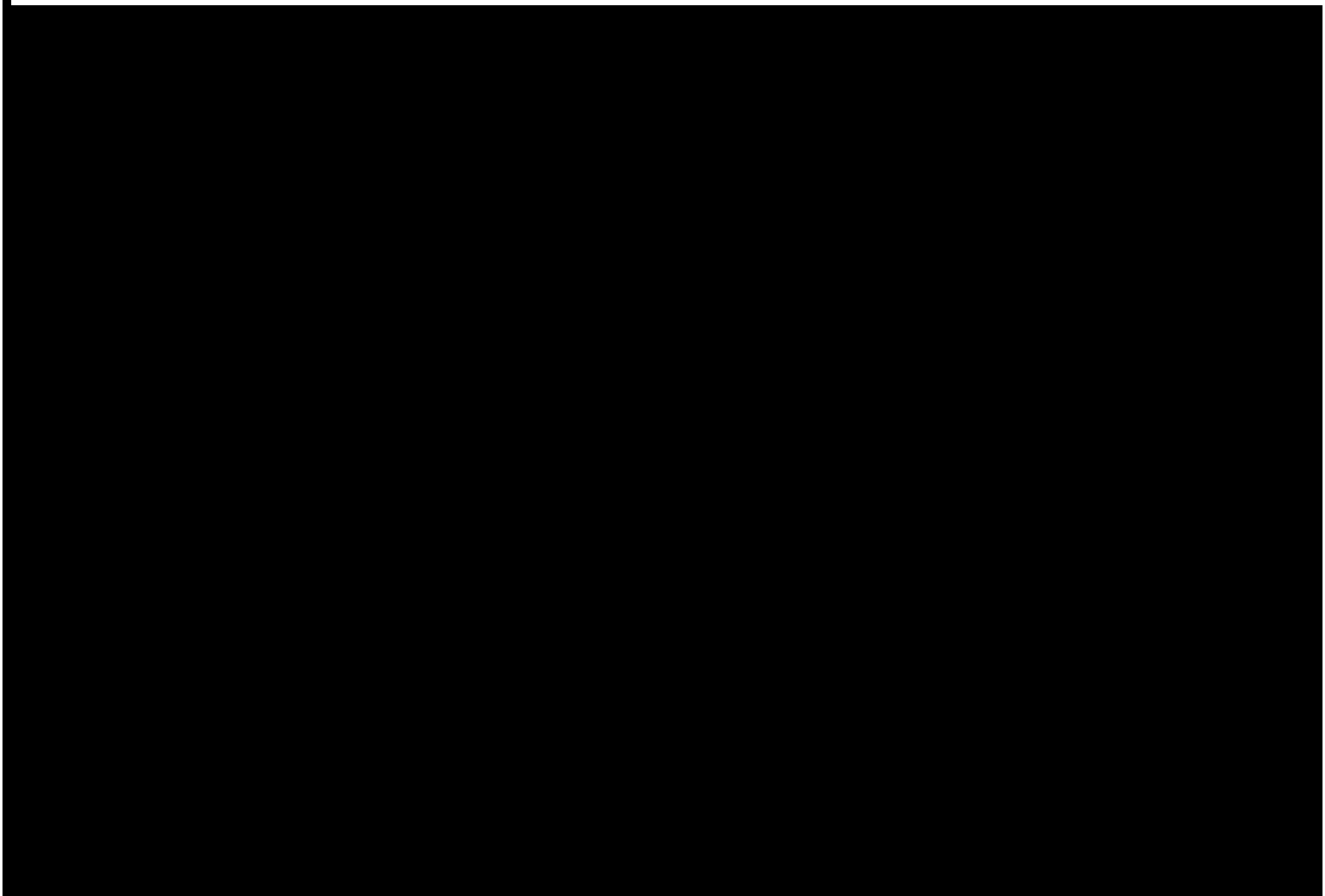


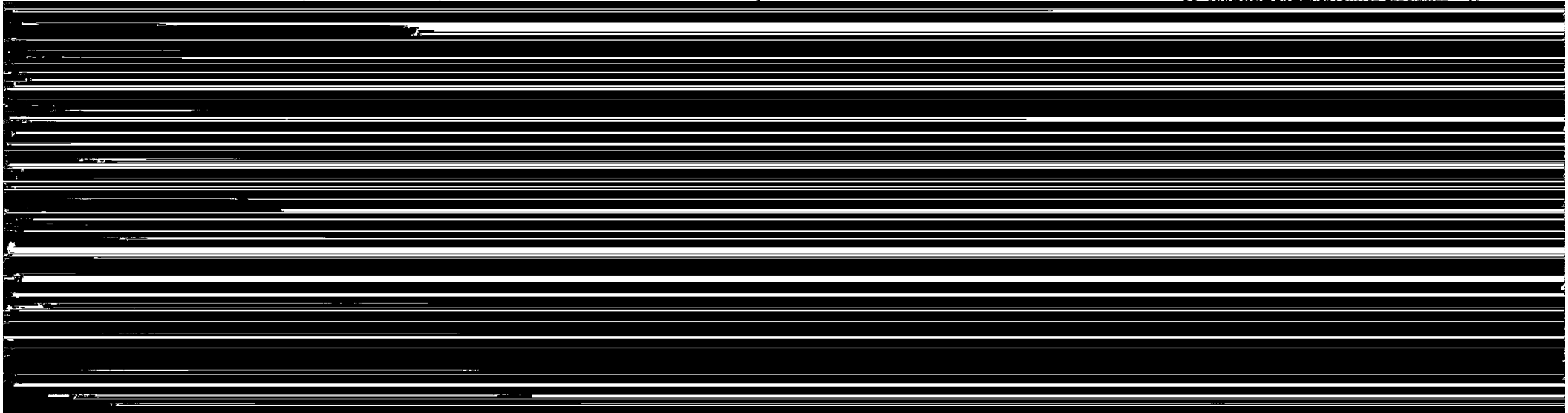


...the sum of  $n$  independent Poisson ran...

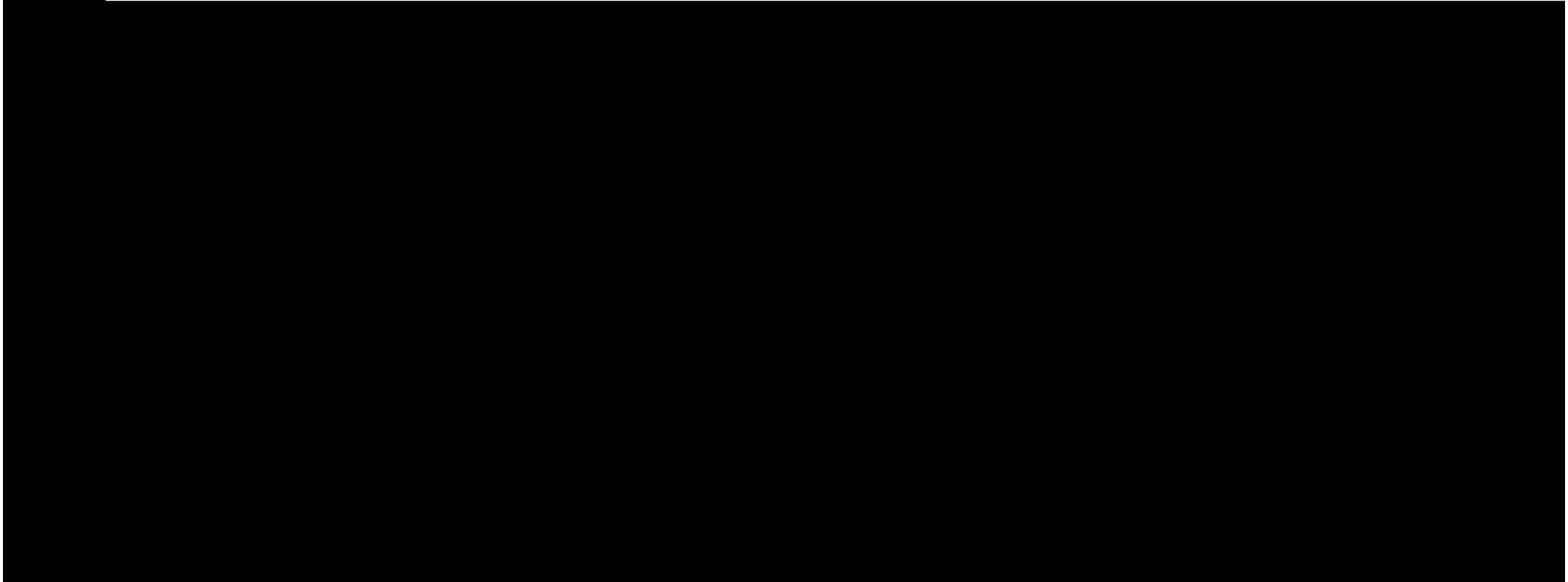


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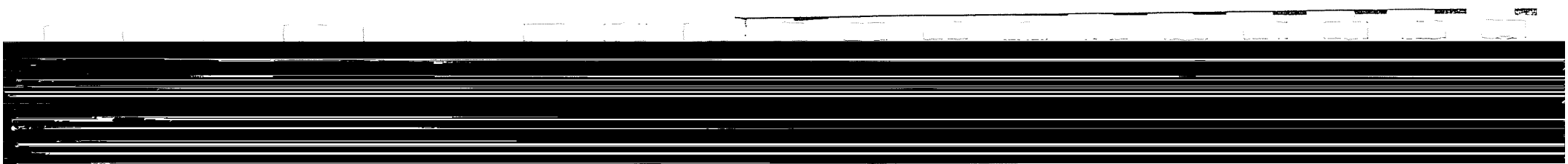




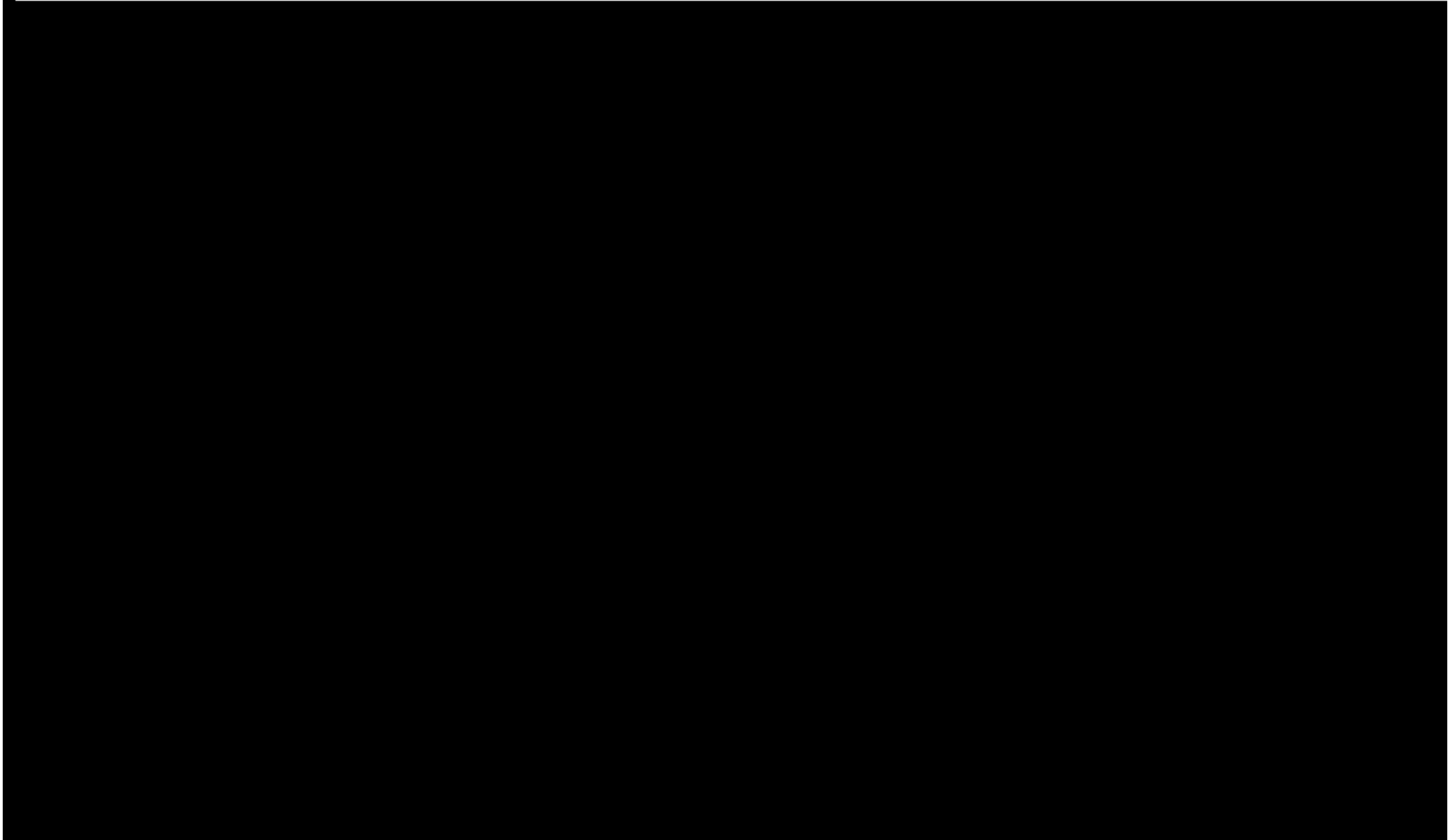
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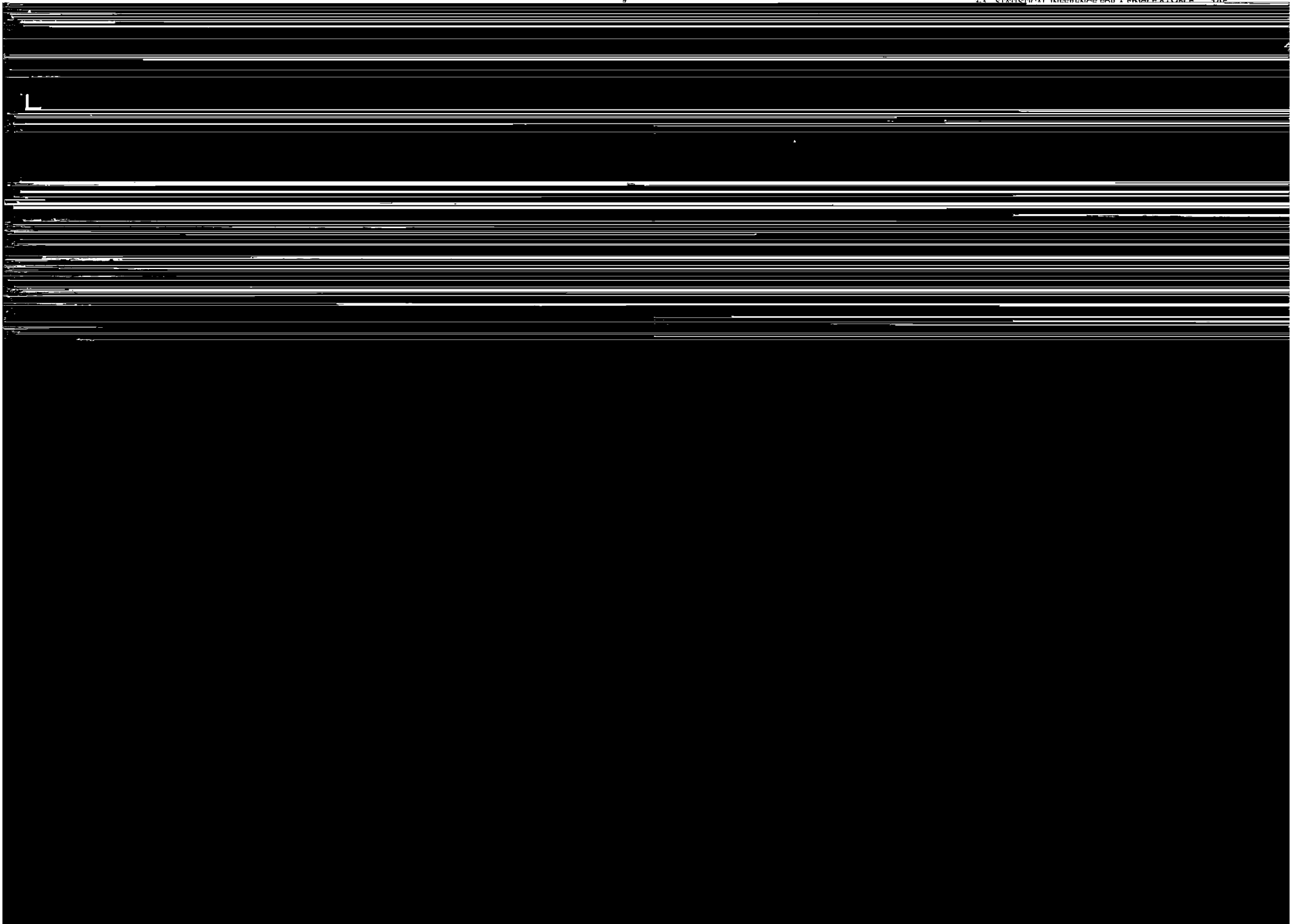


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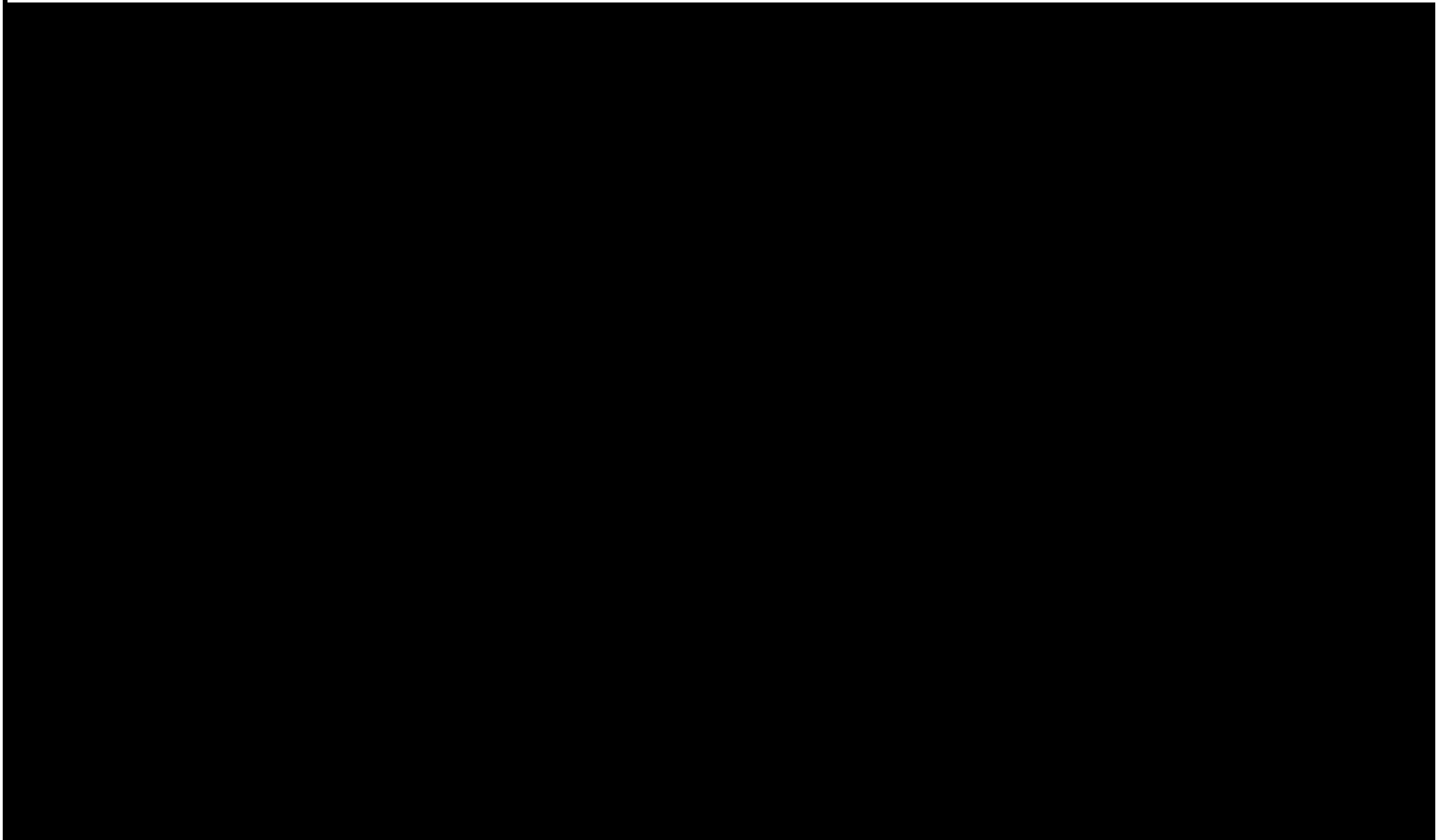


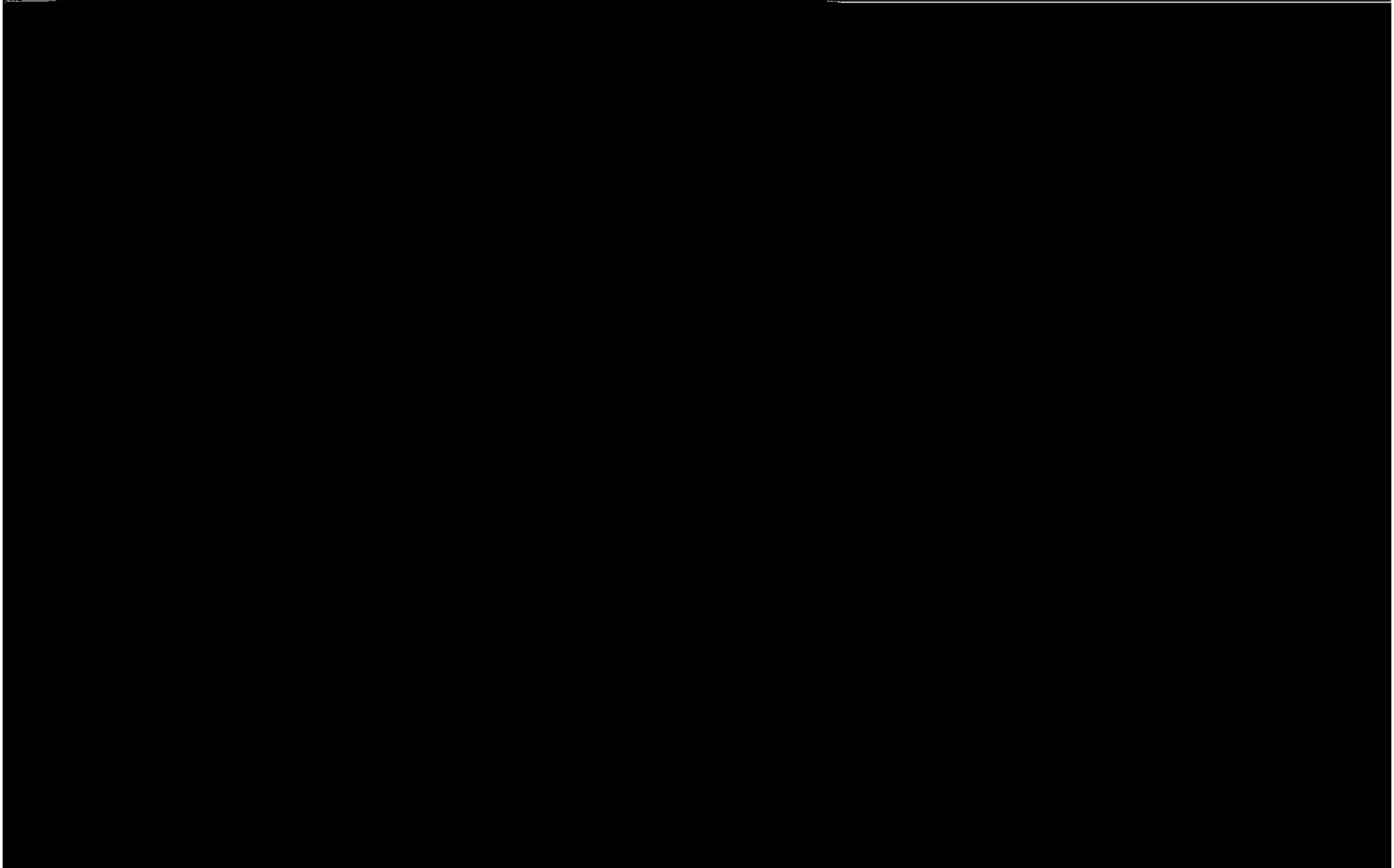
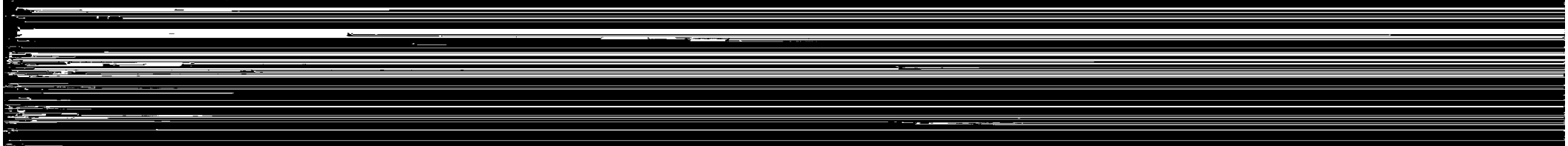
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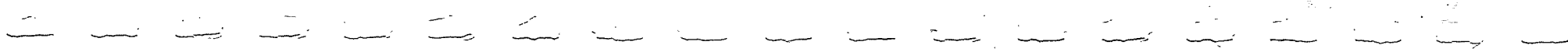


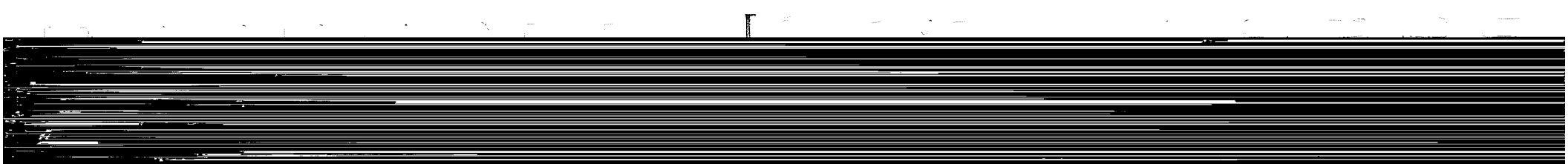




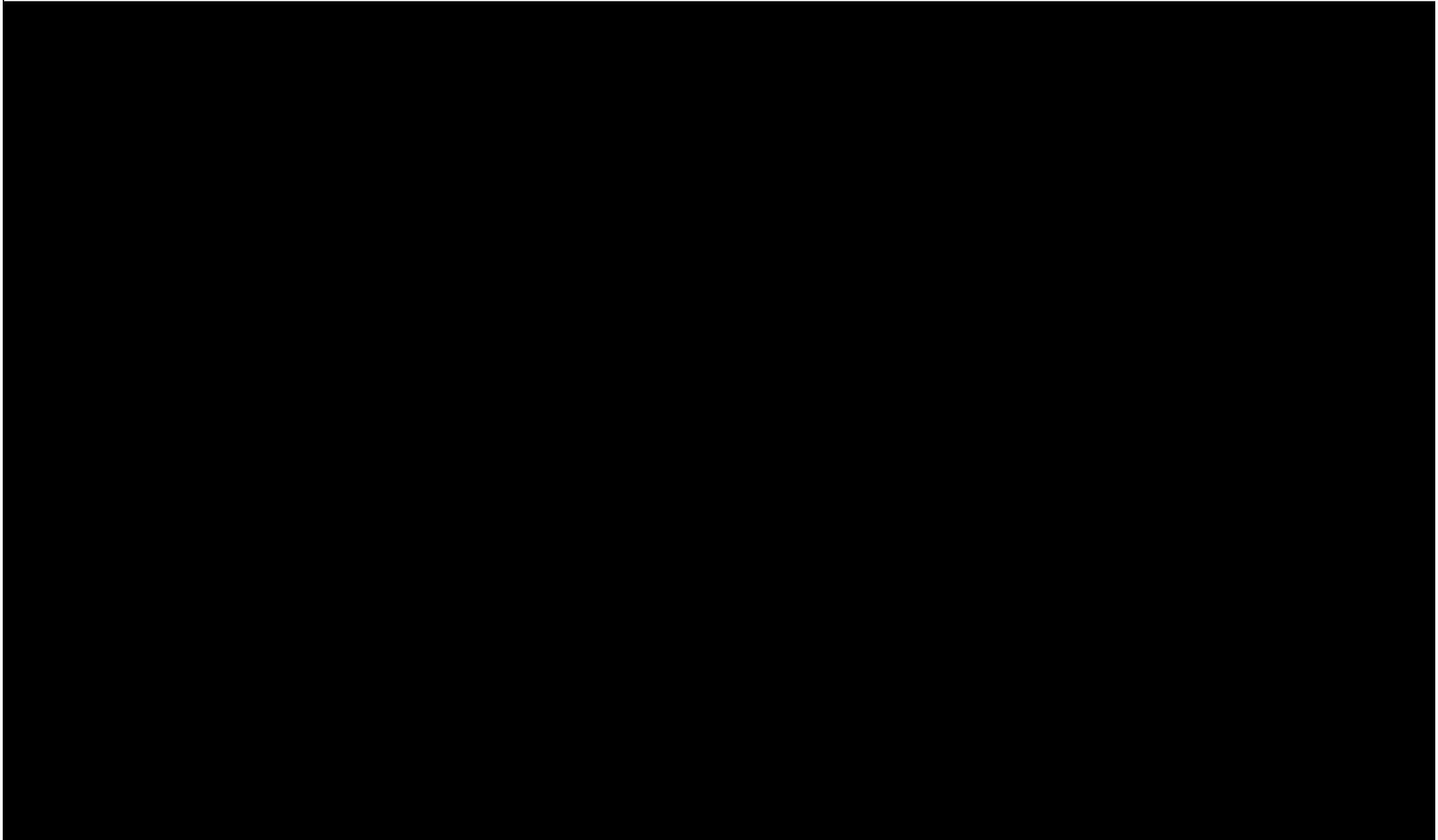
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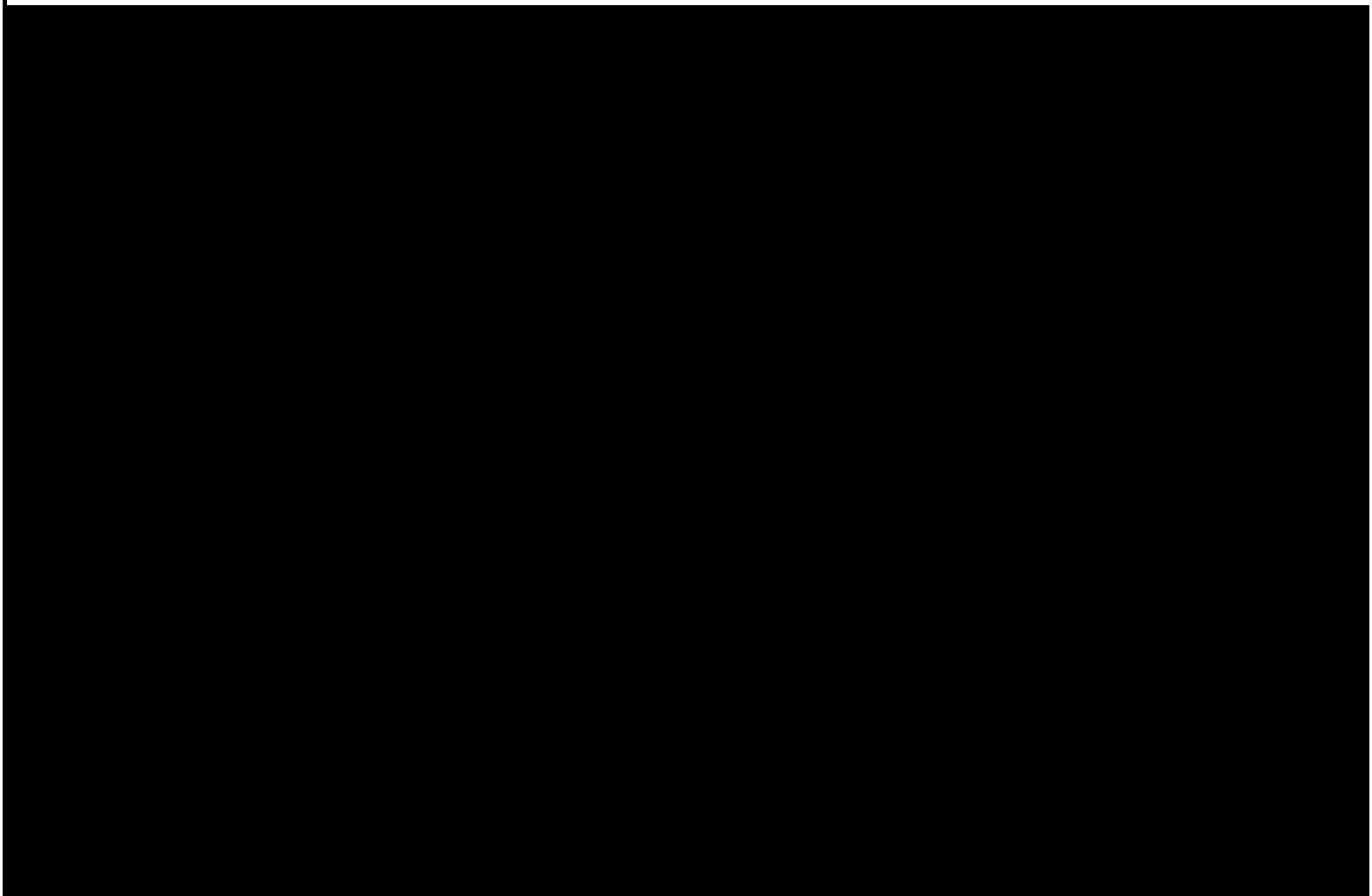
The general situation is shown in Fig. 3-8. Population 1 has mean  $\mu_1$  and standard deviation  $\sigma_1$ .

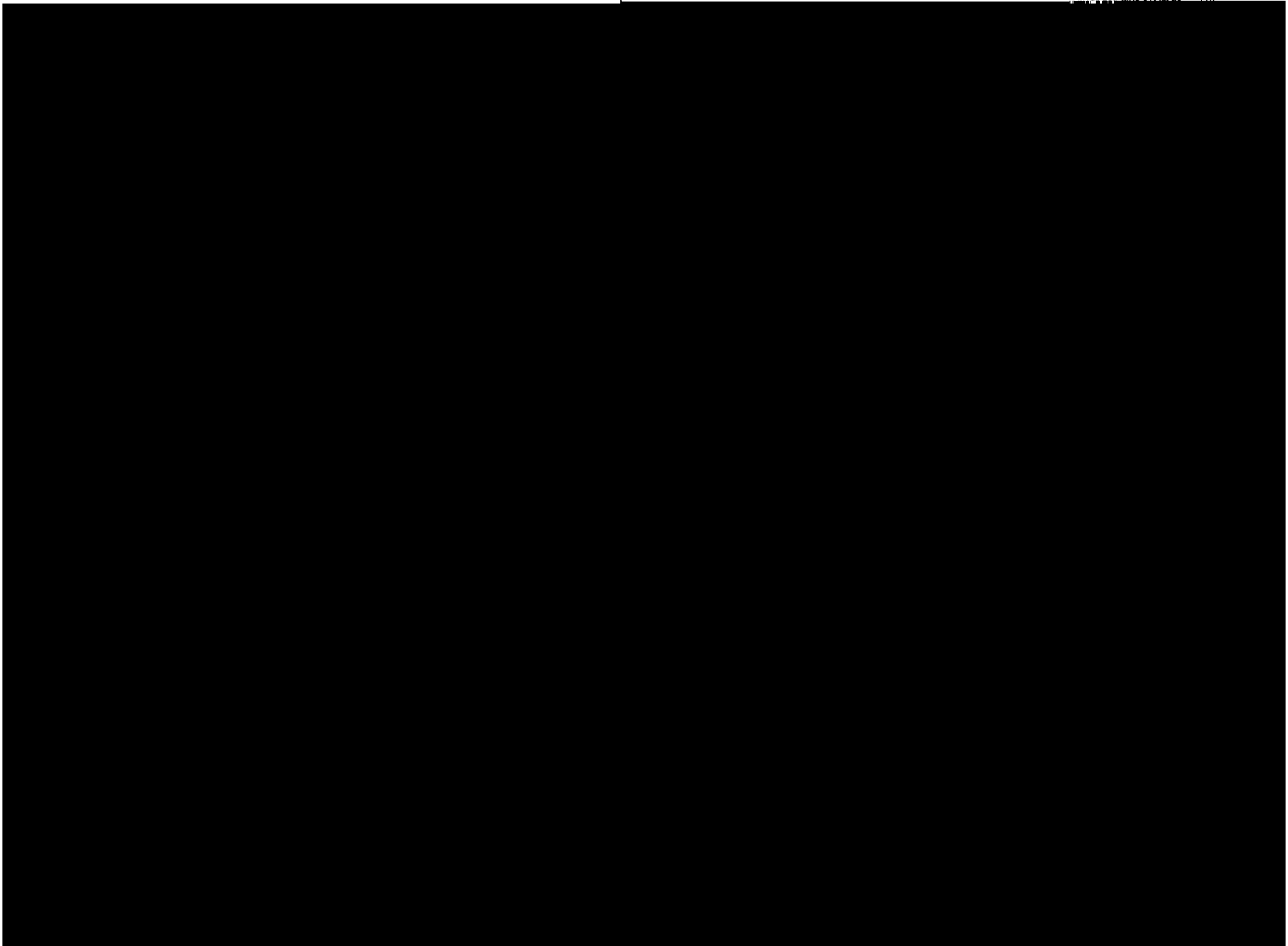




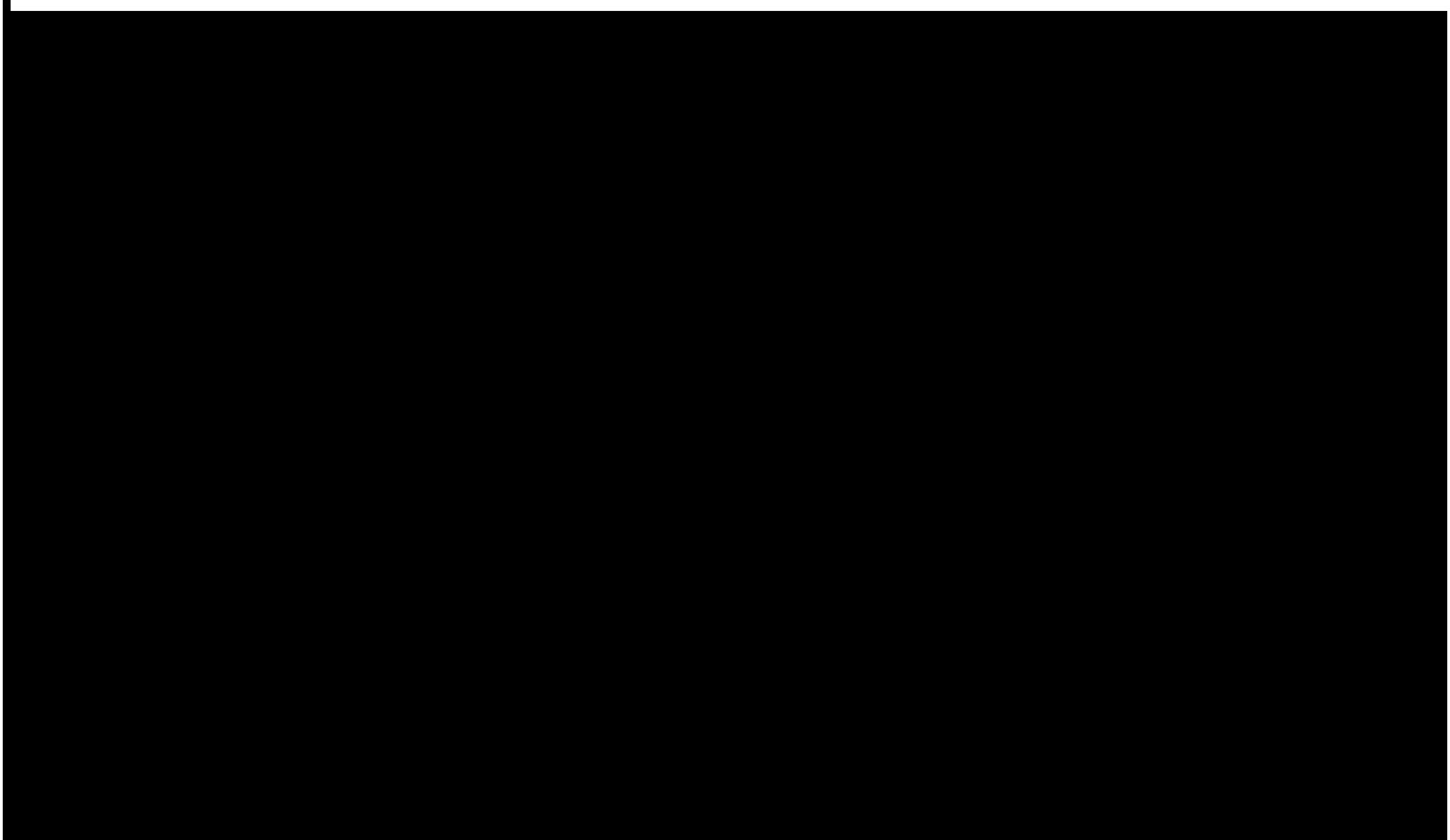
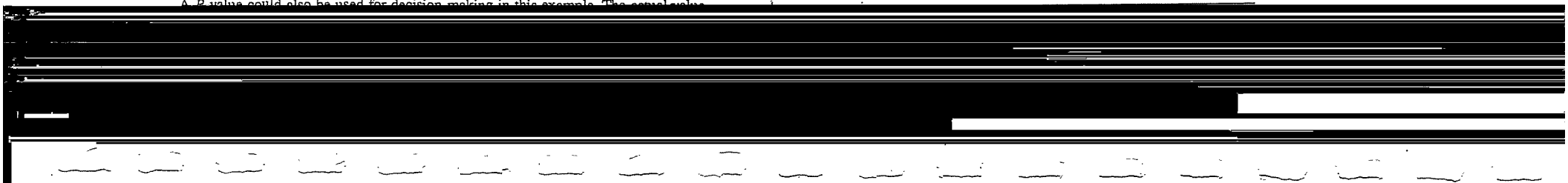
10/10/2020 10:10:10



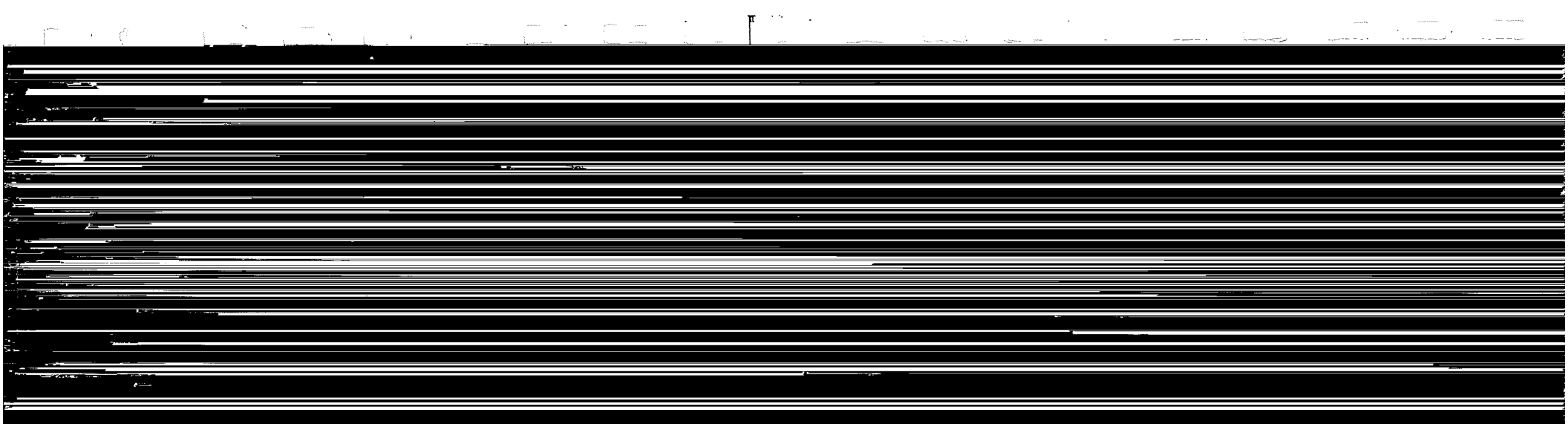




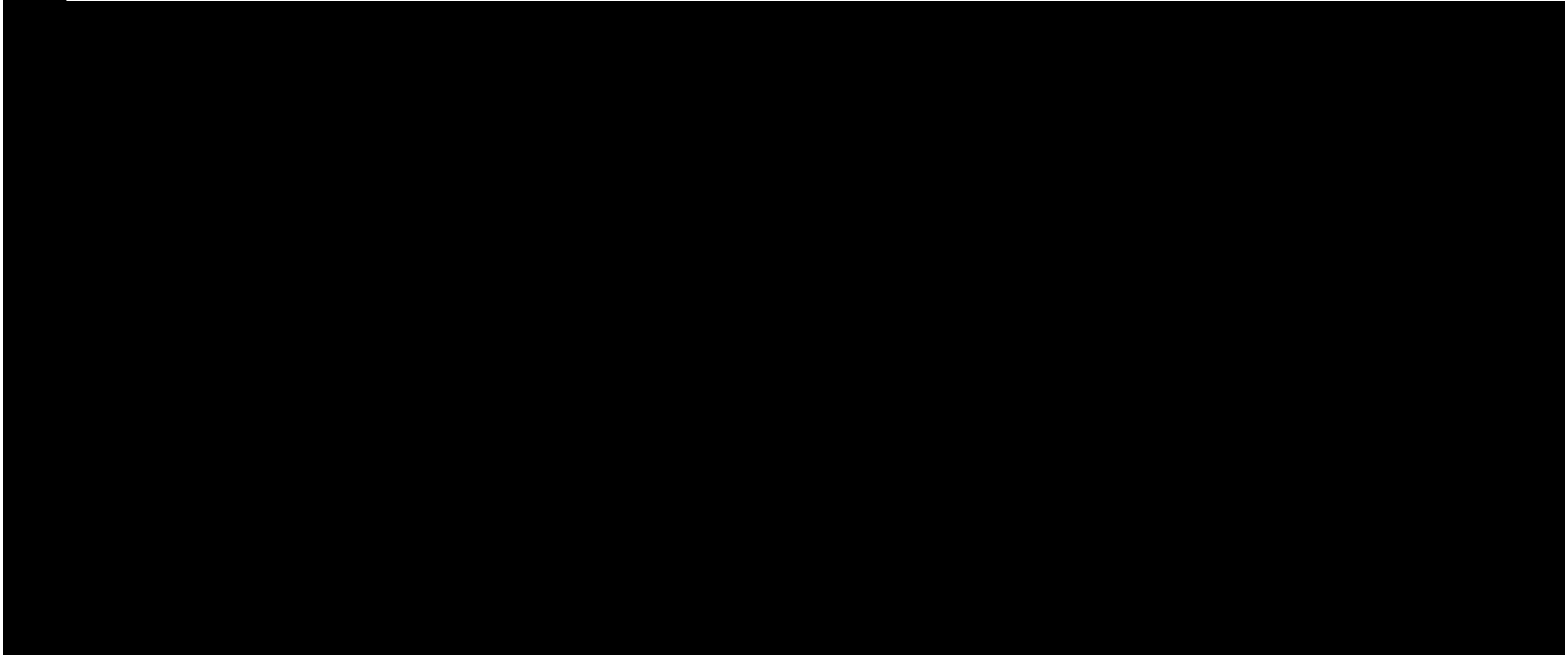
A  $P$  value could also be used for decision making in this example. The  $p$ -value

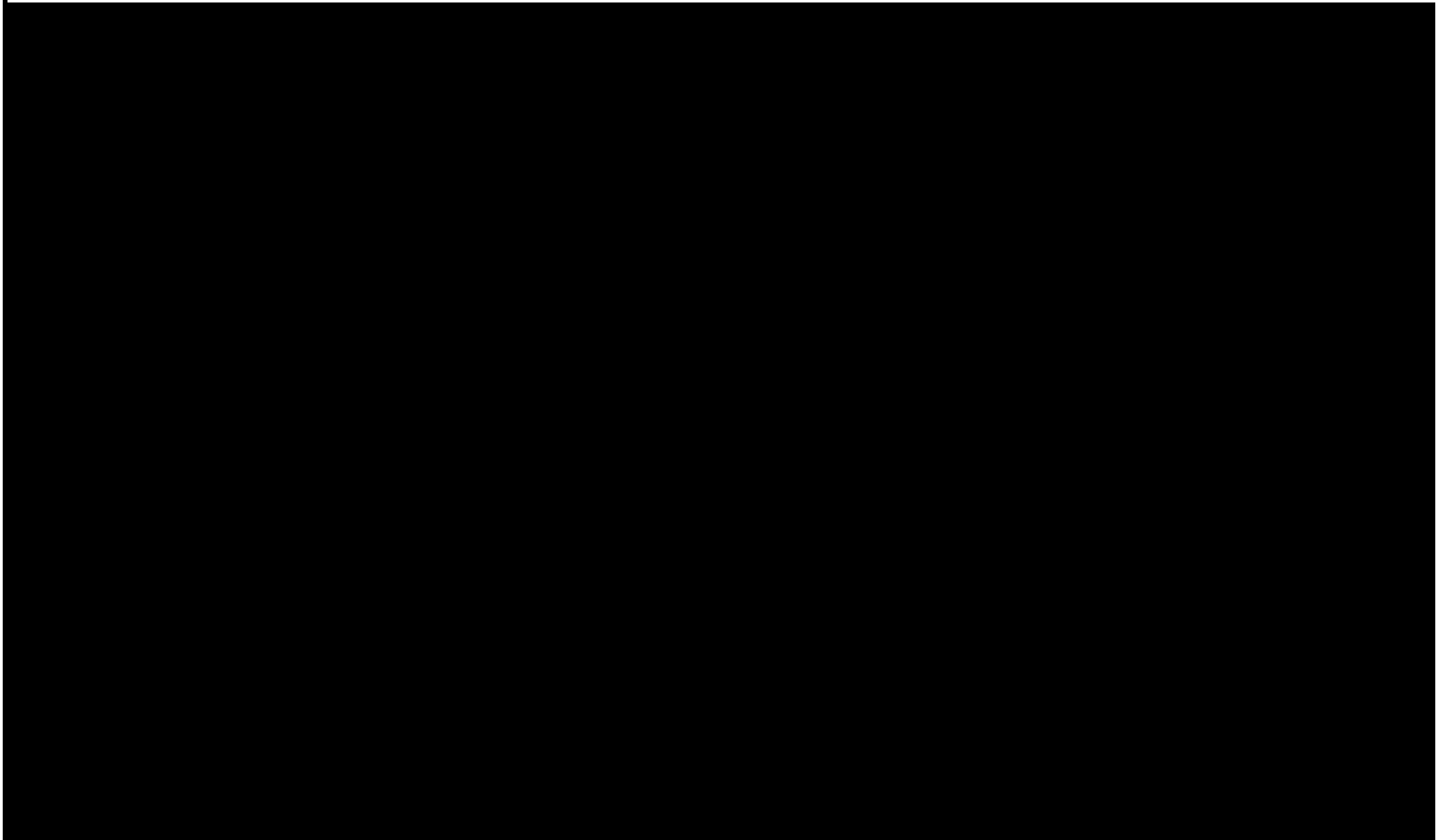
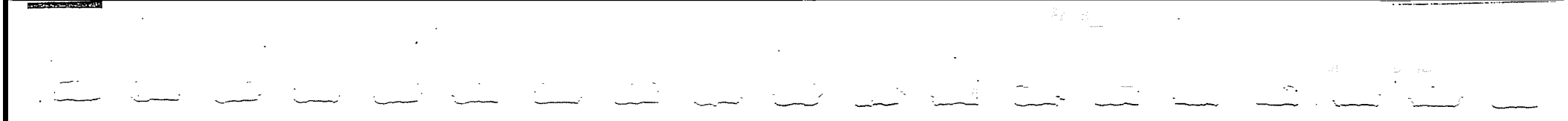
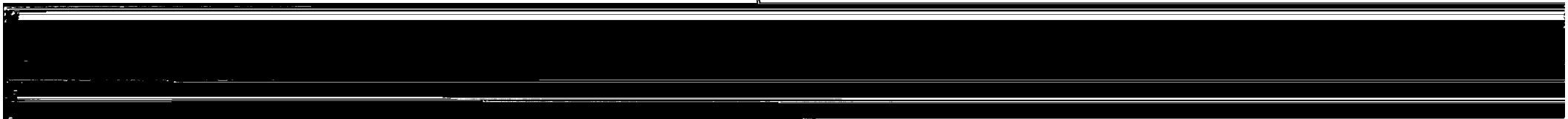


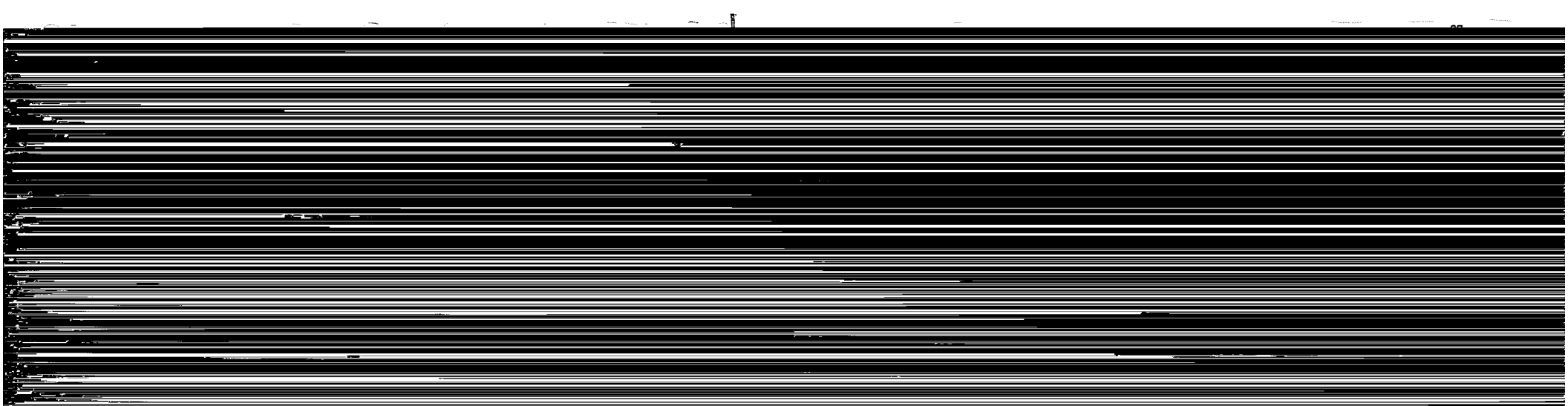




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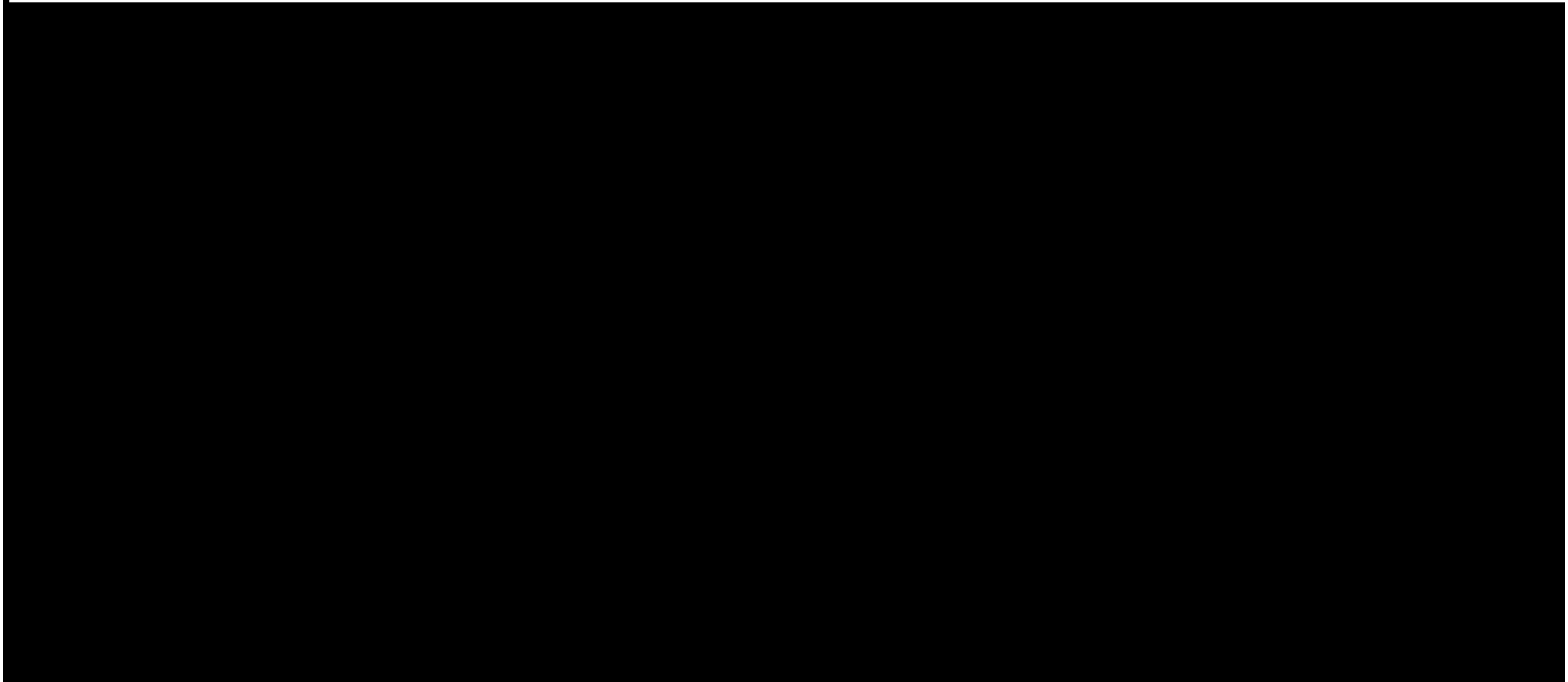
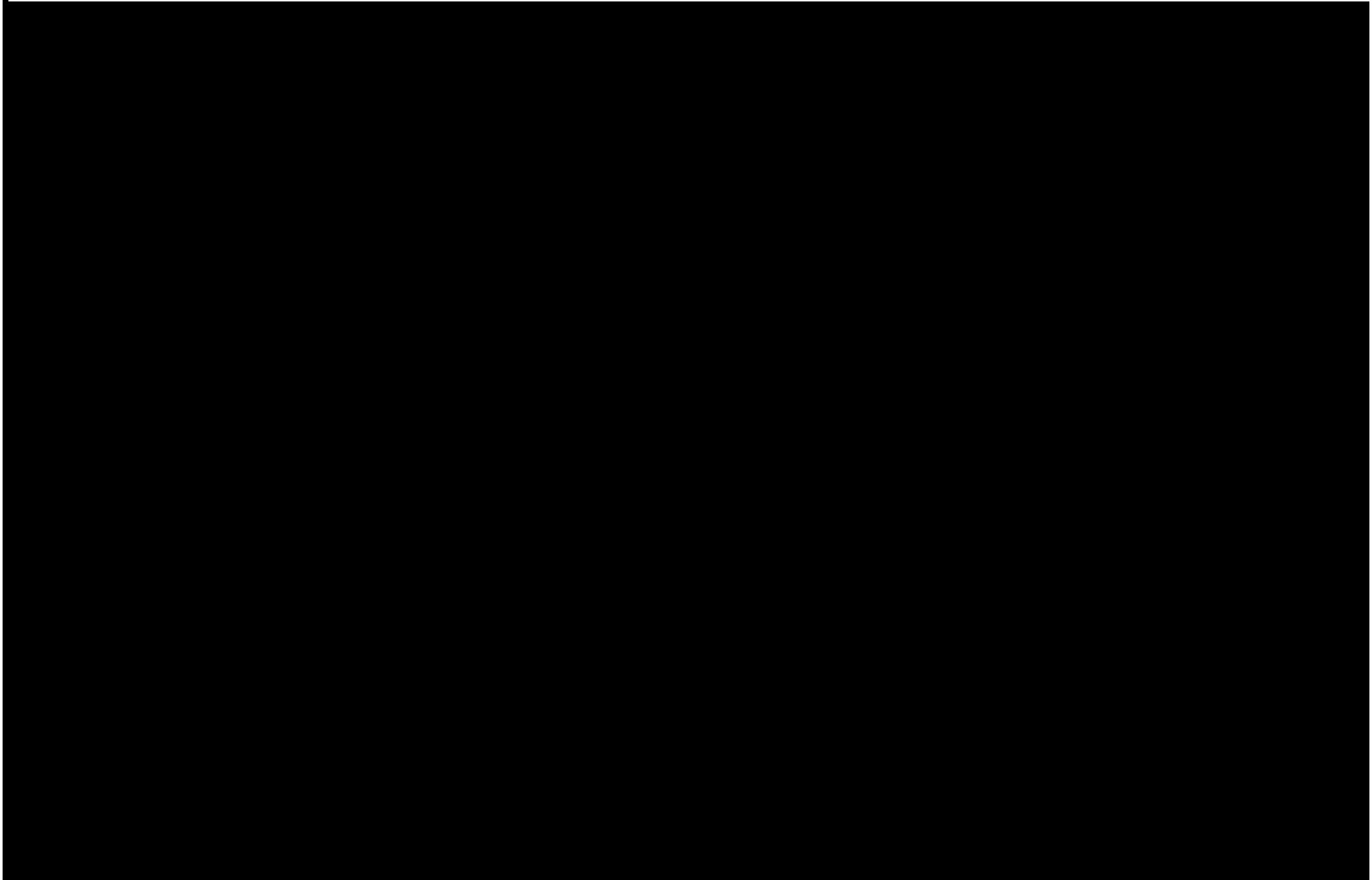
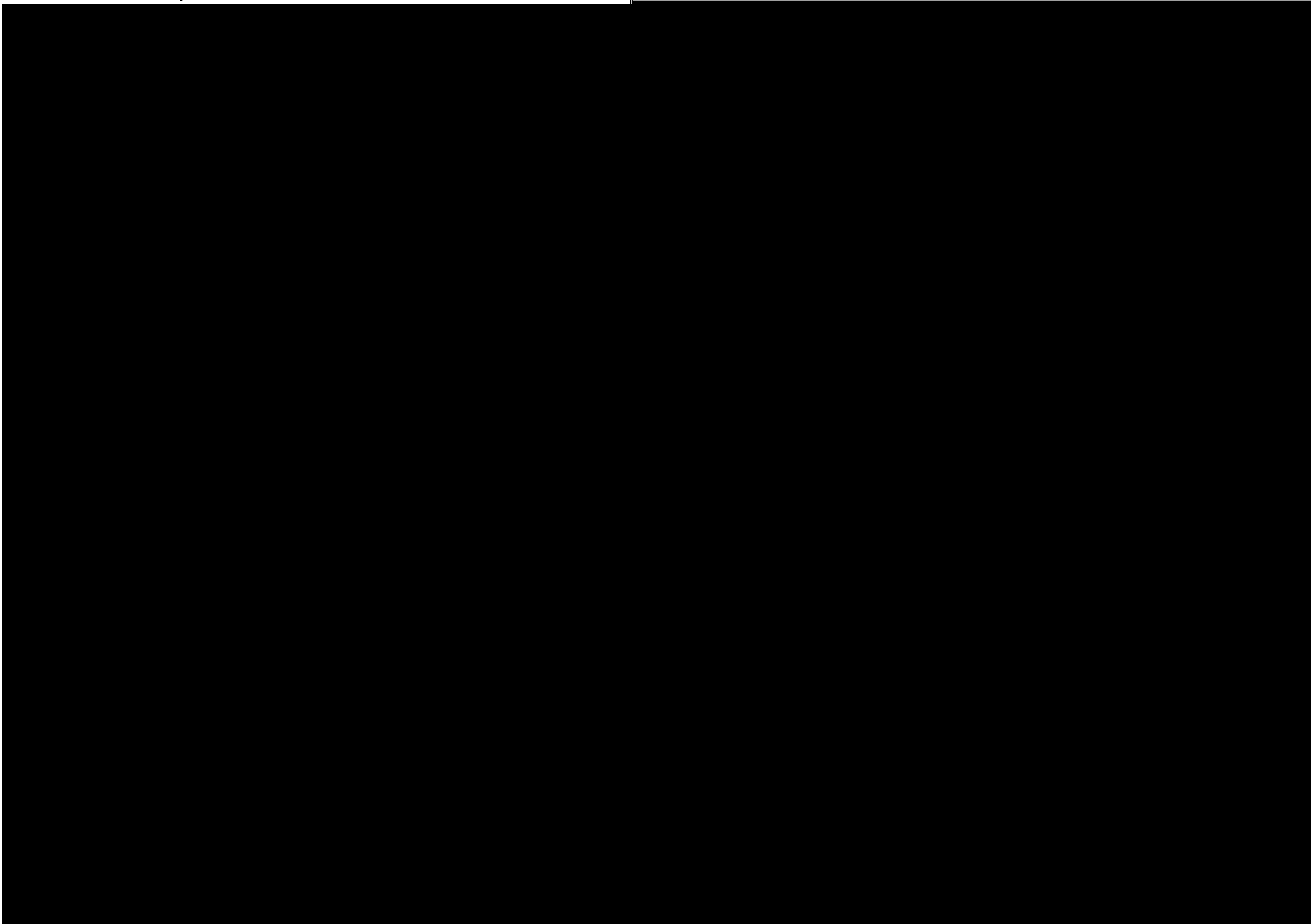


TABLE 1

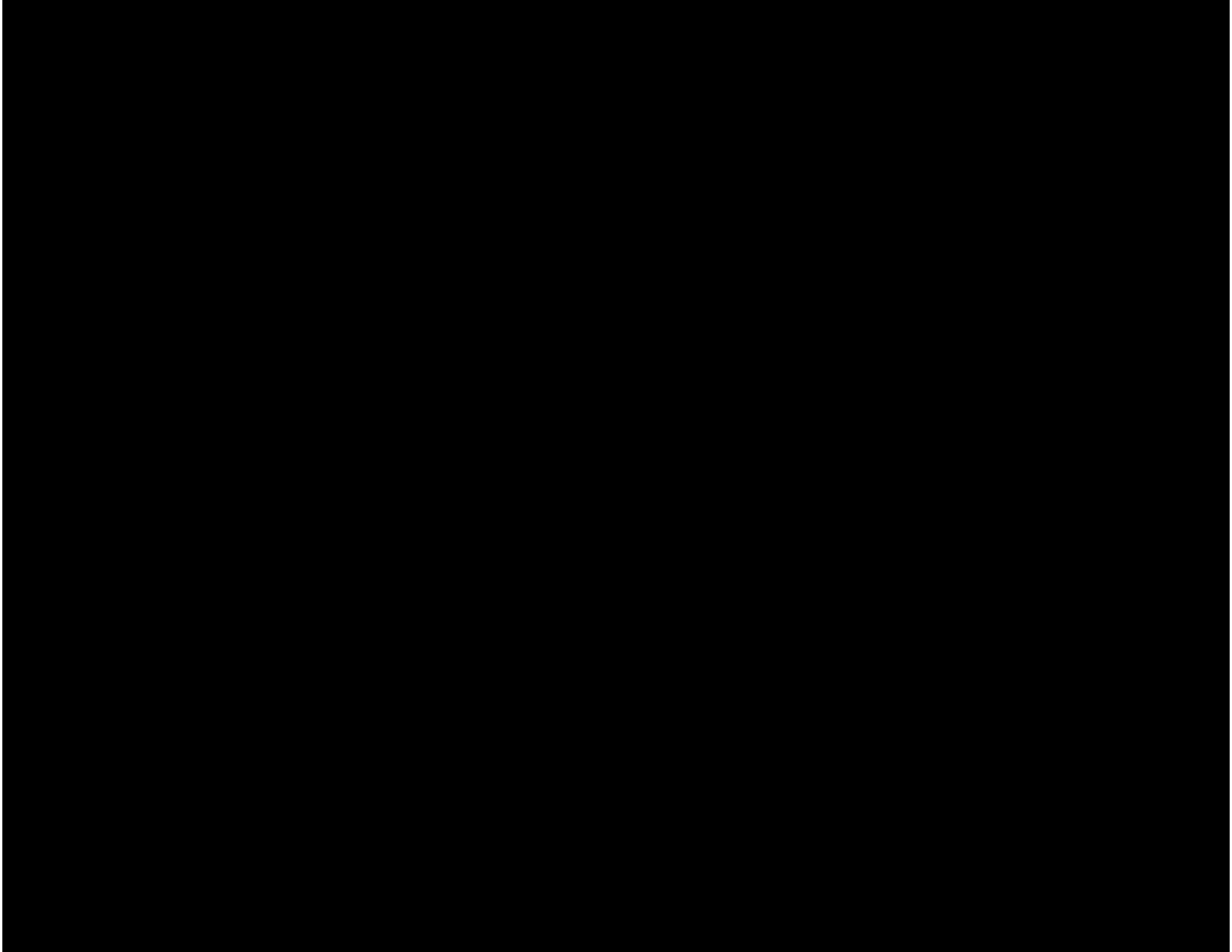
Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Production (1000 tons)	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200





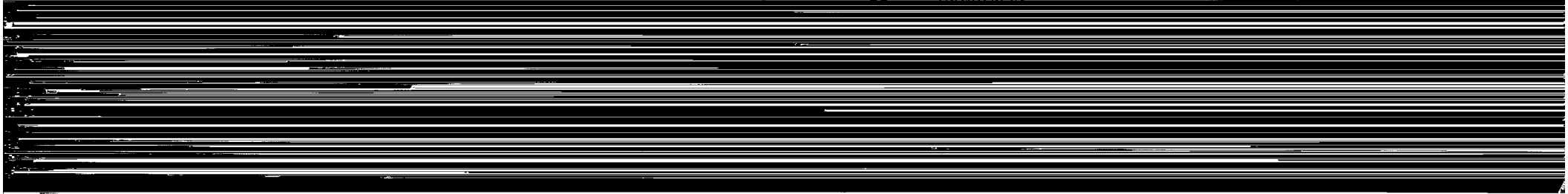




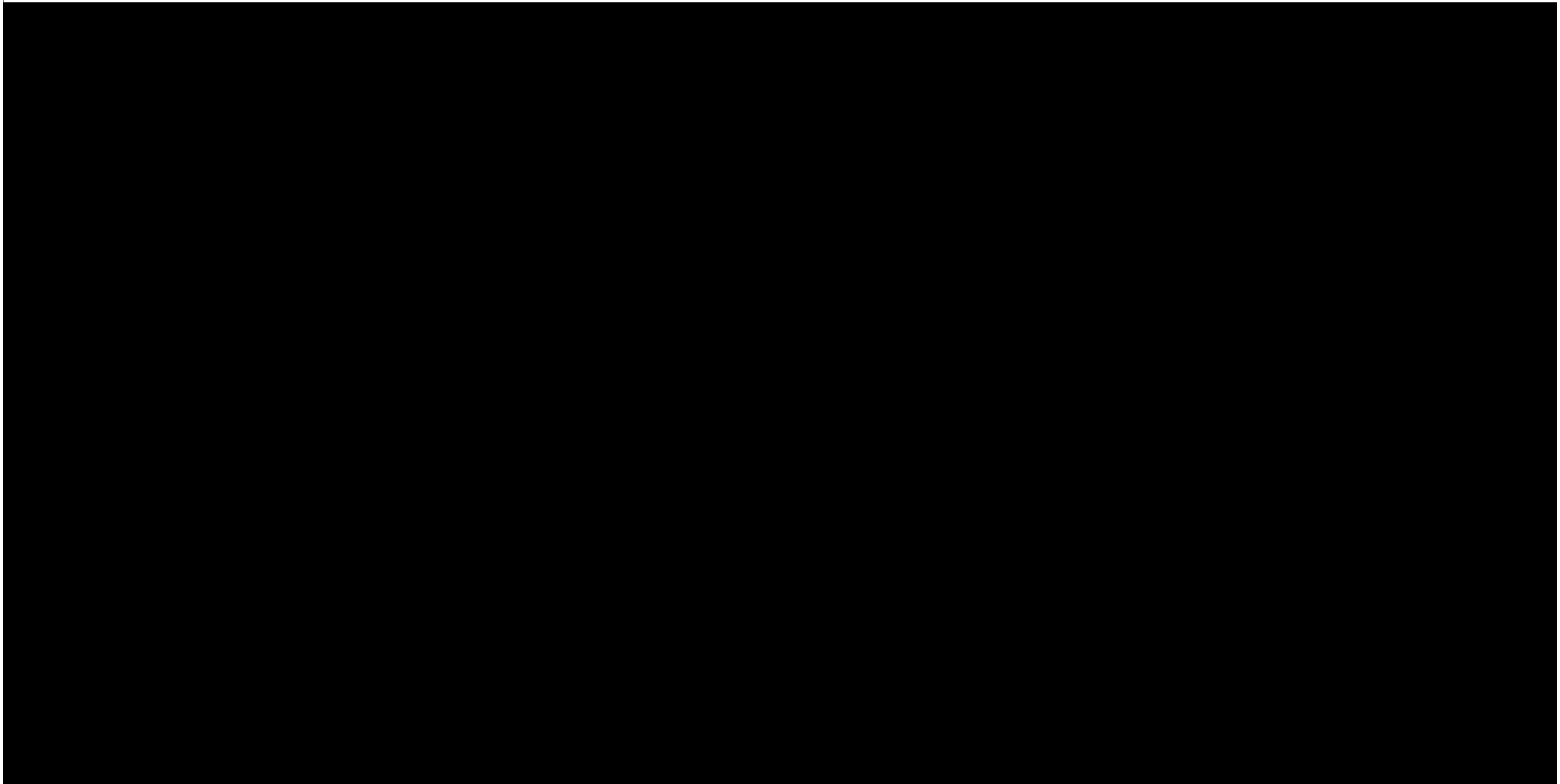


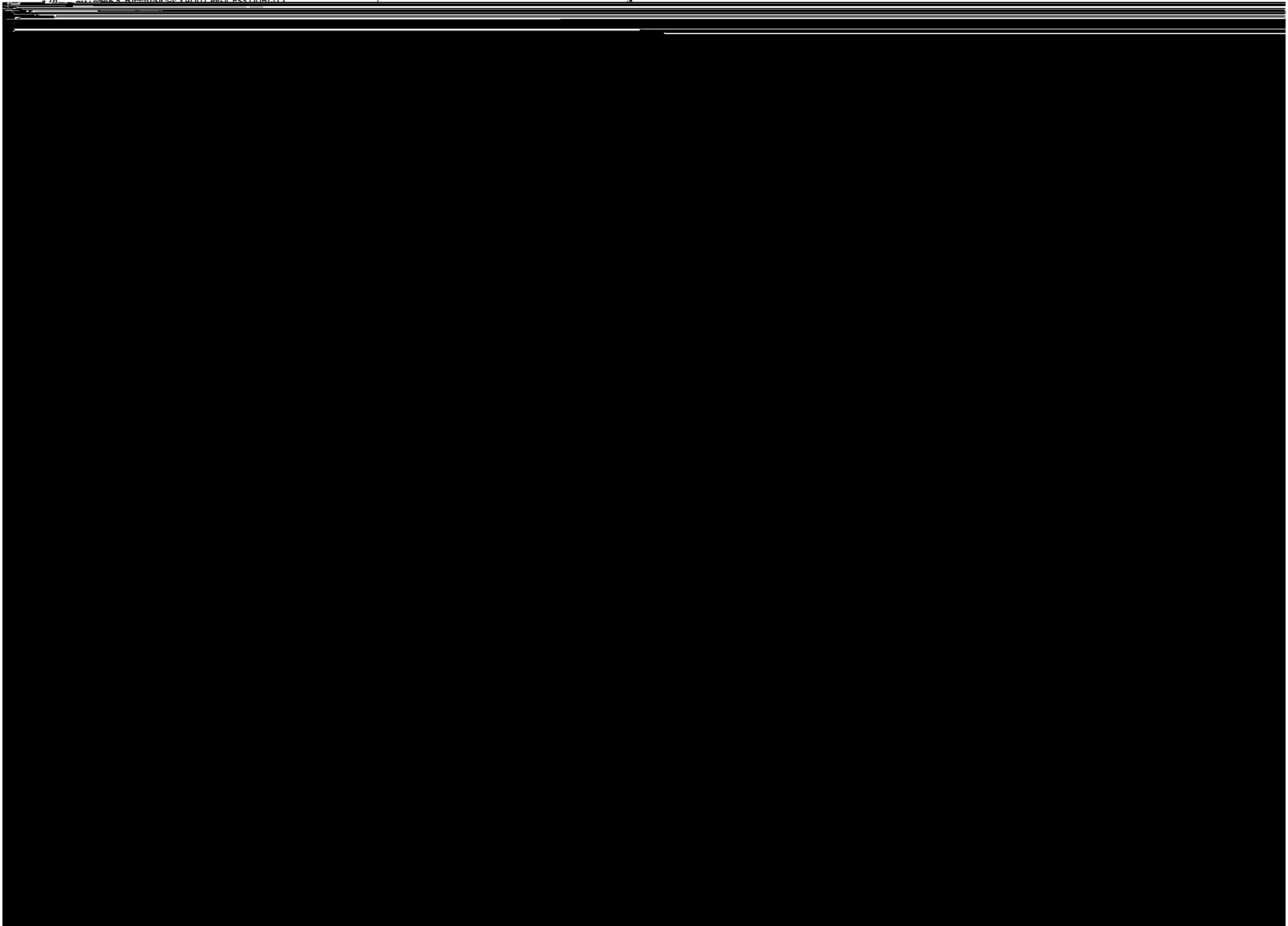


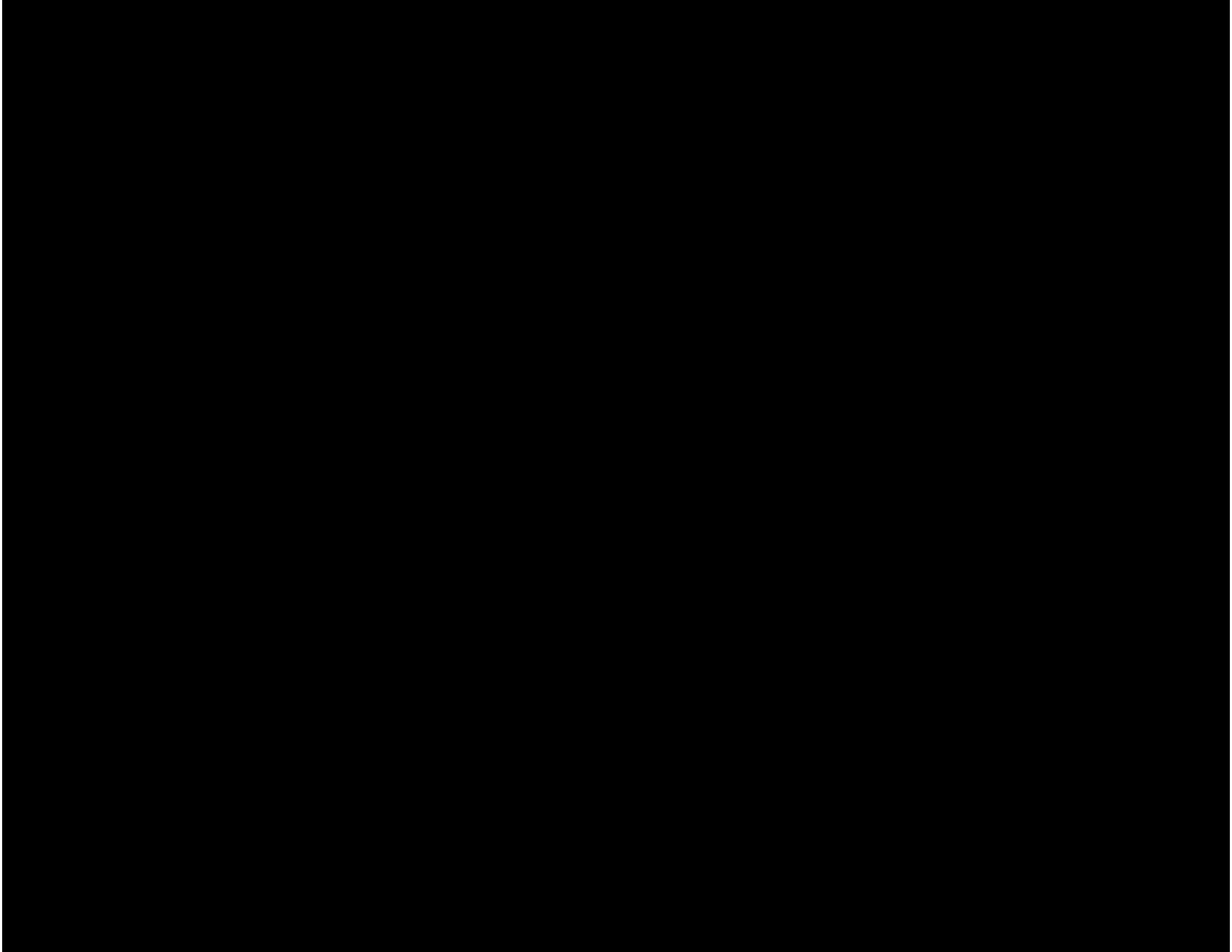
EXERCISES



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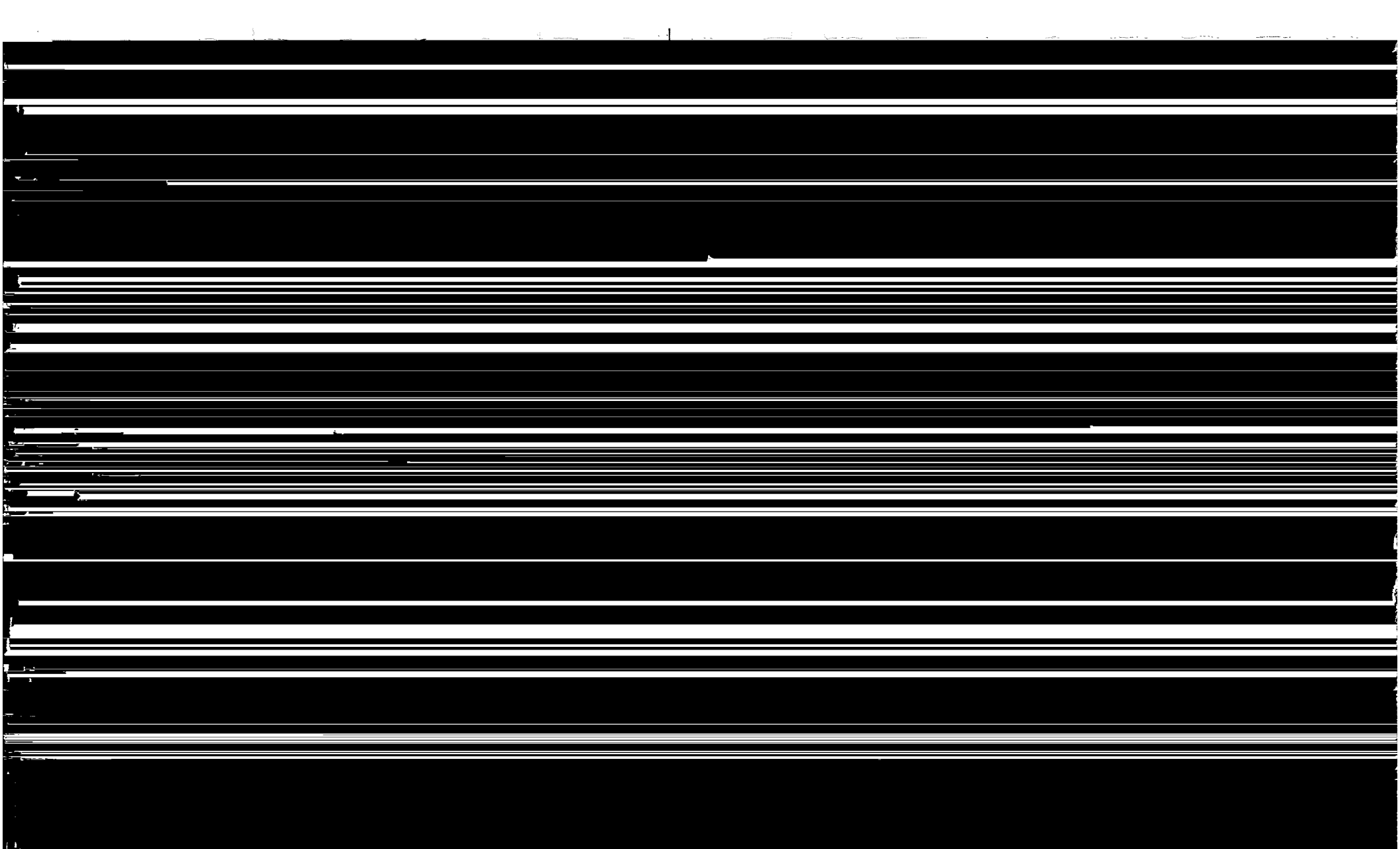


Temperature

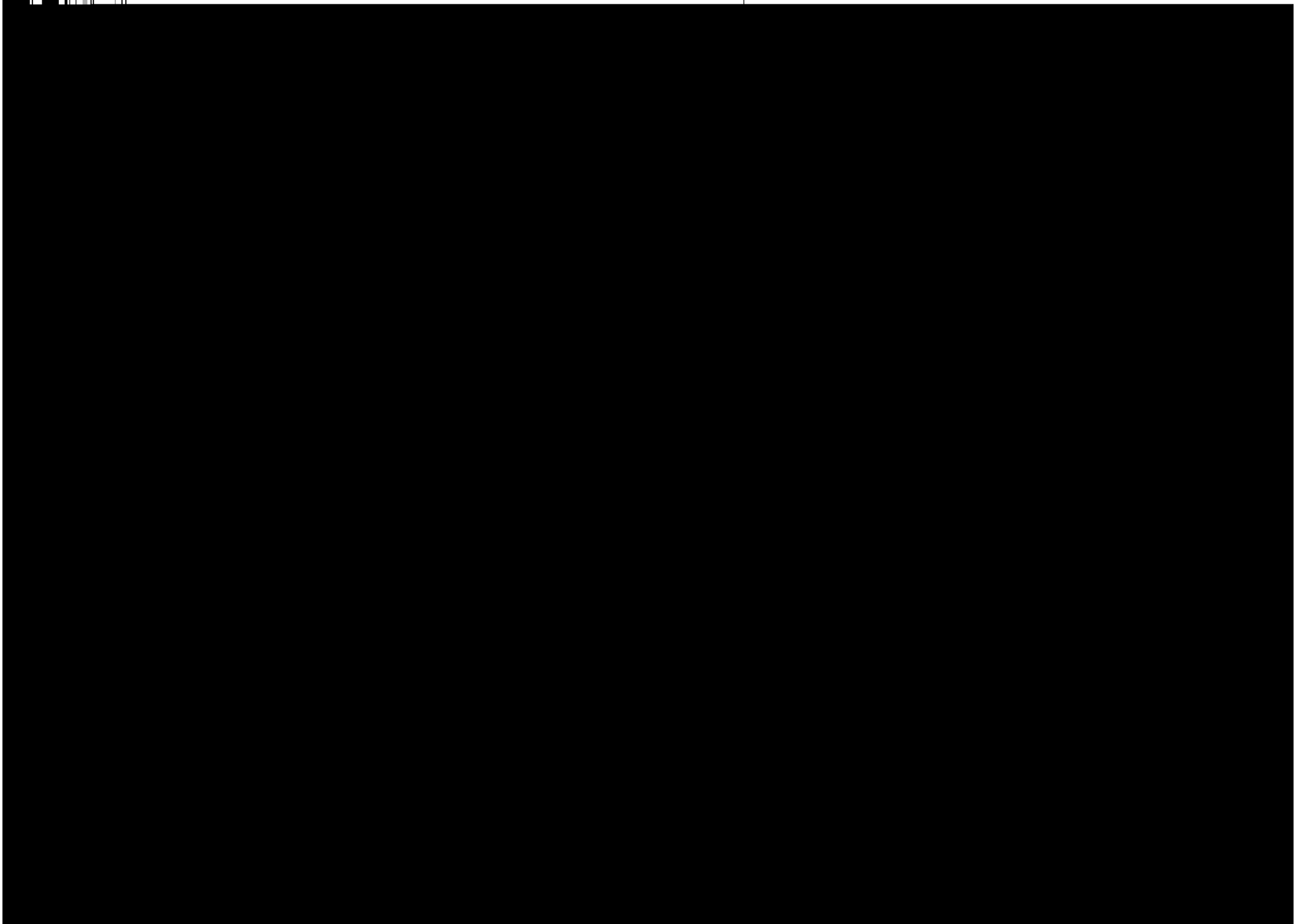
(a) Does the size of the orifice affect the

PART

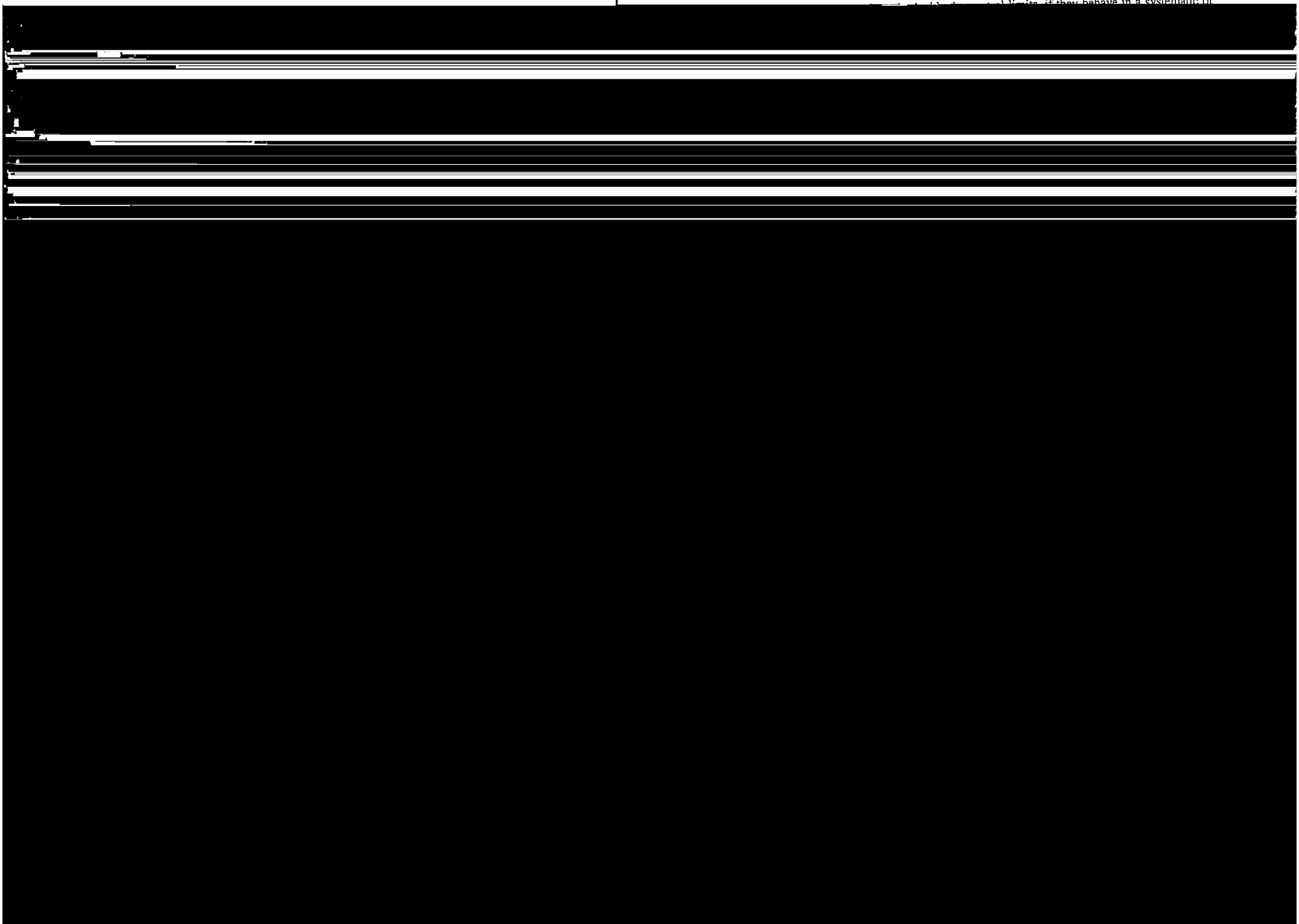


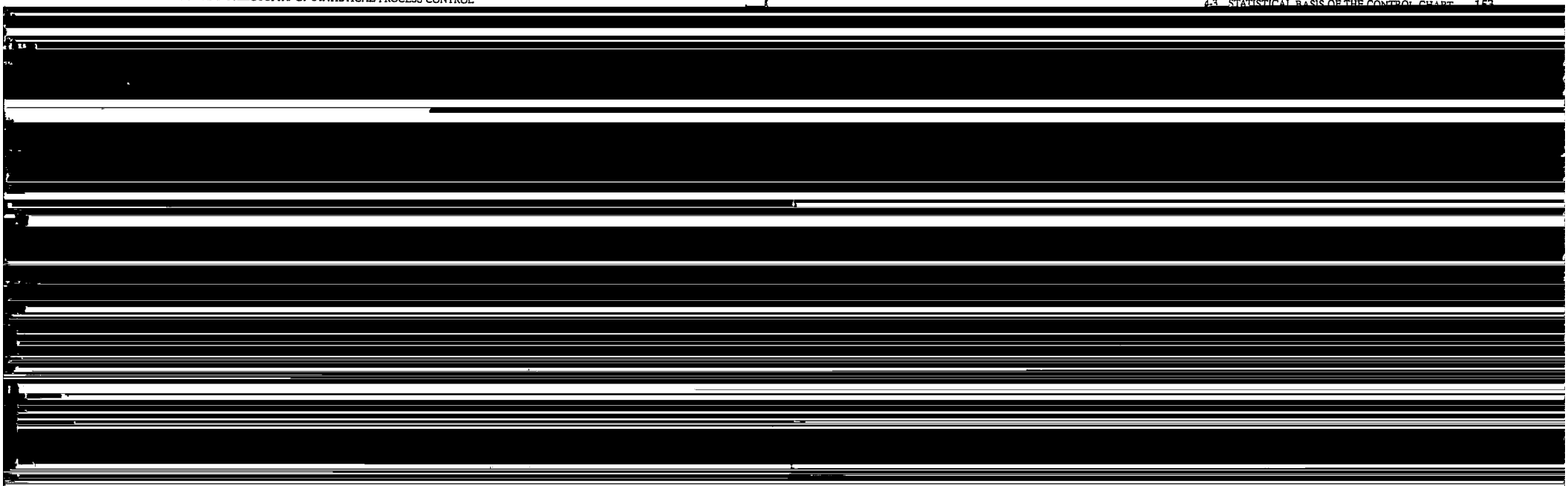


[The content of this section is completely obscured by a large black redaction box.]



... control limits if they behave in a systematic or



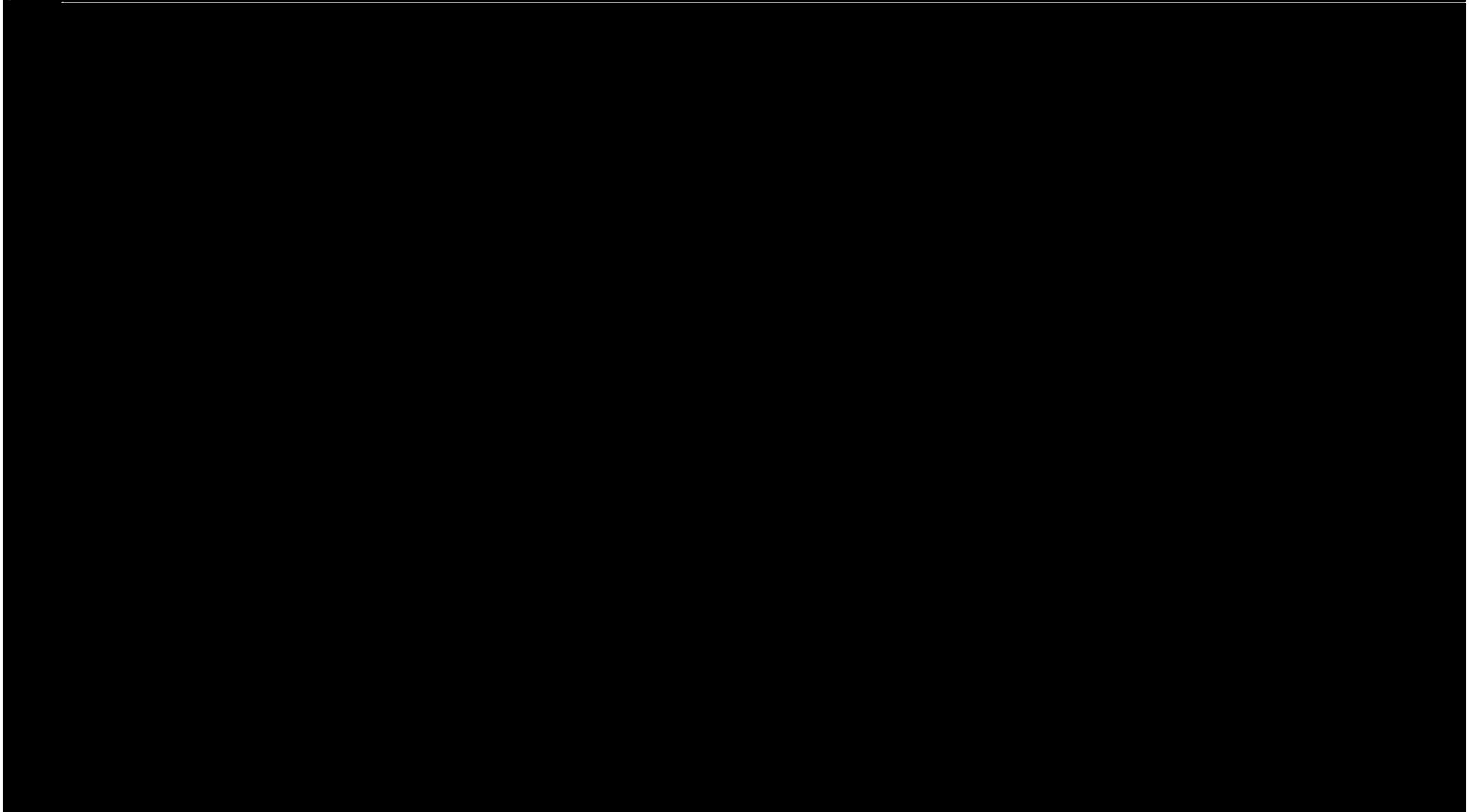
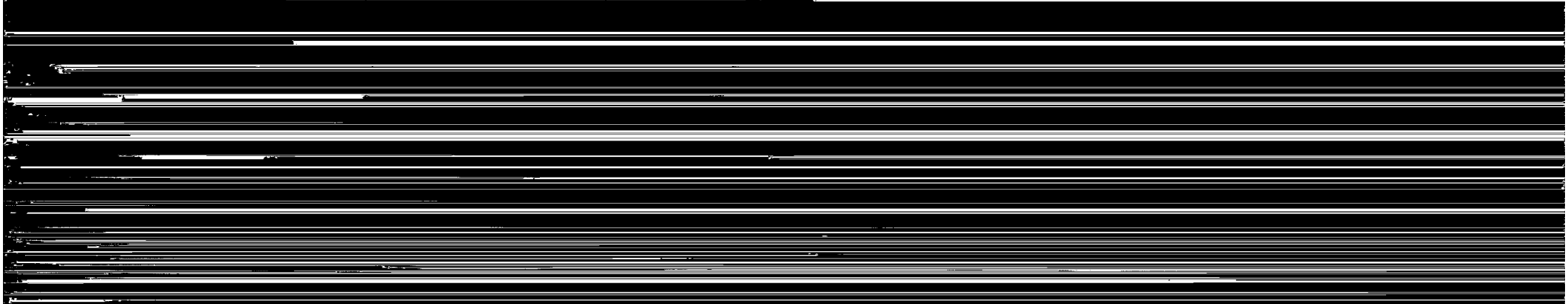


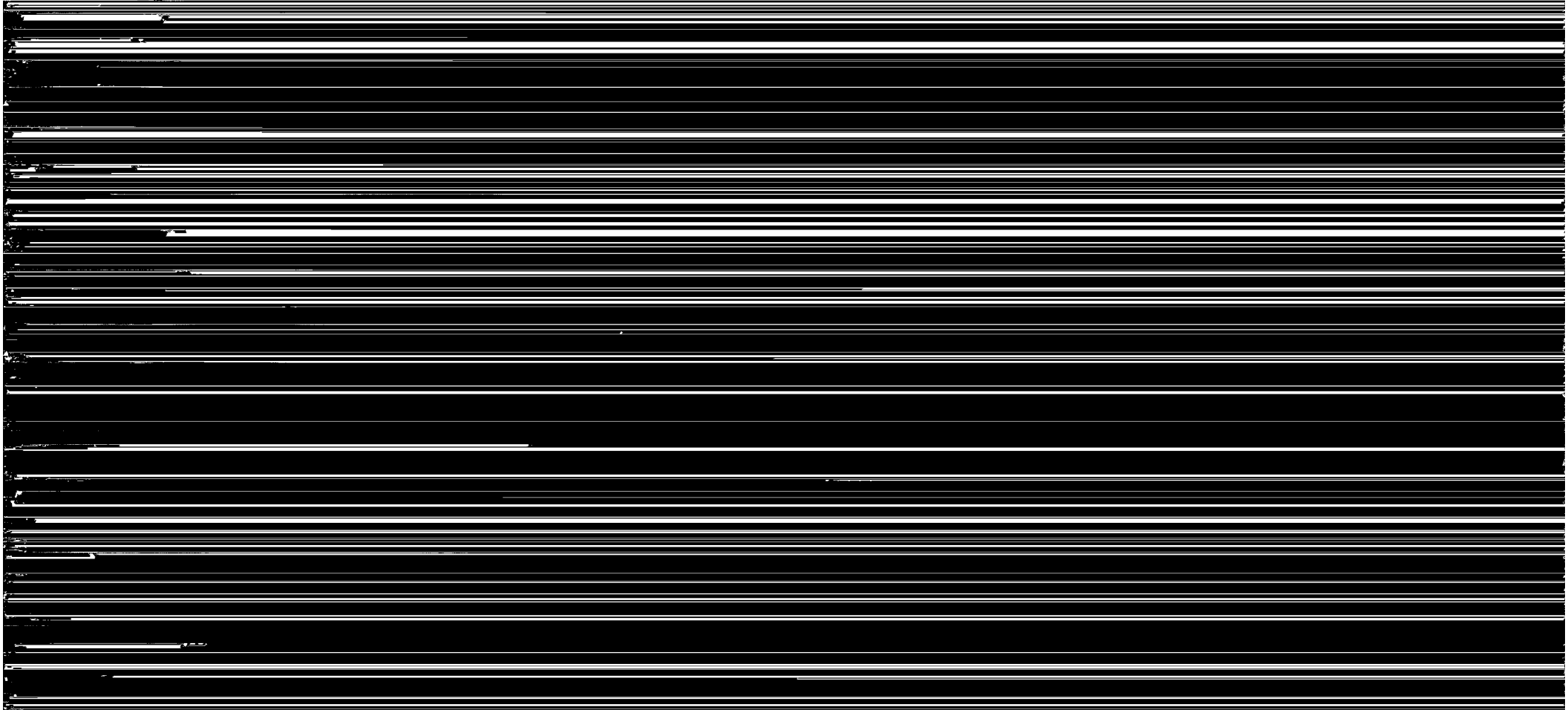


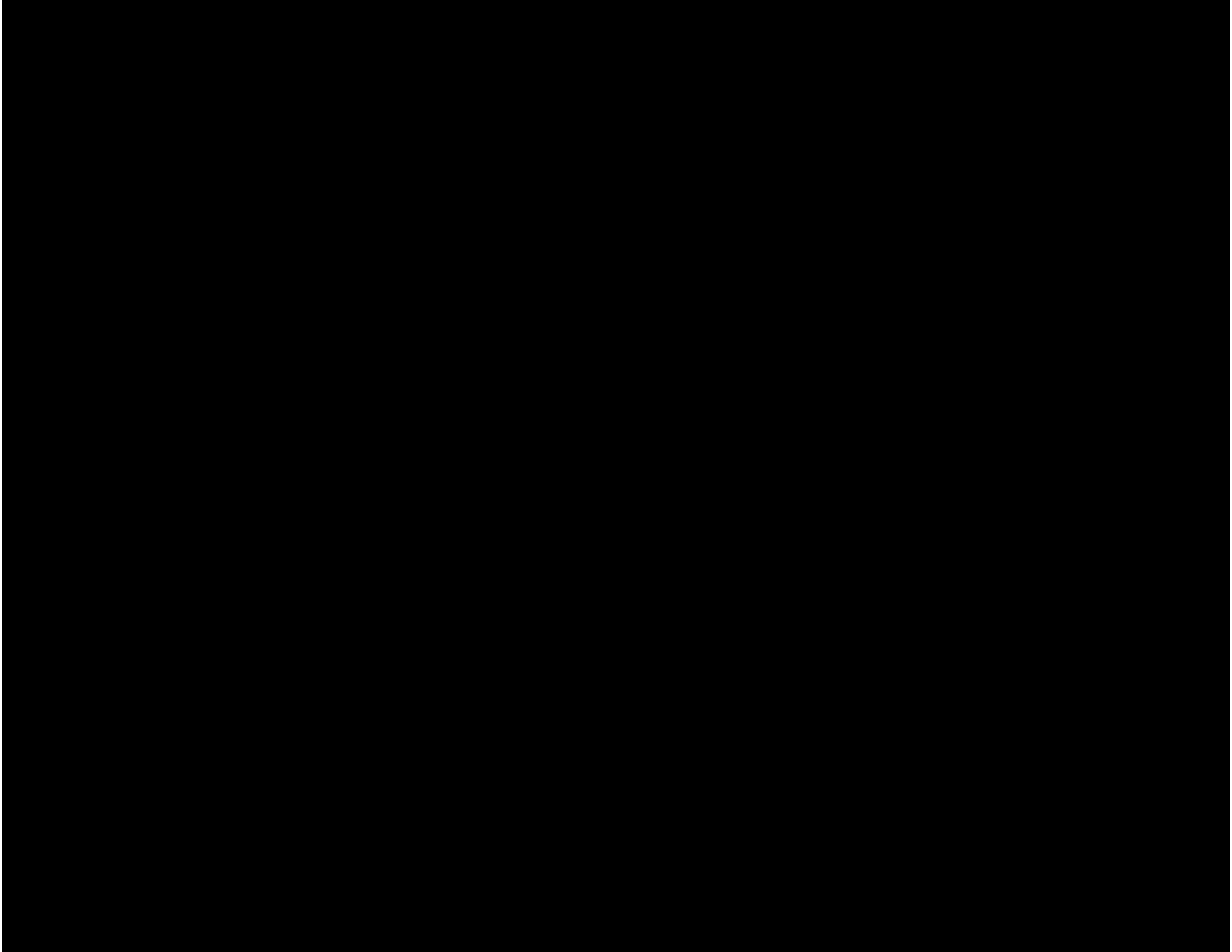
THE THEORY OF STATISTICAL PROCESS CONTROL

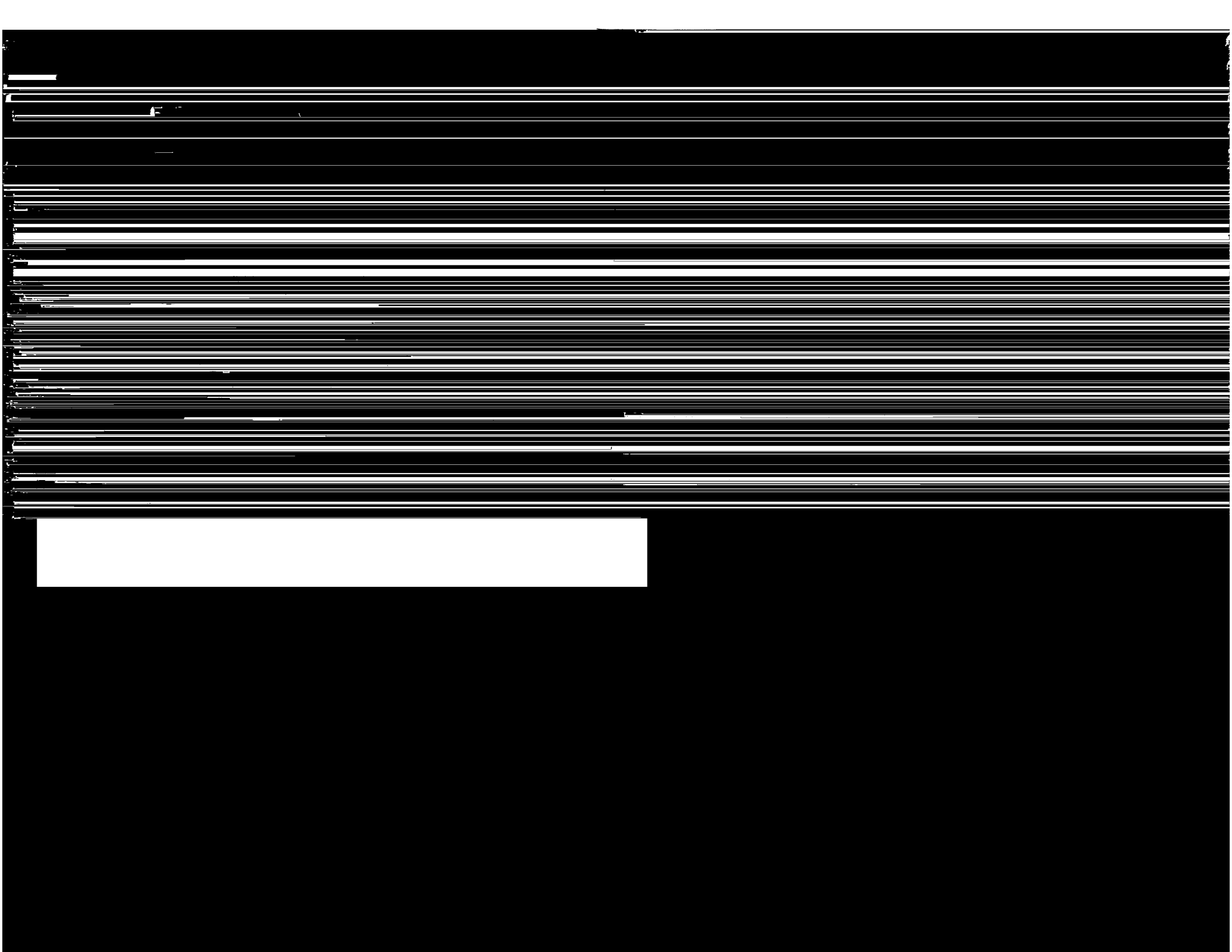


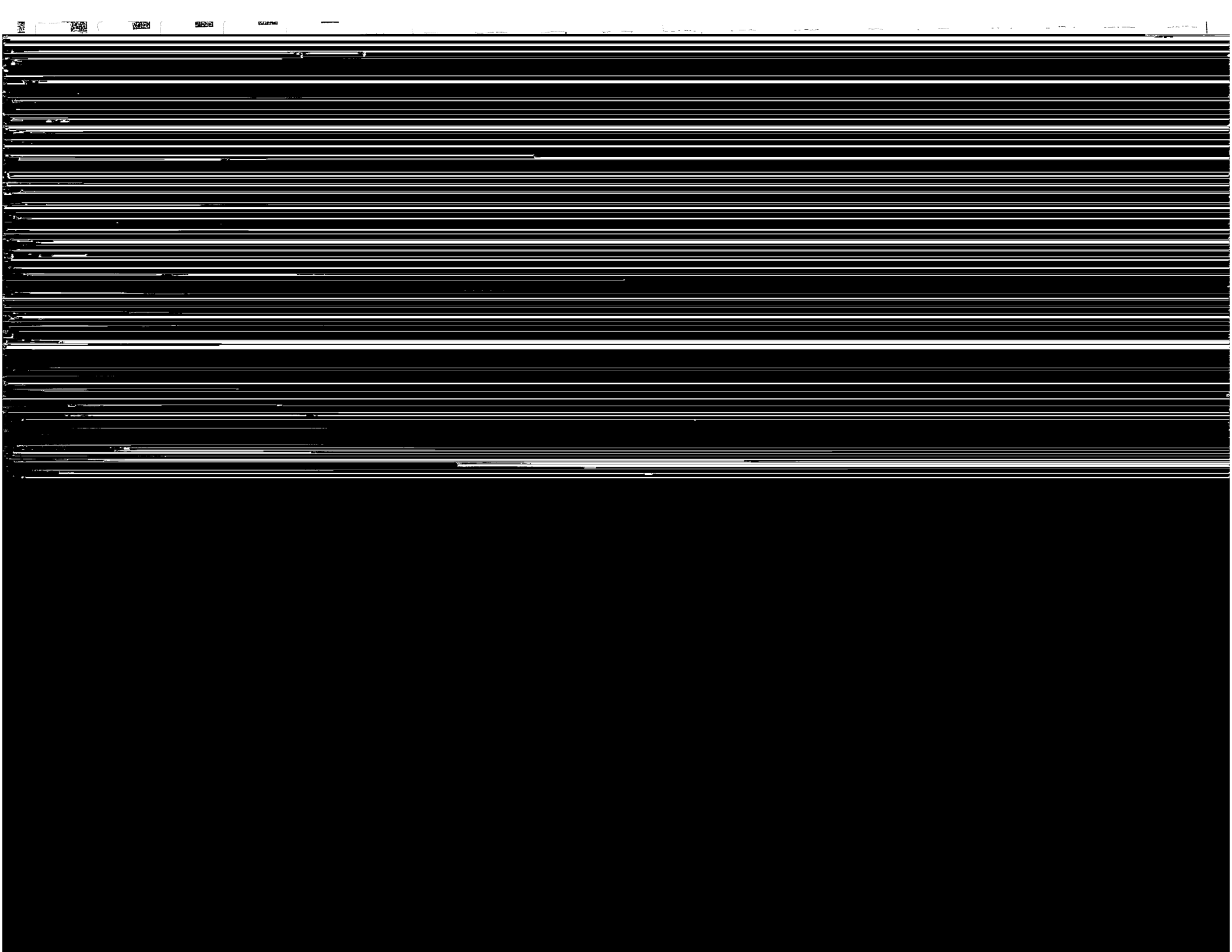


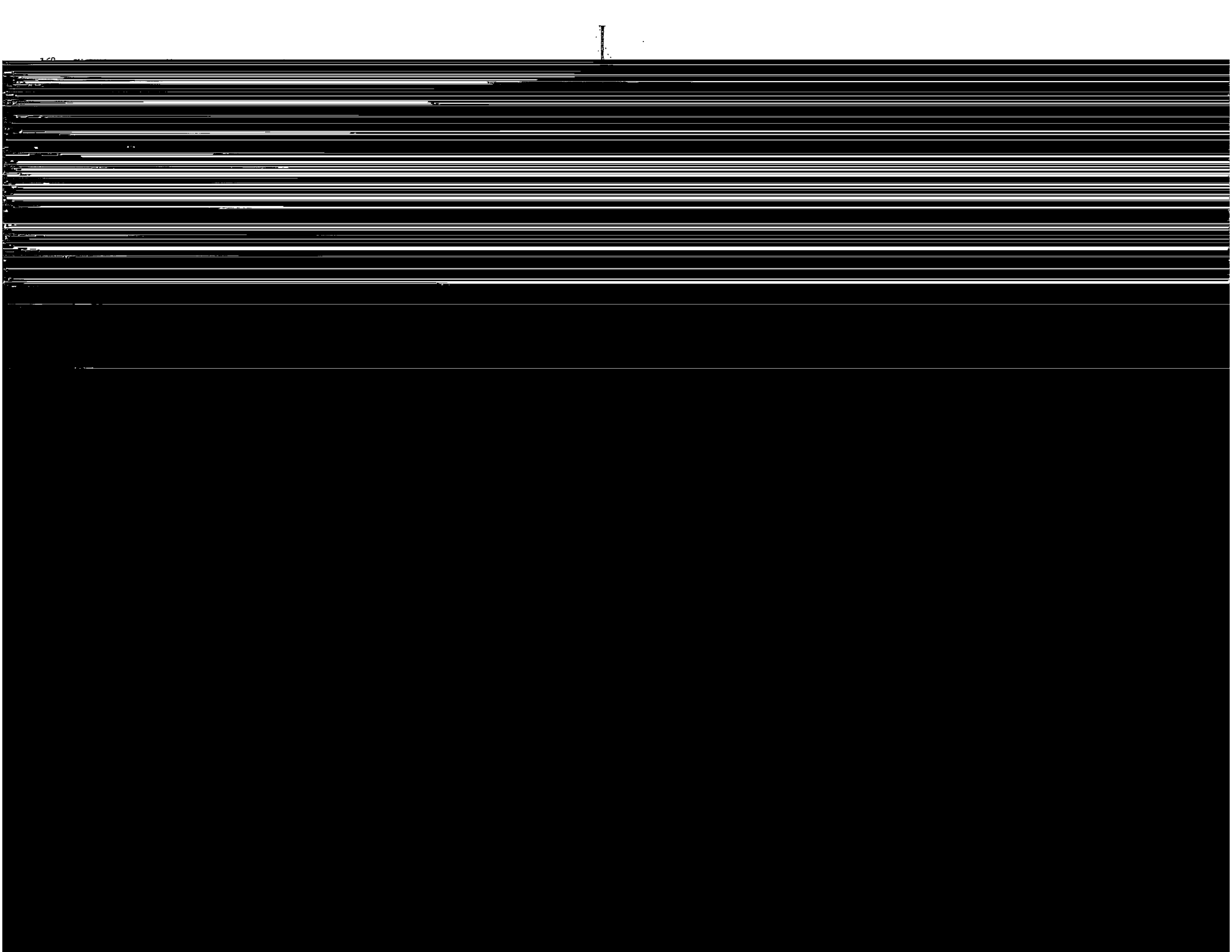




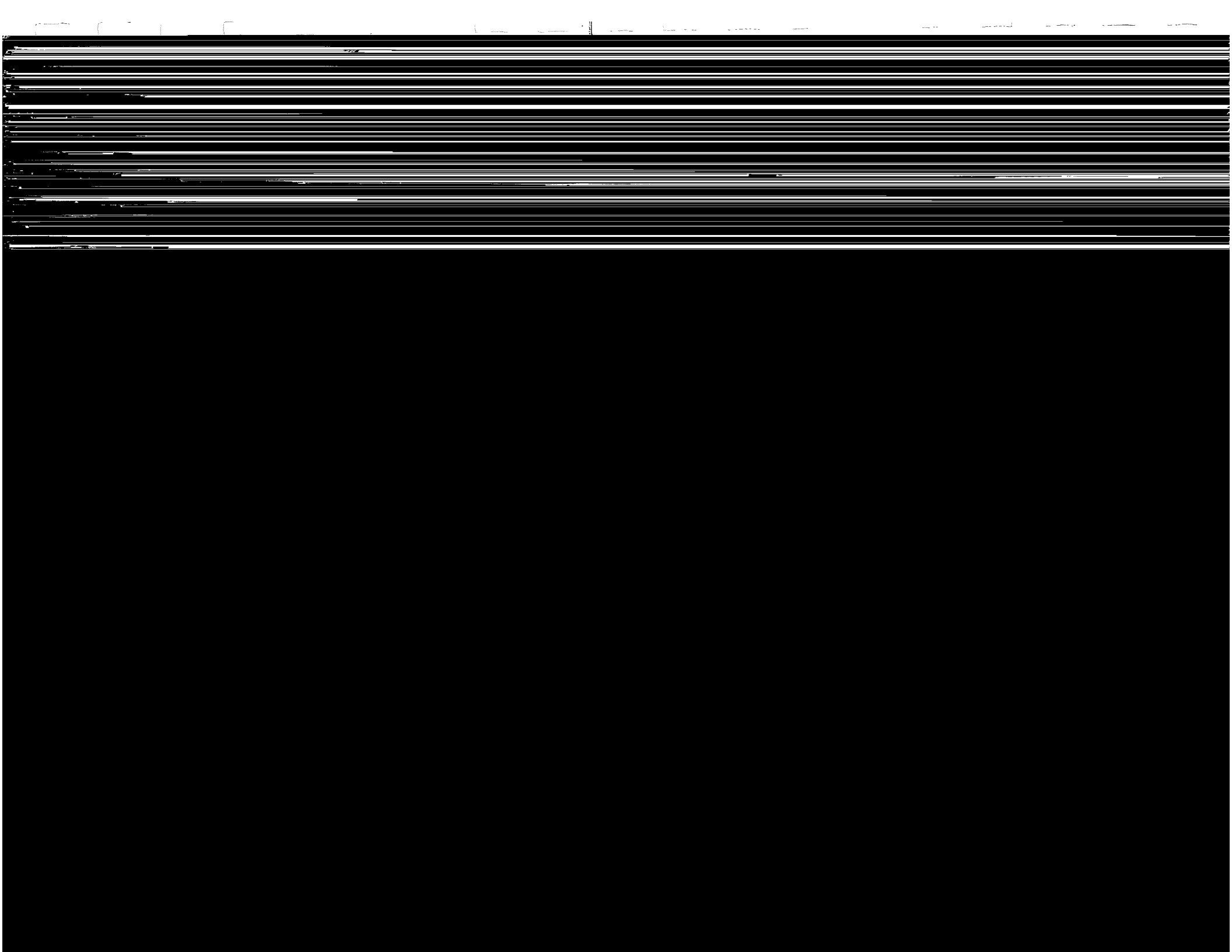


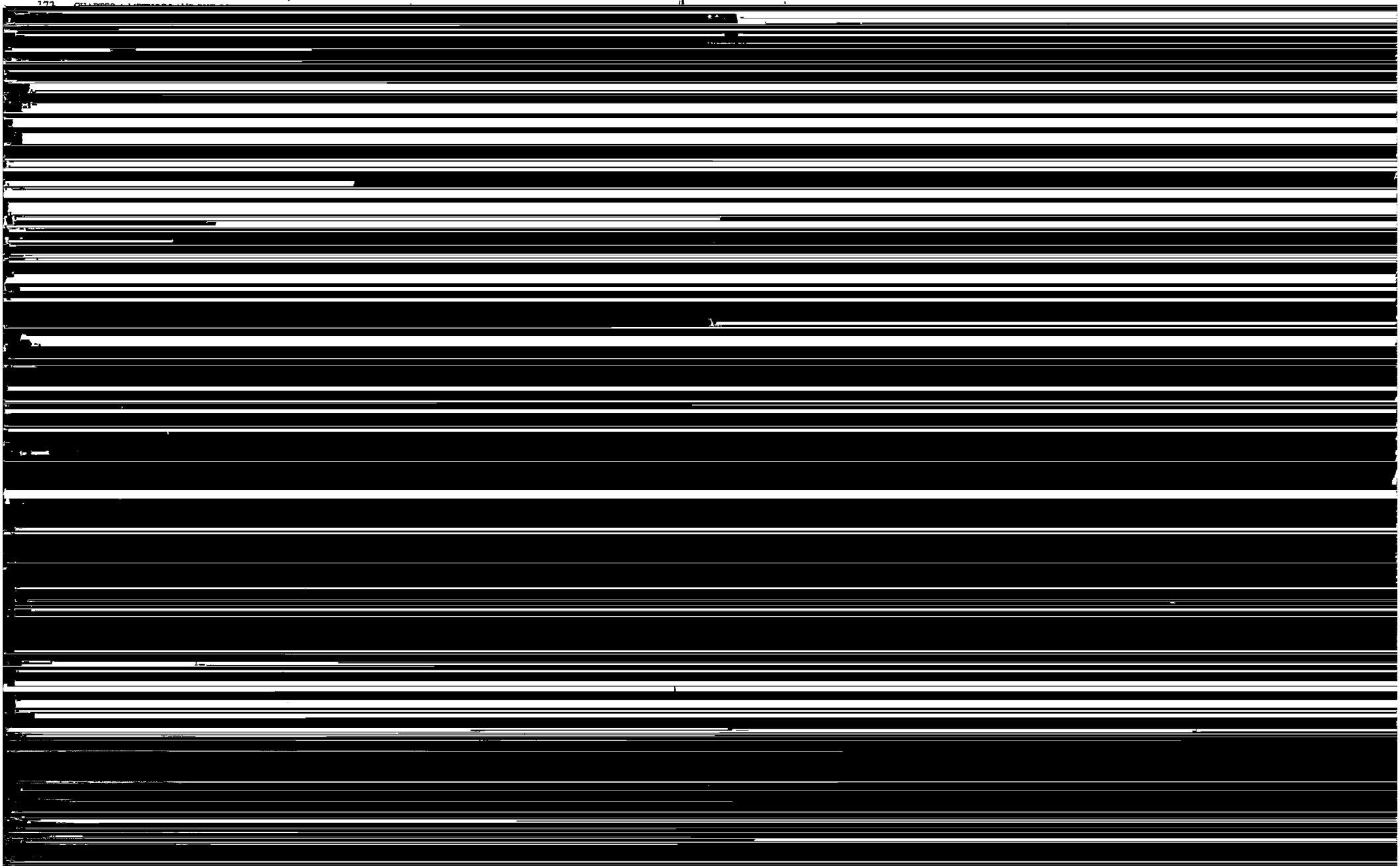




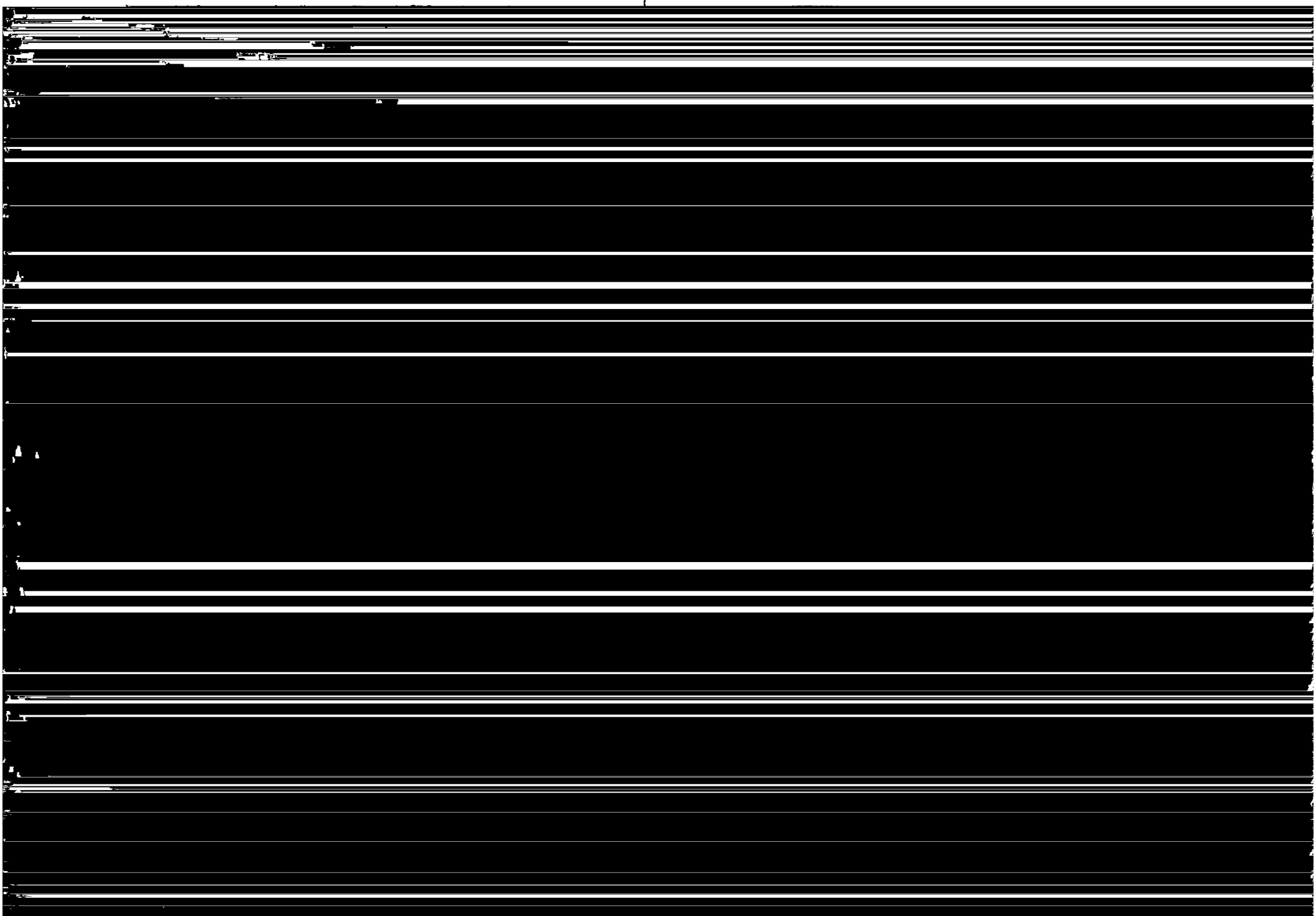


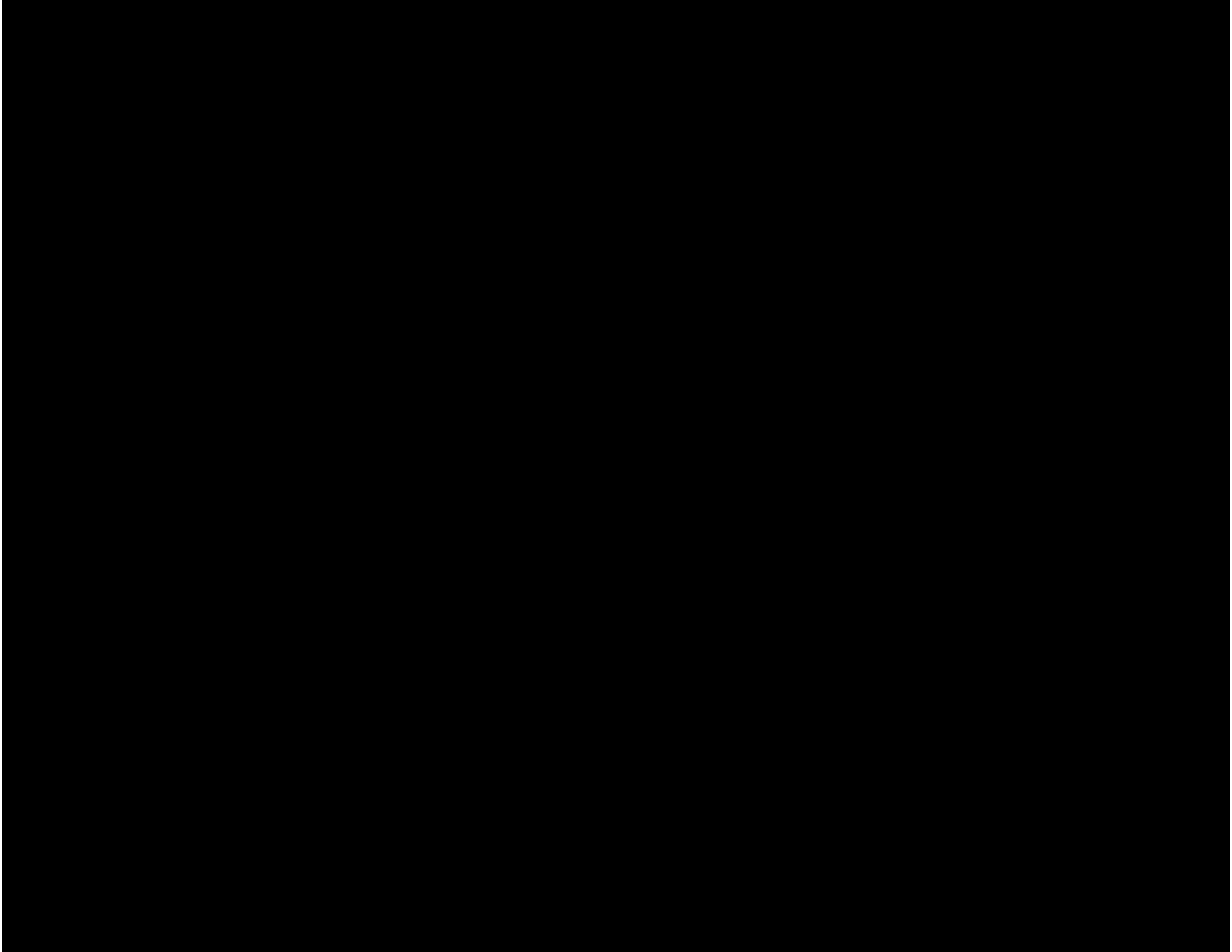






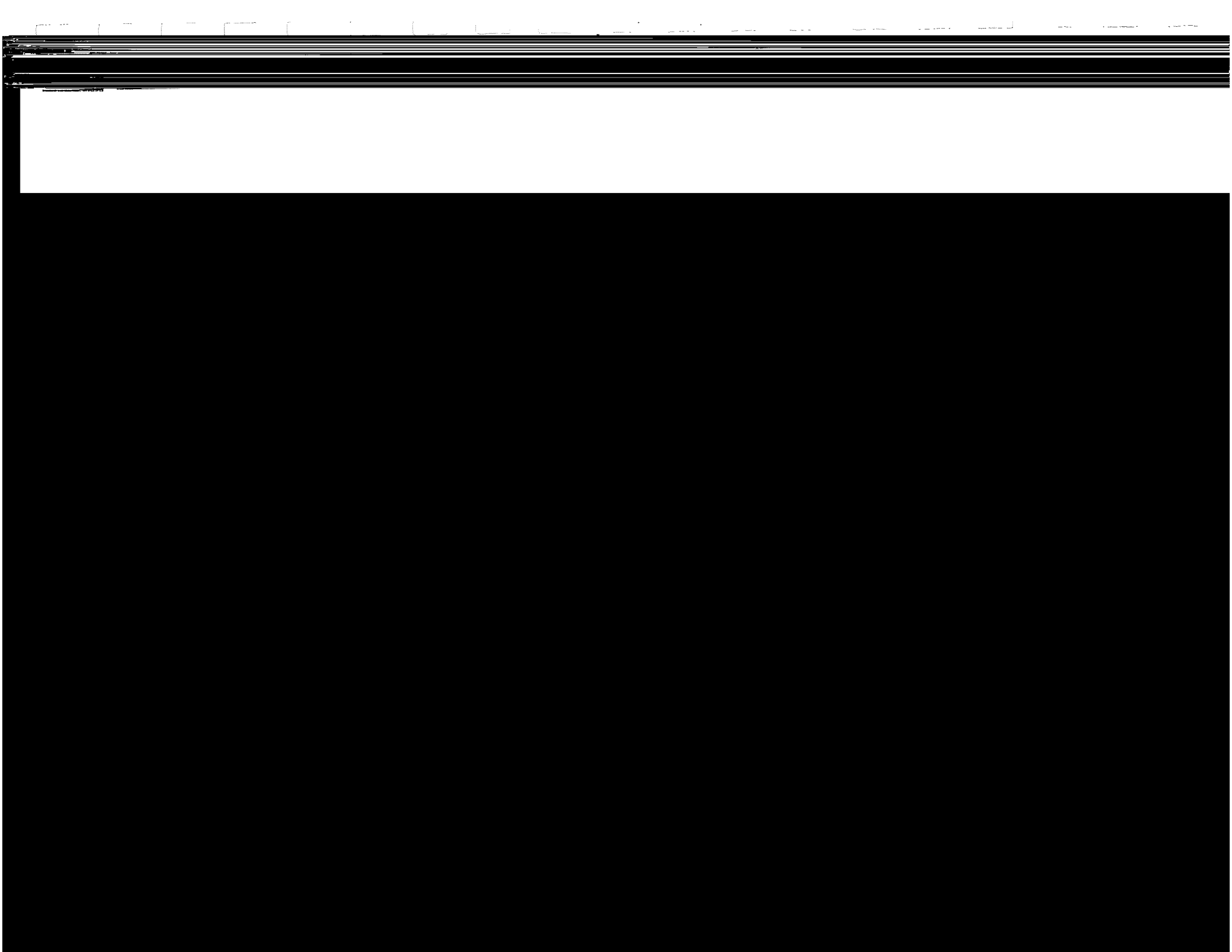


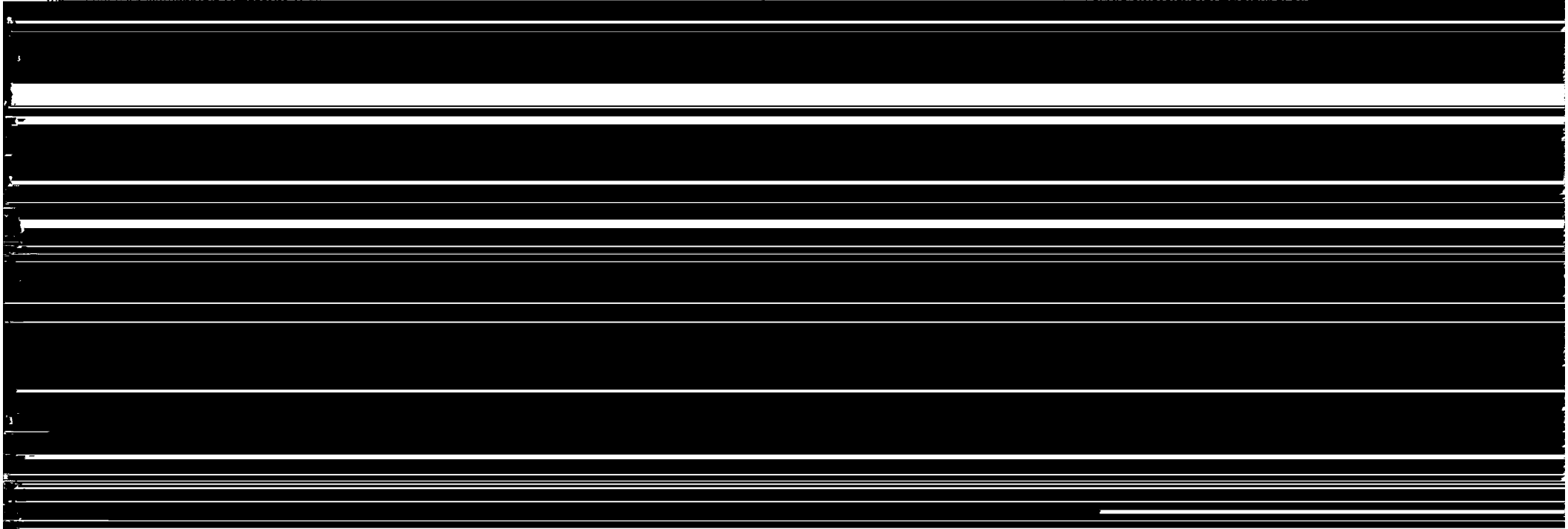




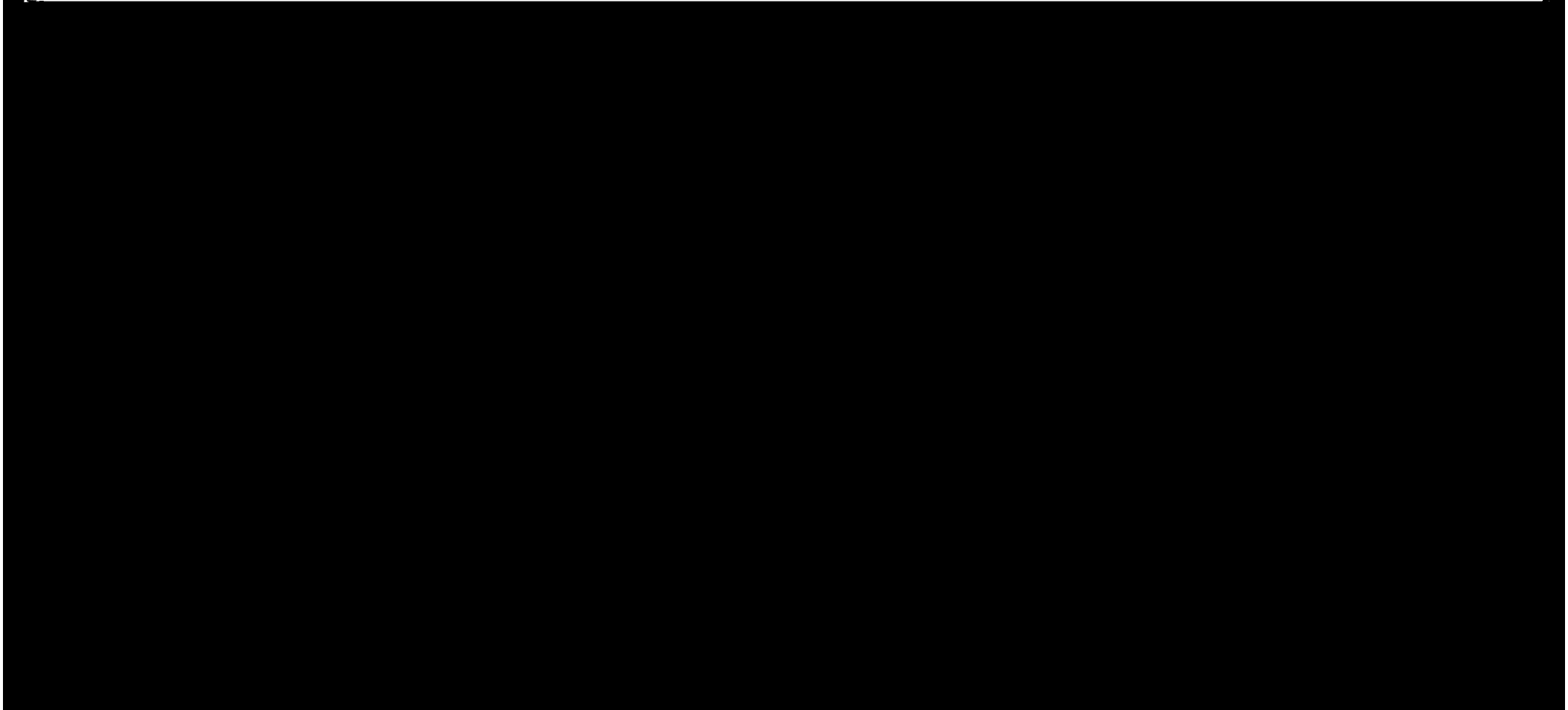
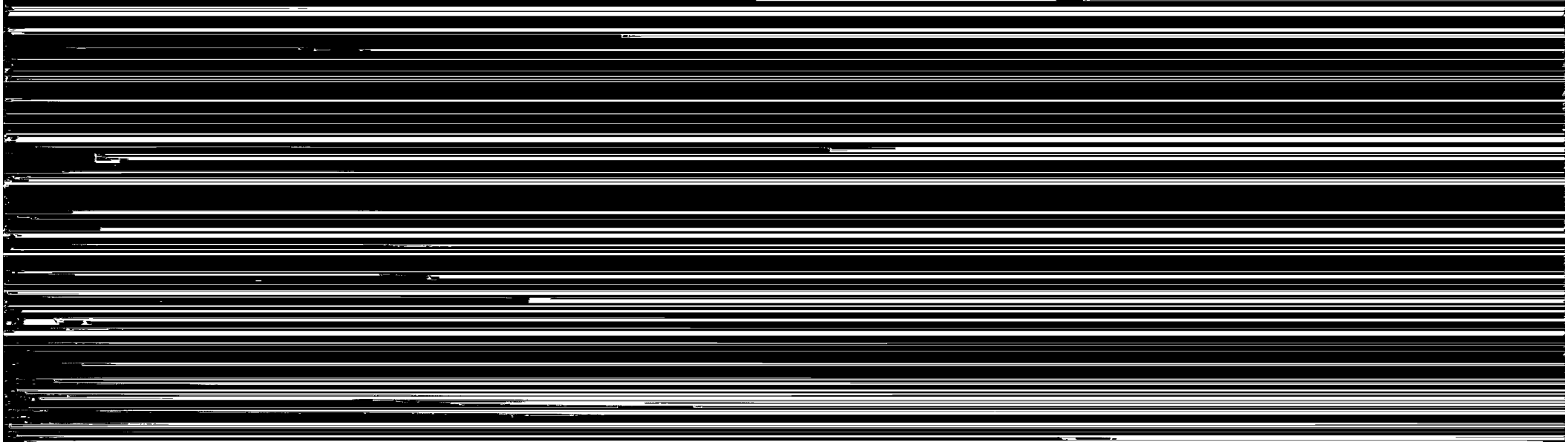
had been in a shutdown mode because of holidays. Apparently, when the process was

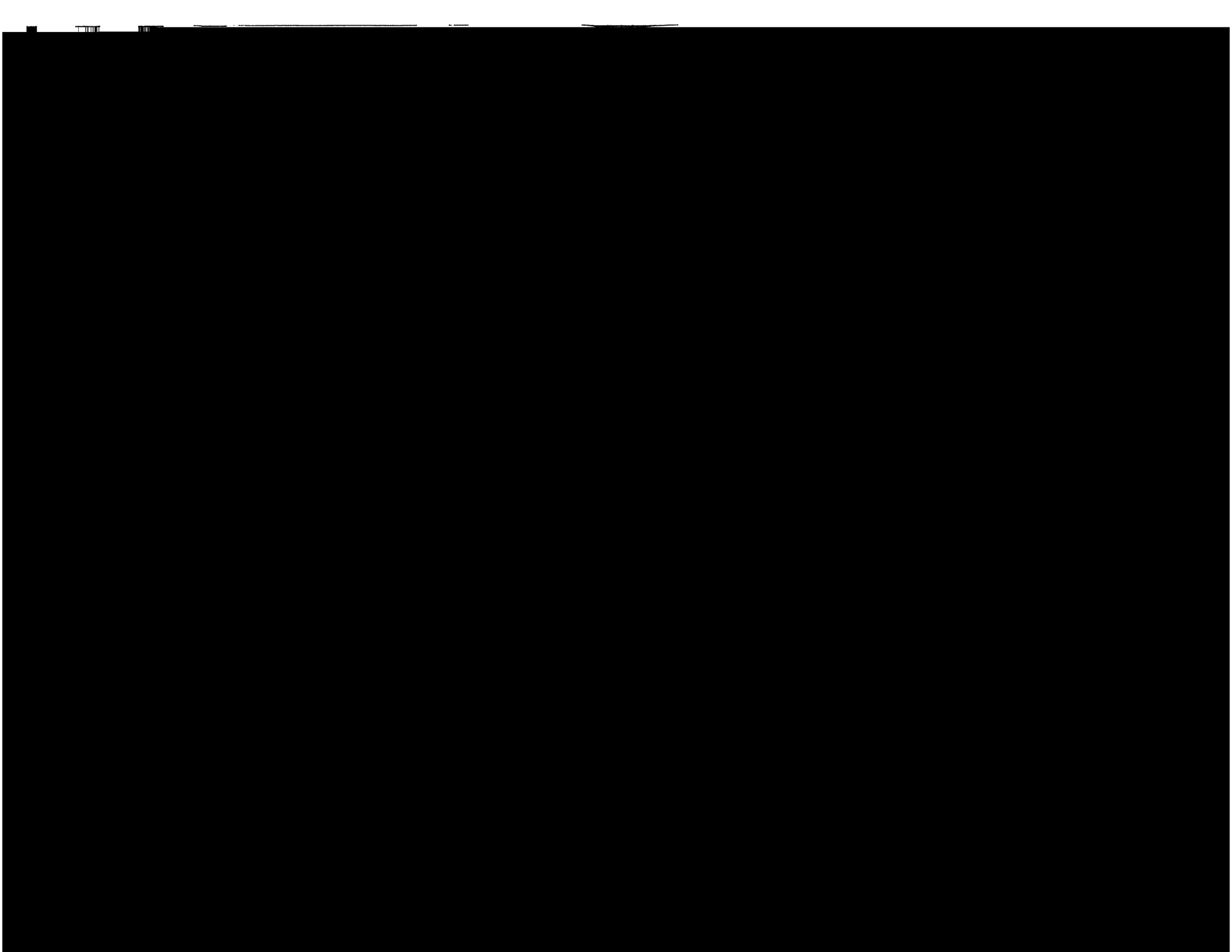






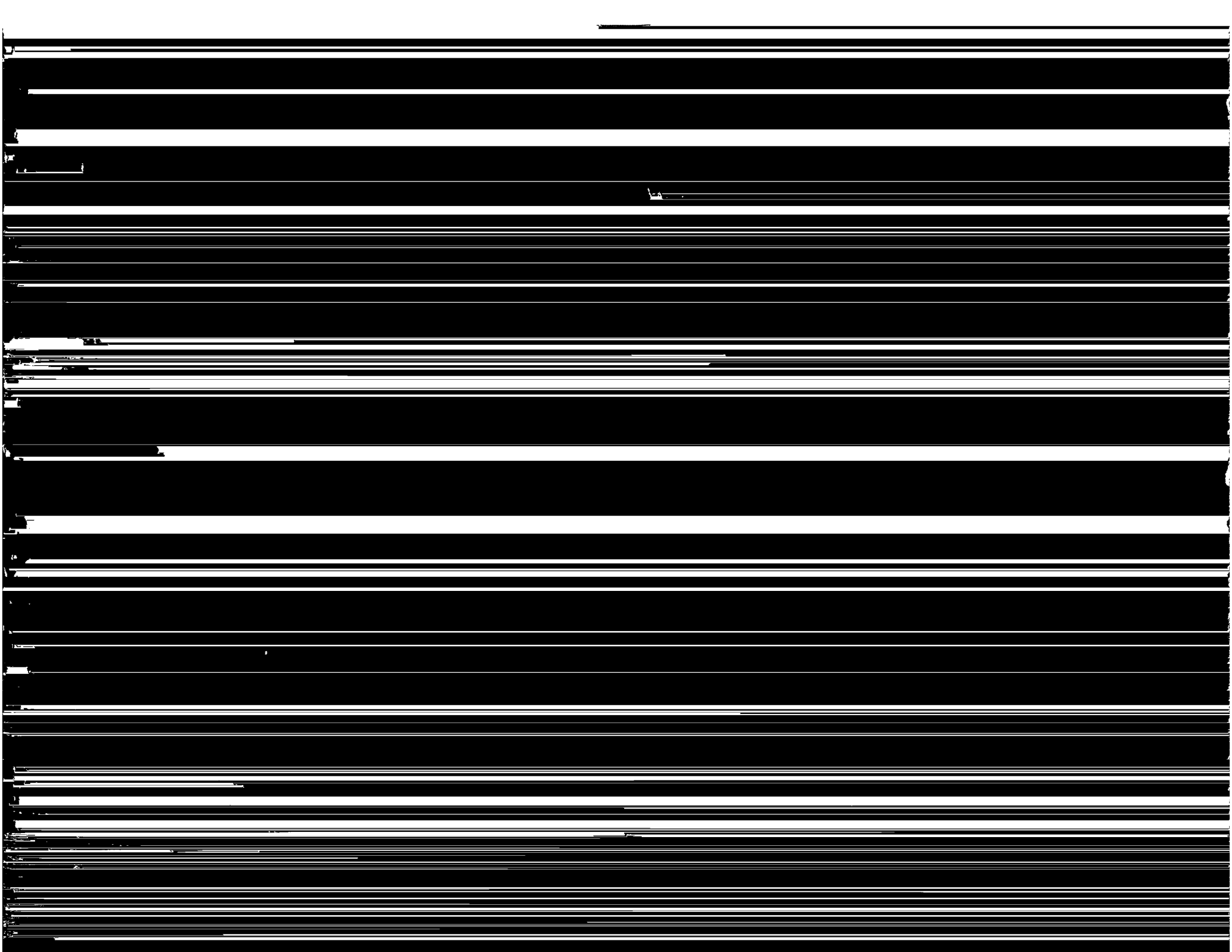


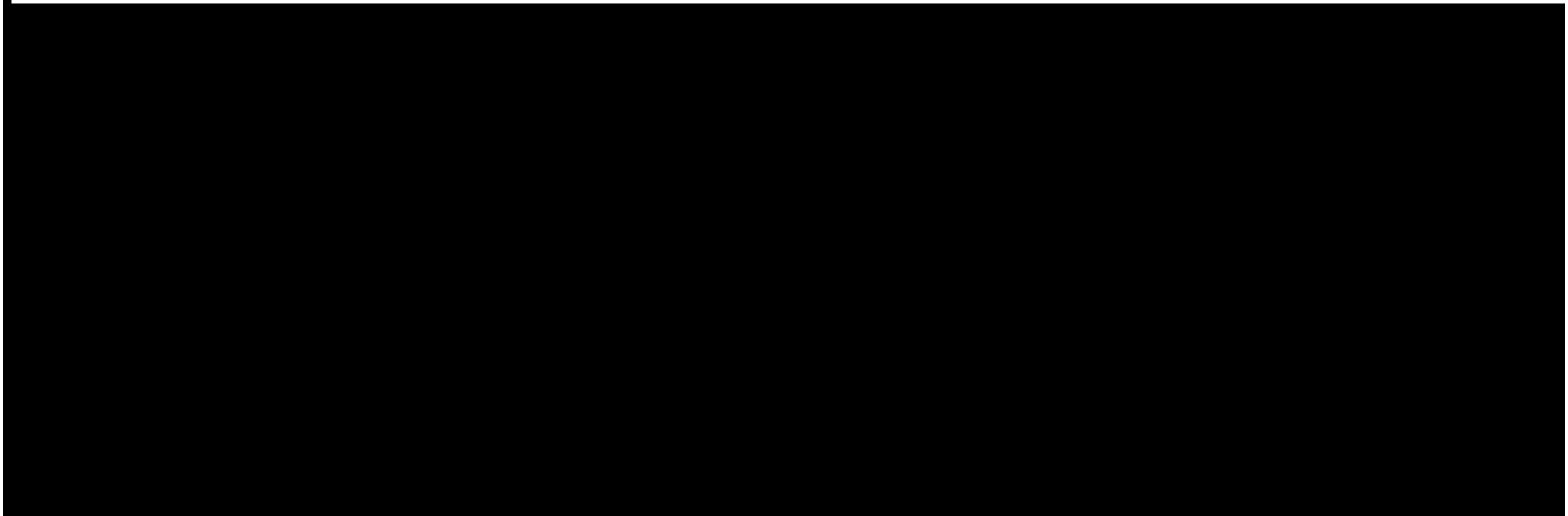
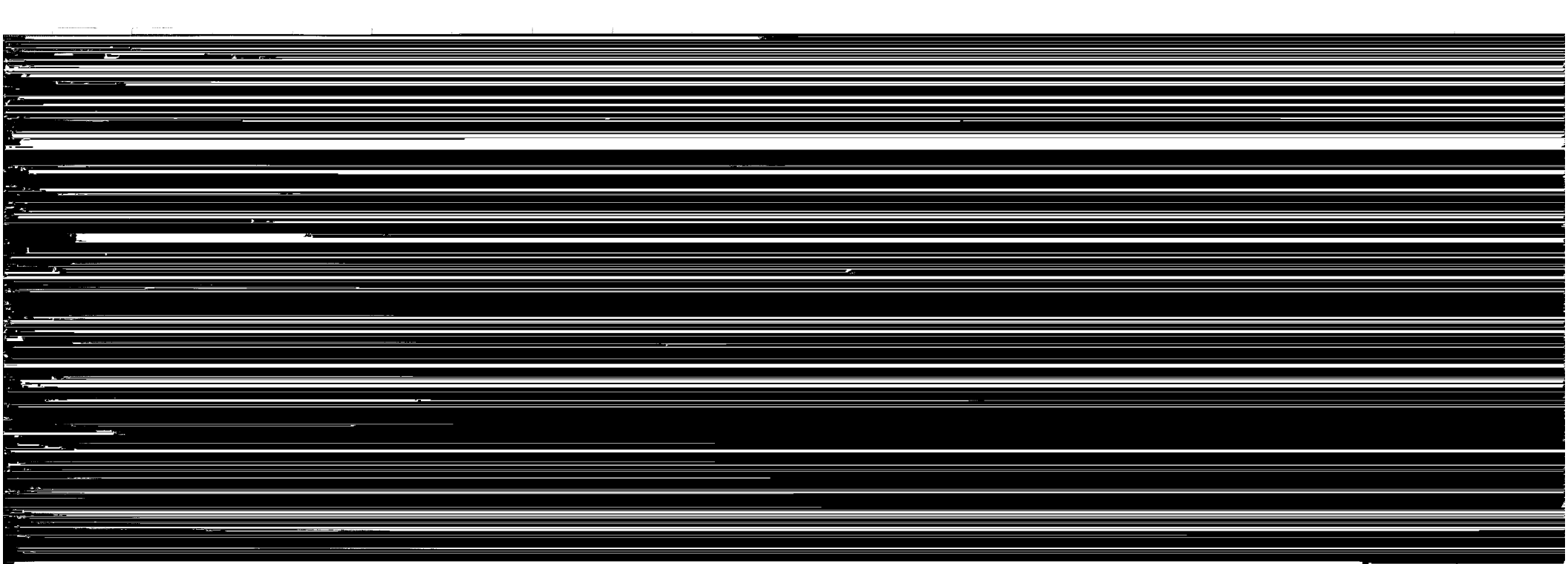


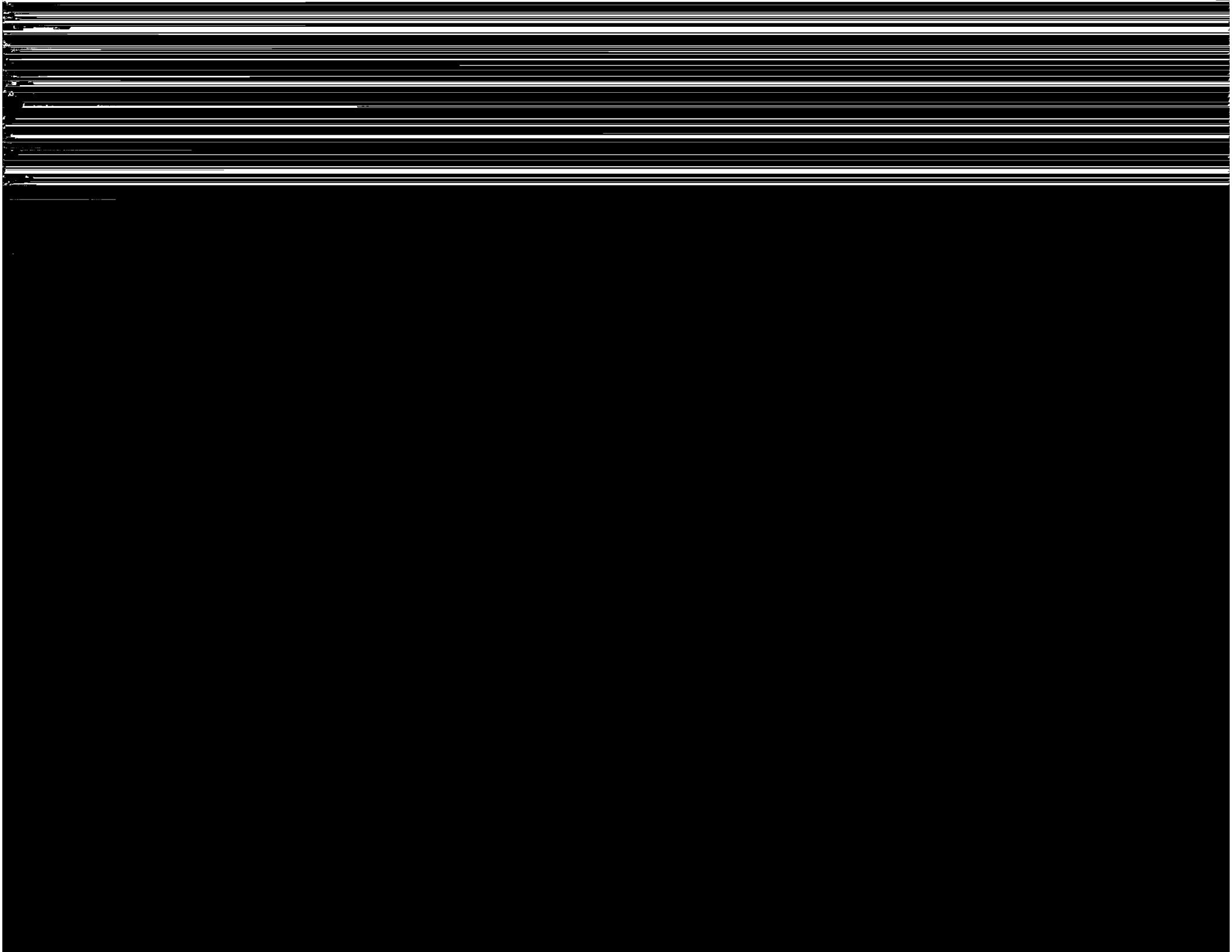


*Handwritten notes:*  
#100 & #101  
#102 & #103





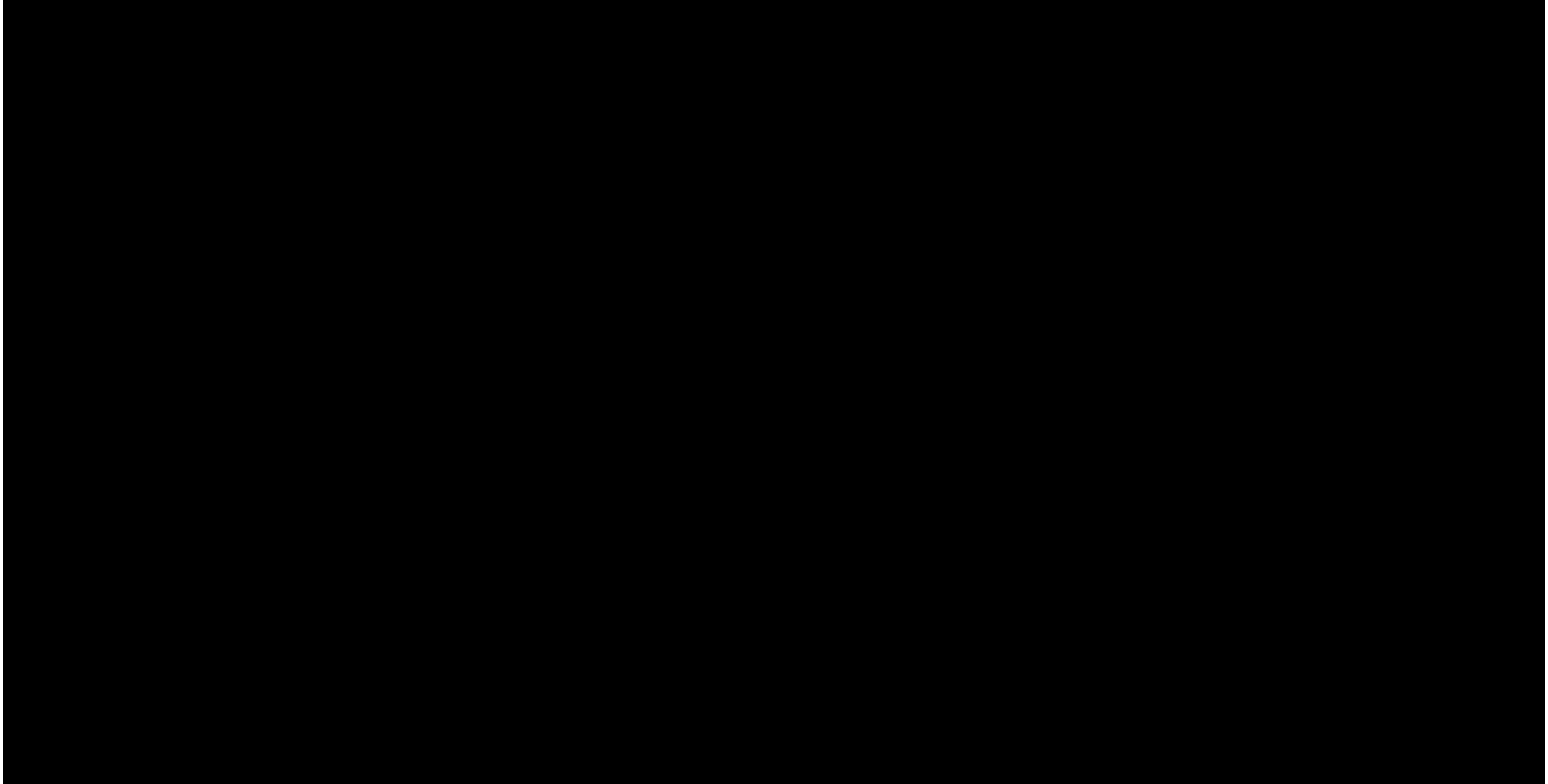
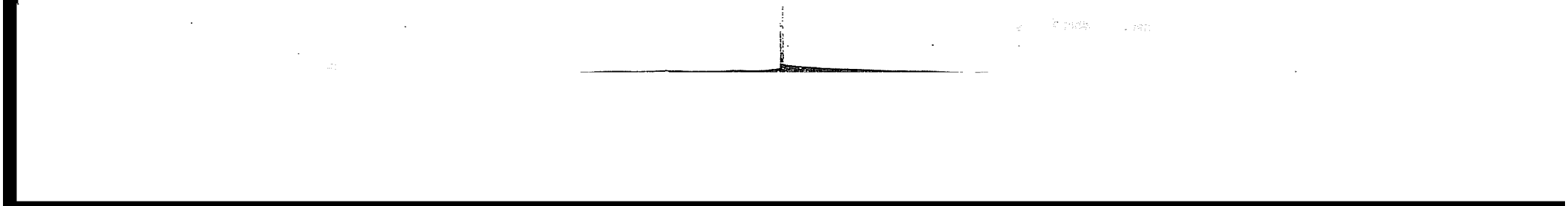
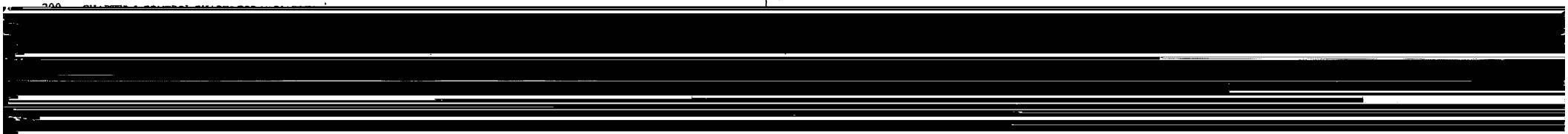




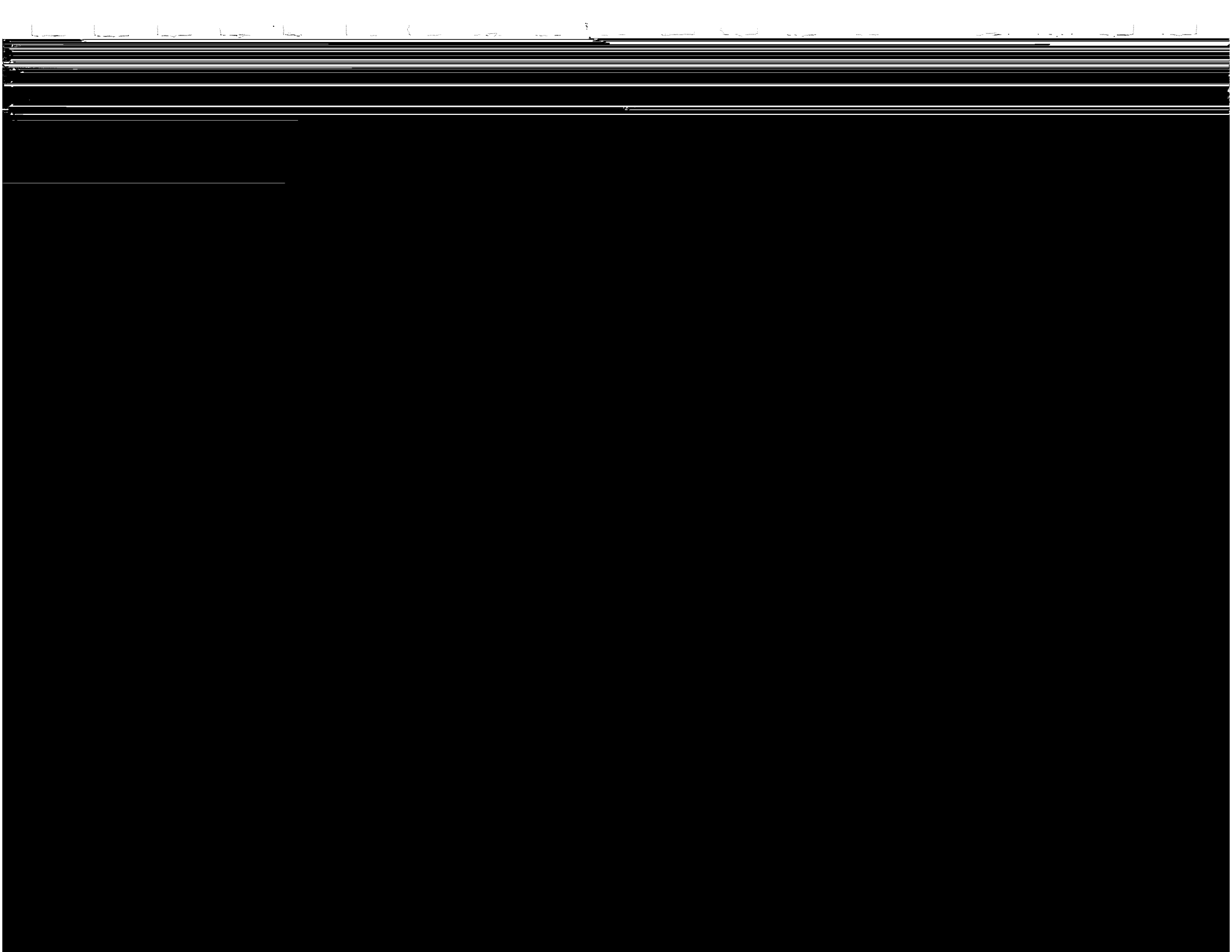


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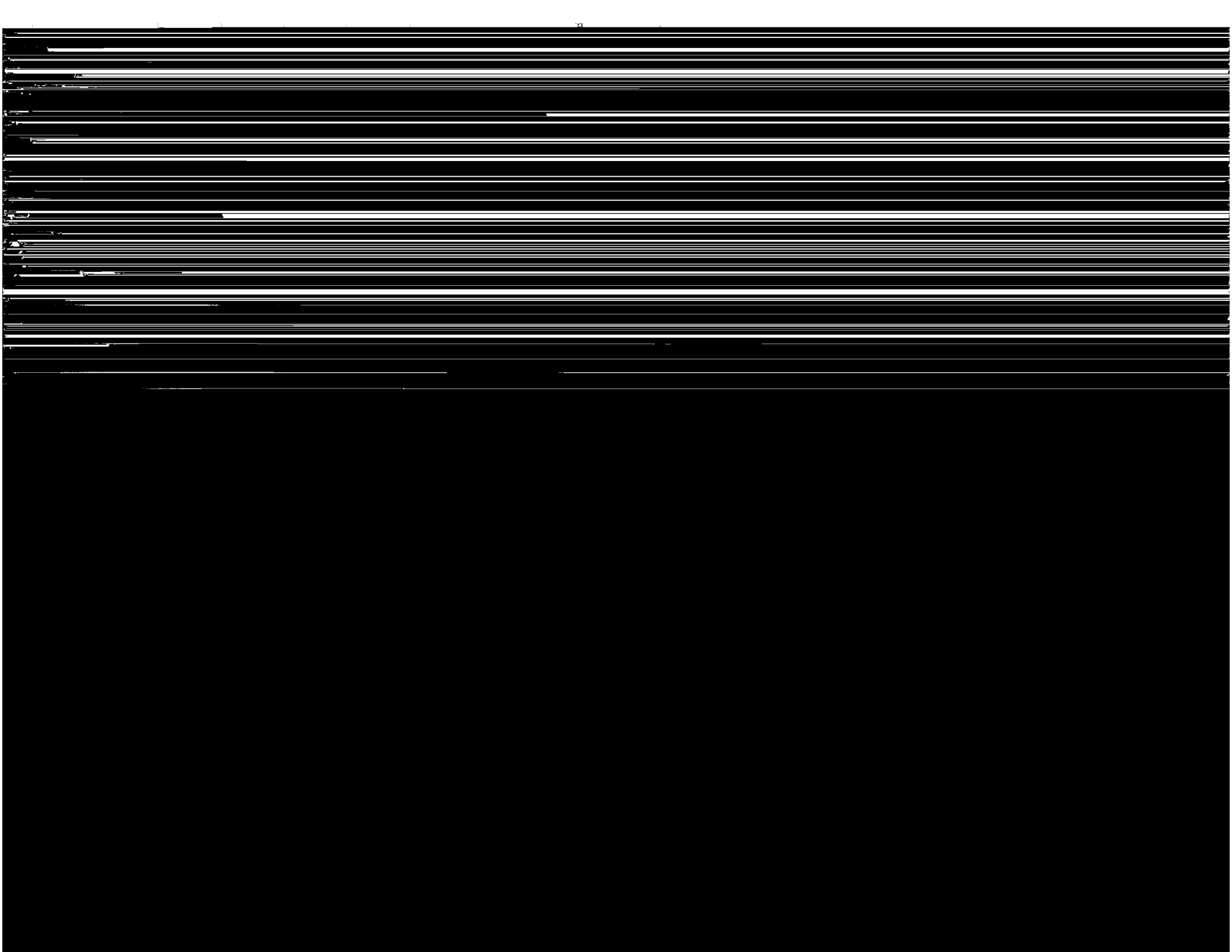


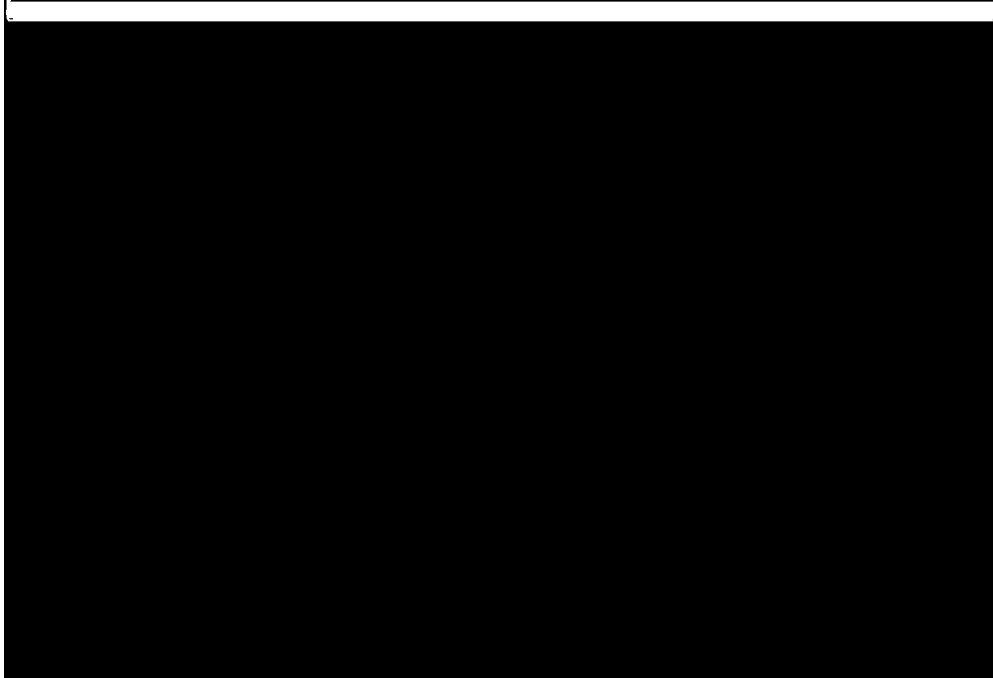
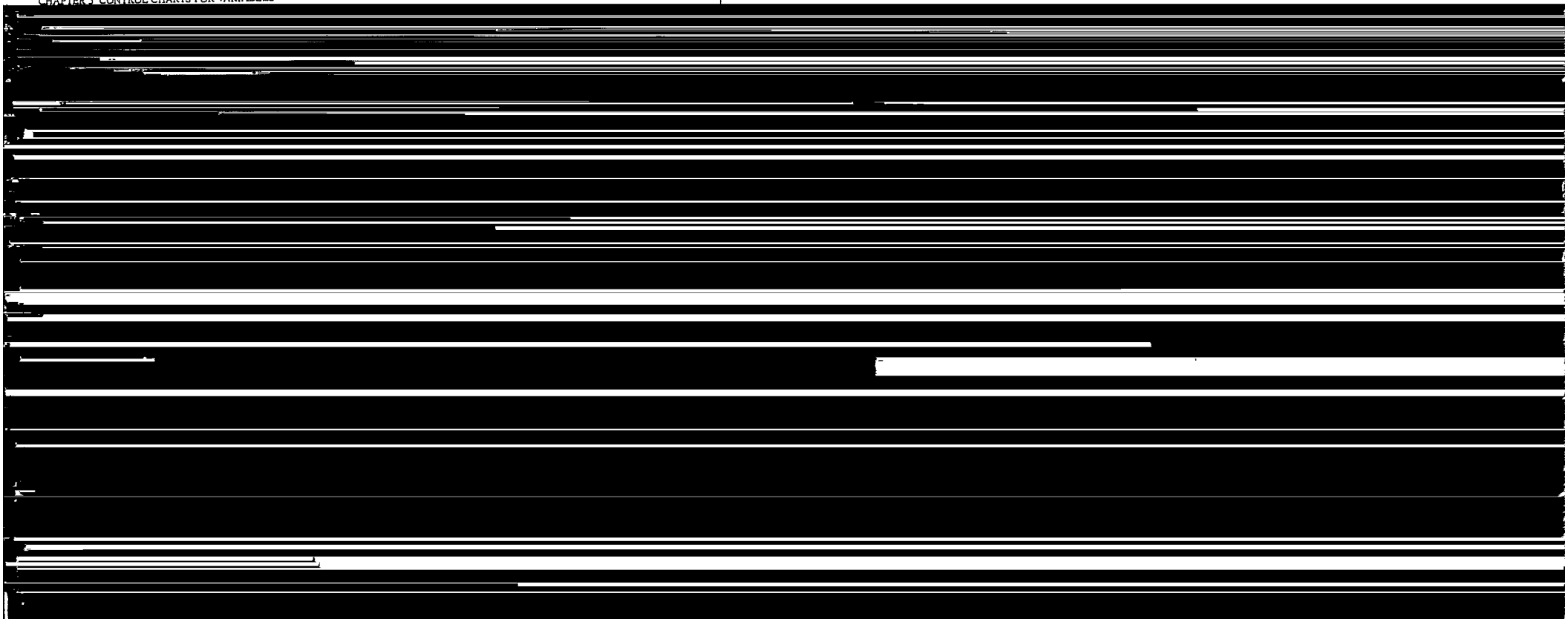


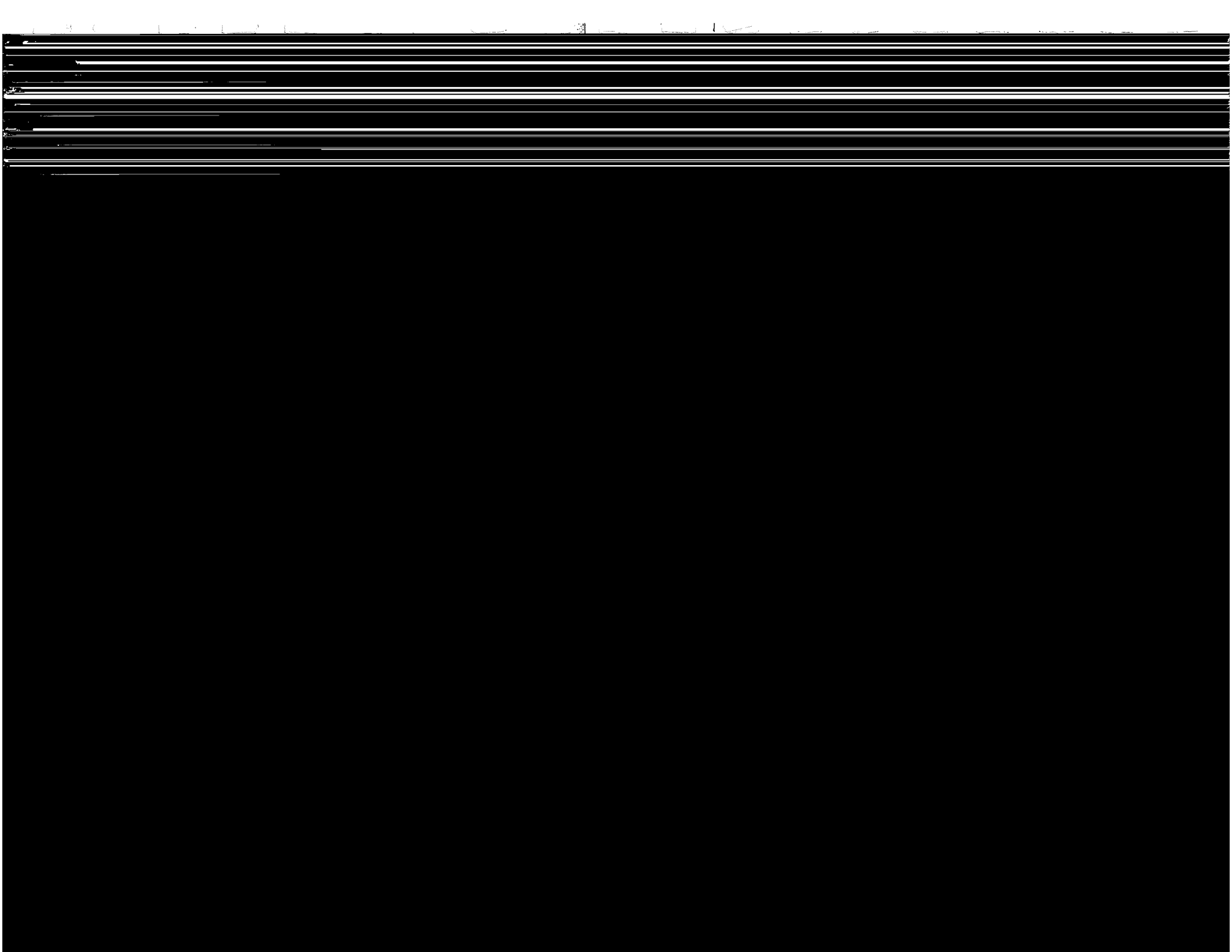


Note that all the cases in Fig. 5-3 assume that the process is centered at the midpoint

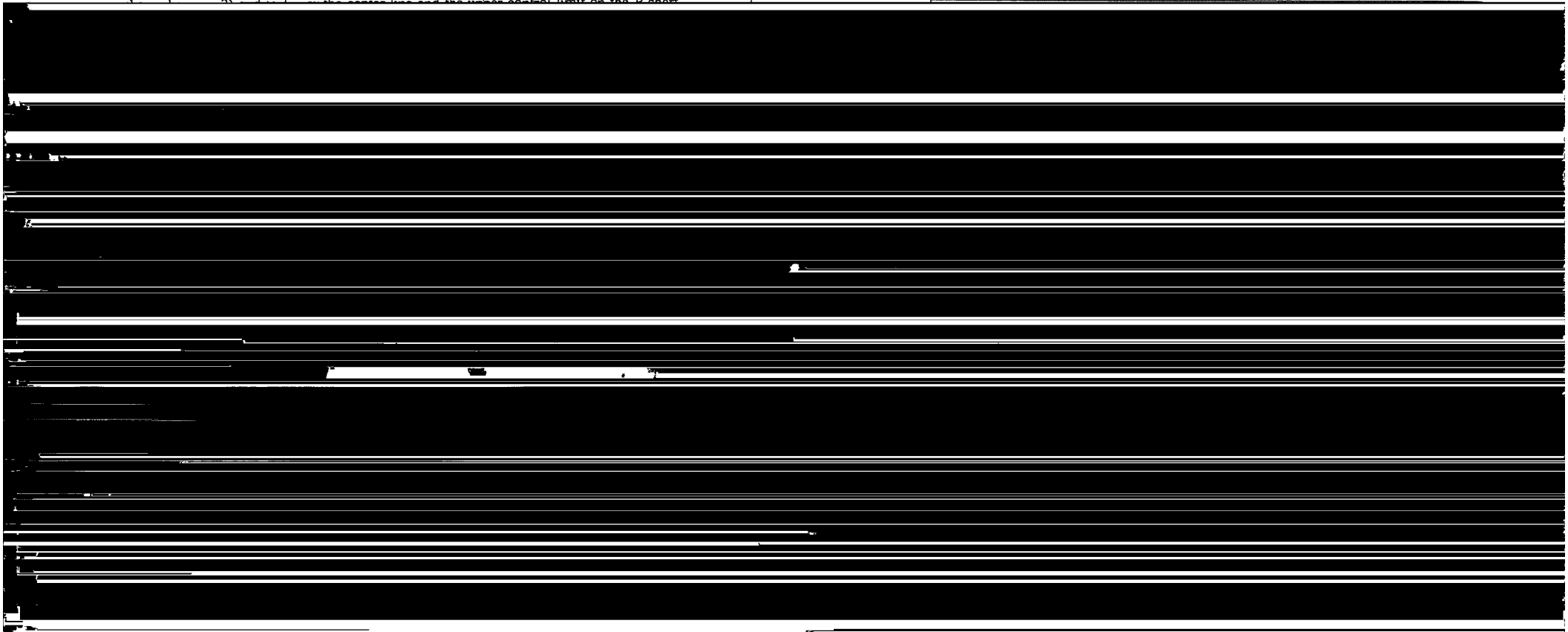
This unusual pattern in the data points may show that a particu-

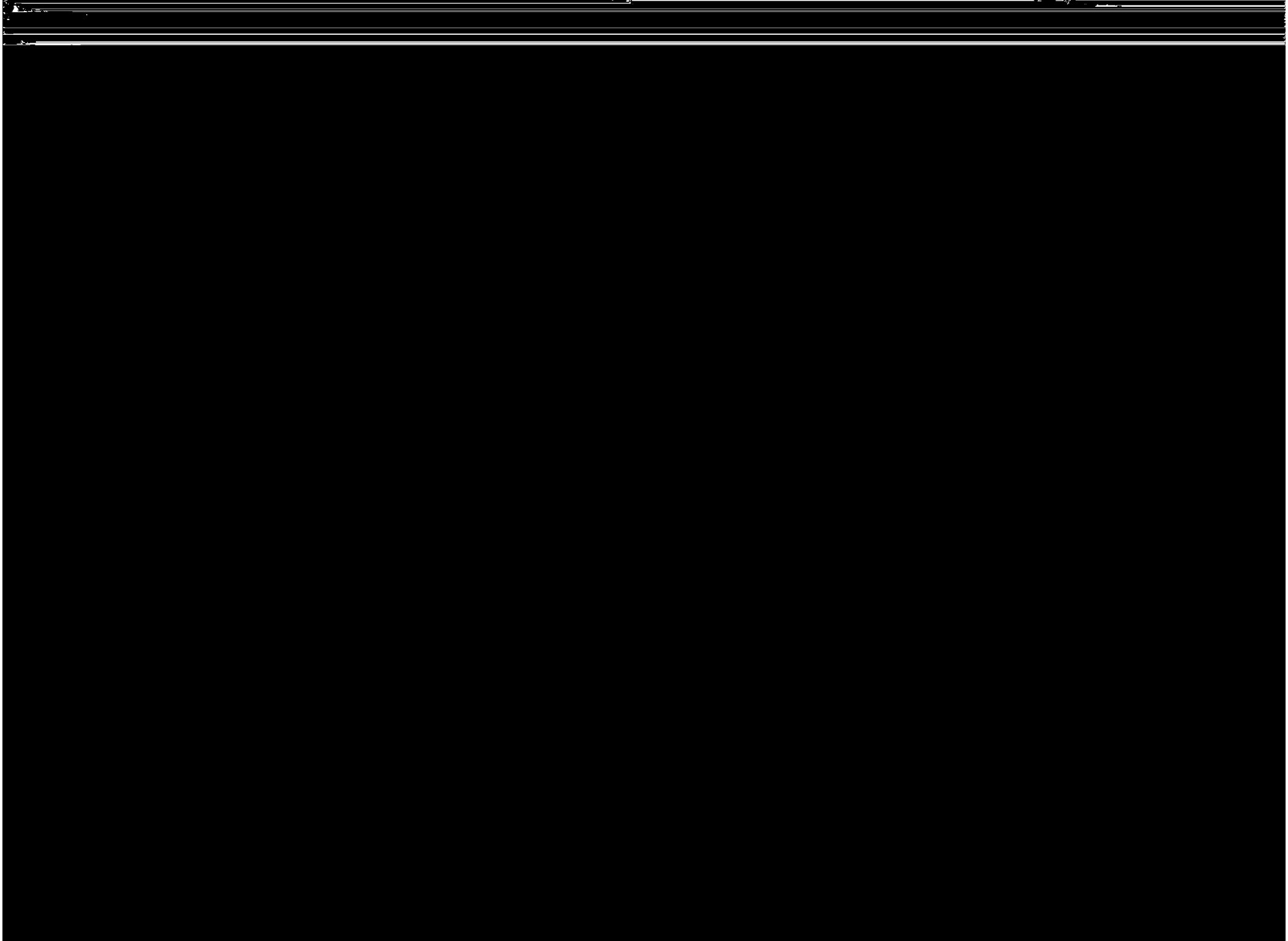




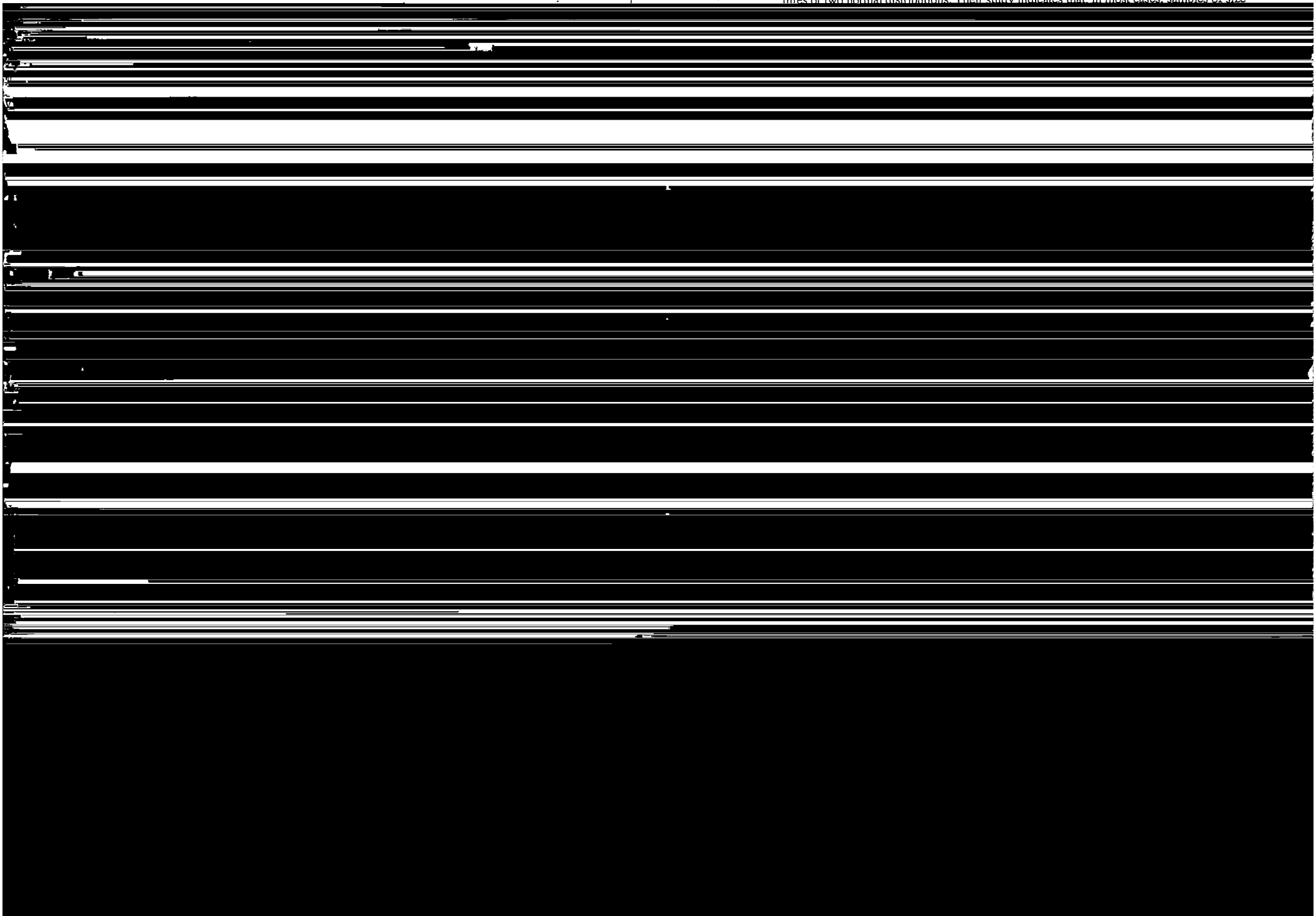


2. The center line and the upper control limit on the  $\bar{P}$  chart

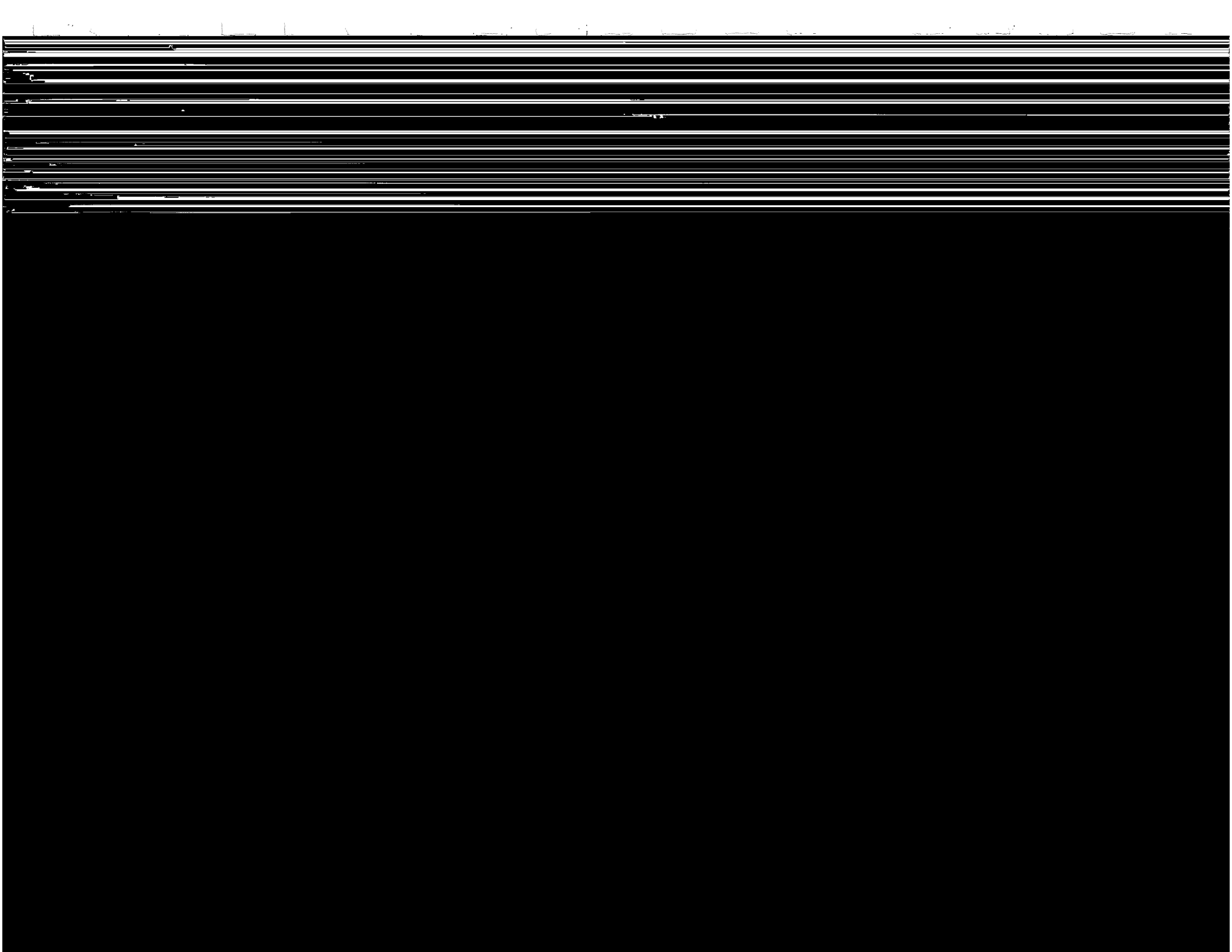


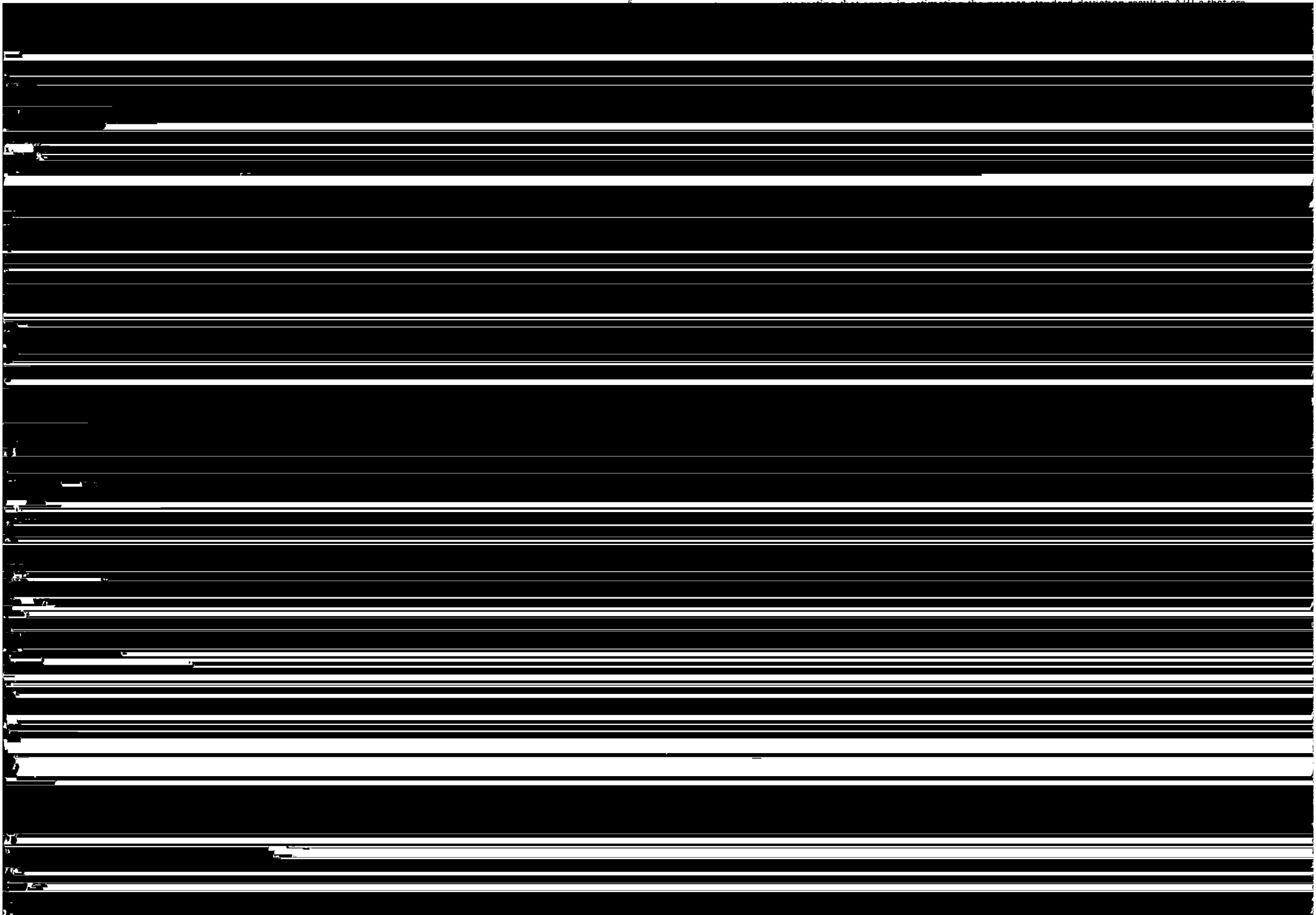


tures of two normal distributions. Their study indicates that, in most cases, samples of size



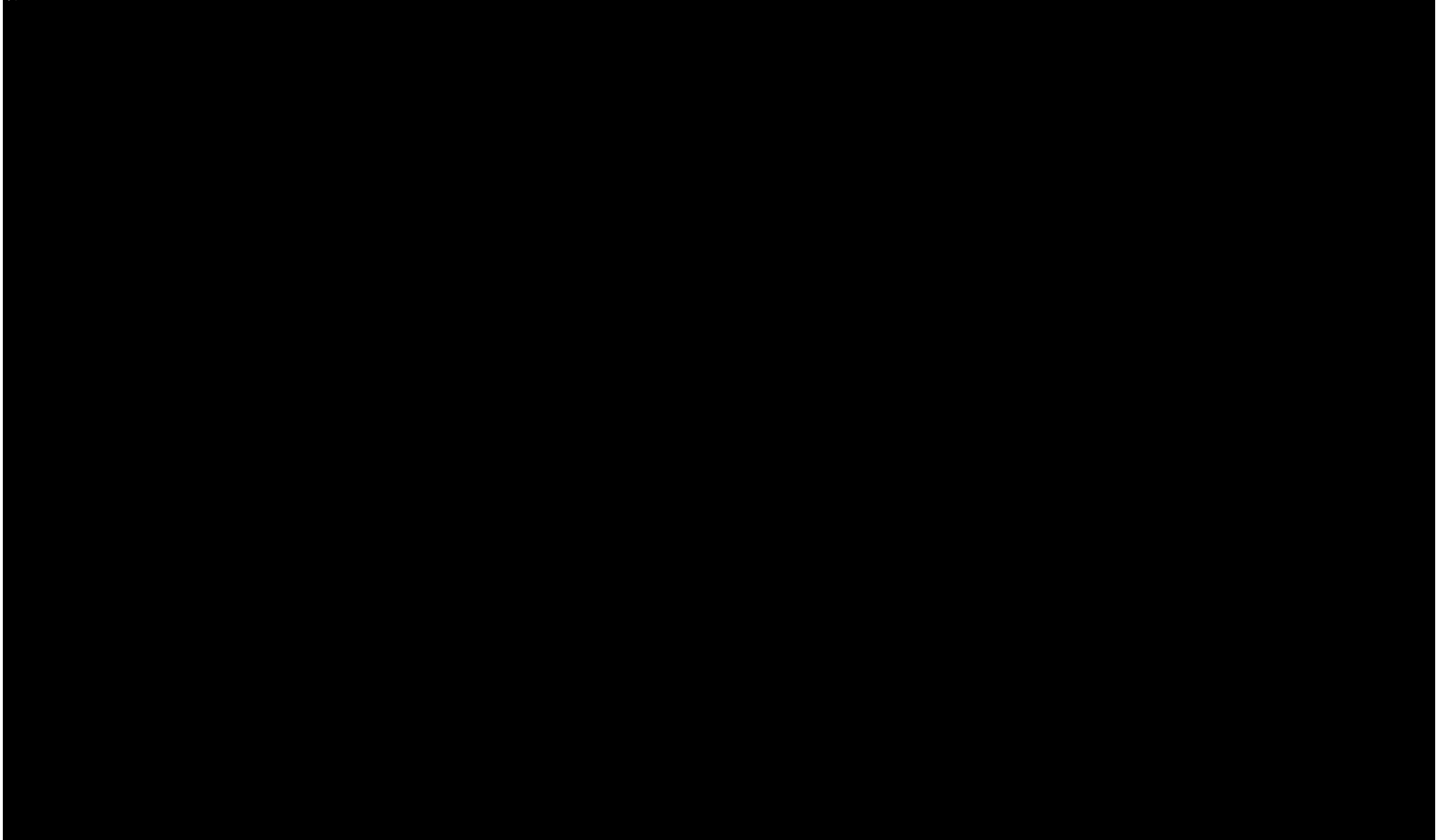
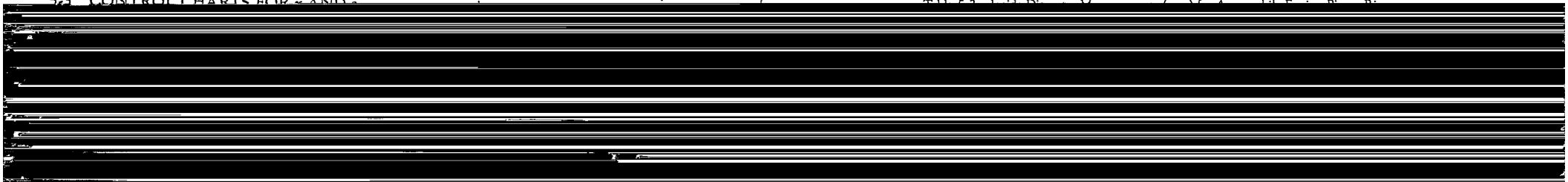


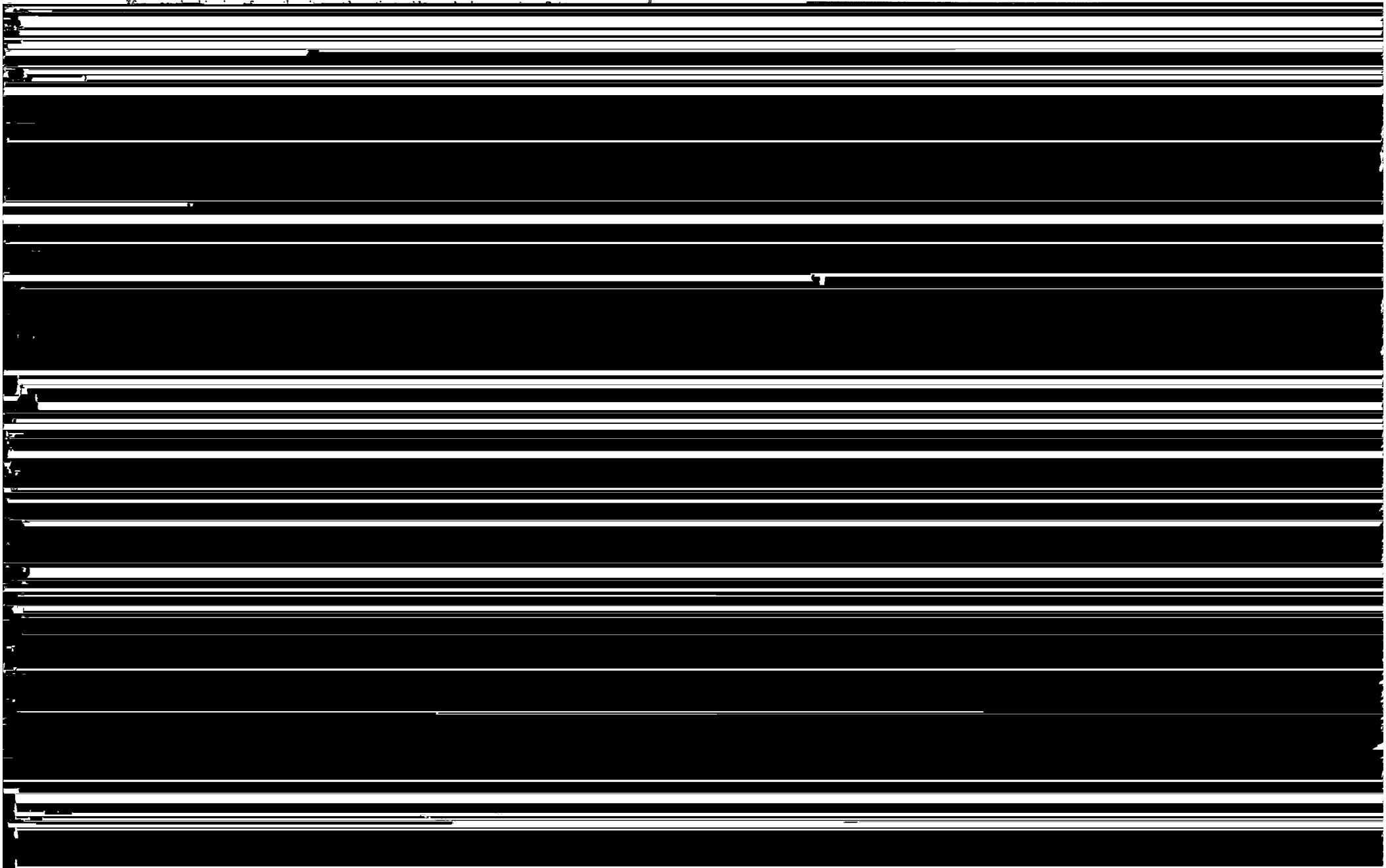


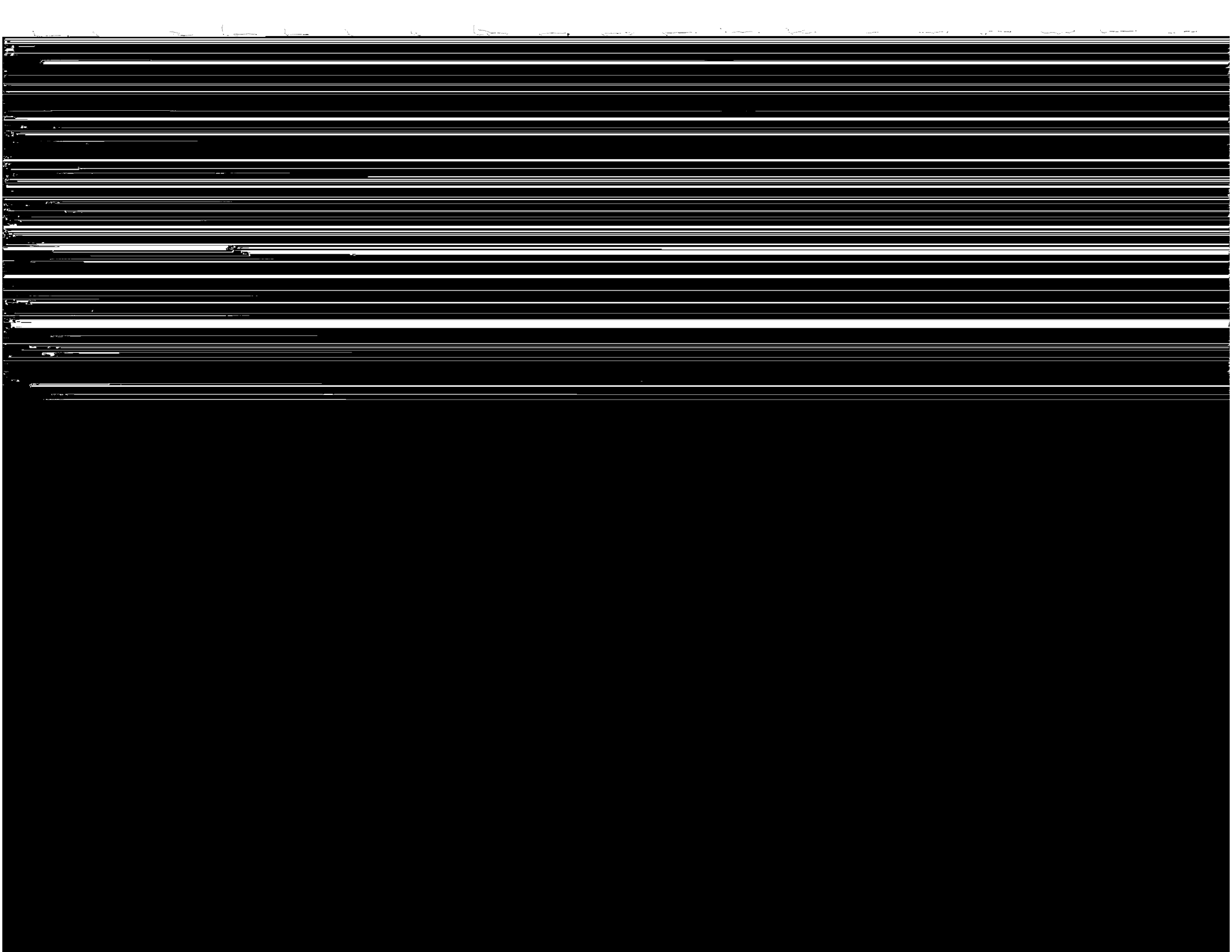


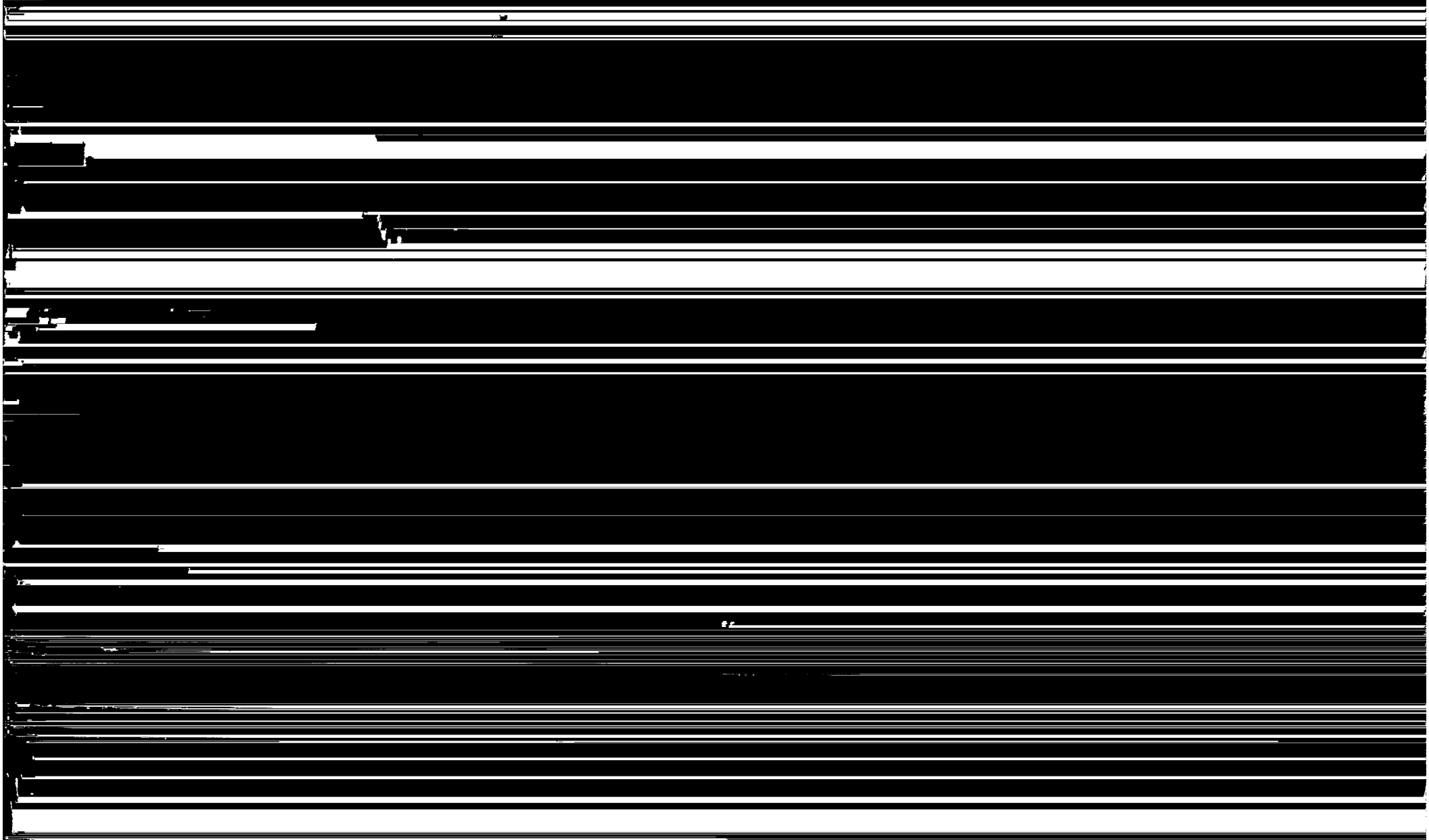
5.3 CONTROL CHARTS FOR  $\bar{X}$  AND S

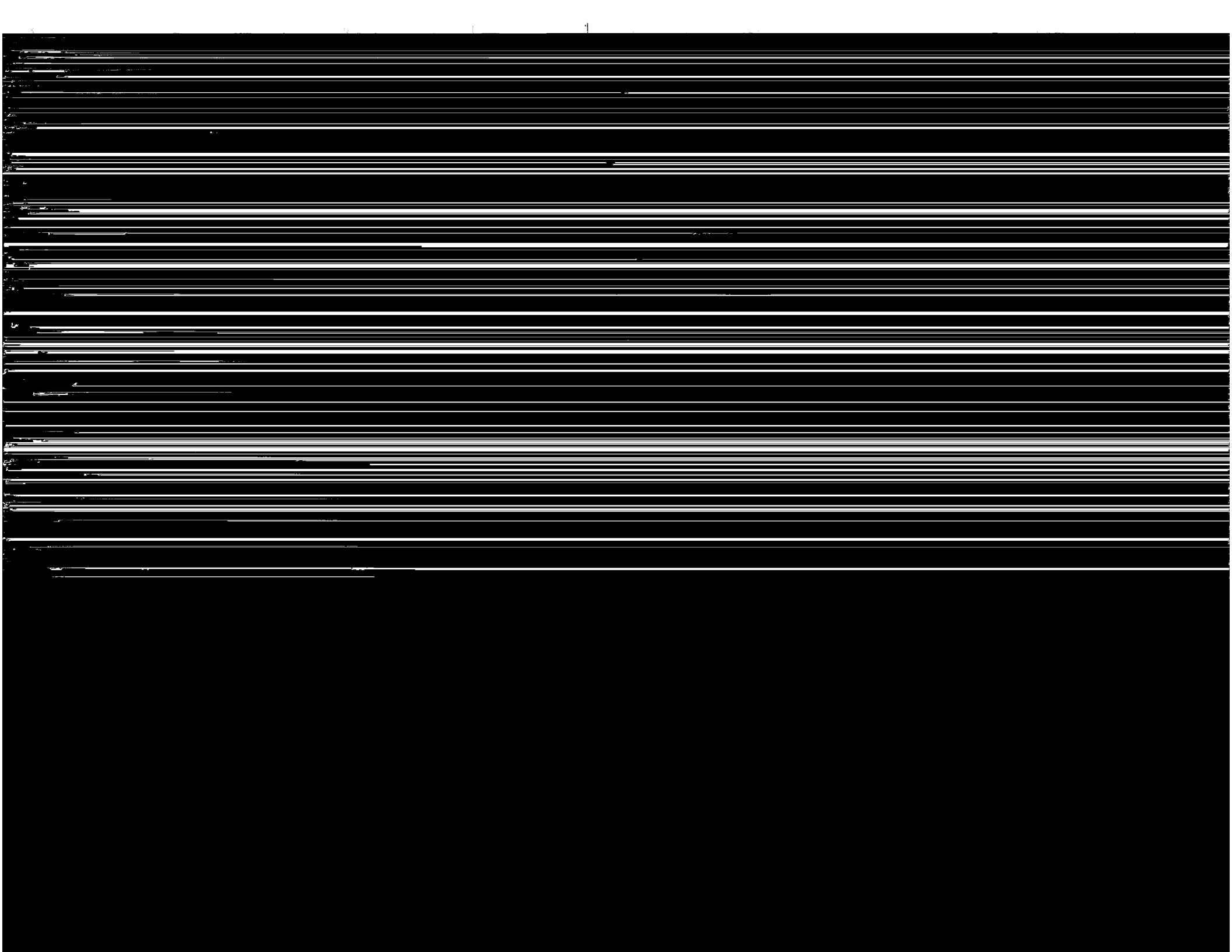
THESE CHARTS ARE USED TO MONITOR THE MEAN AND VARIATION OF A PROCESS

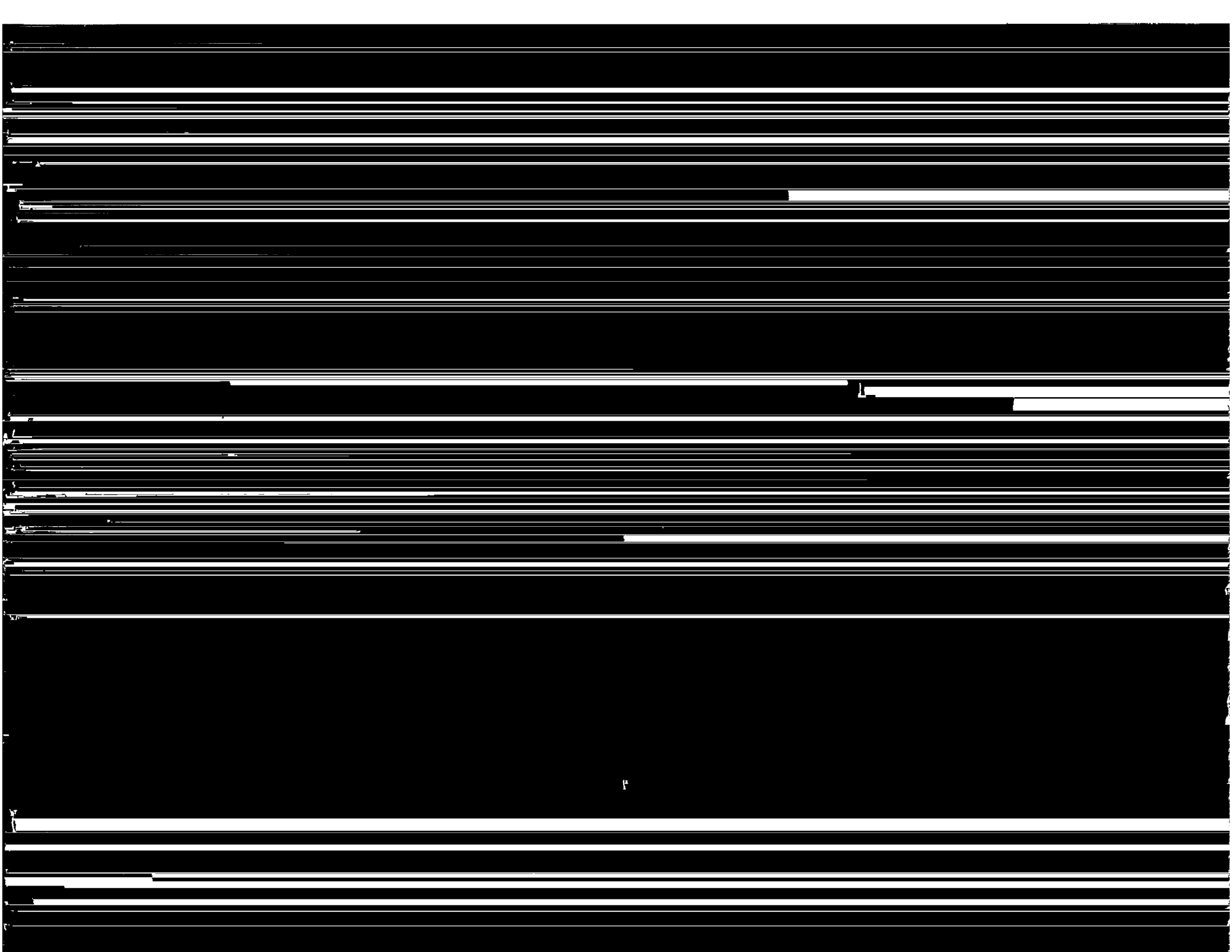






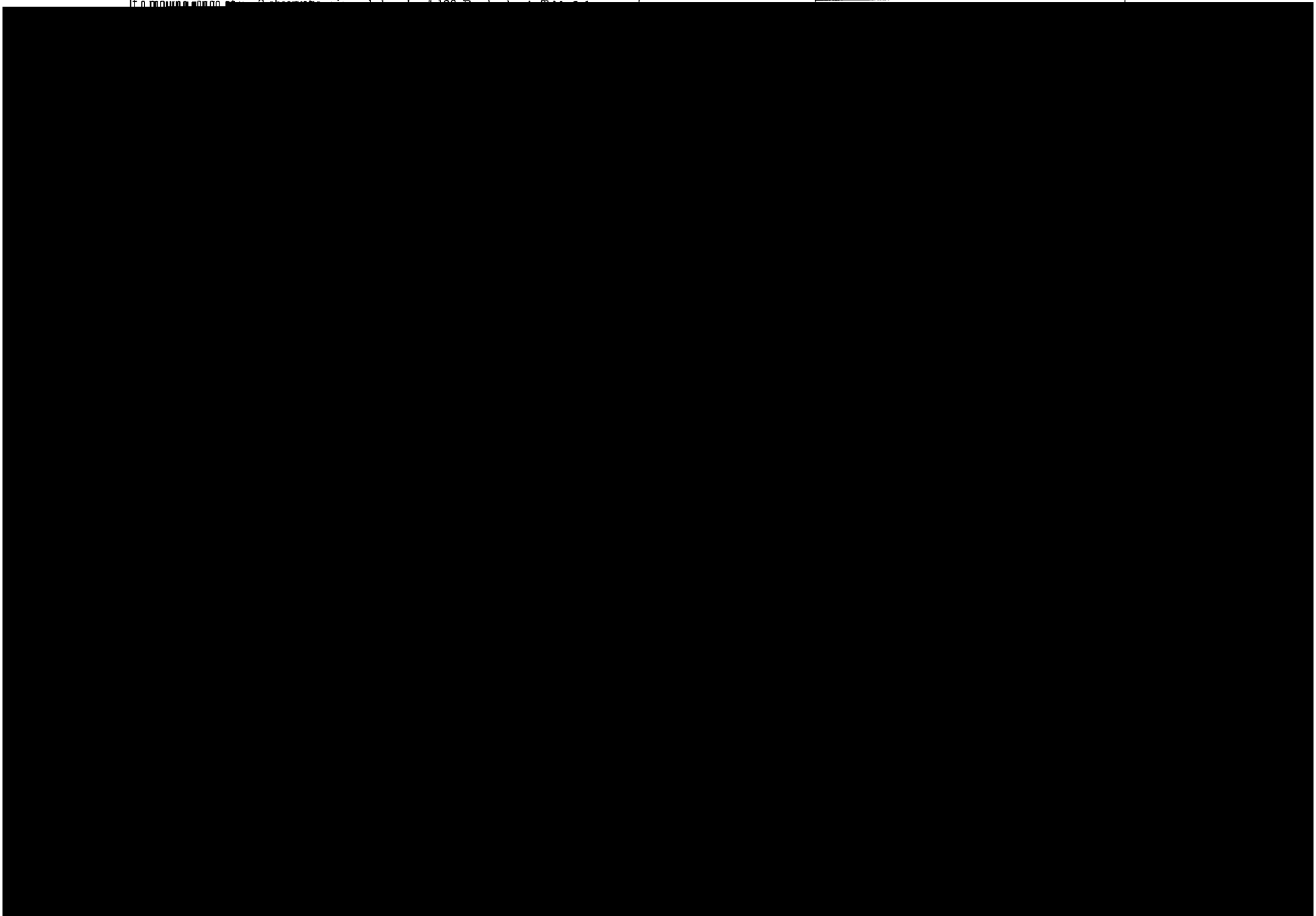




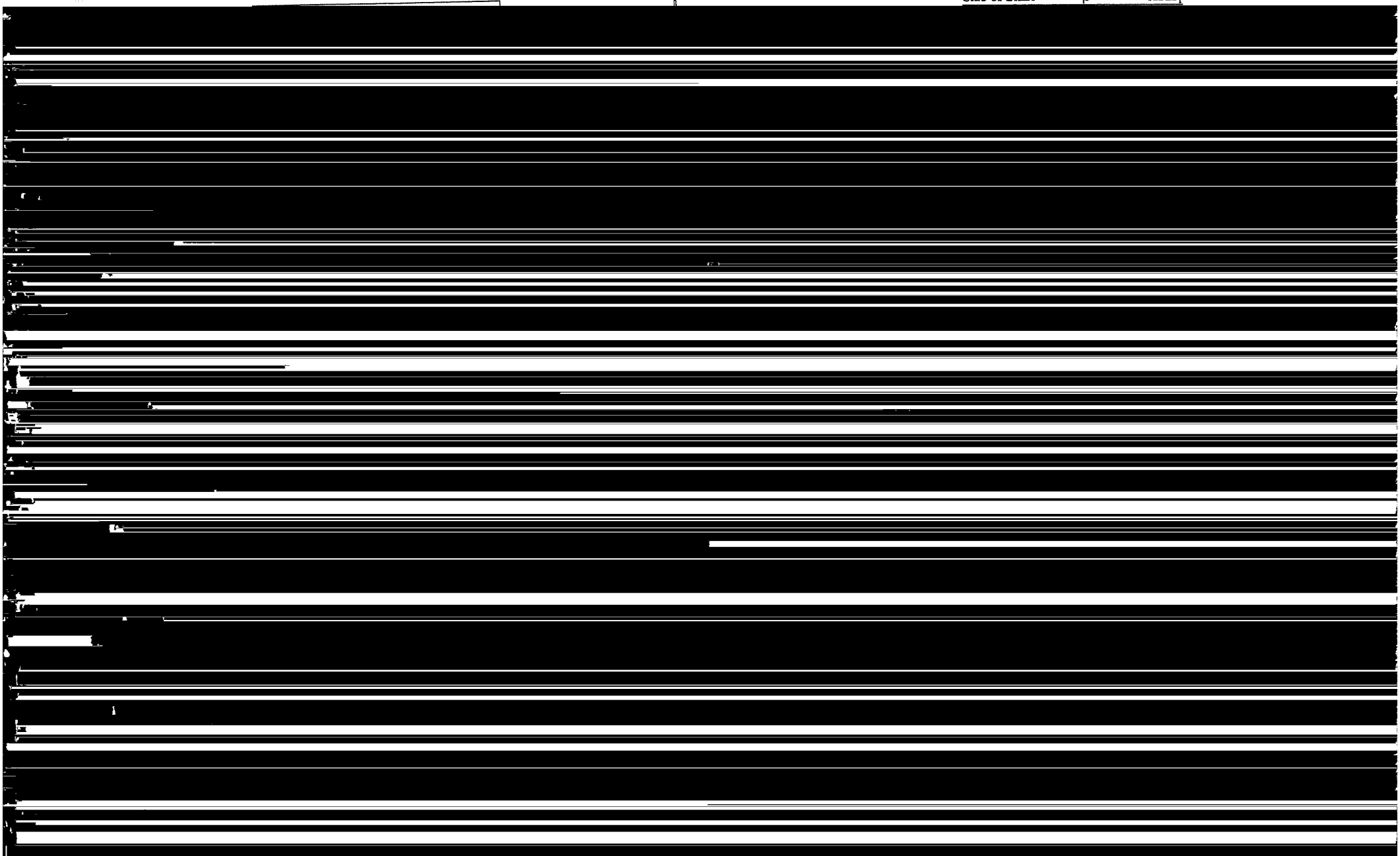


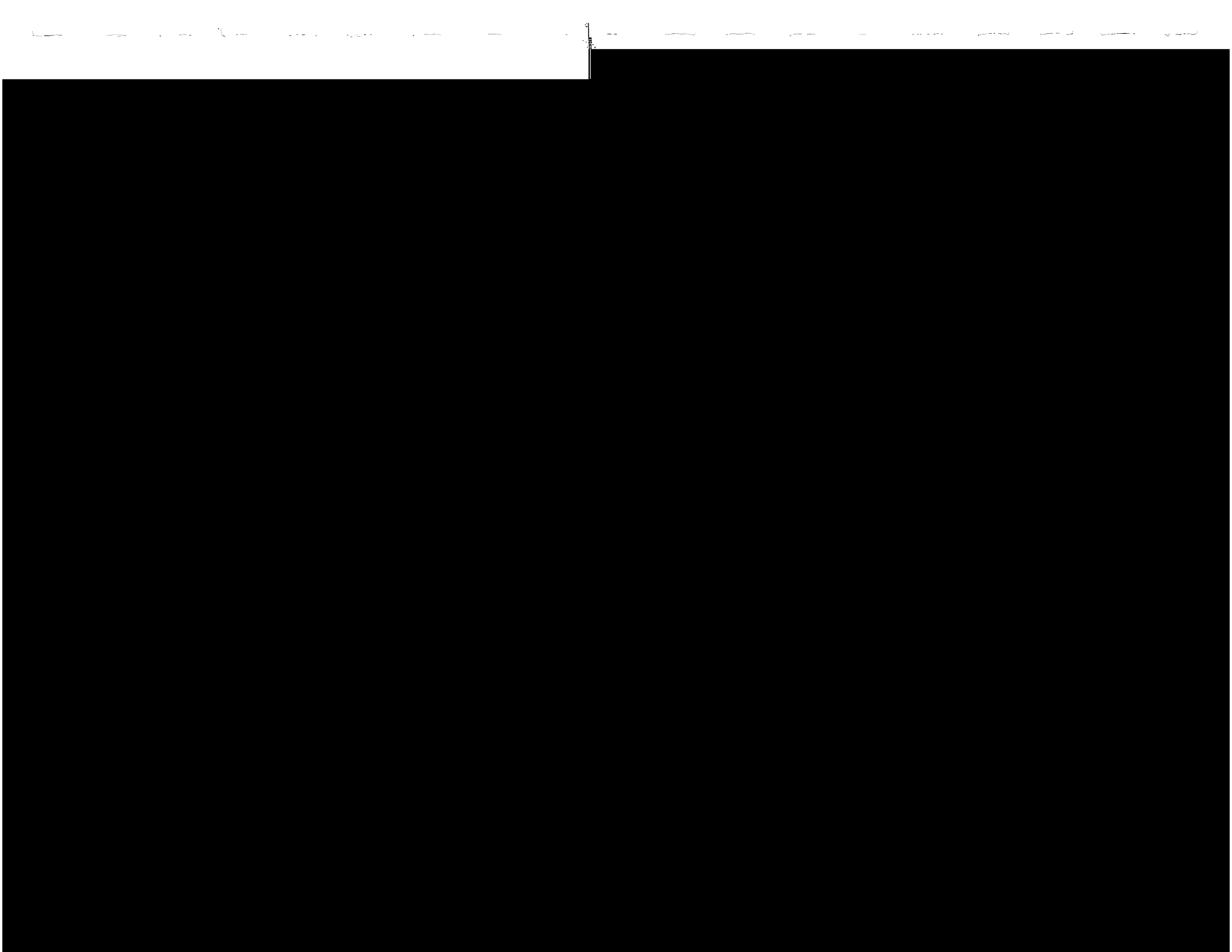


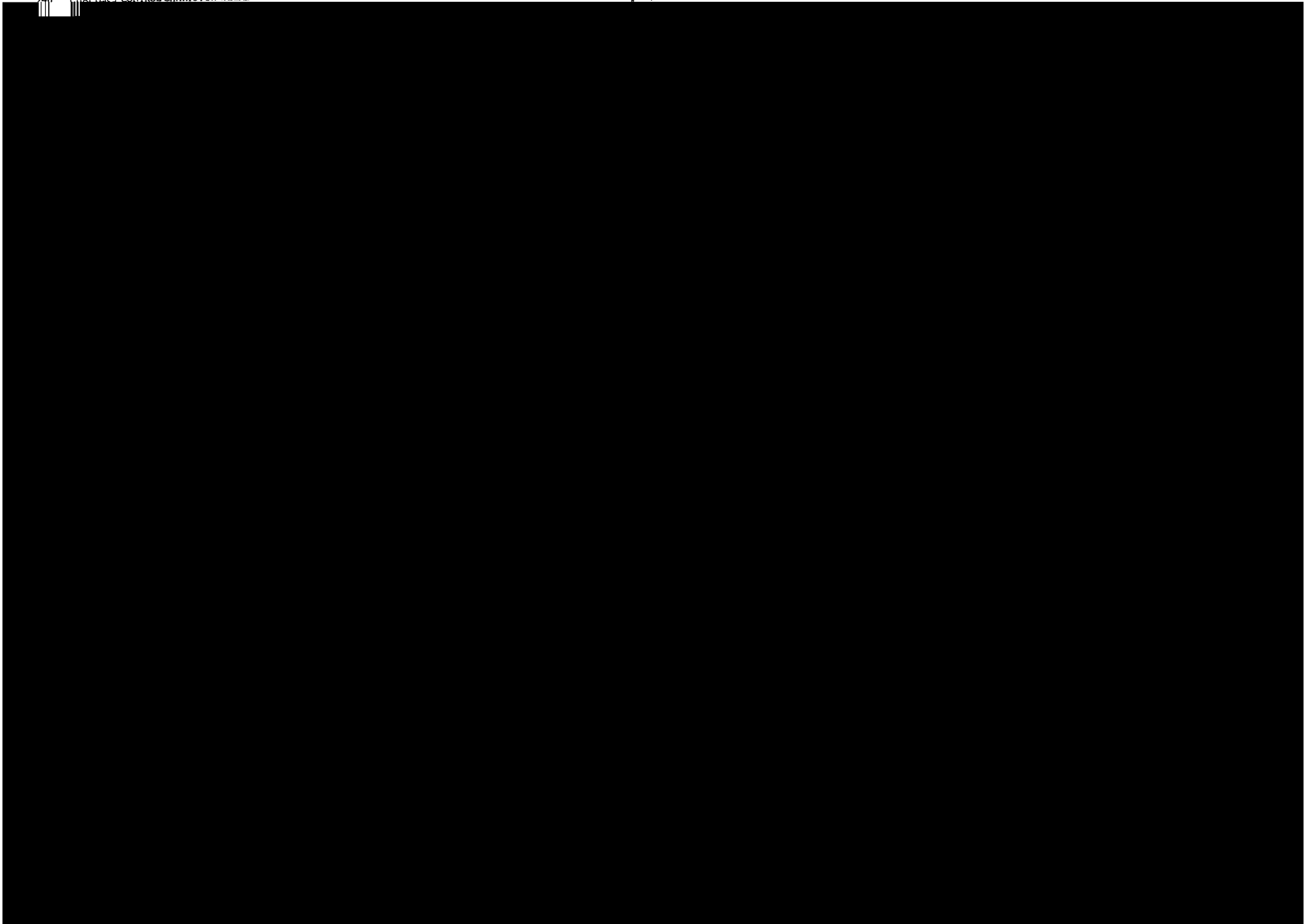
If a minimum number of observations is required, the control chart should be modified.

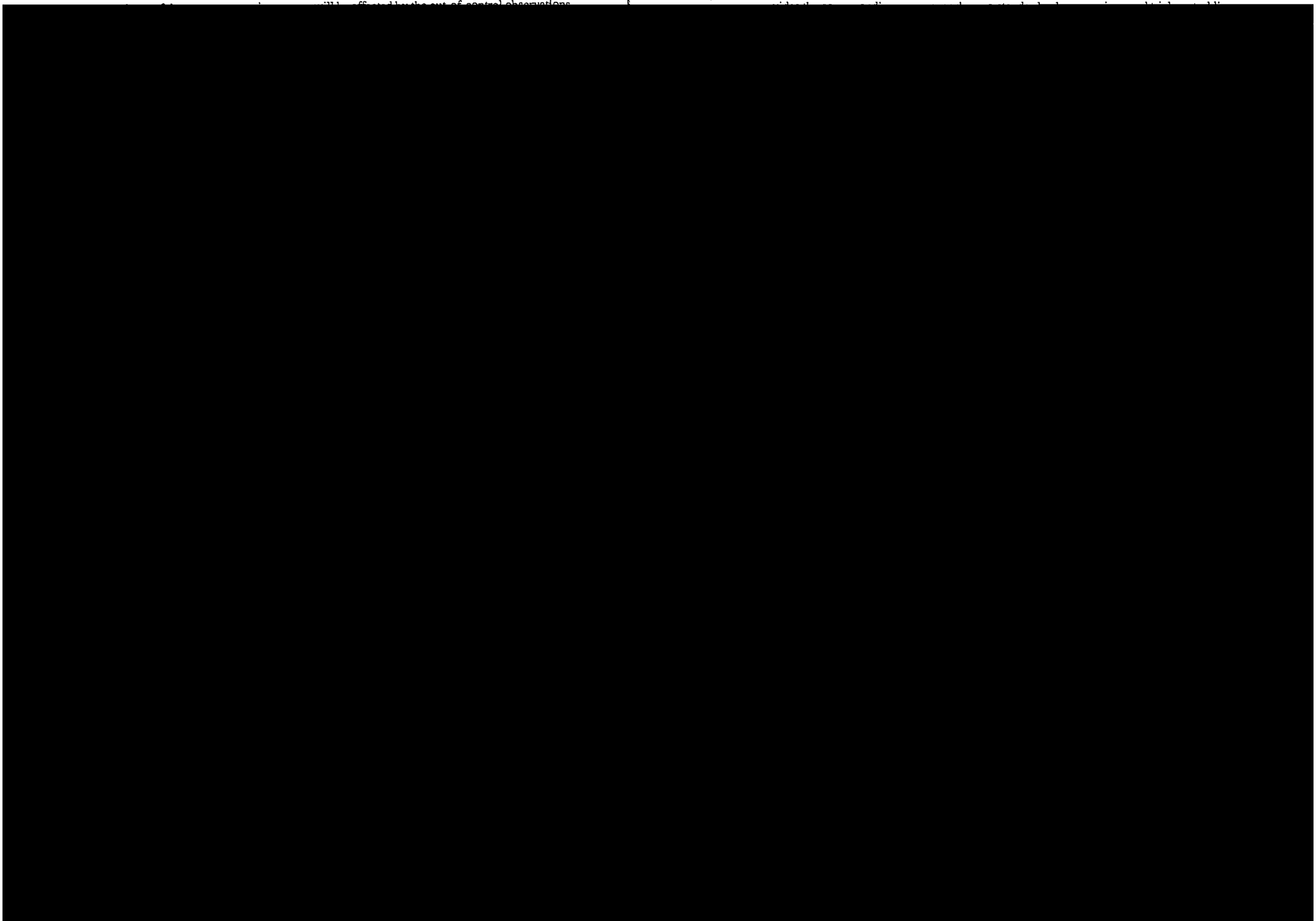


Size of Shift  $\beta$   $ARL_1$

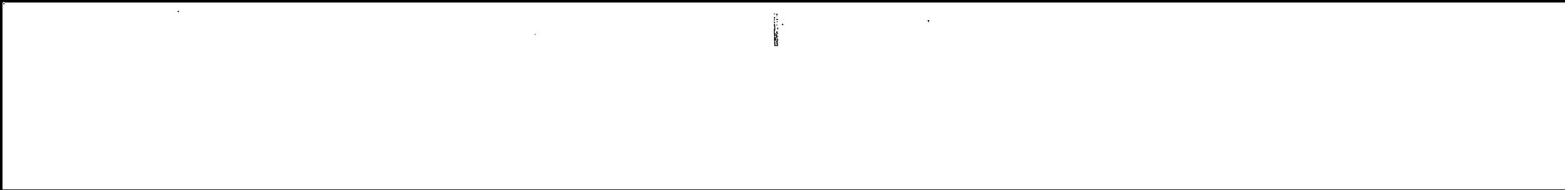
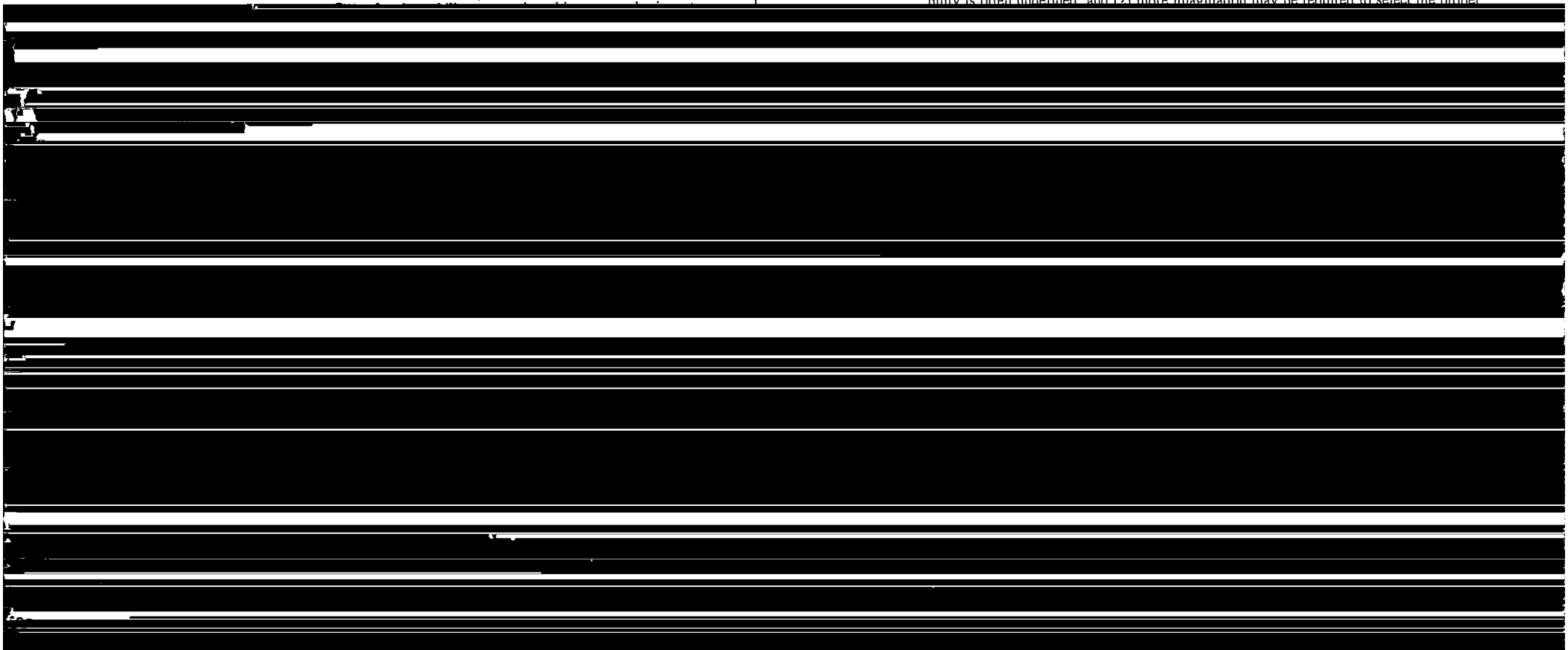


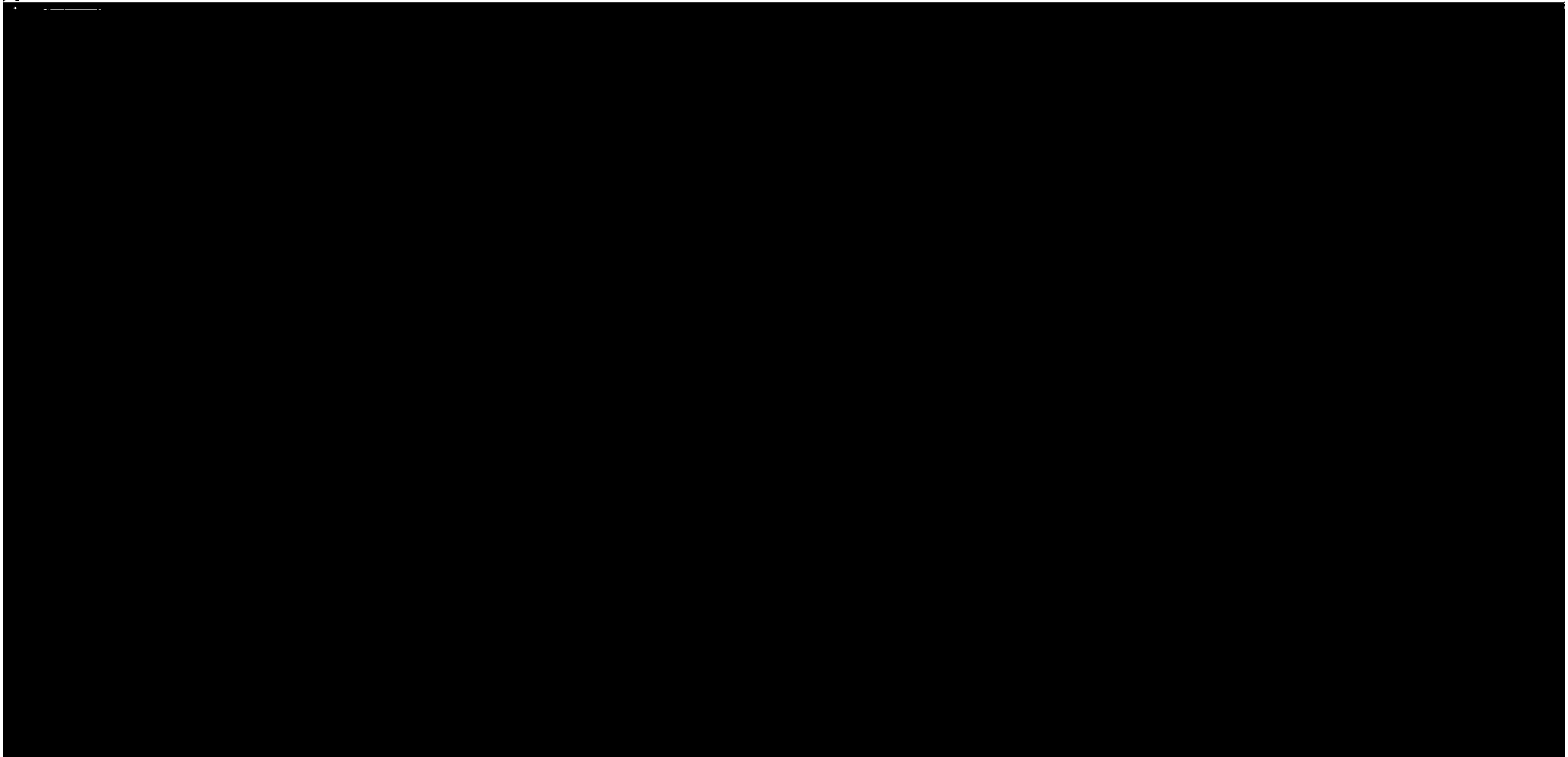
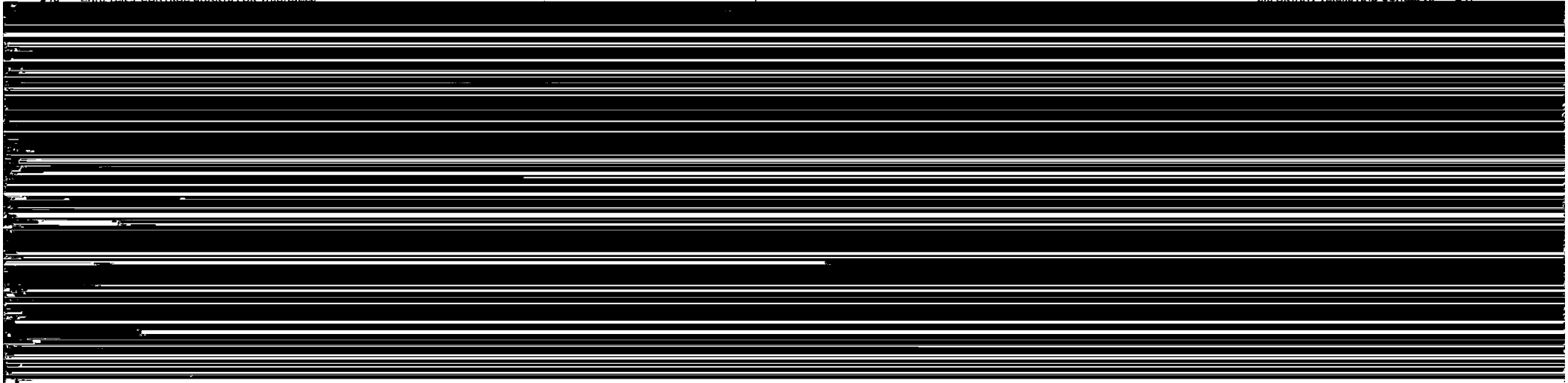






bility is often undefined; and (2) more imagination may be required to select the proper





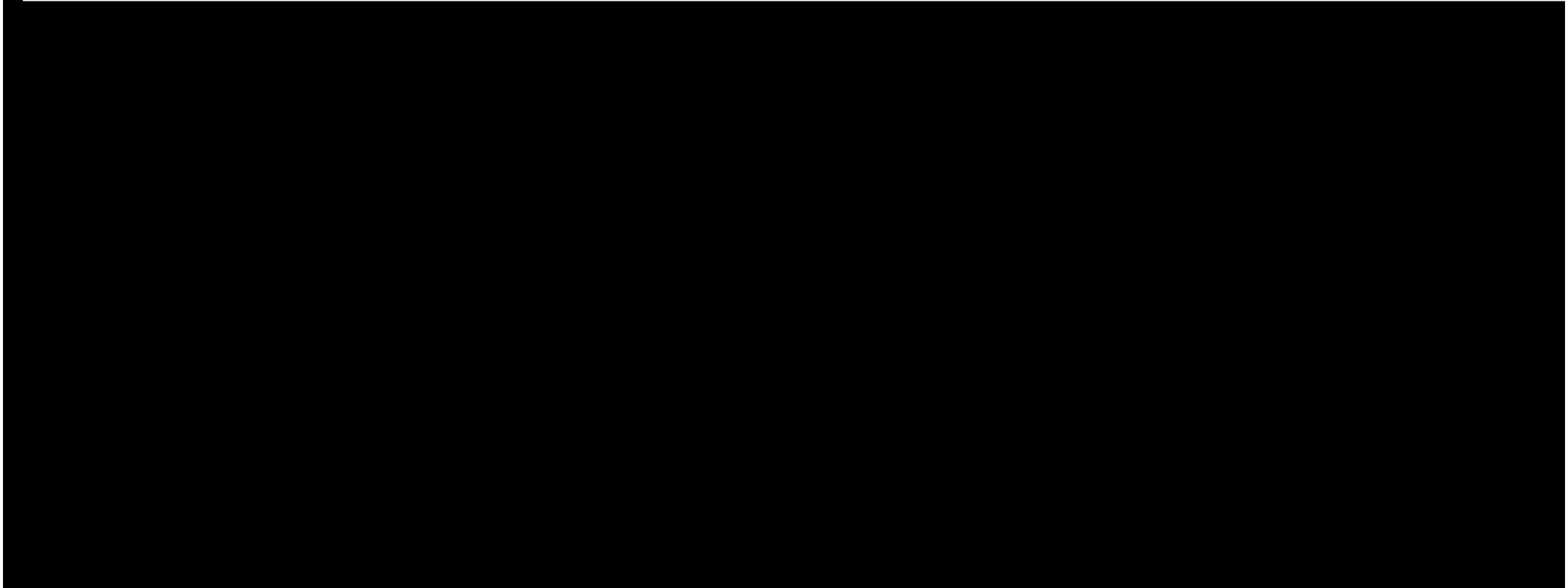
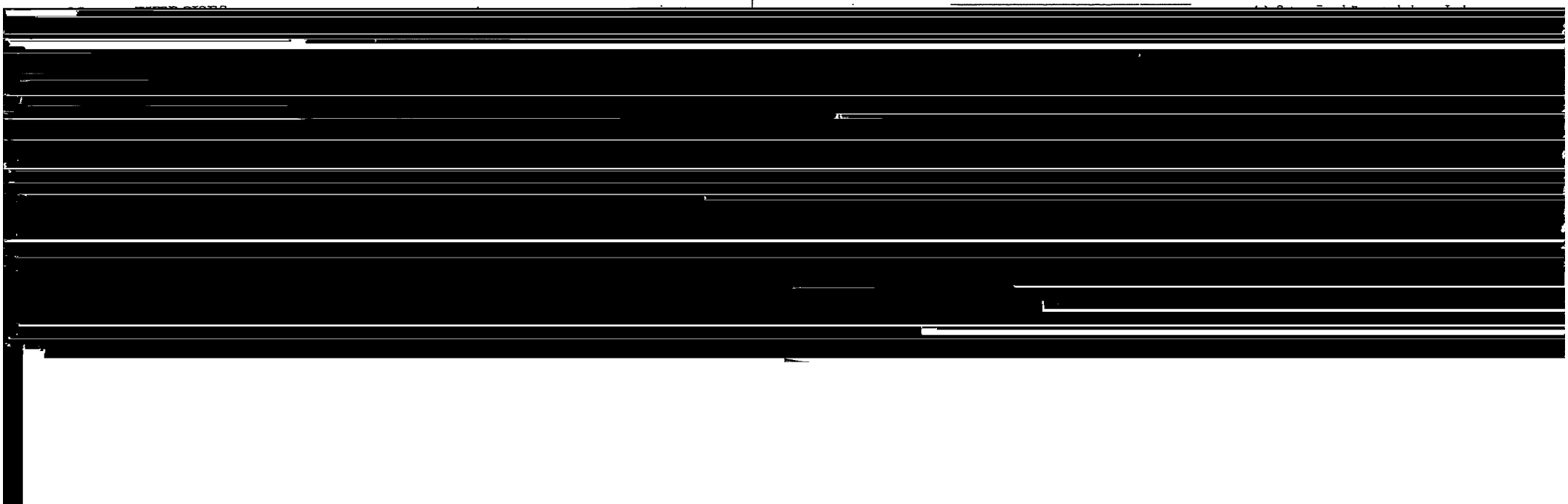
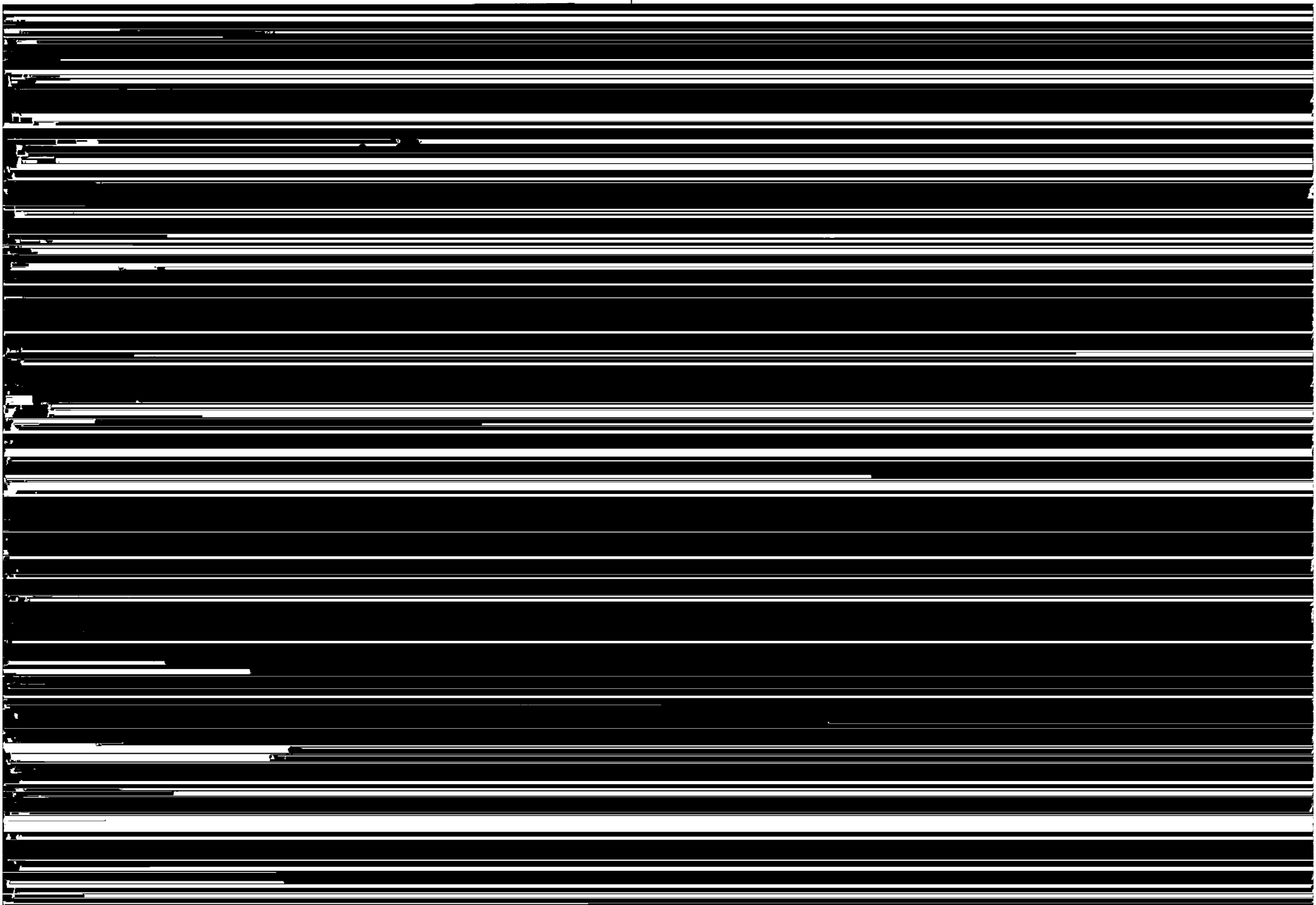
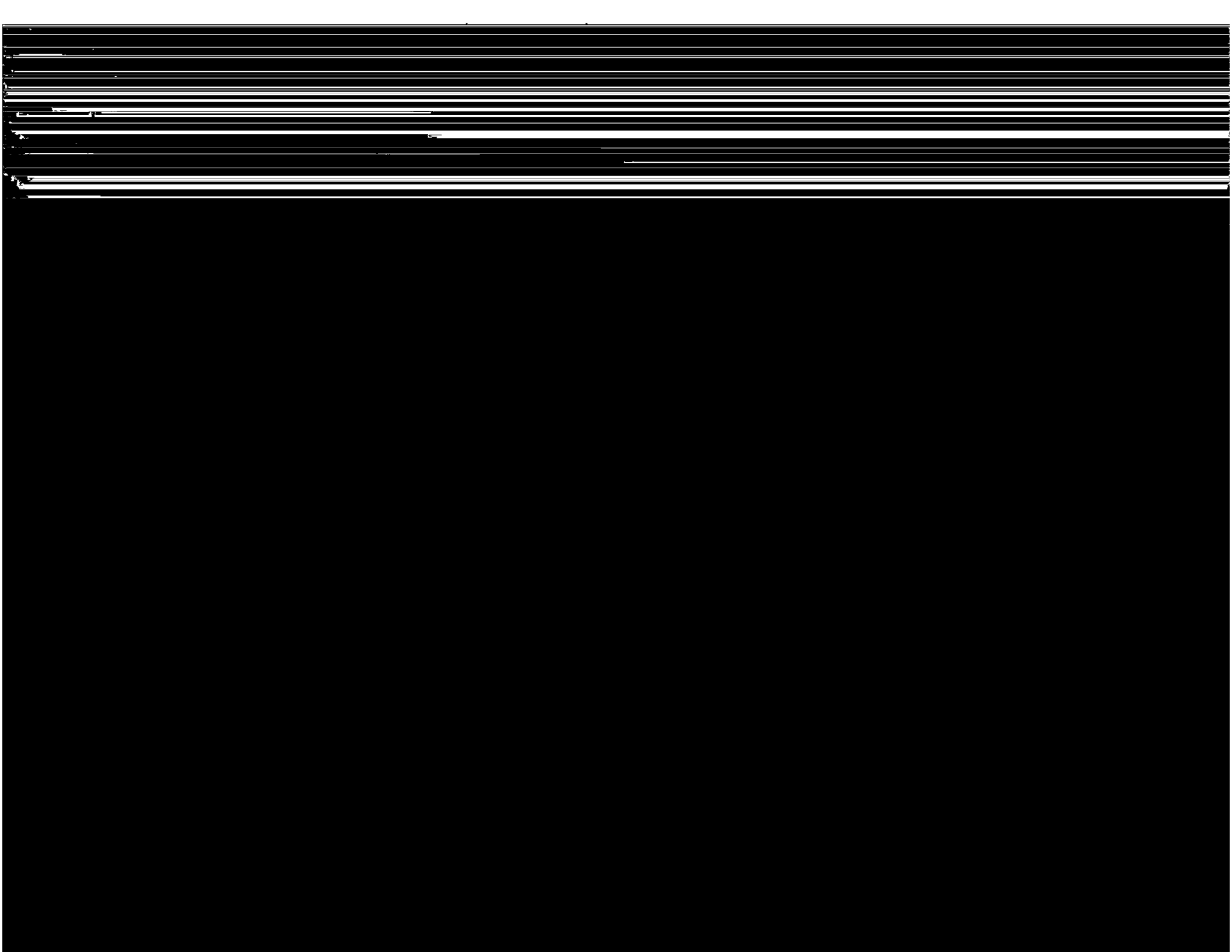




TABLE 5.14 The table shows results of 20 subgroups



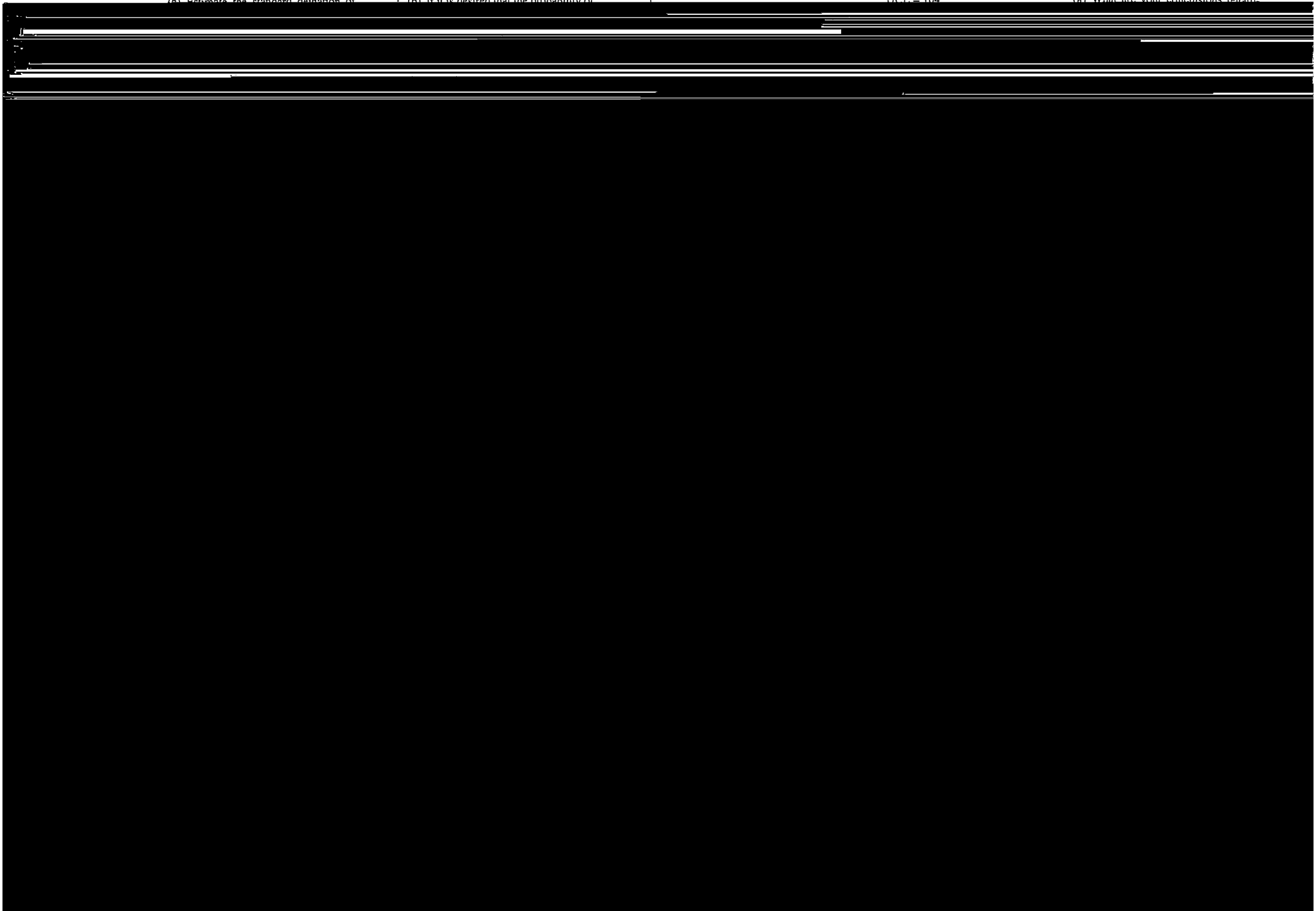


(c) Estimate the standard deviation of \_\_\_\_\_

(b) If it is desired that the probability of \_\_\_\_\_

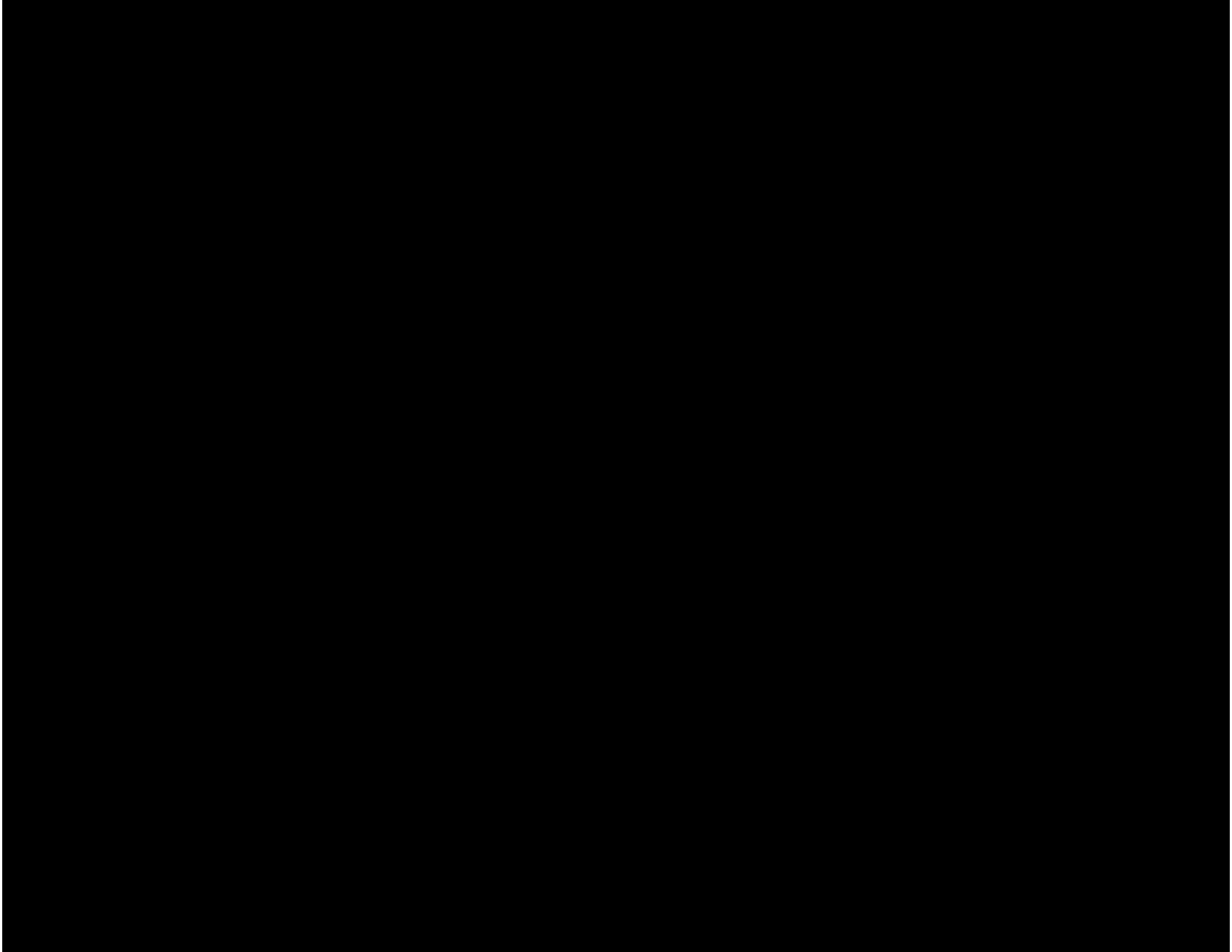
$UCL = 104$

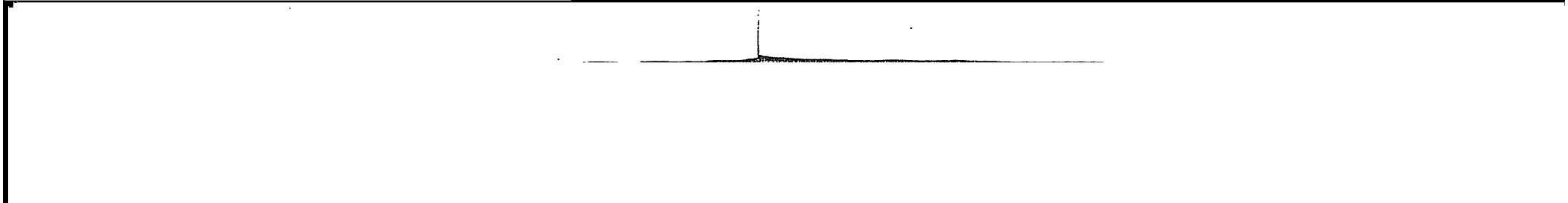
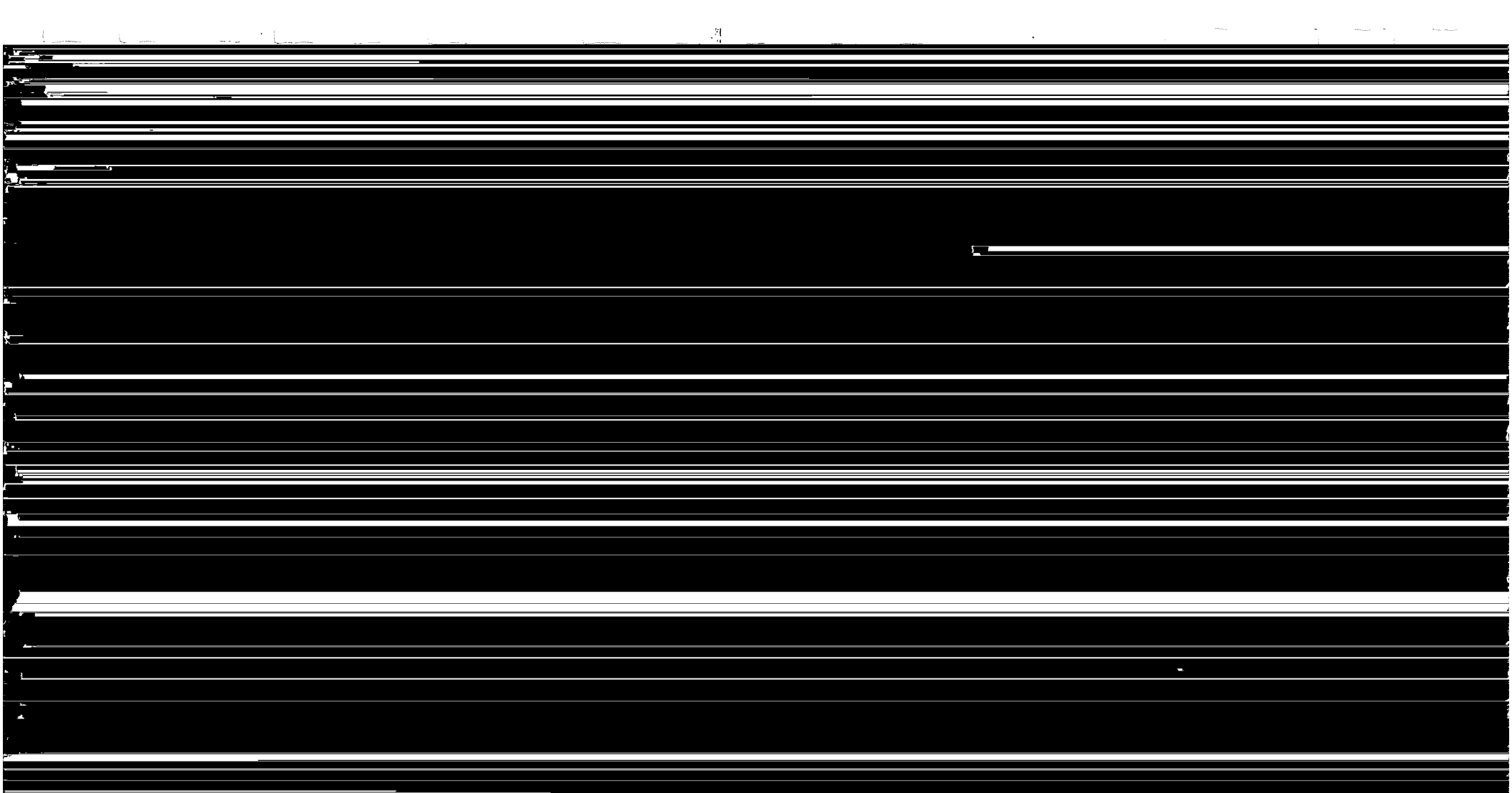
(a) What are your conclusions regard \_\_\_\_\_

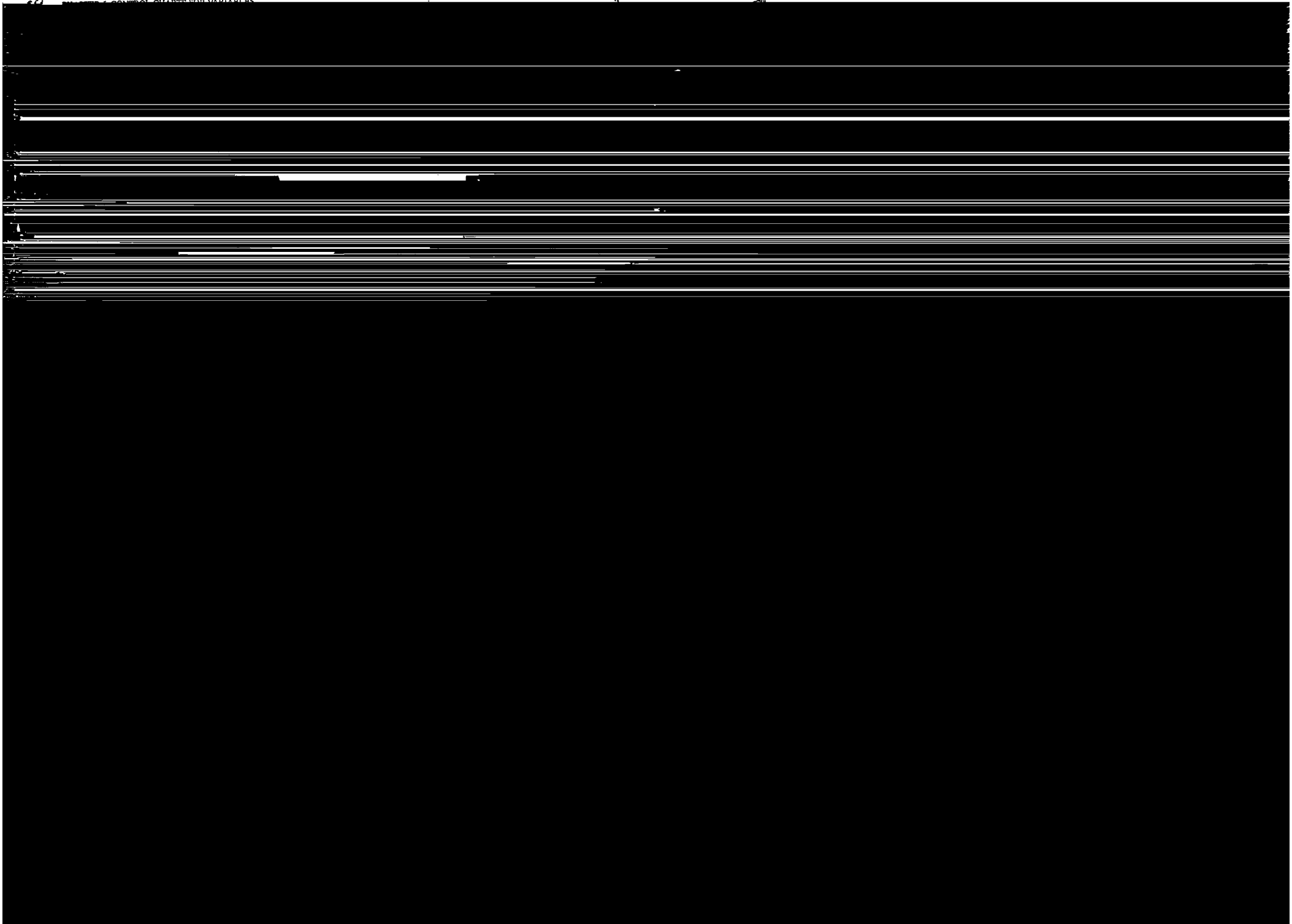


of the can, any package that weighs less

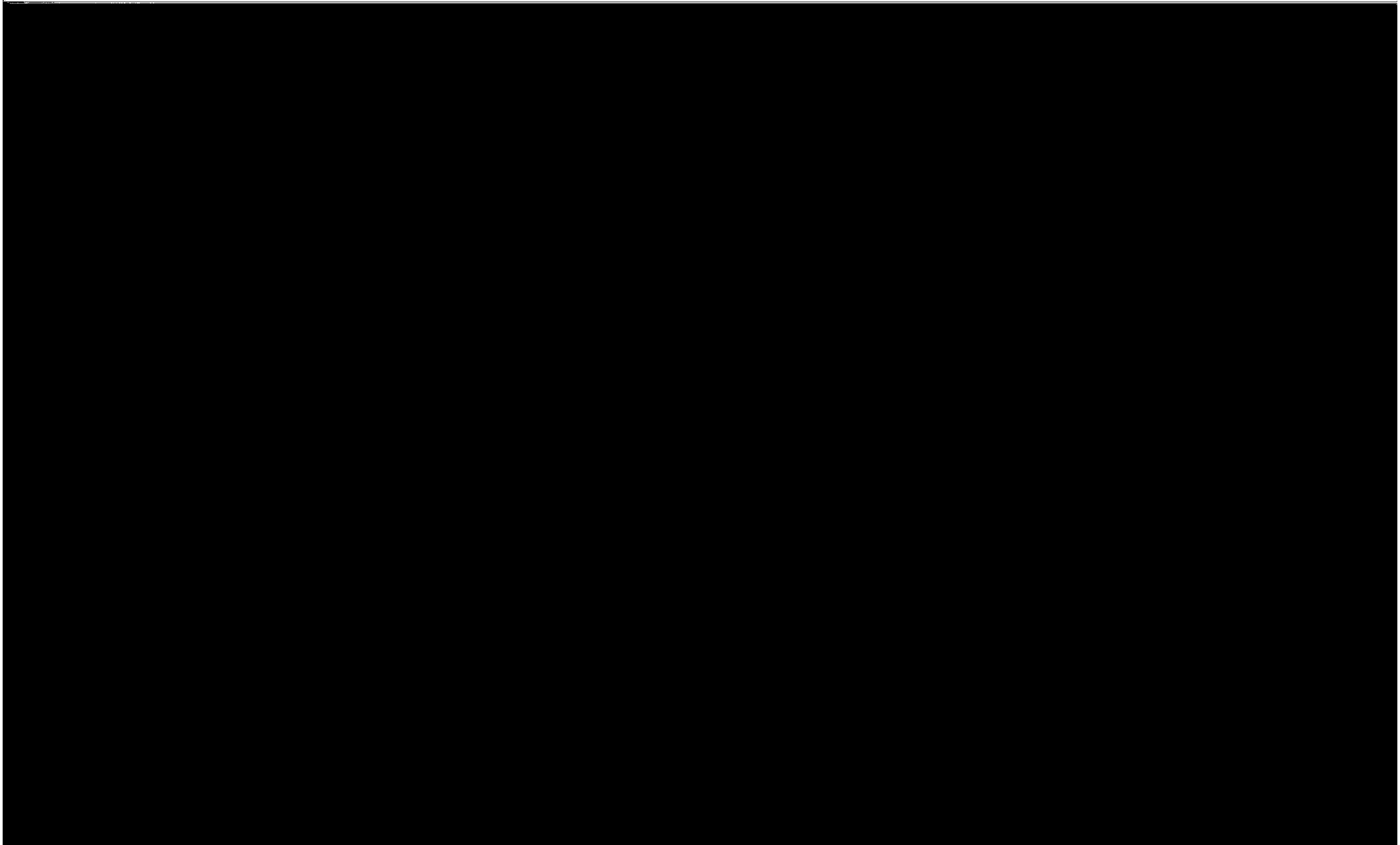
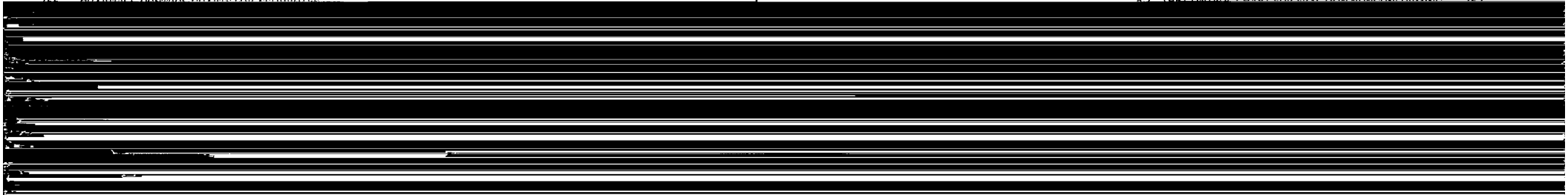


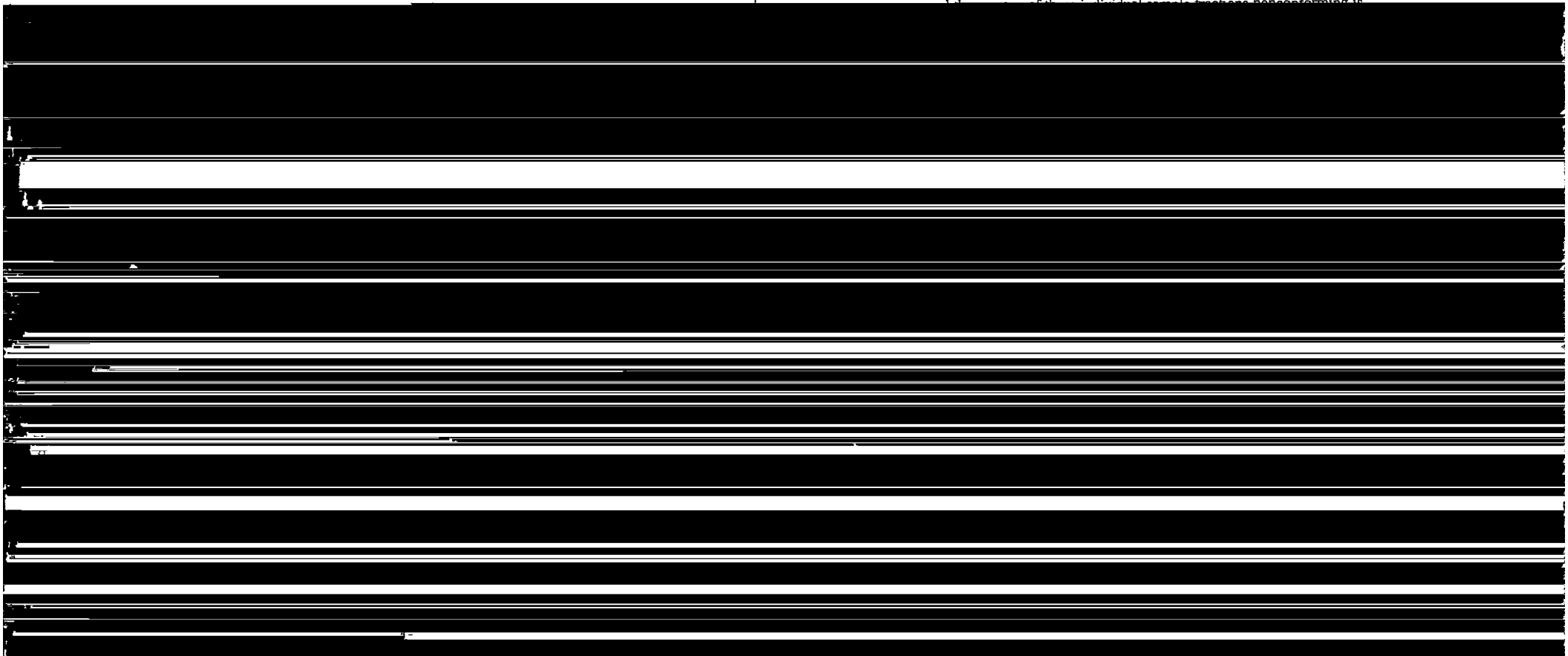




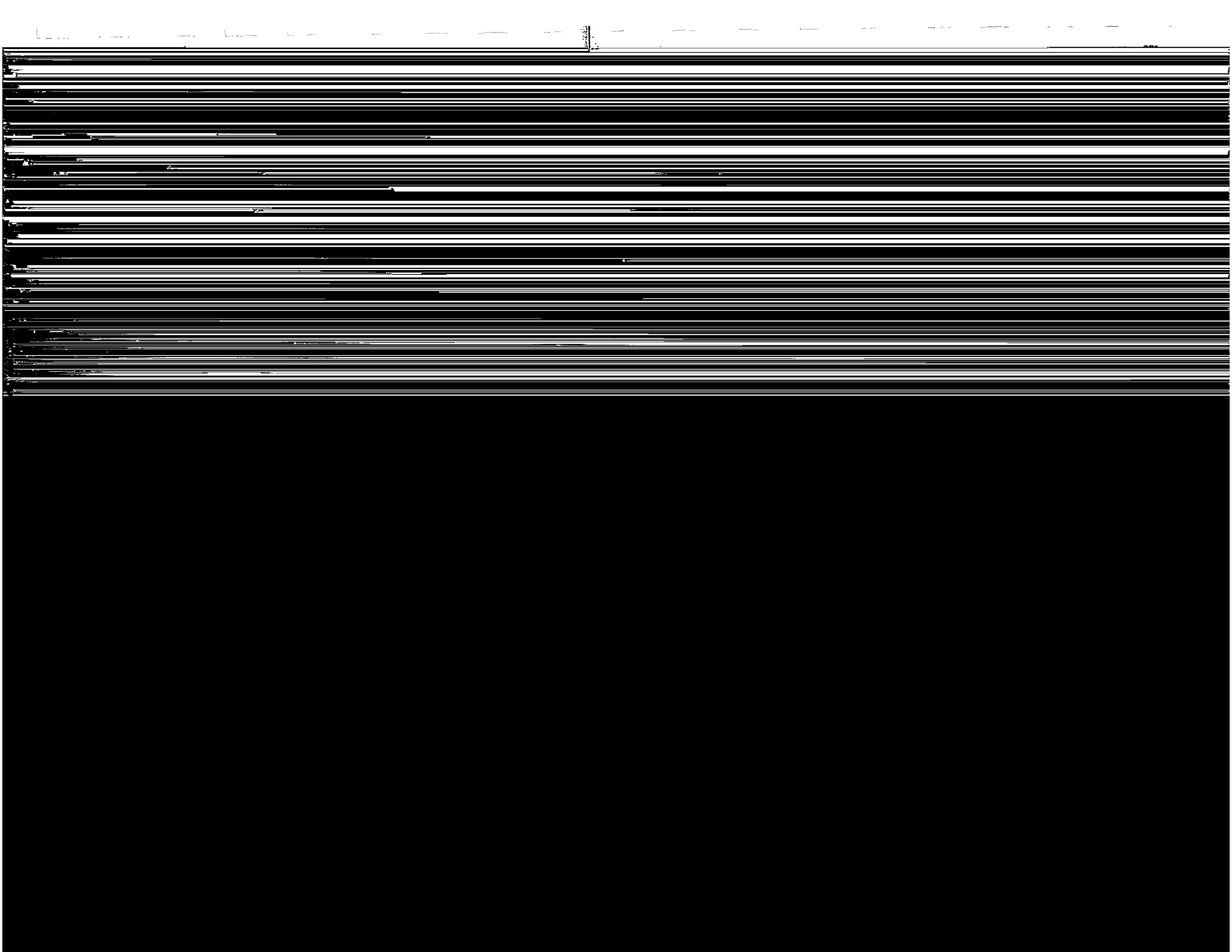


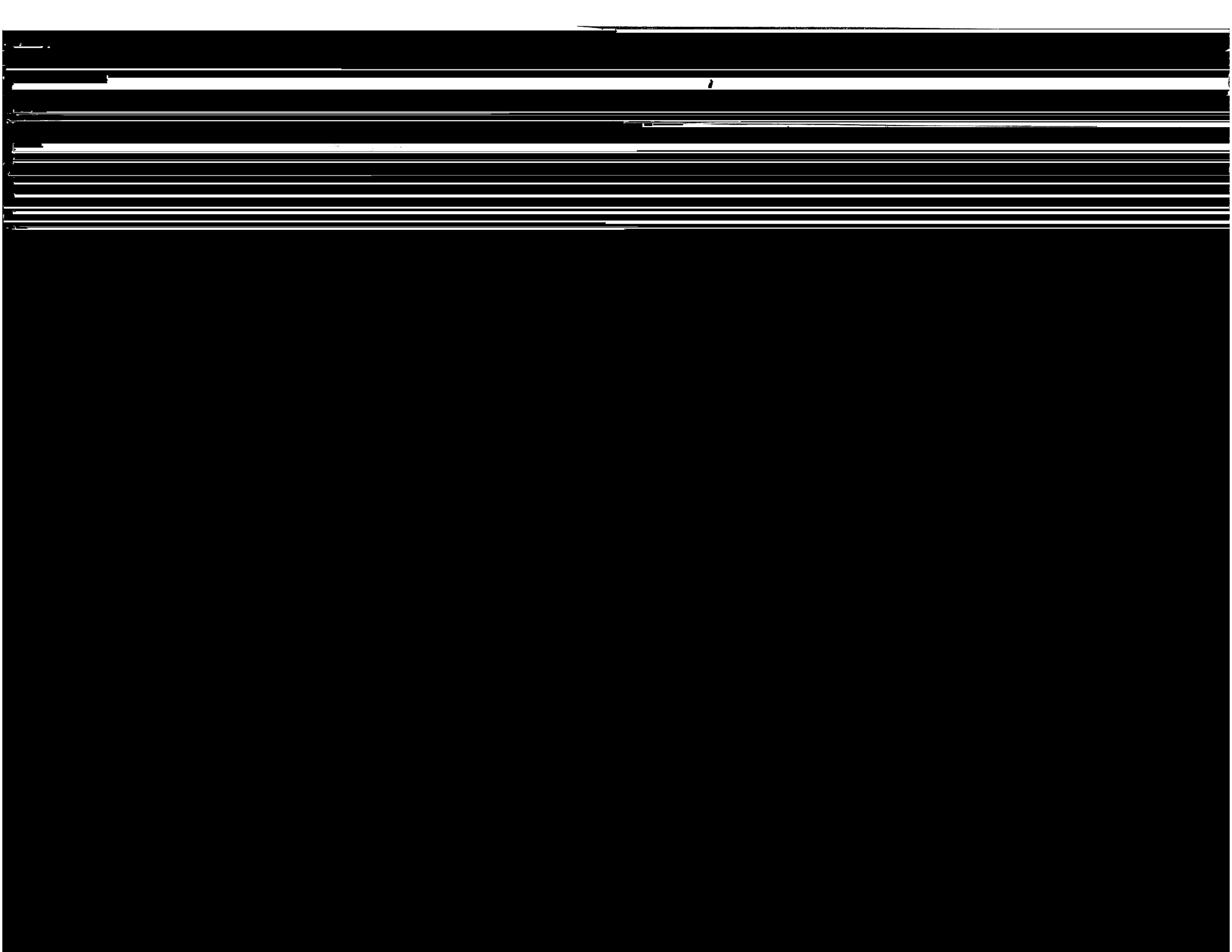


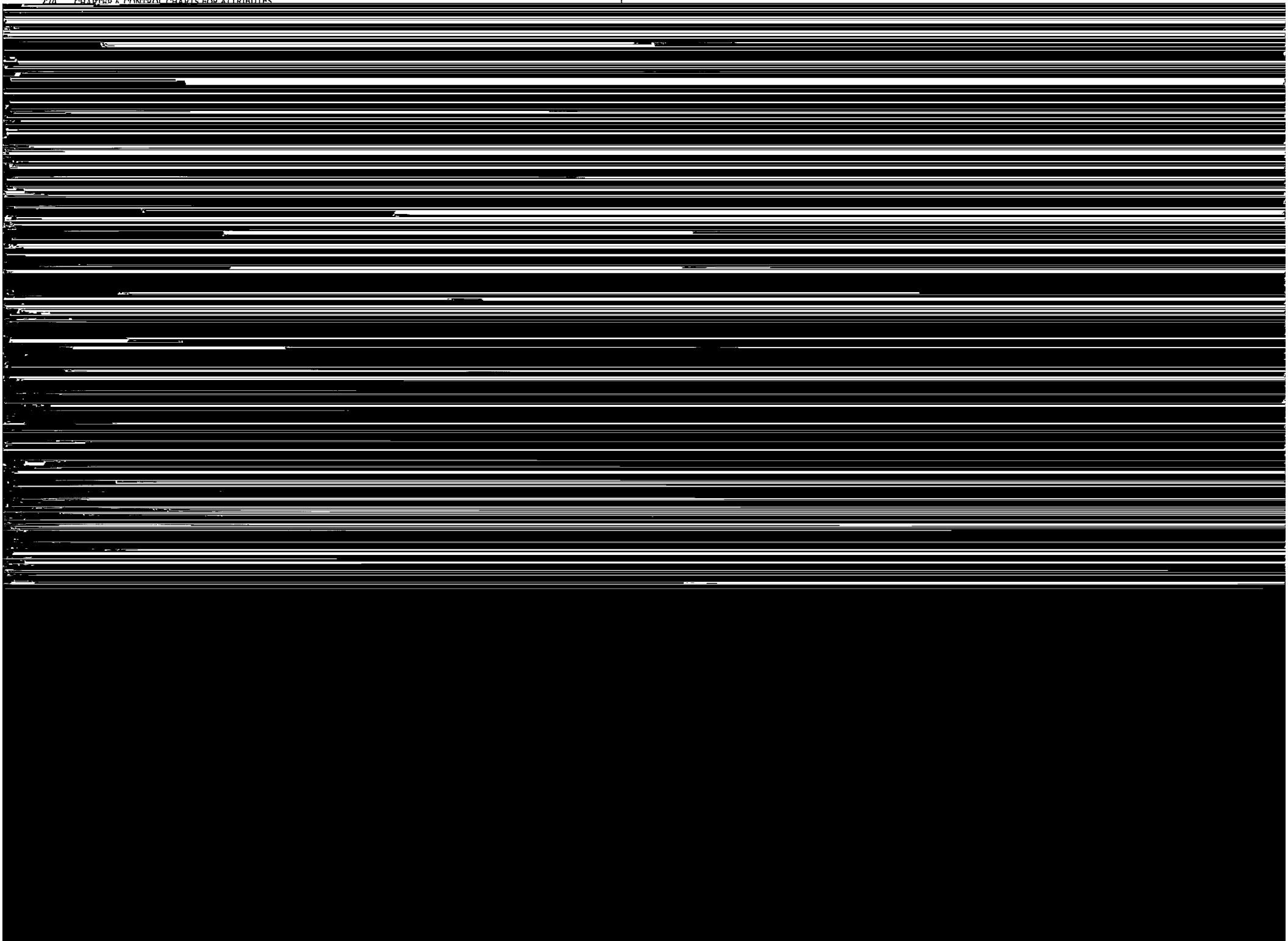




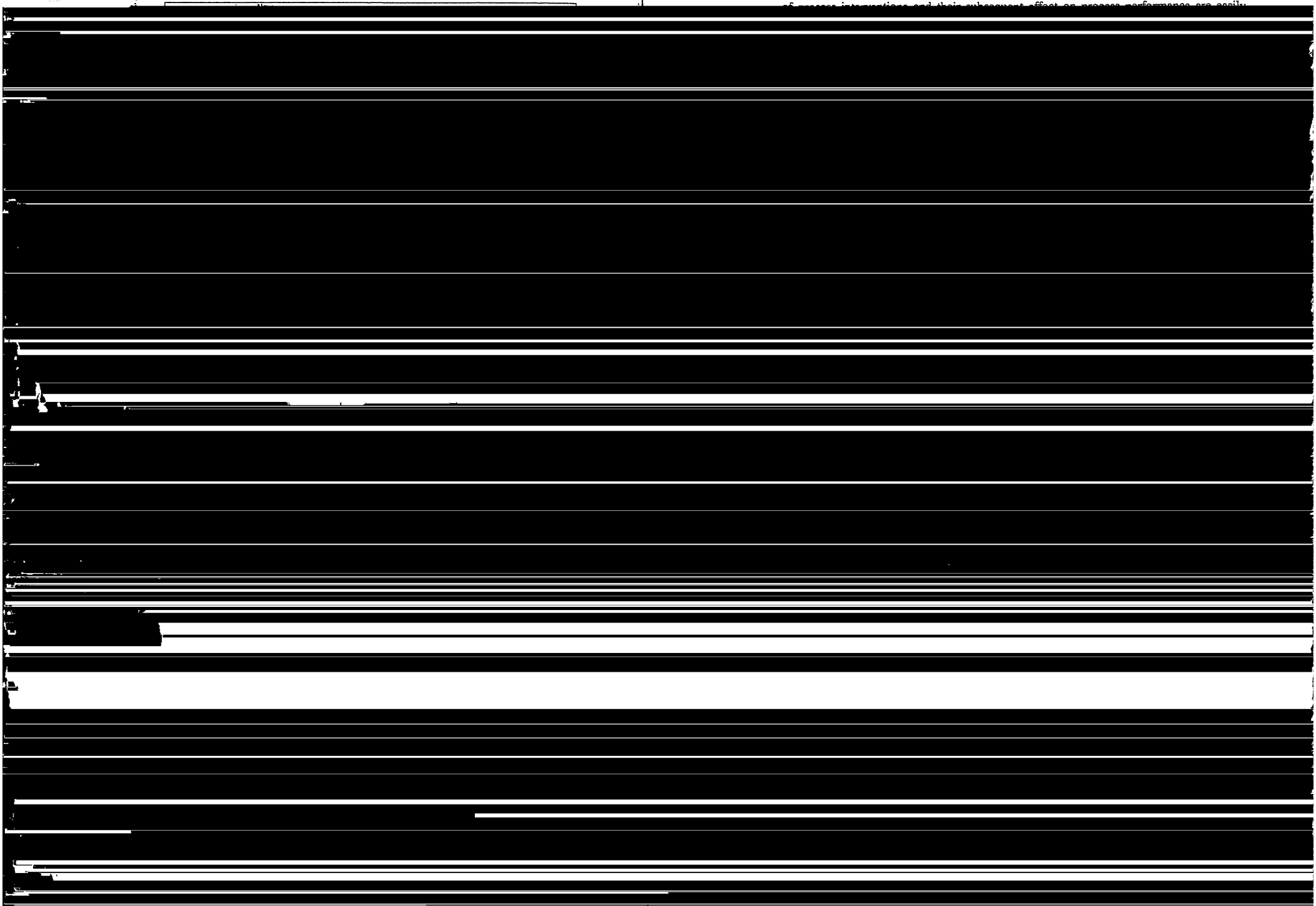
1. The fraction of individual sample fractions nonconforming is

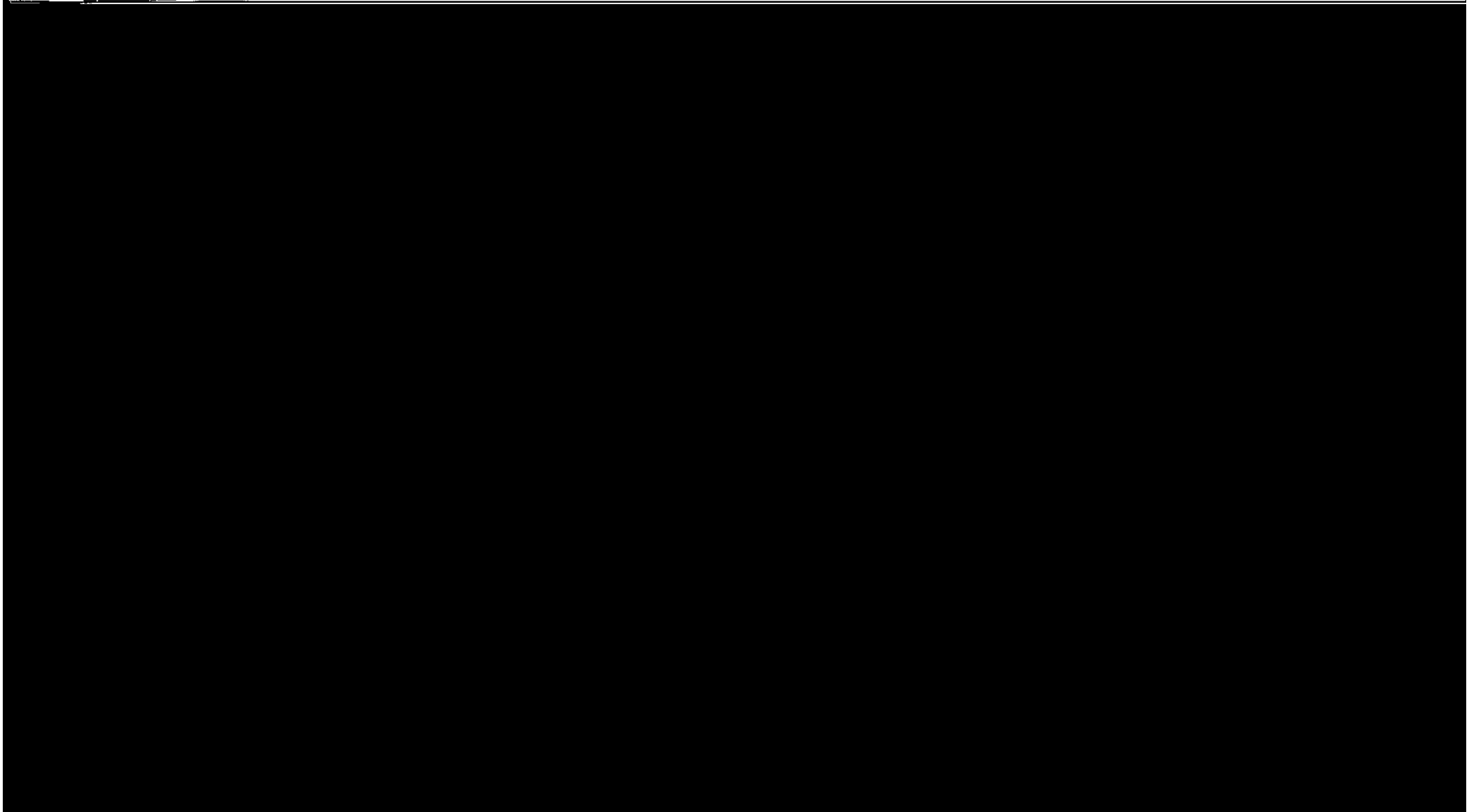
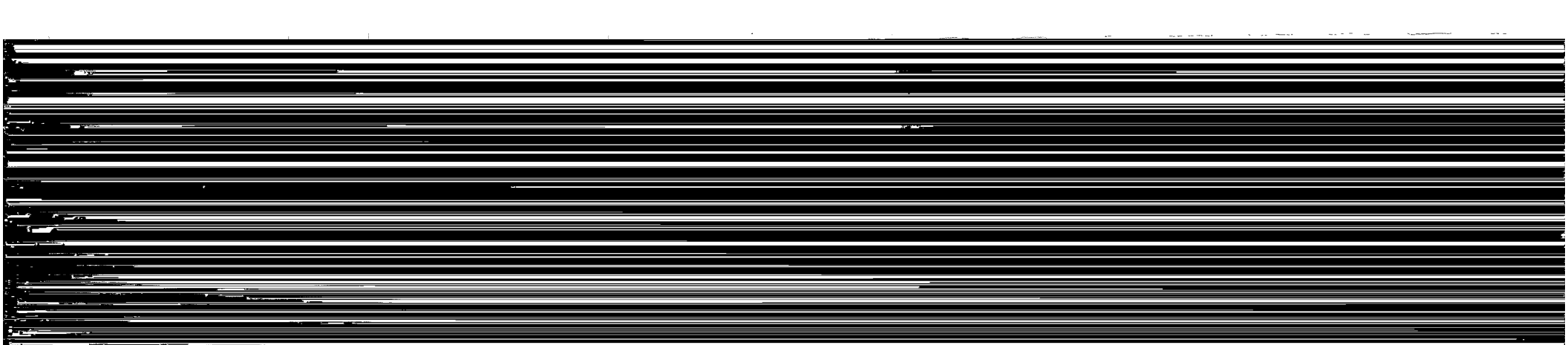


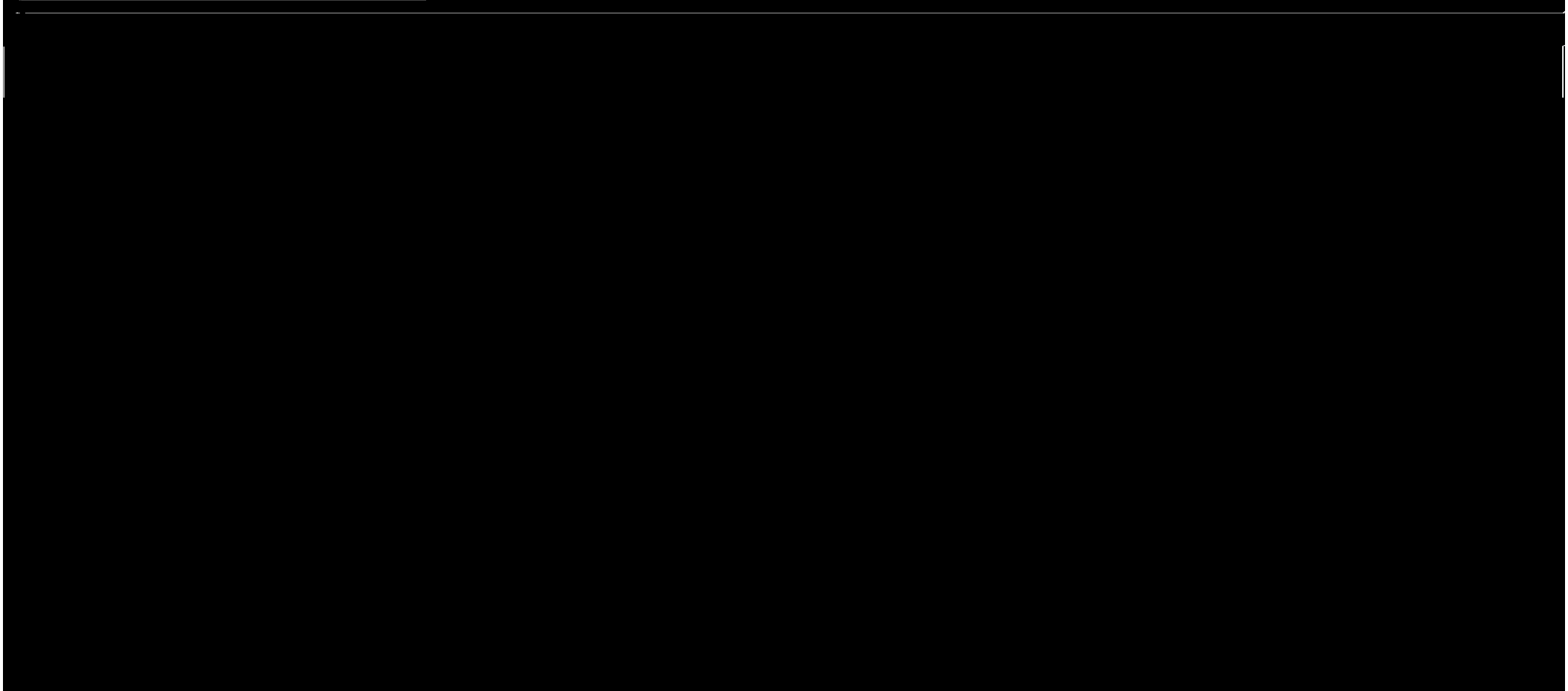




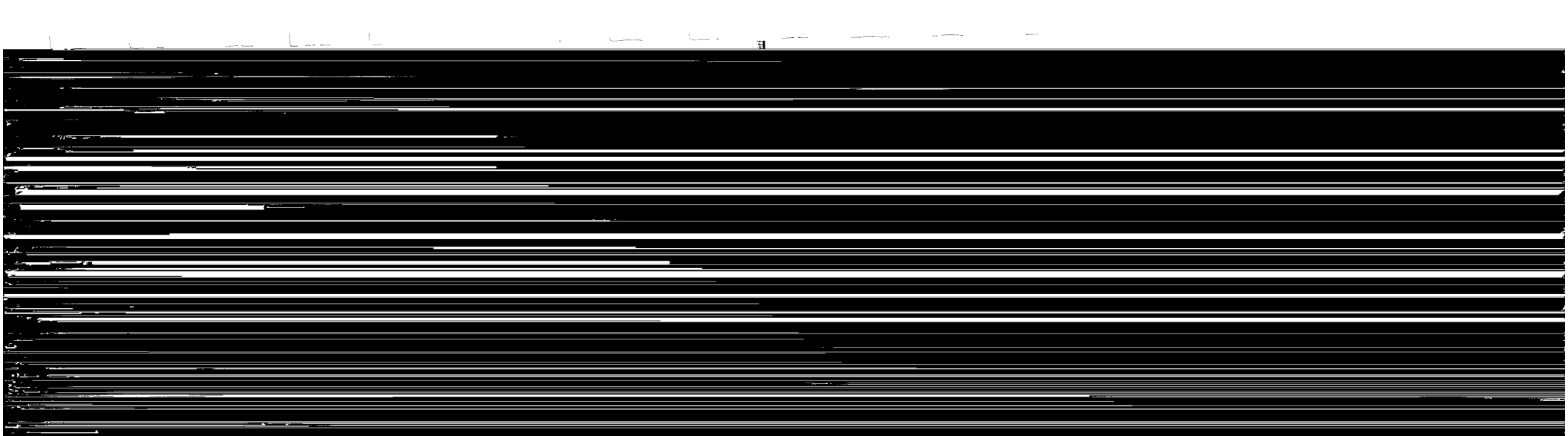
of process interruptions and their subsequent effect on process performance are easily



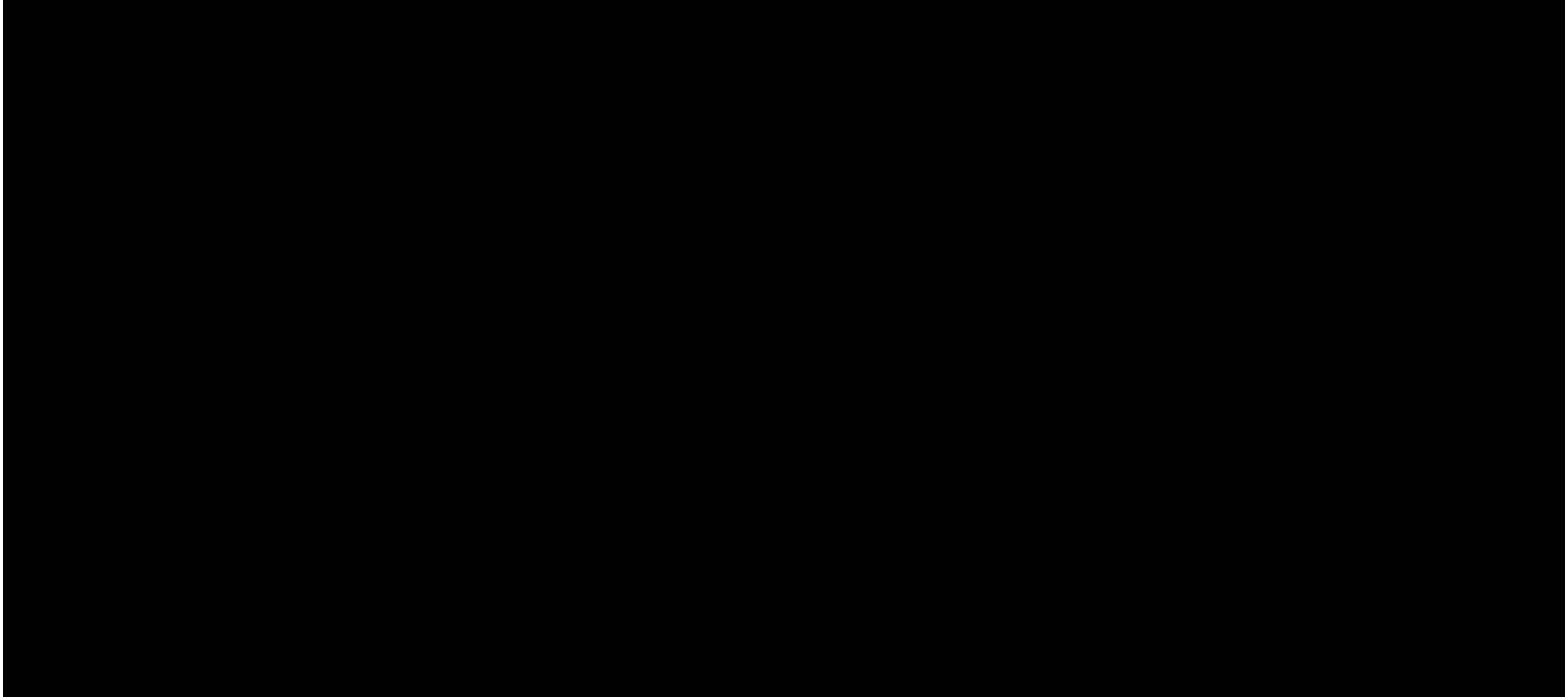


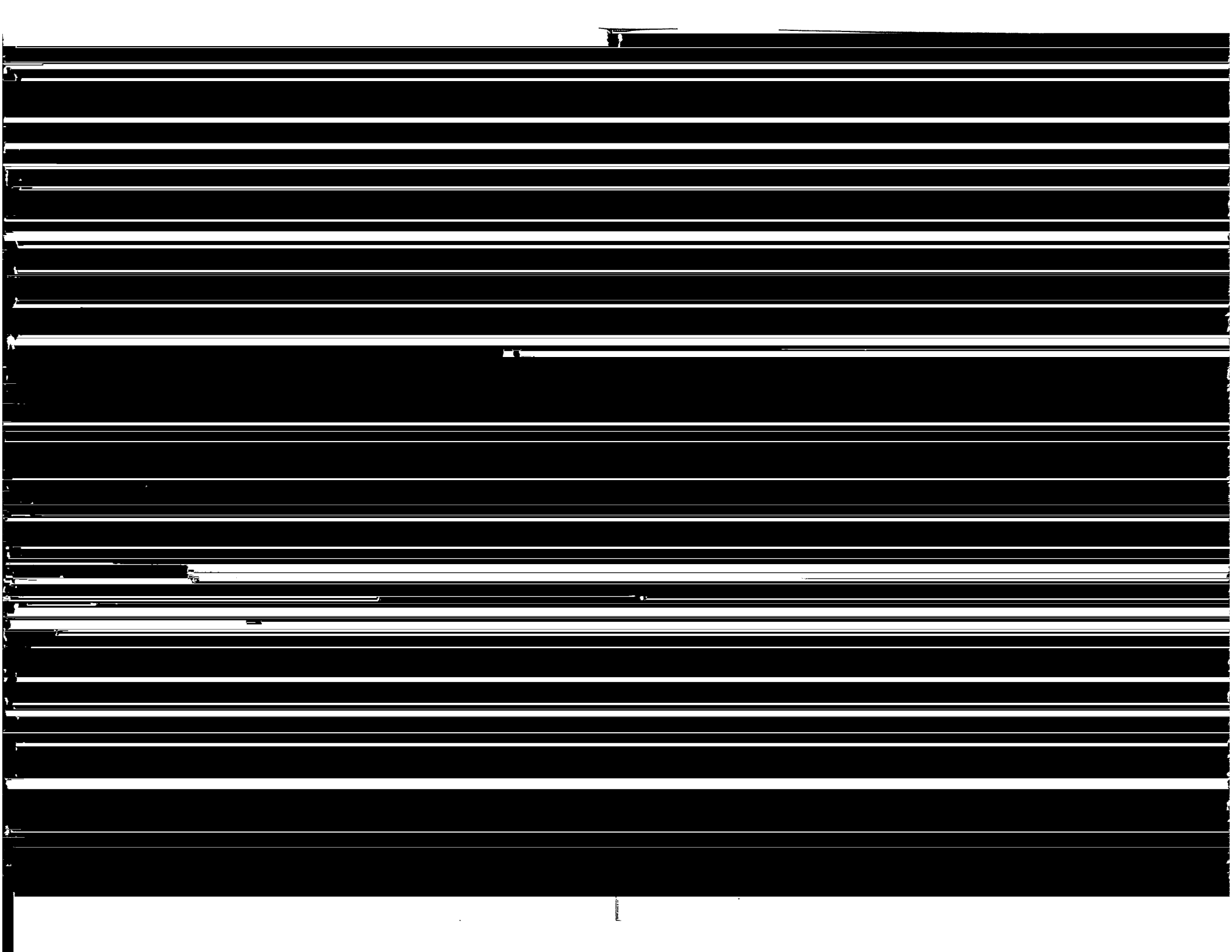


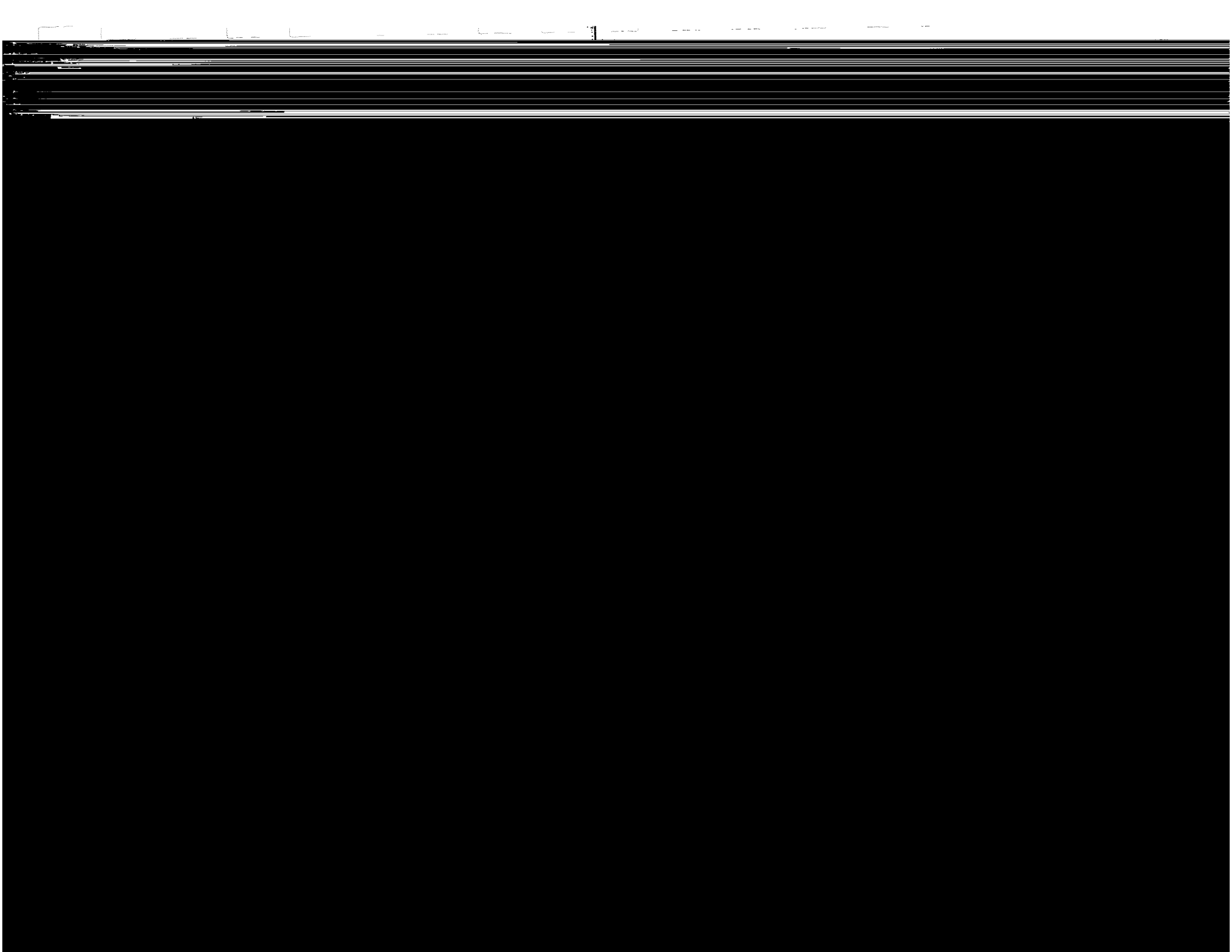




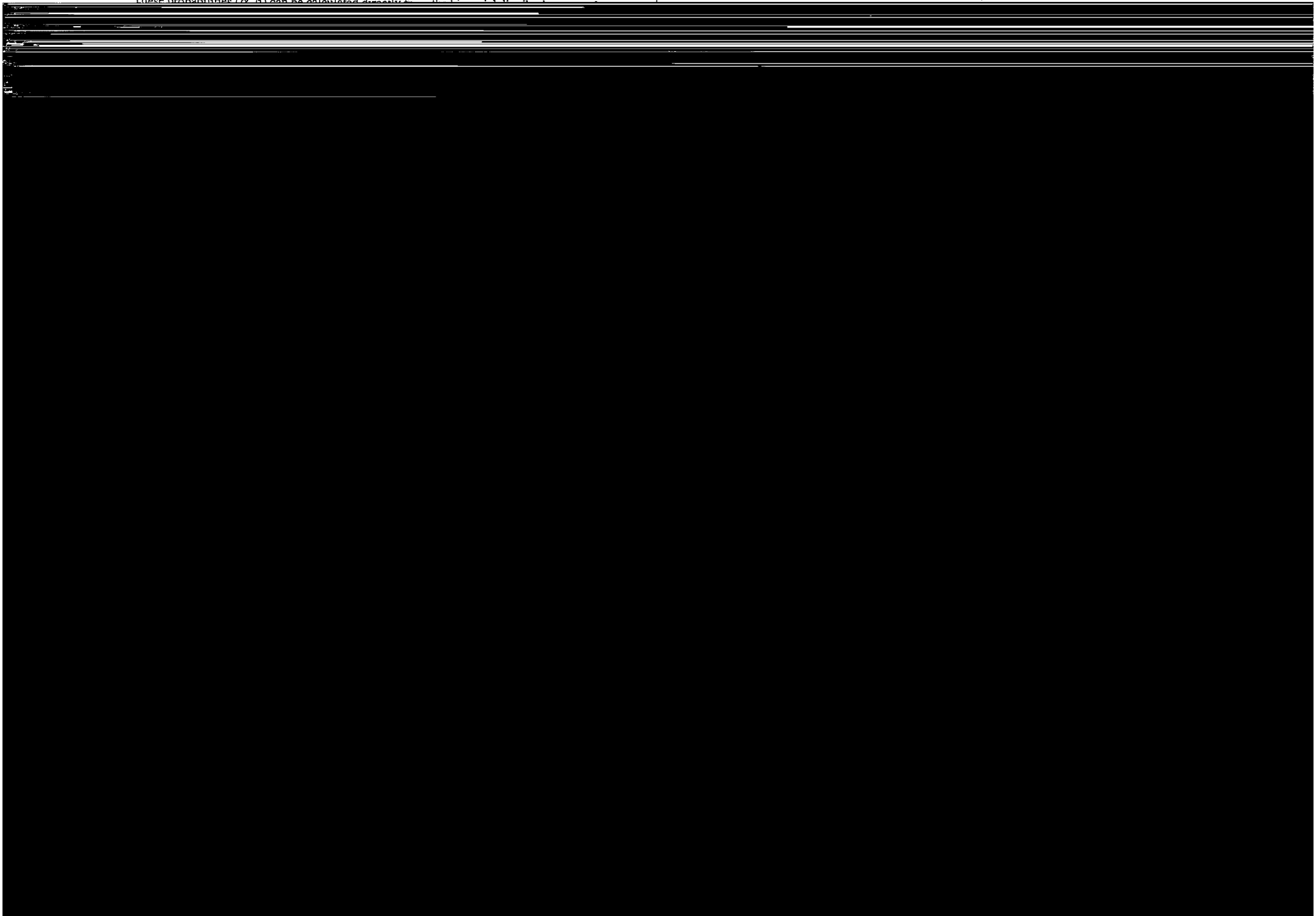
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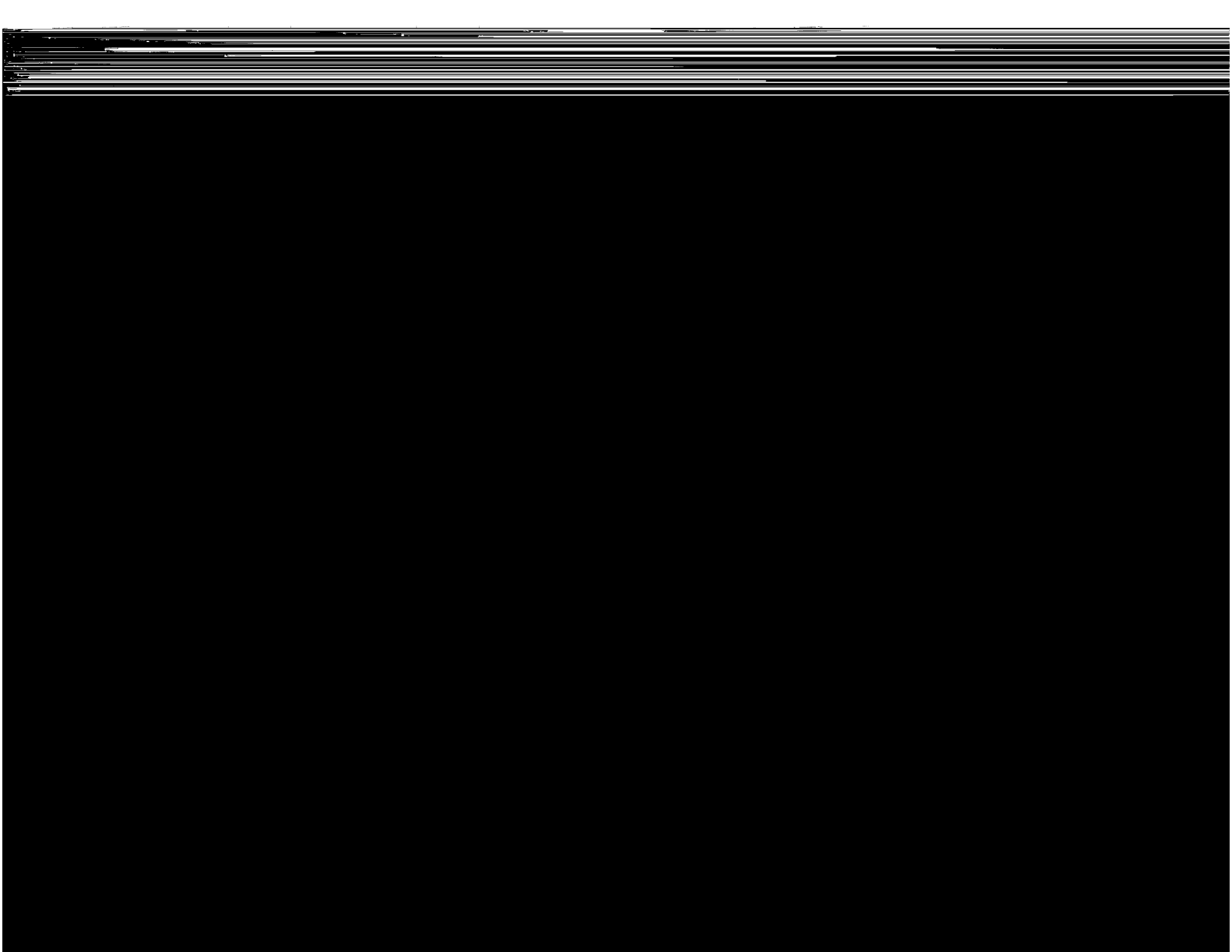


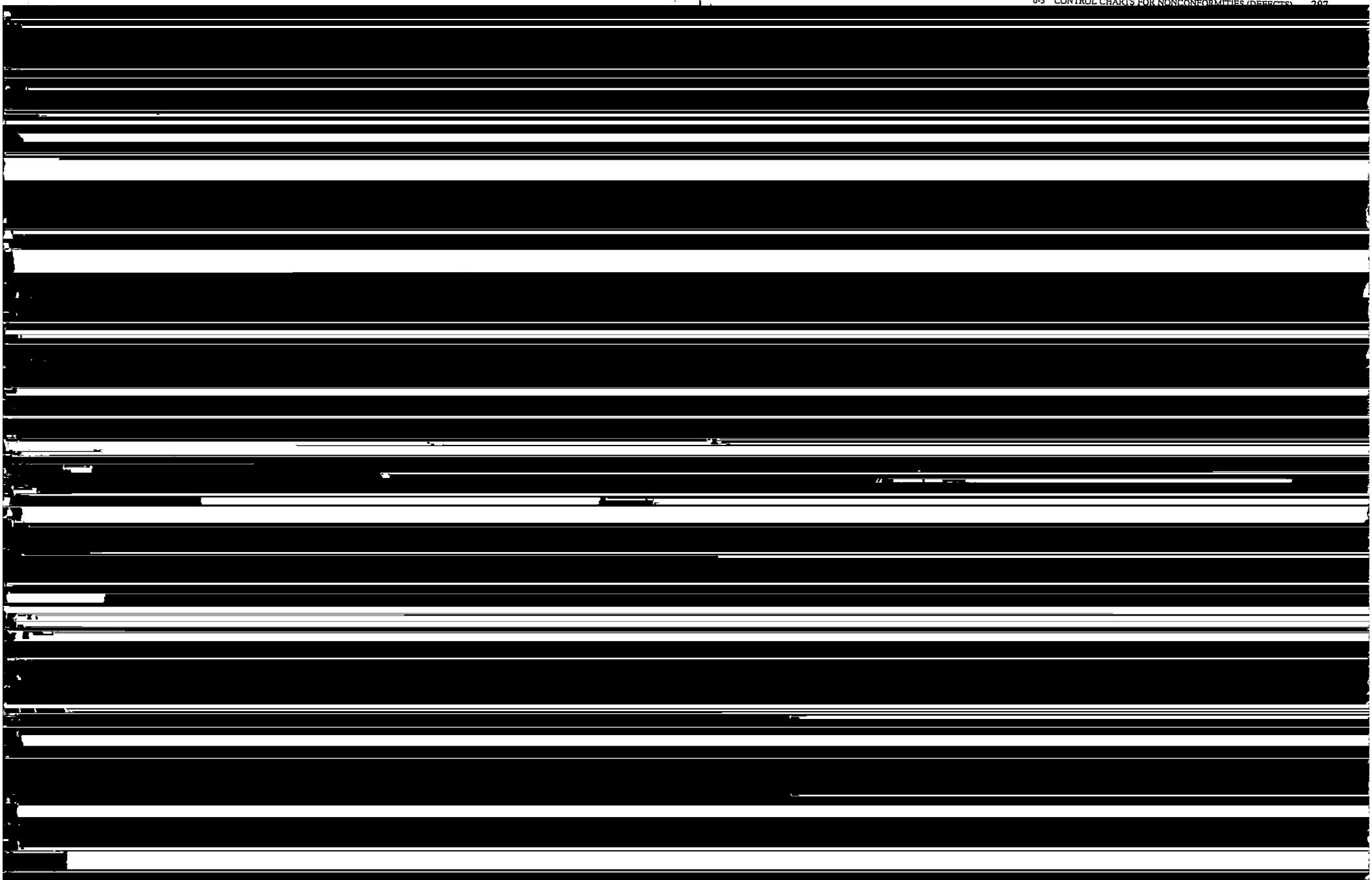
These probabilities ( $\alpha$ ,  $\beta$ ) can be calculated directly from the binomial distribution.



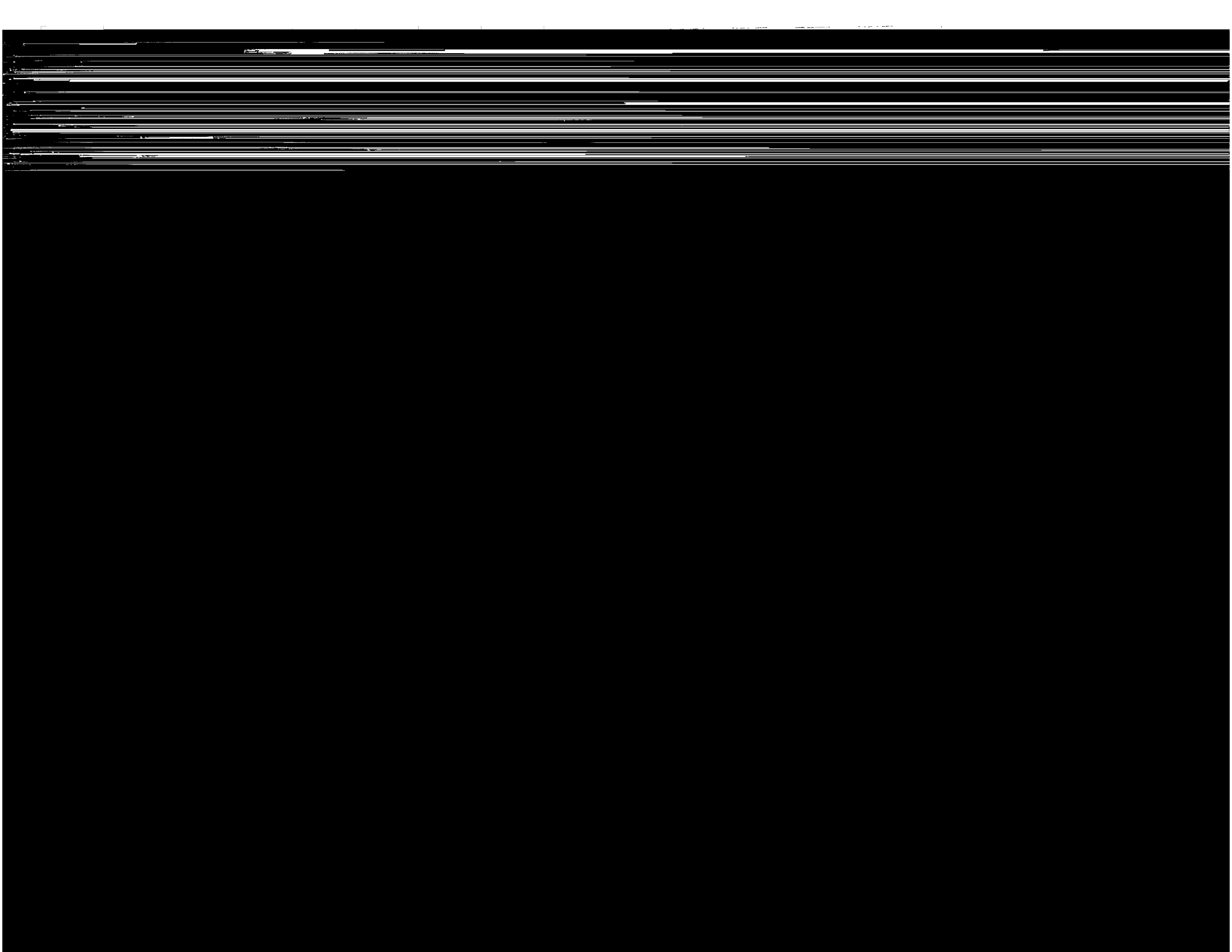


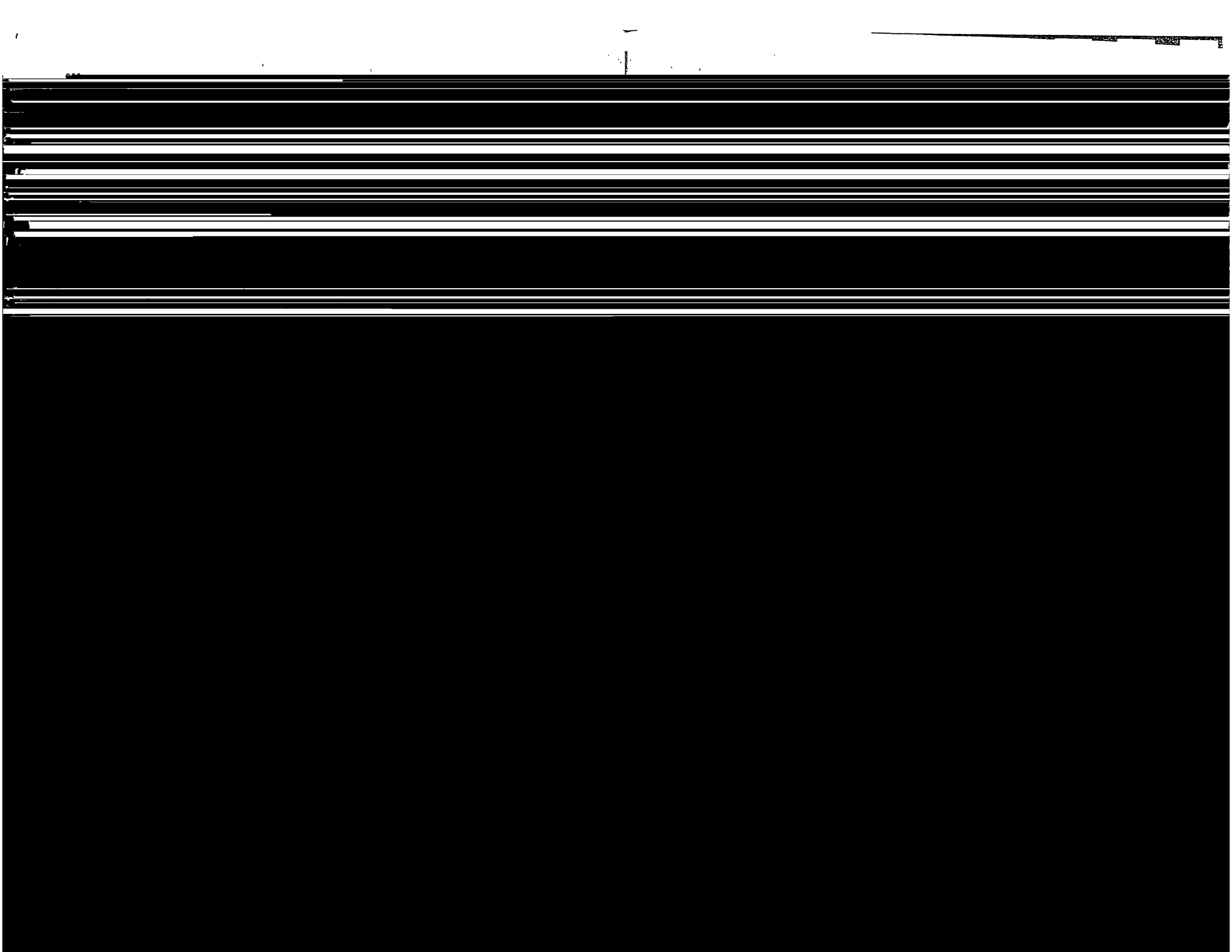


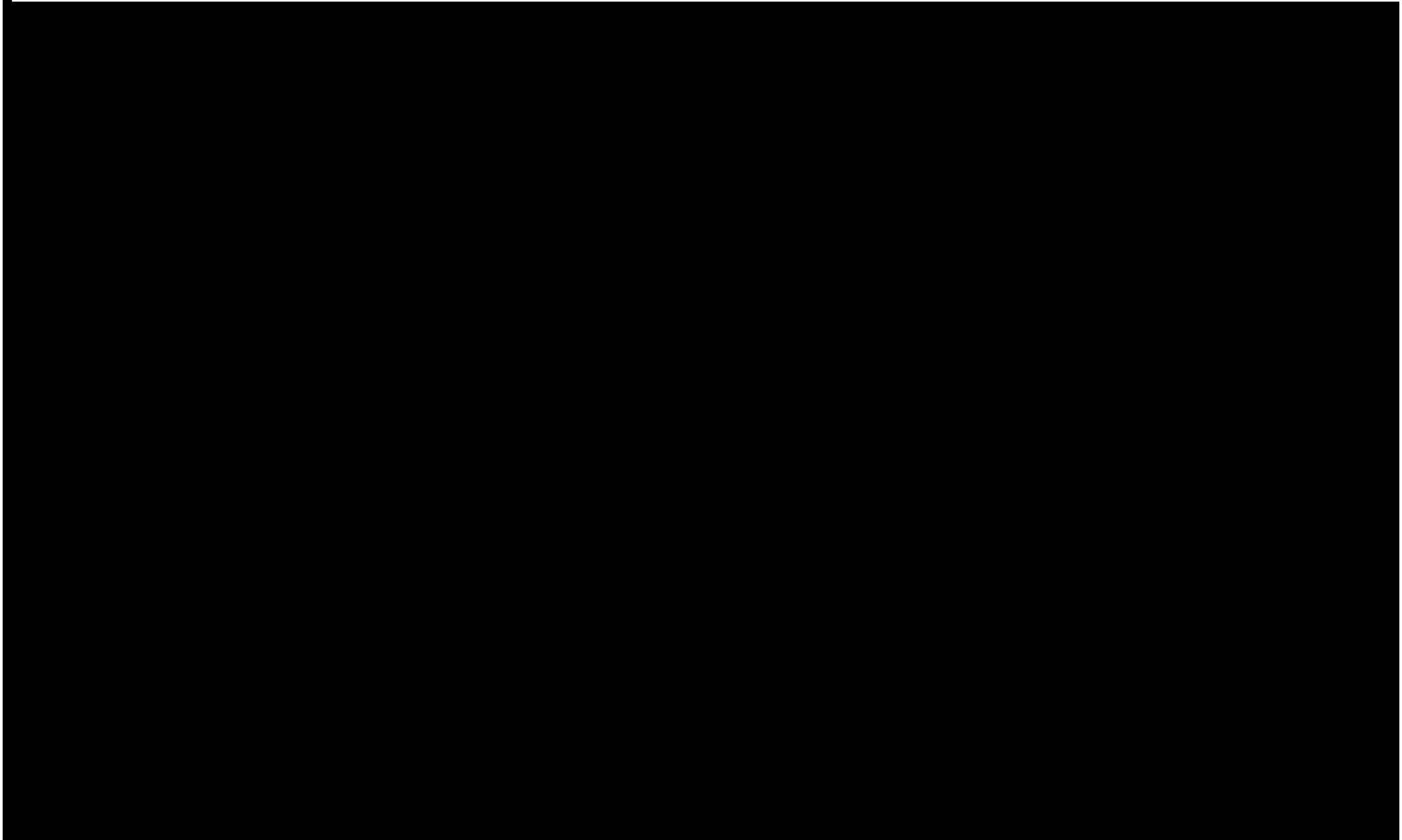




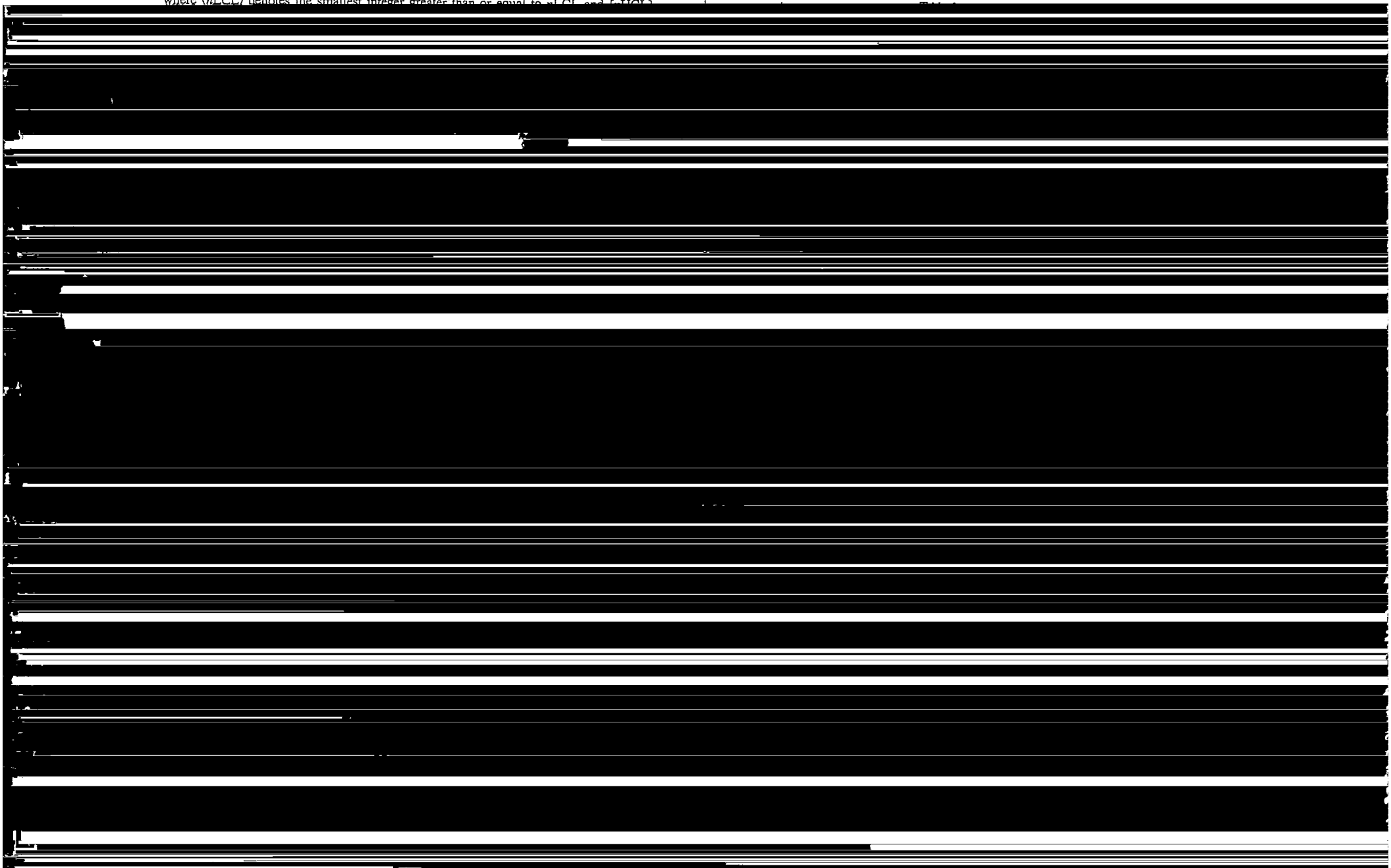


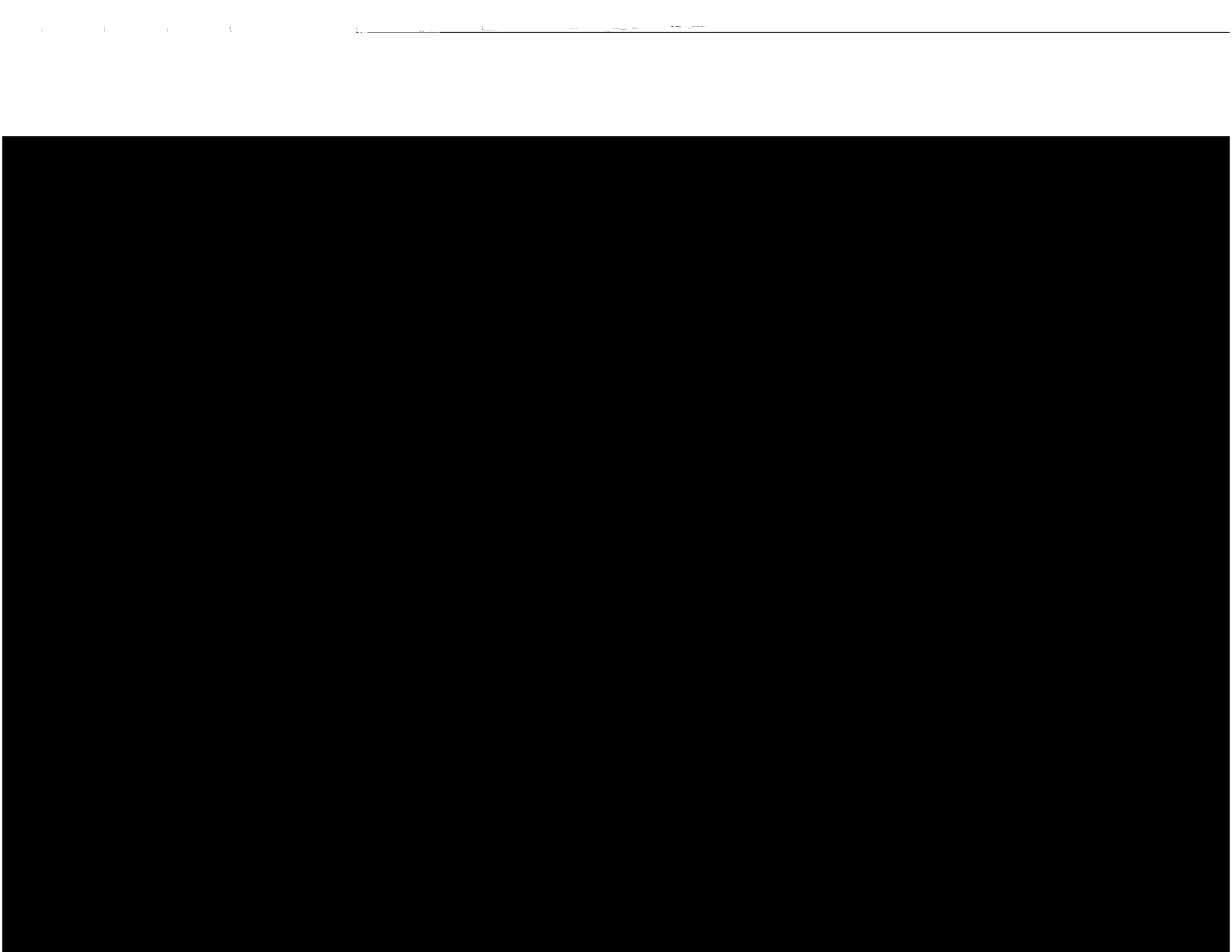






where  $\langle nLCL \rangle$  denotes the smallest integer greater than or equal to  $nLCL$  and  $\langle nUCL \rangle$

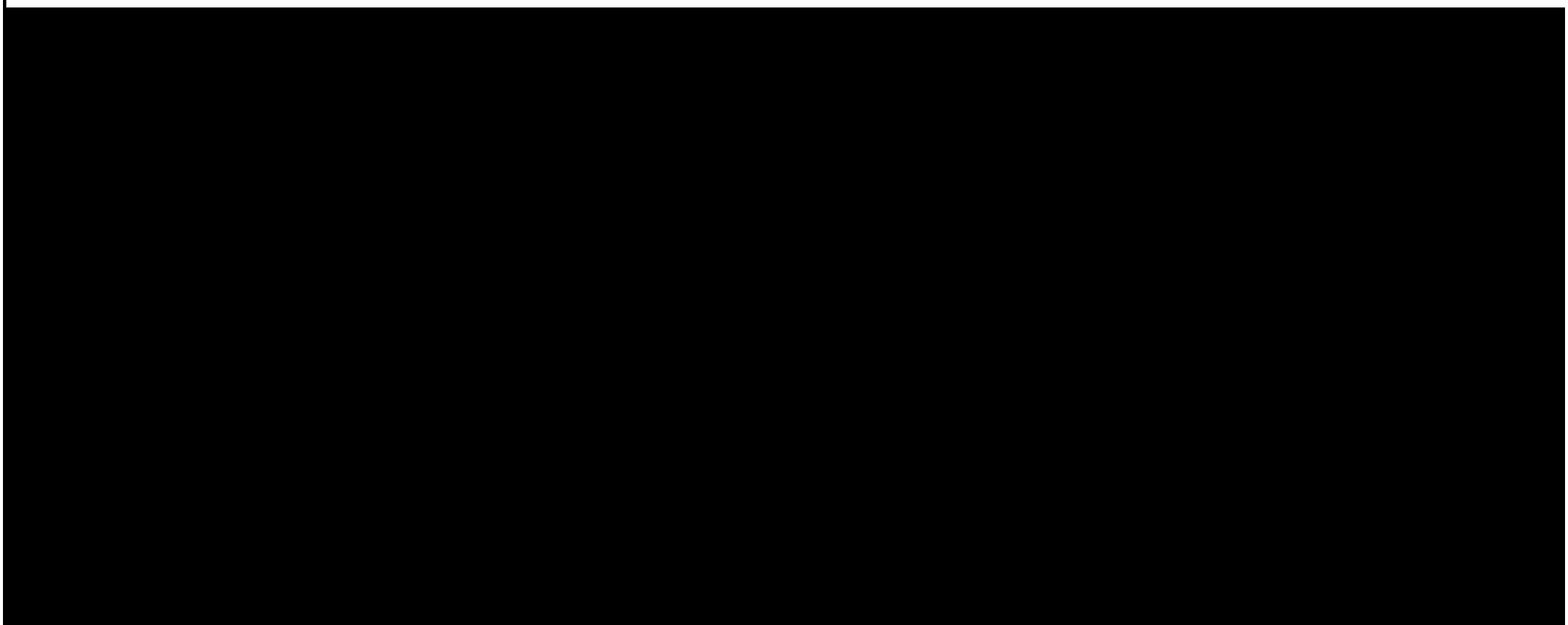
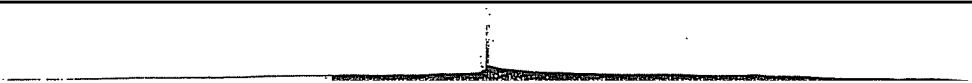
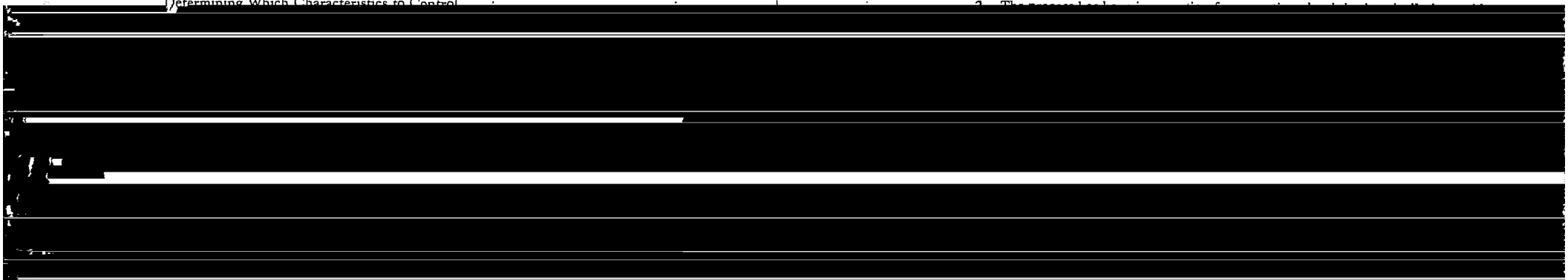








Determining Which Characteristics to Control



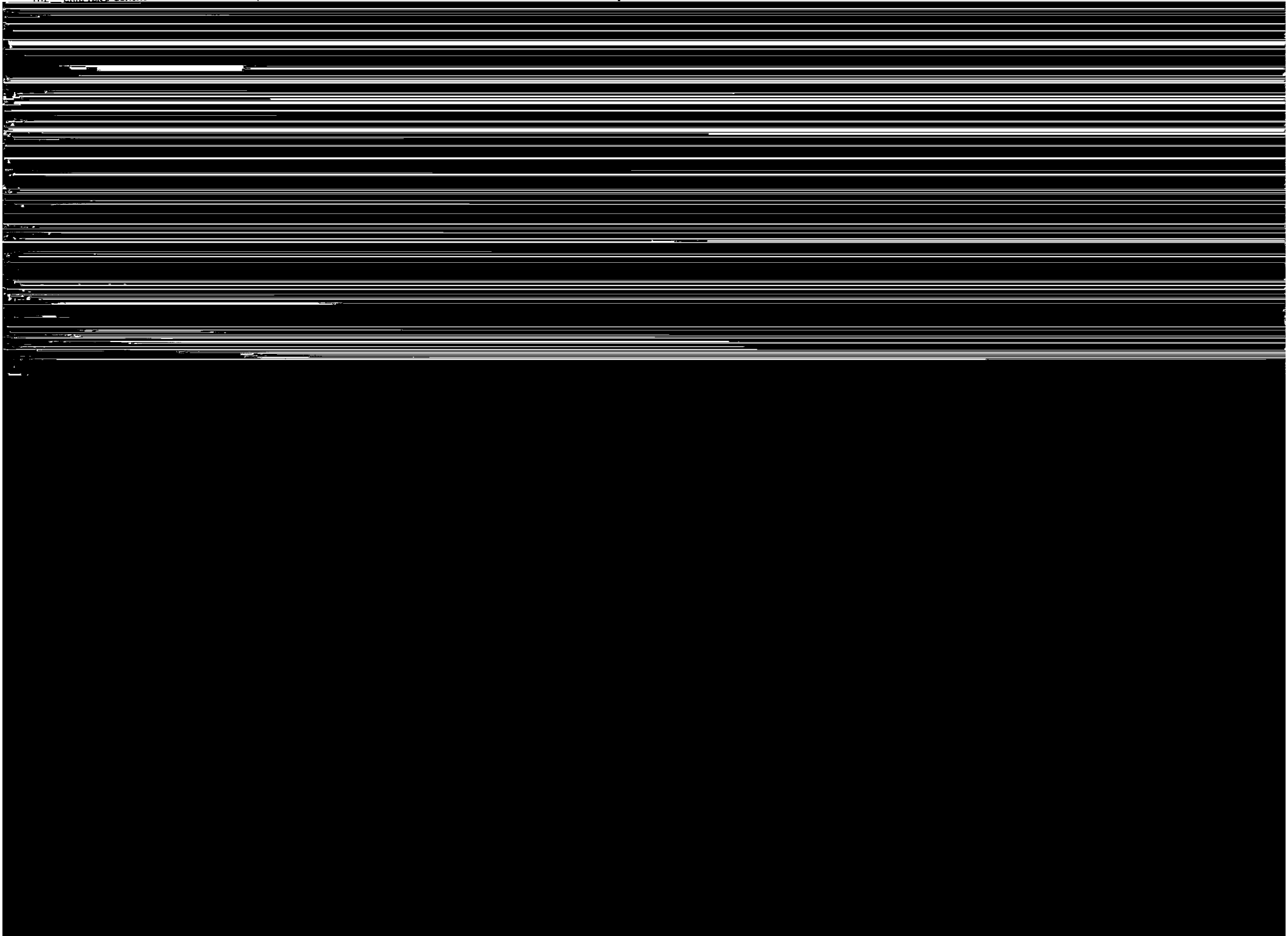




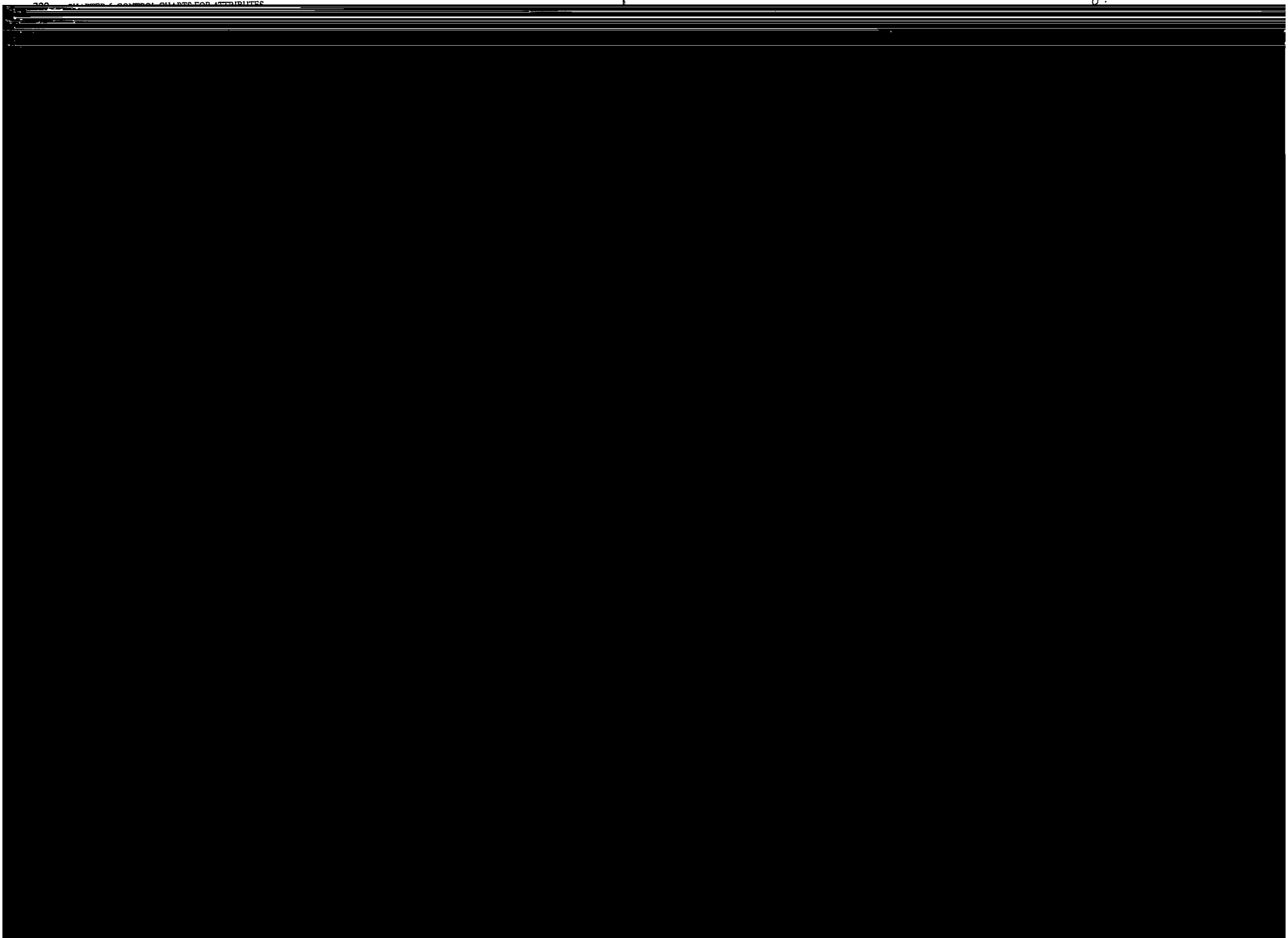
tailor or customize the system for each application, although this installation cost

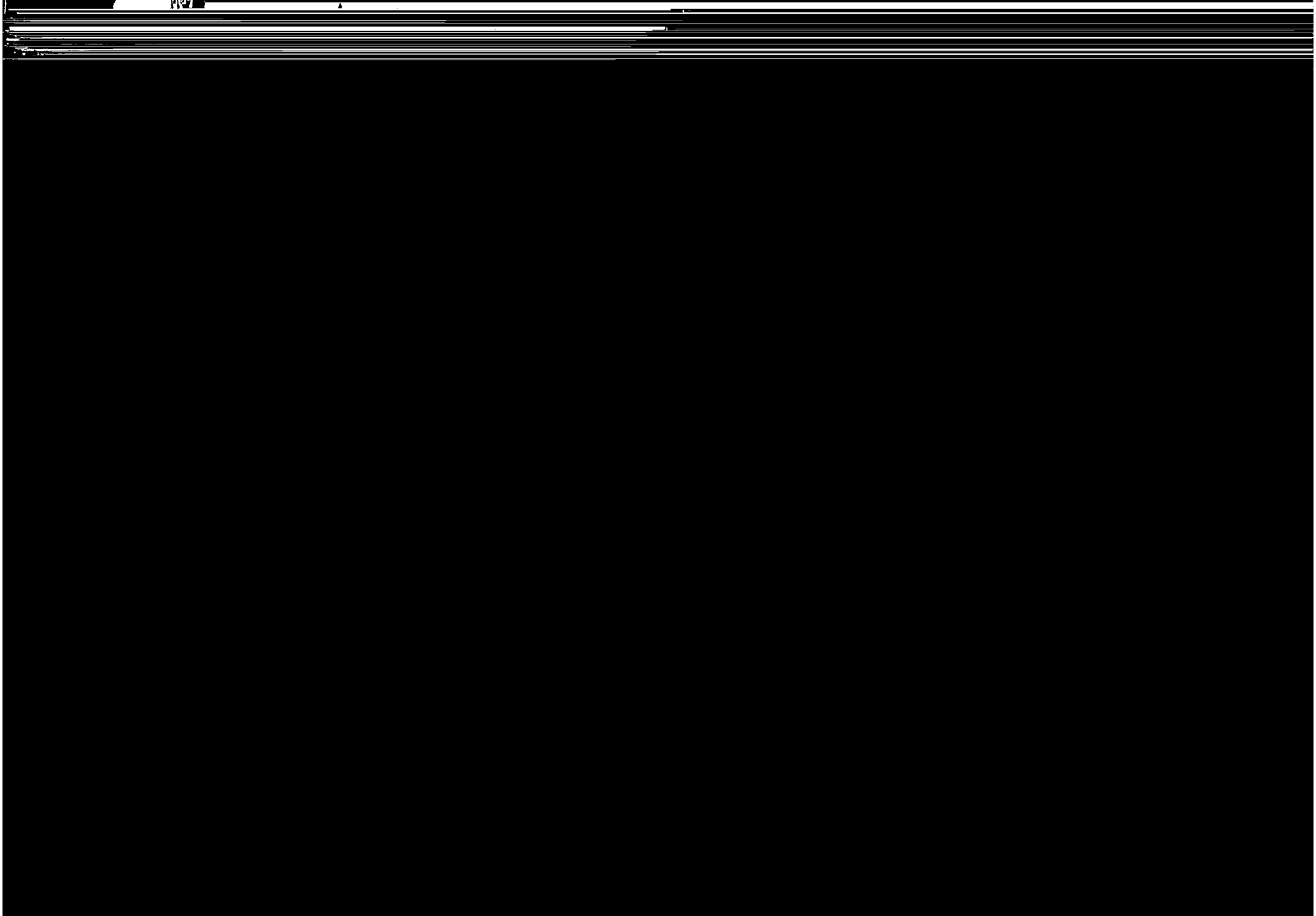


### EXERCISES



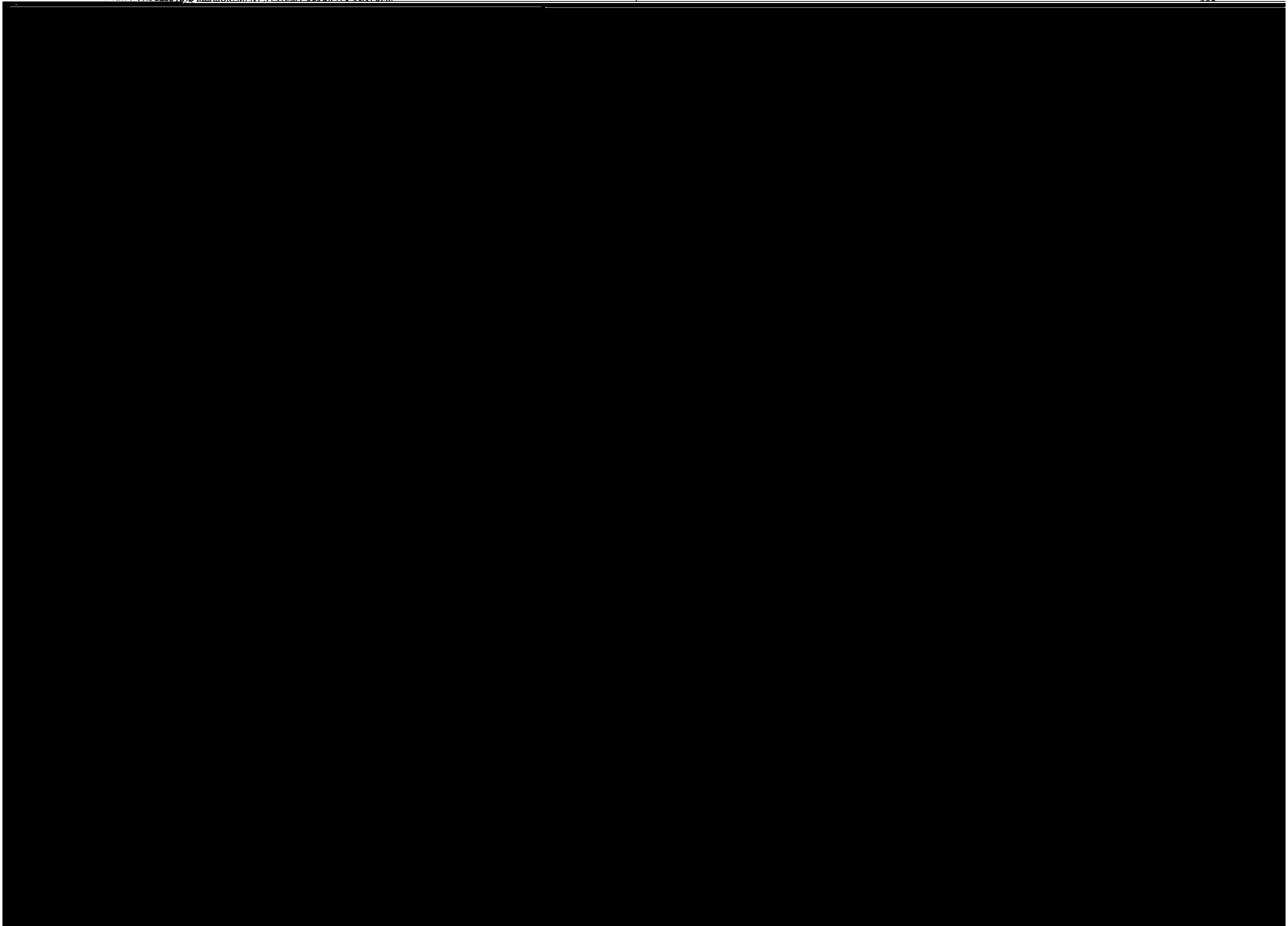




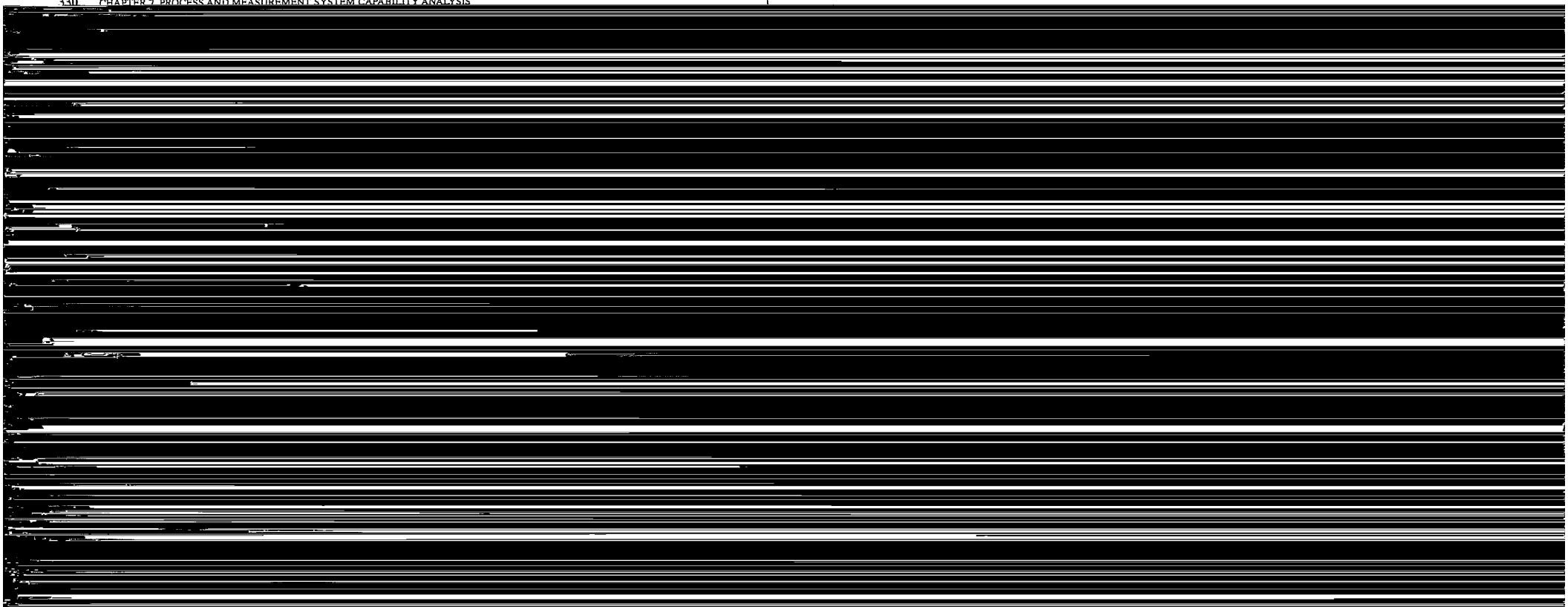


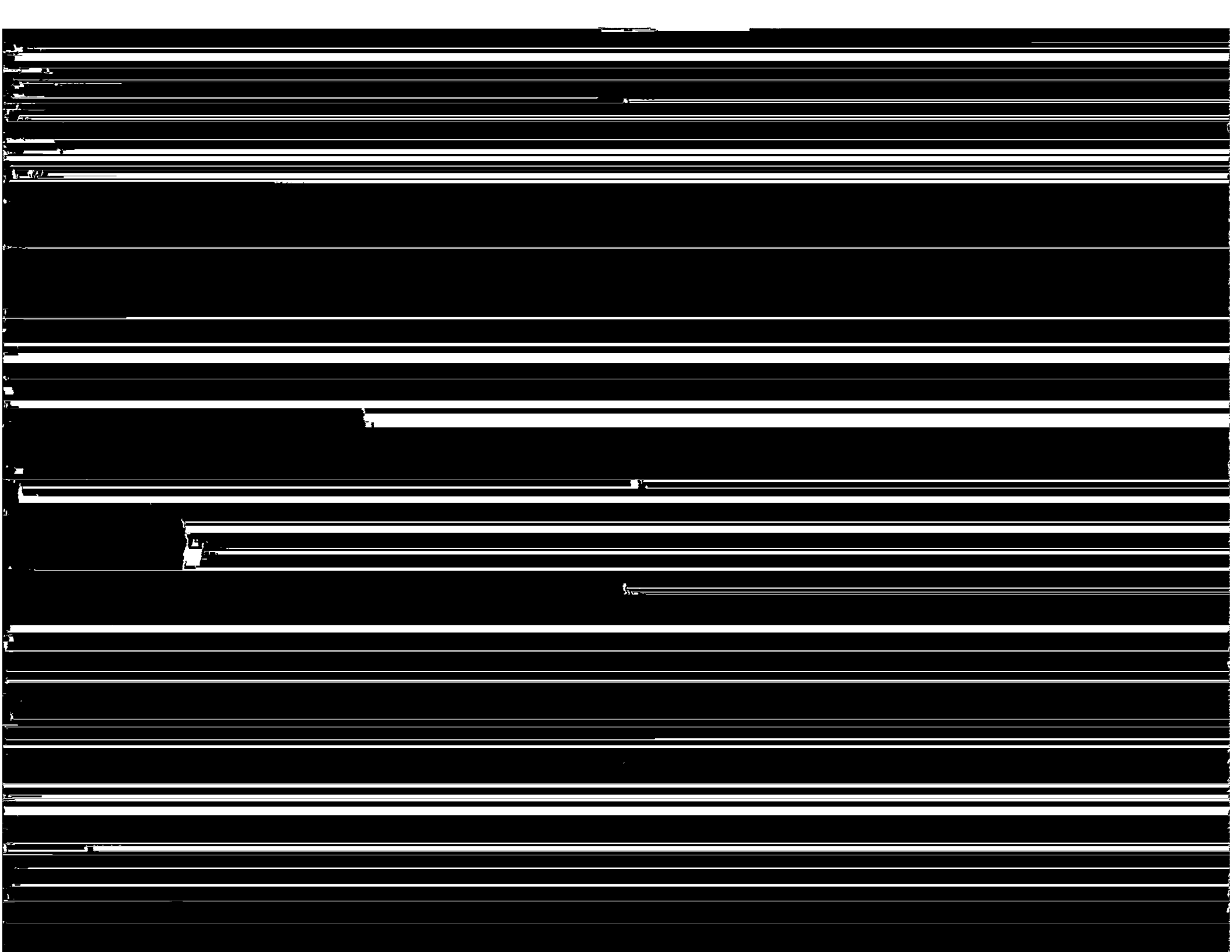
... illustrating graphical methods as well as

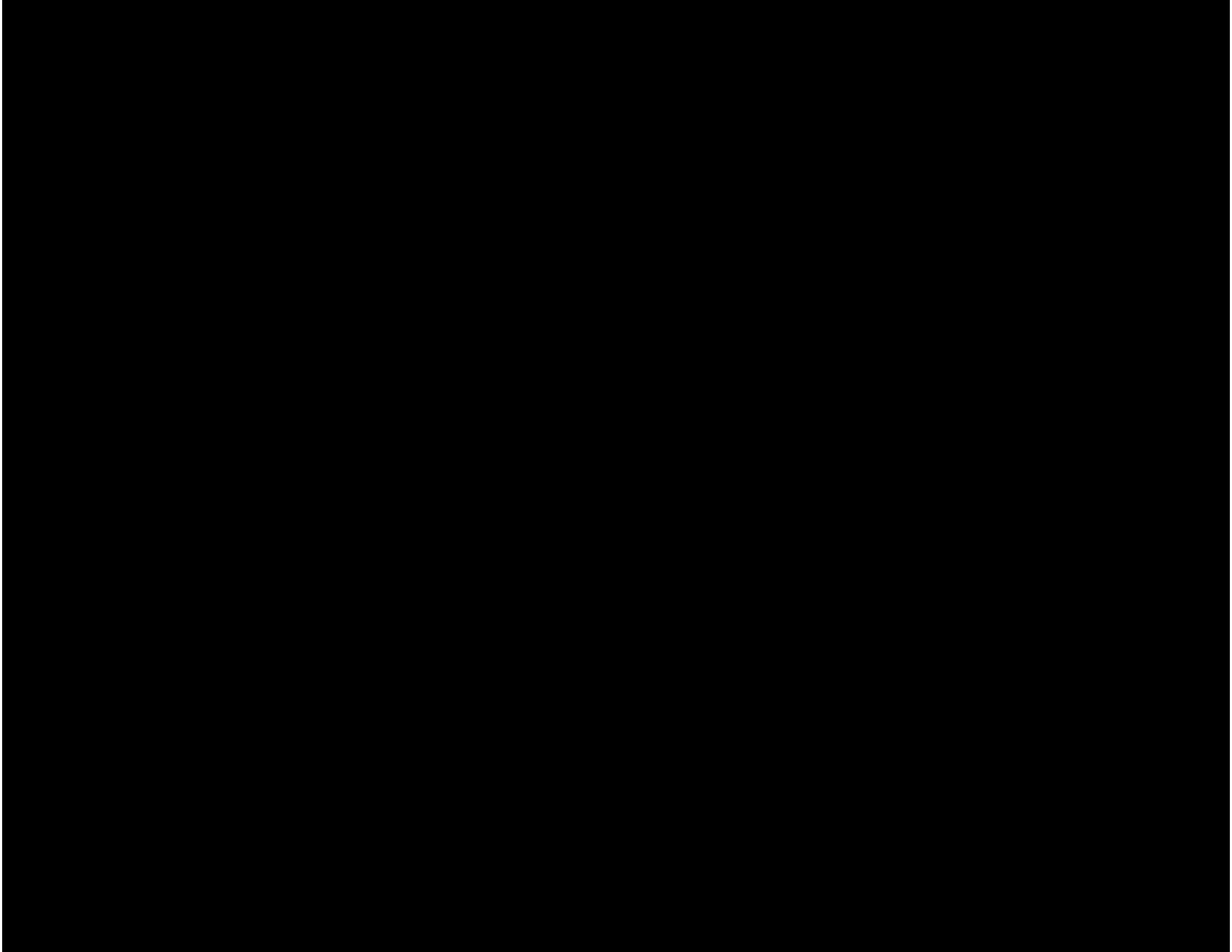


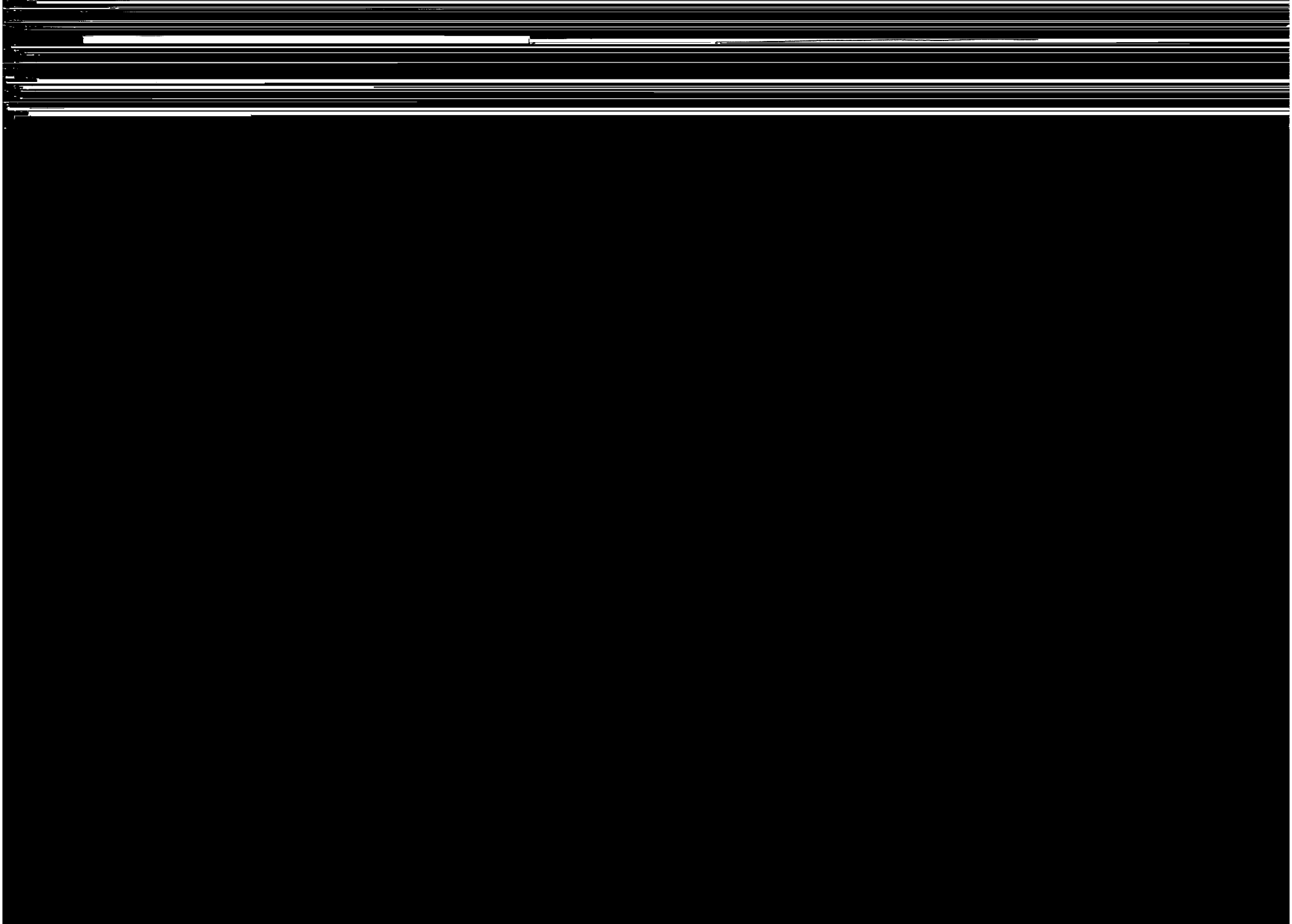










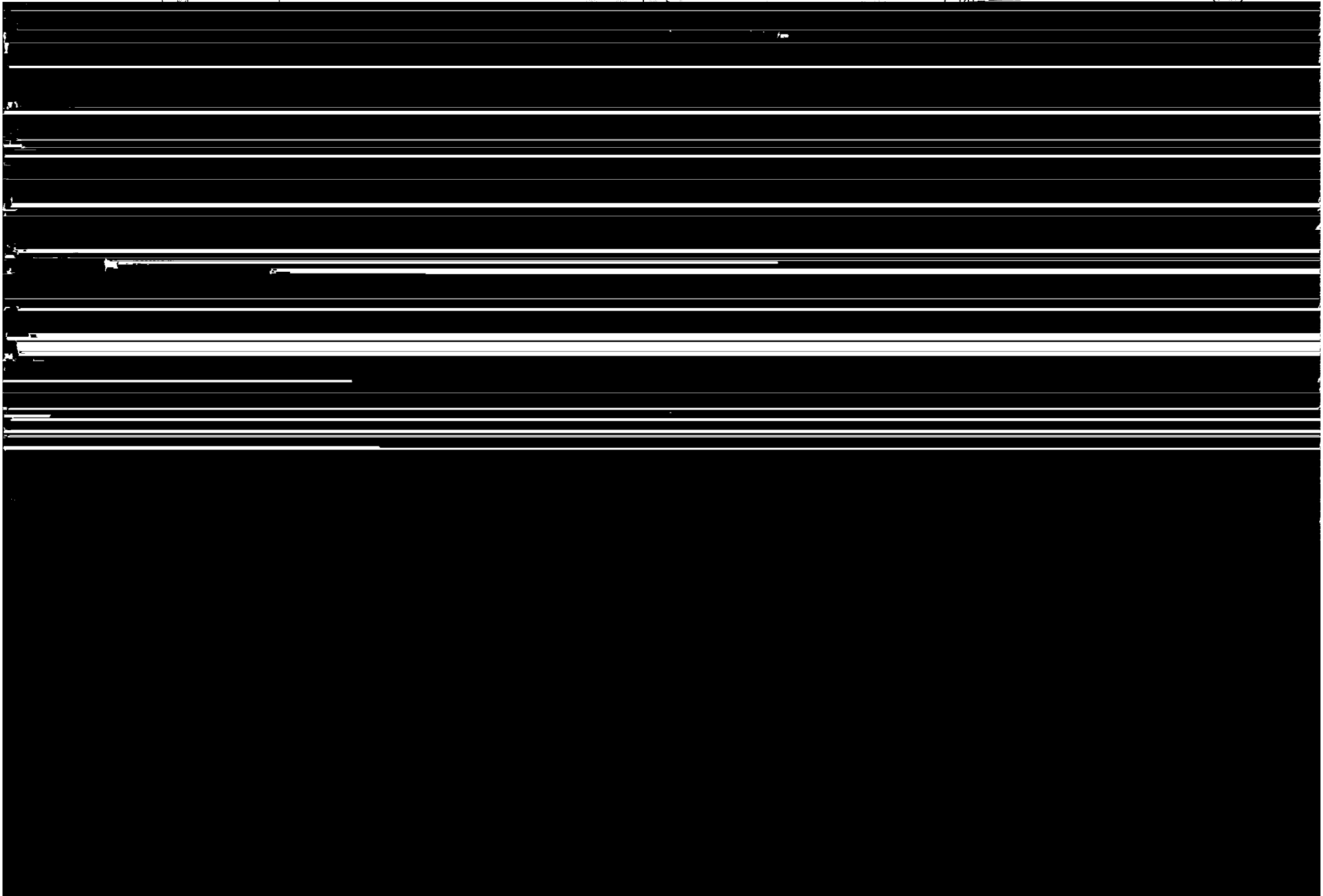


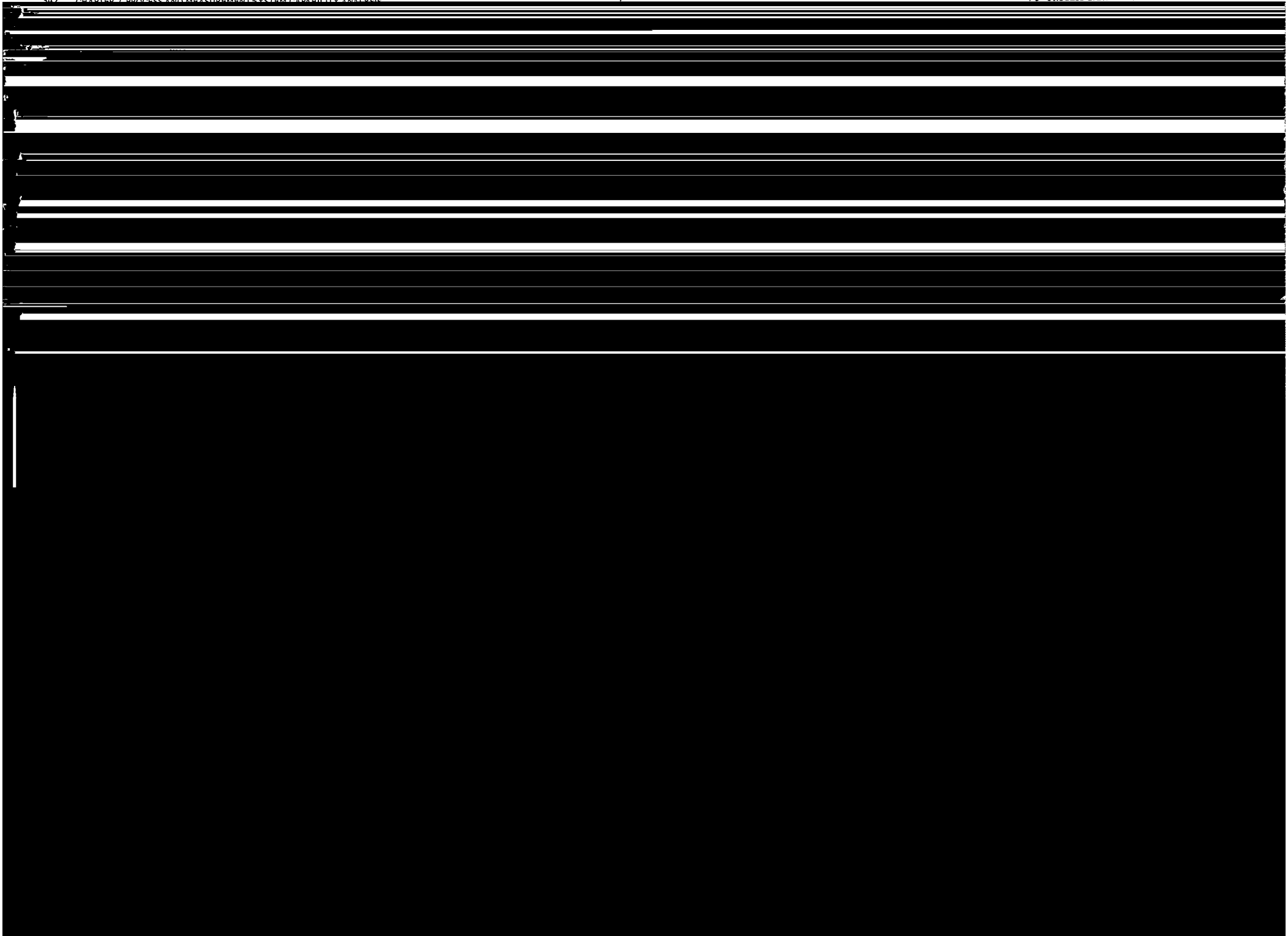


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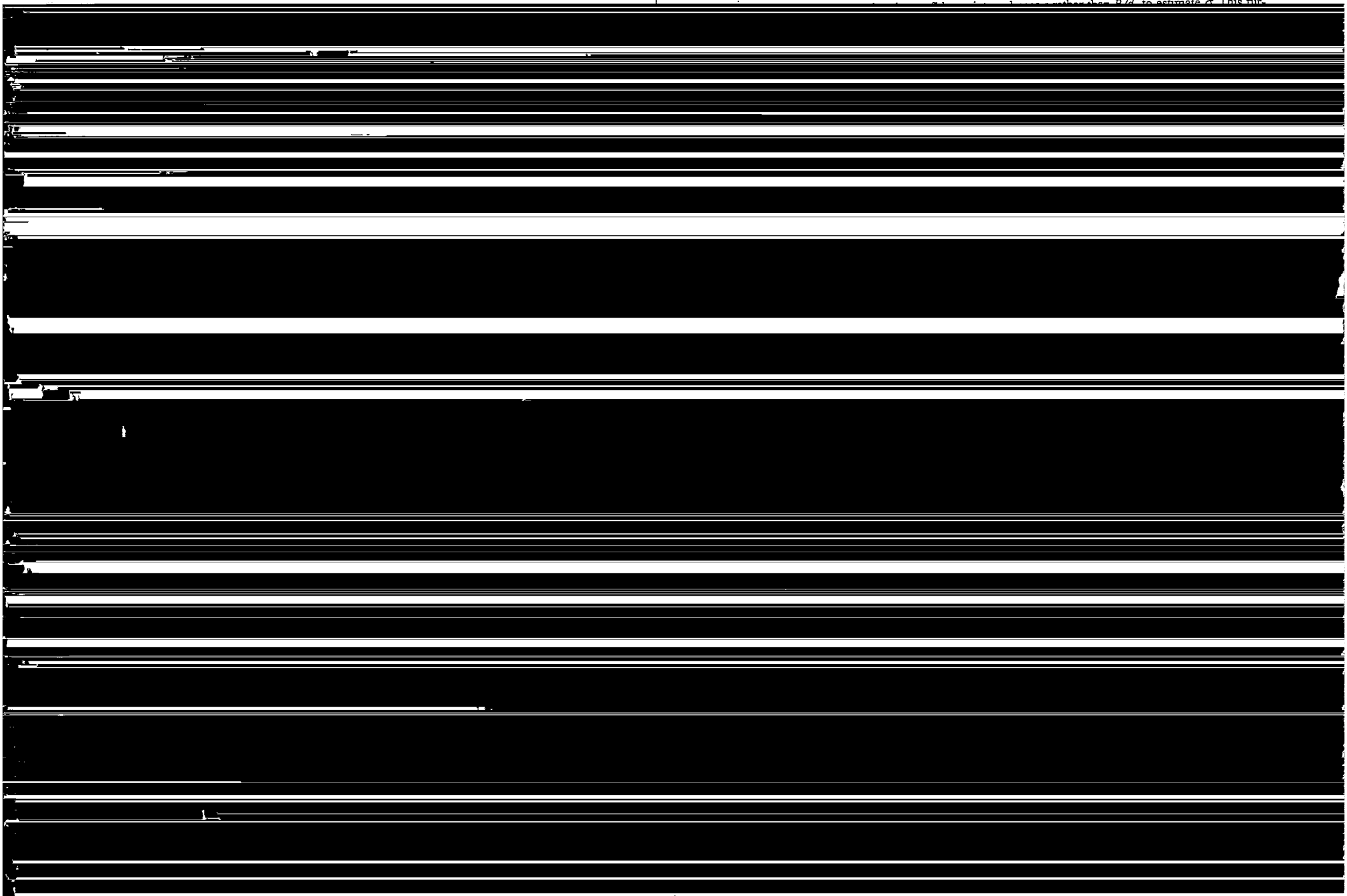


$$C_p = \frac{USL - LSL}{\sigma} \quad (7-11)$$

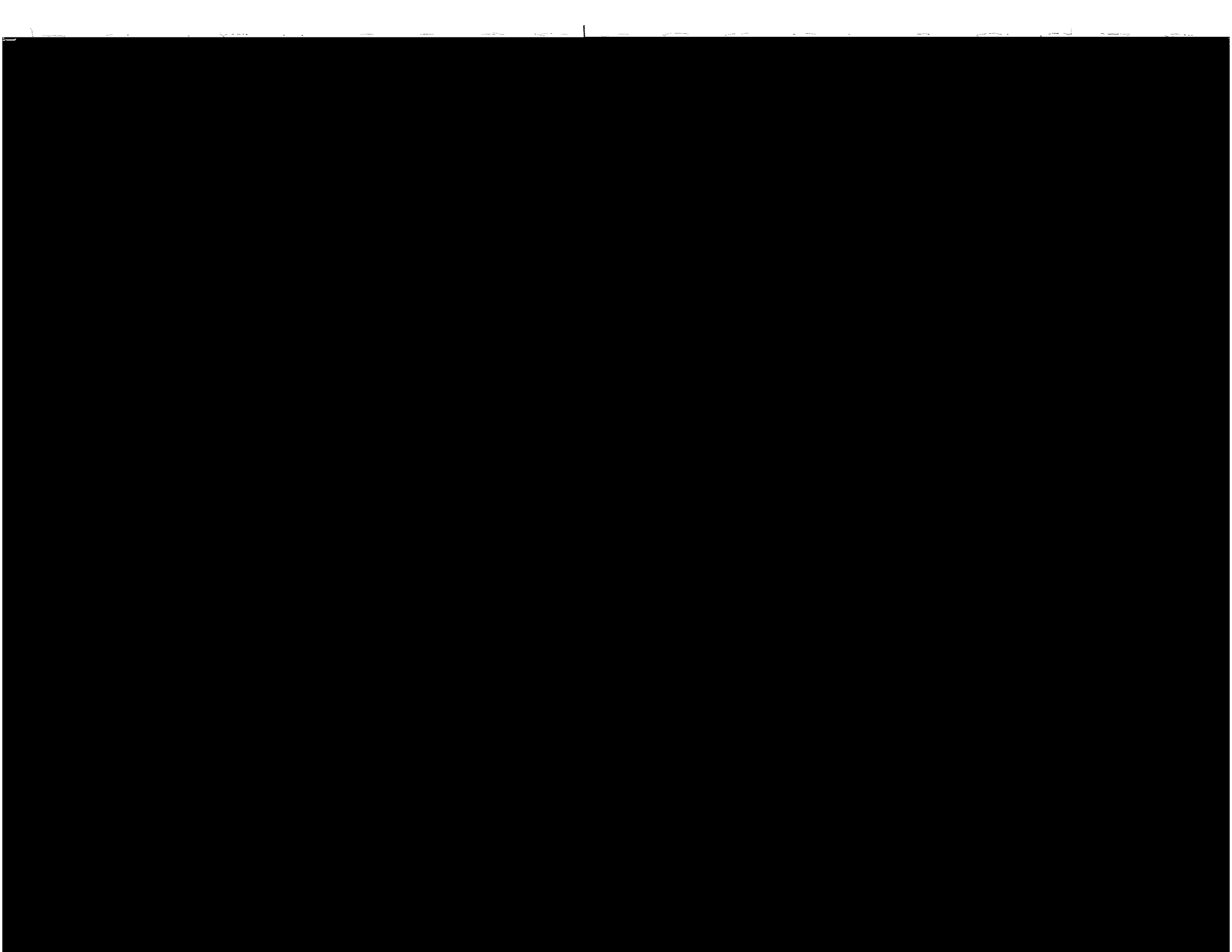




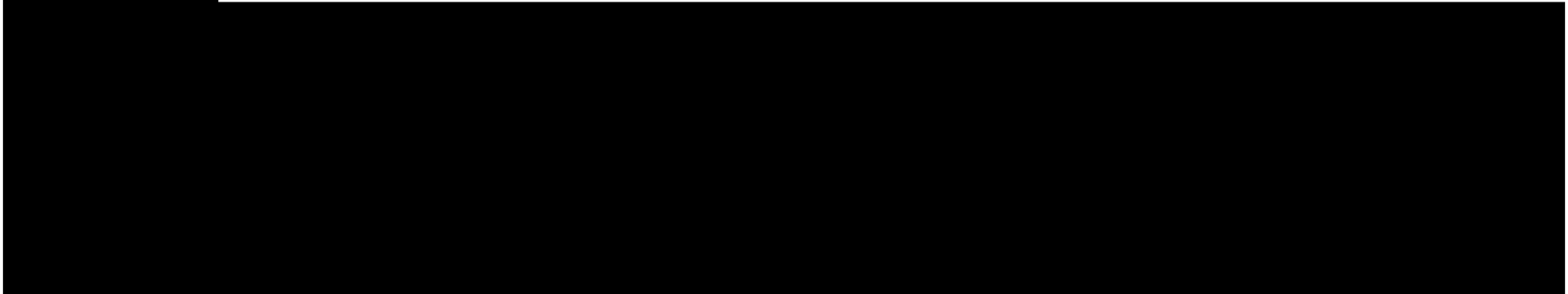
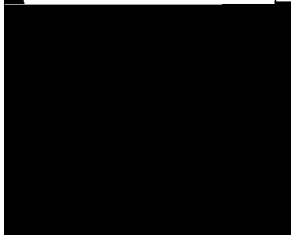
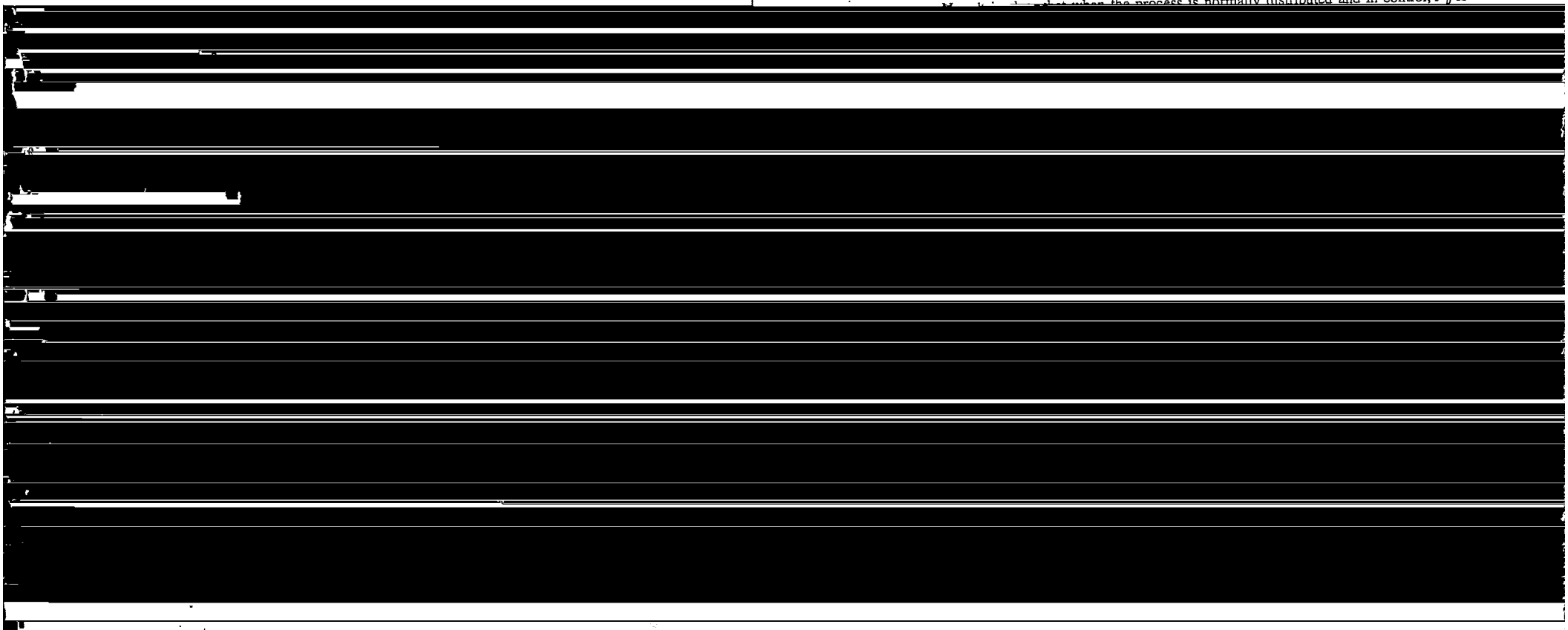
... rather than  $\bar{\bar{x}}$  to estimate  $\sigma$ . This fur

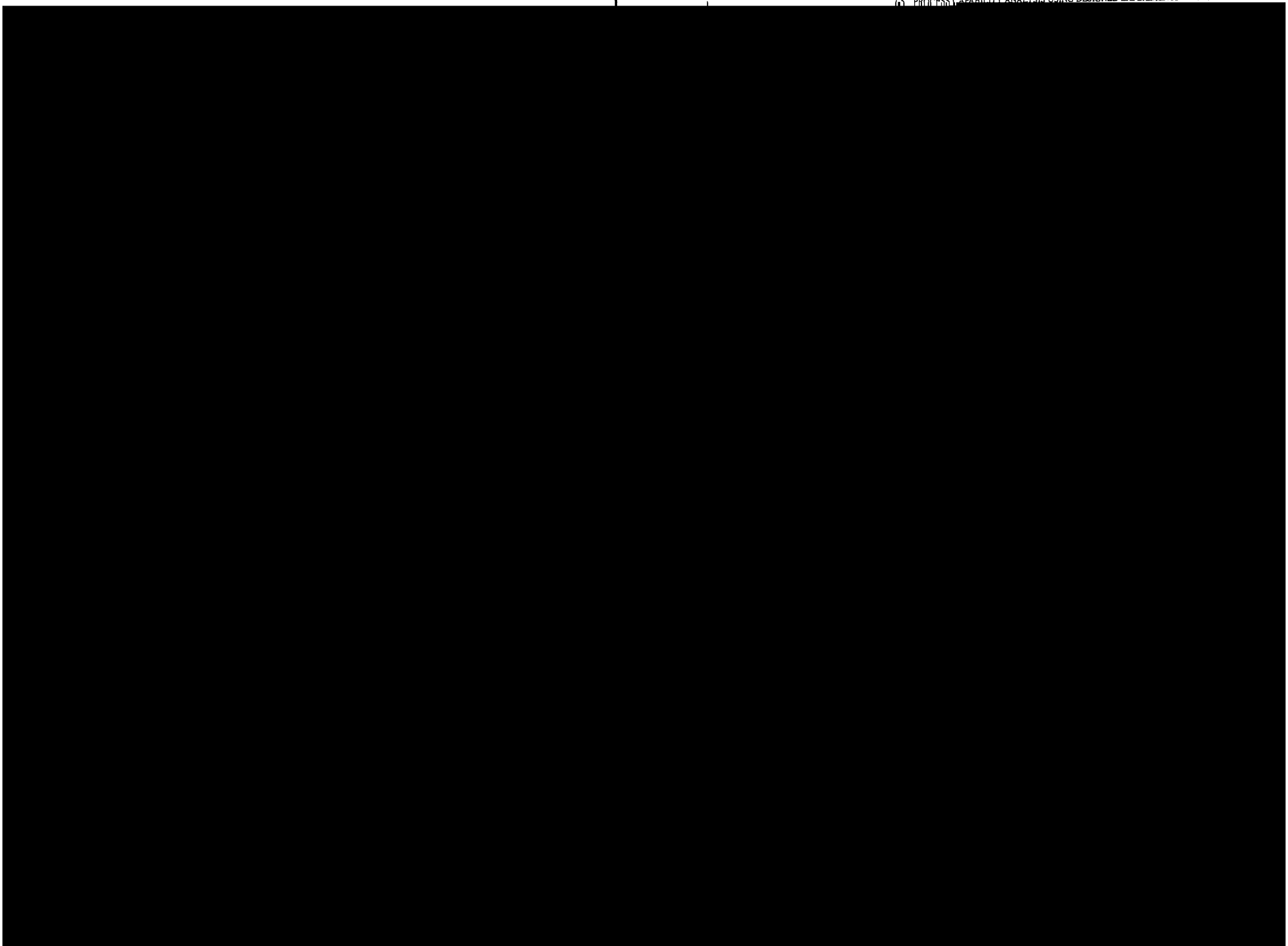






... that when the process is normally distributed and in control,  $\bar{\bar{p}}$  is





Measurement variability

measured, and some of the variability will result from the measurement system that is



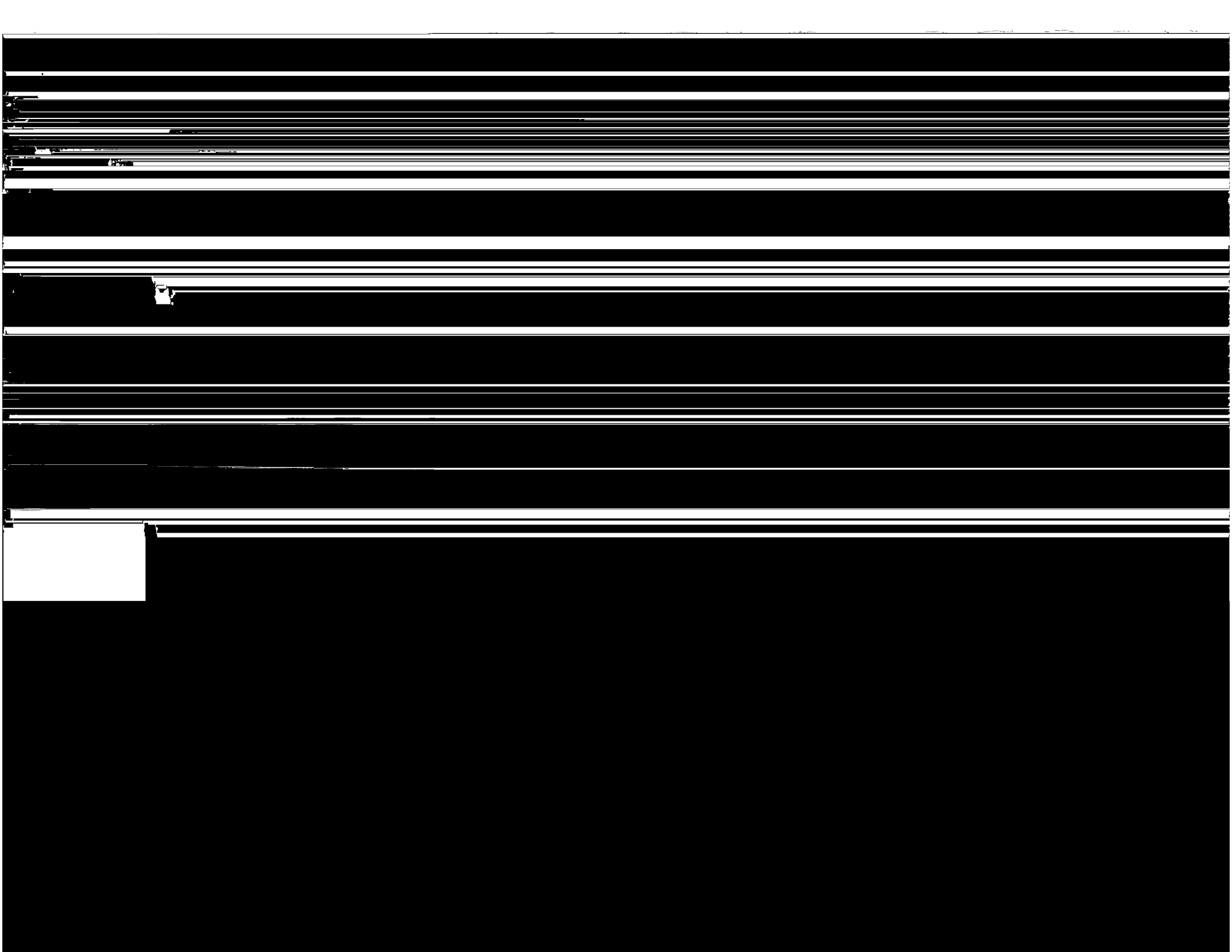


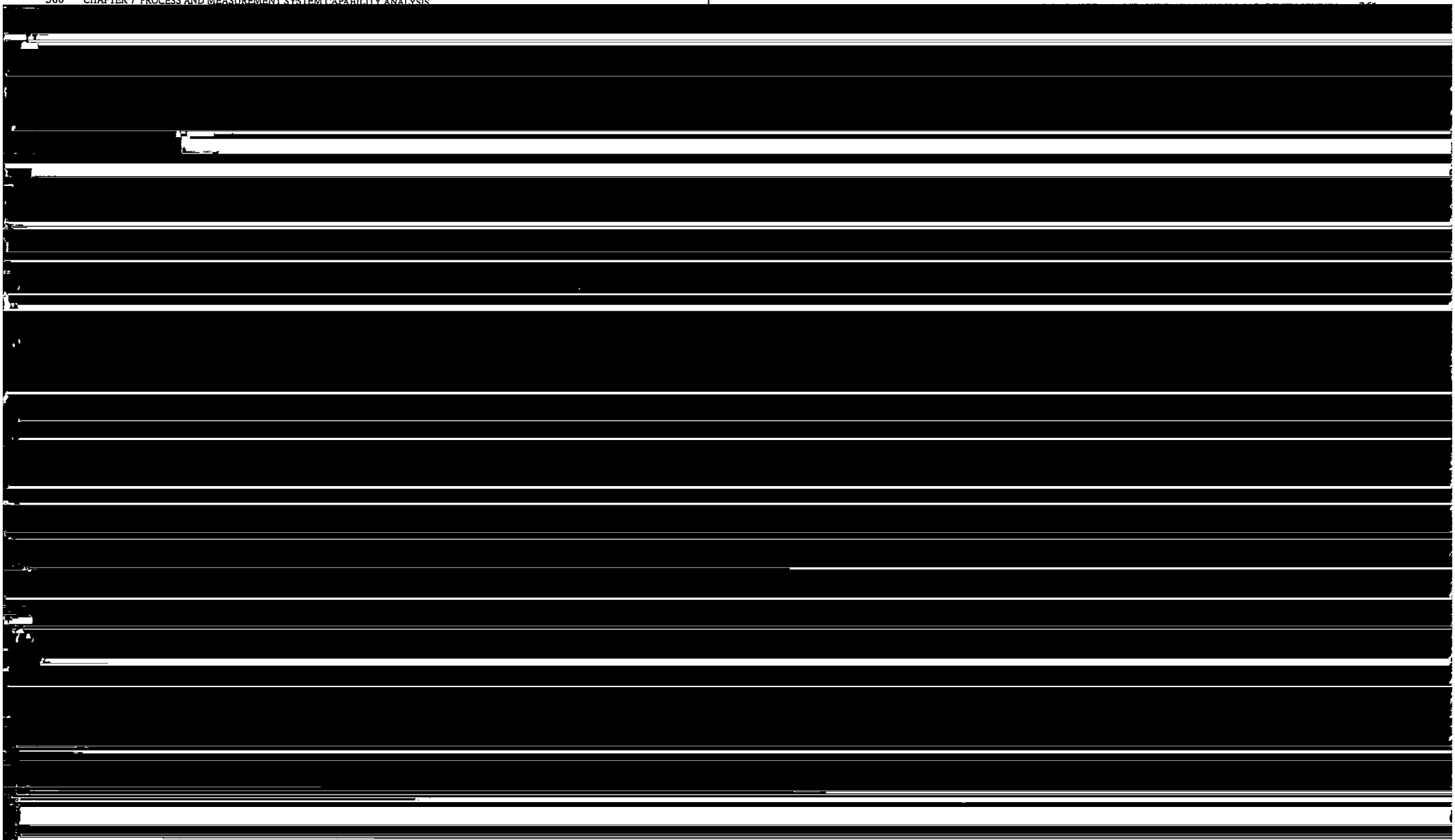
13

14

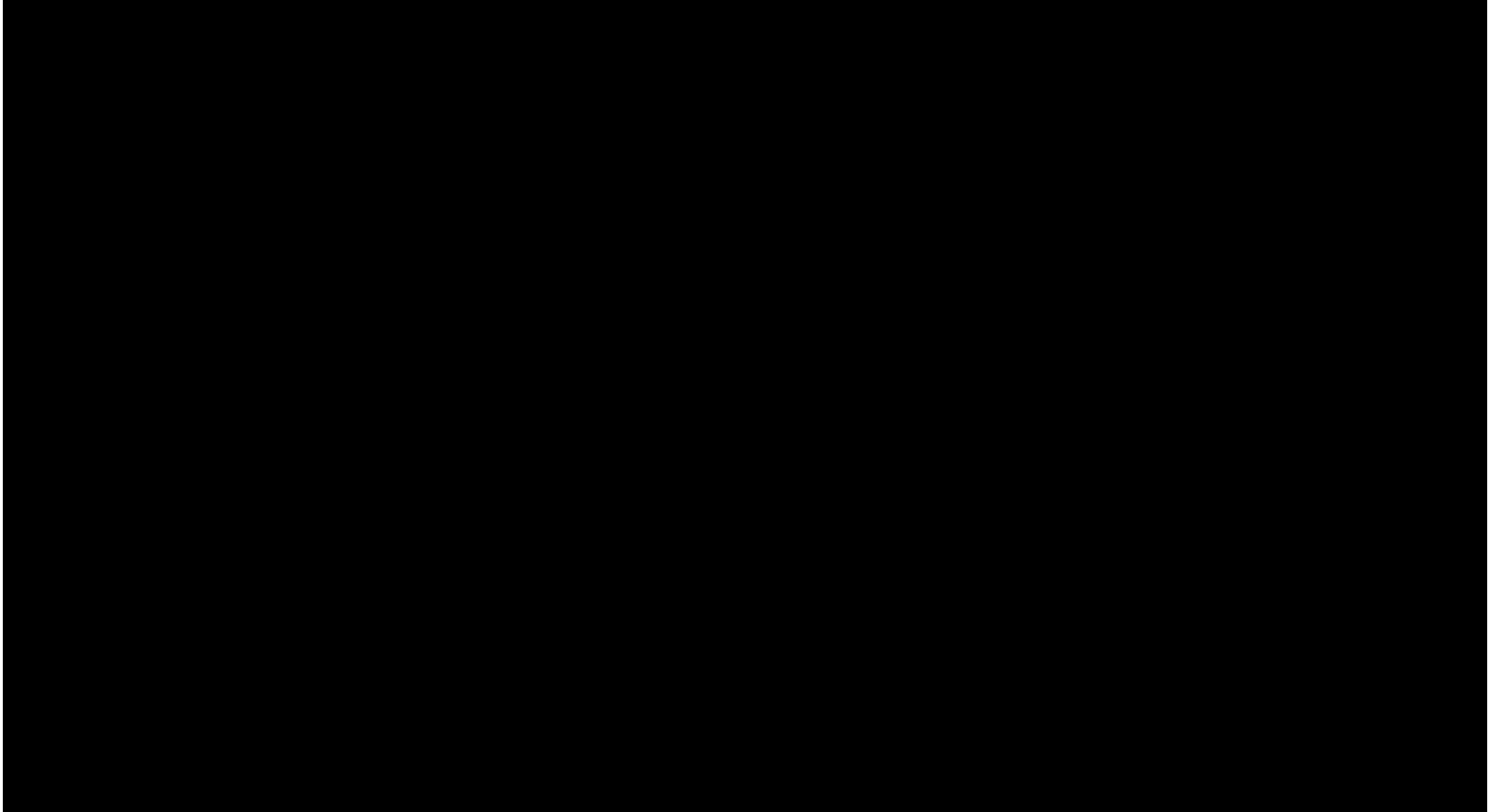
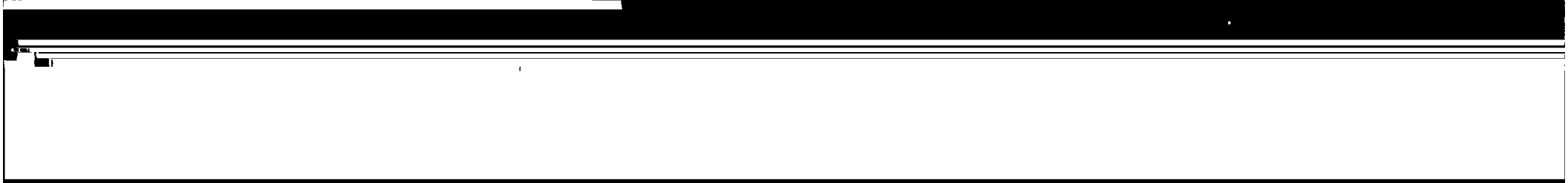
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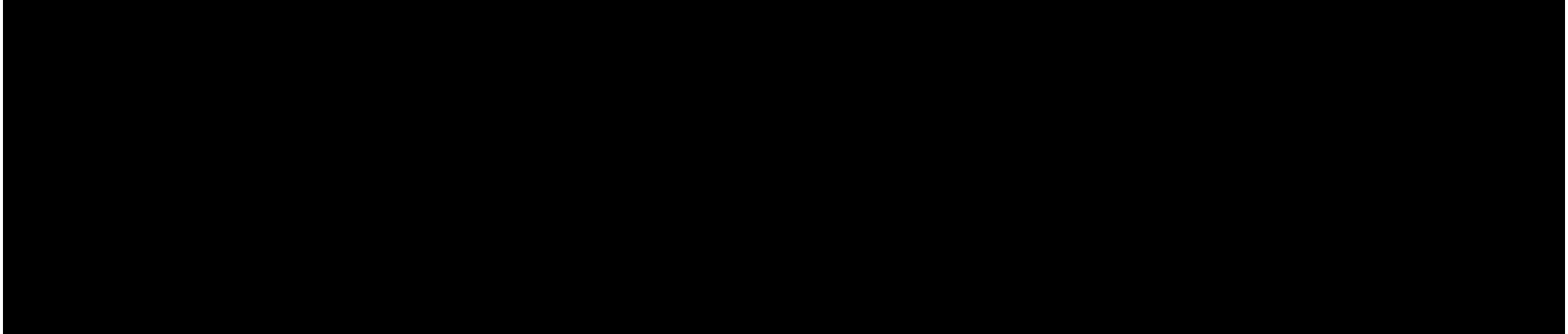
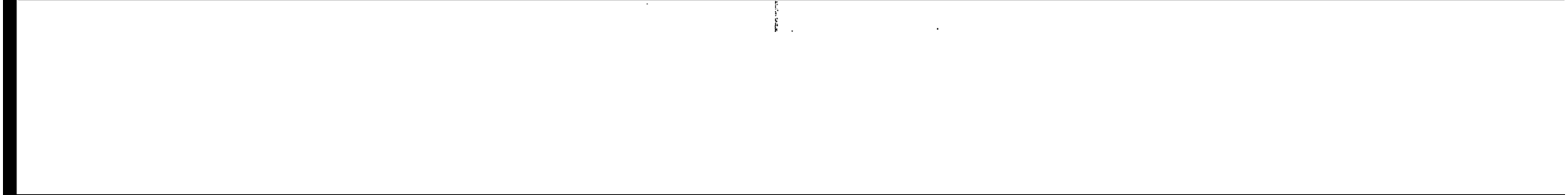
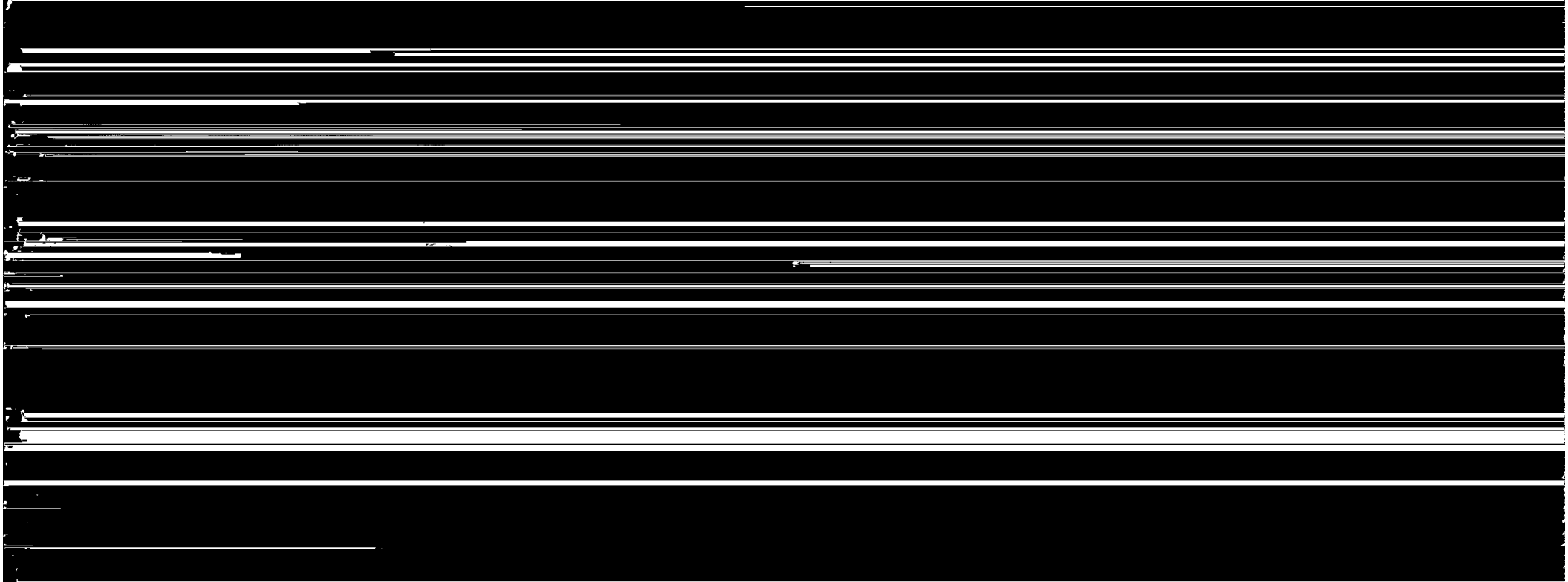
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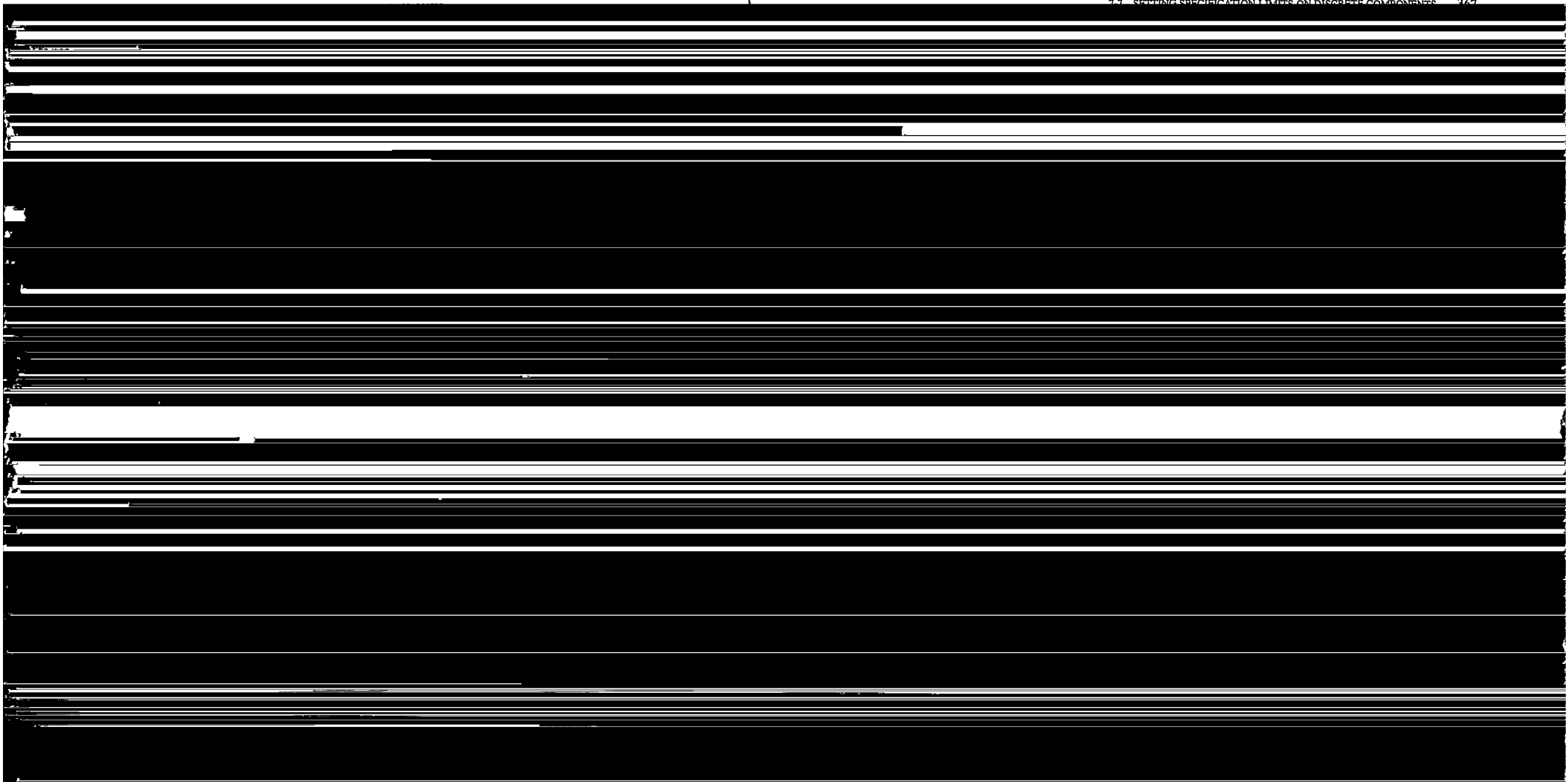






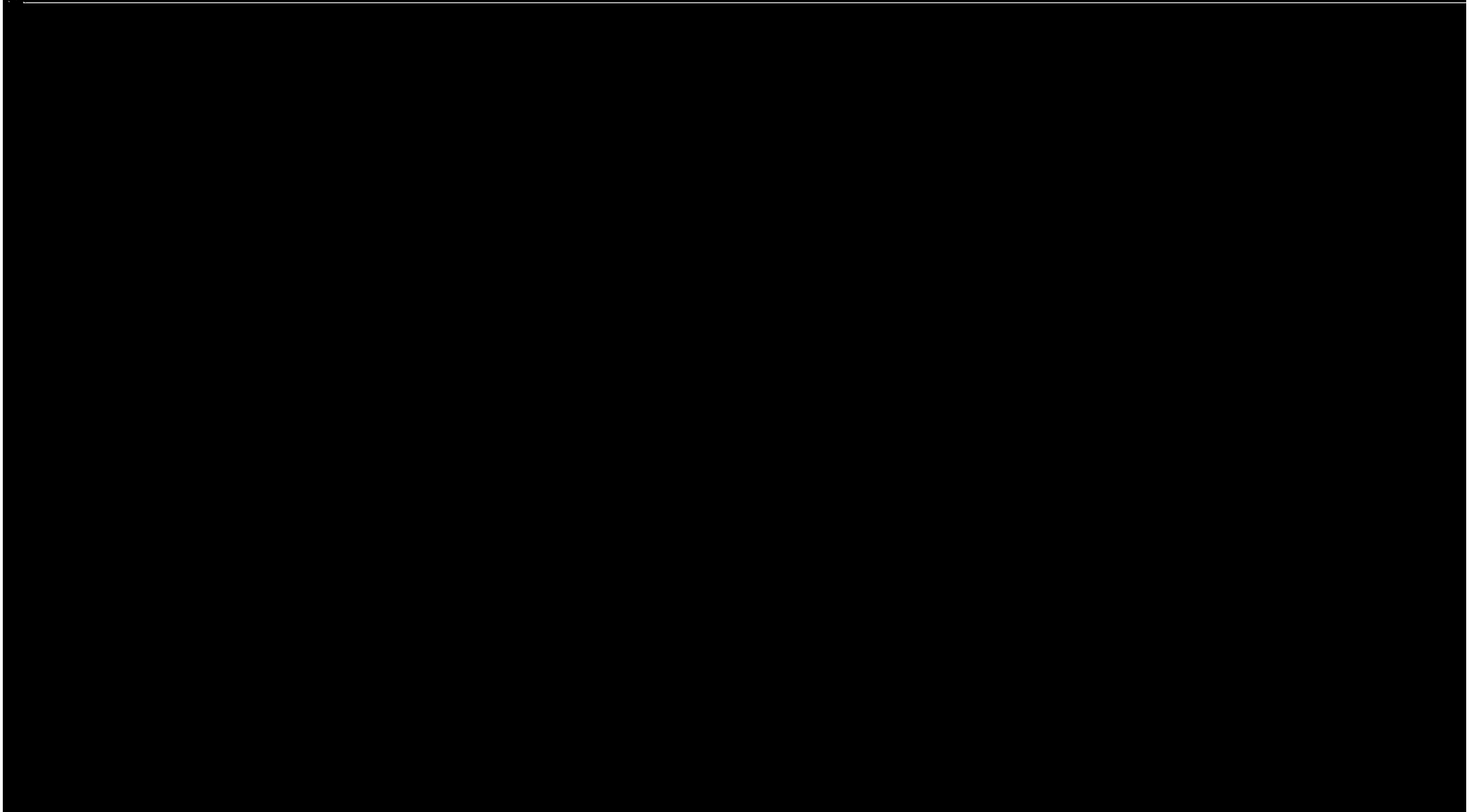


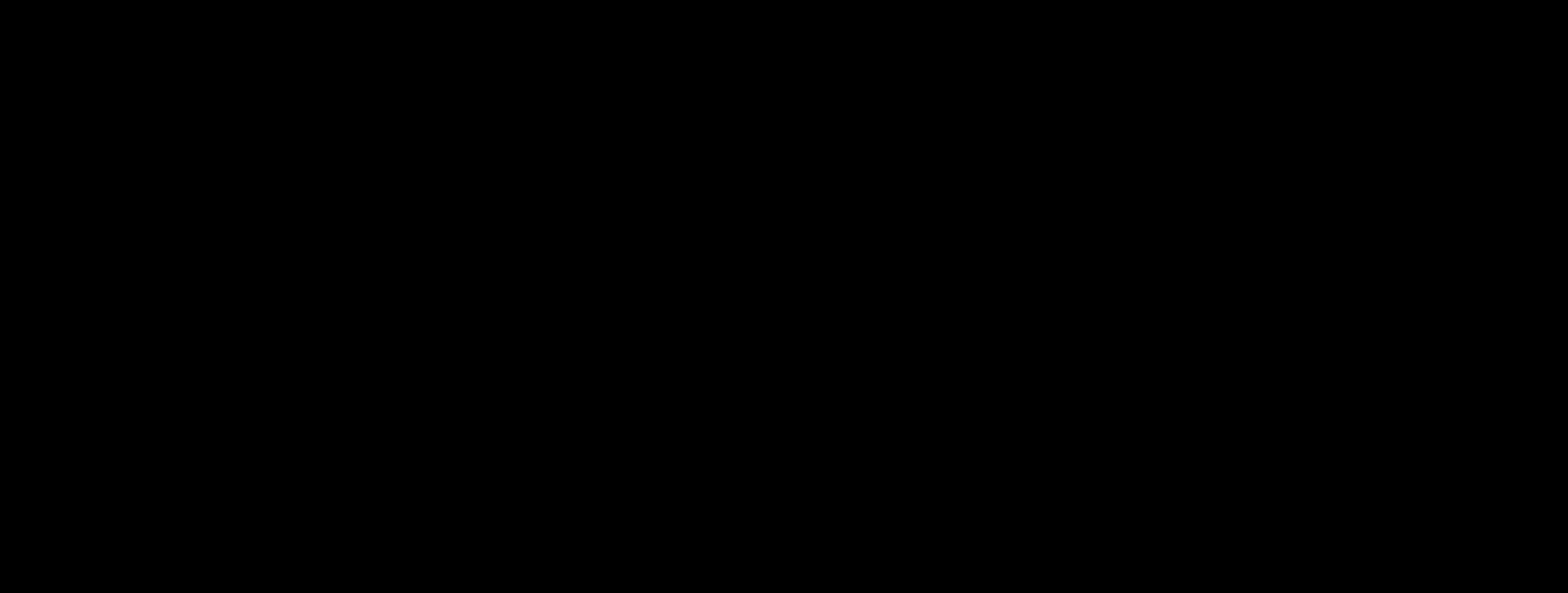
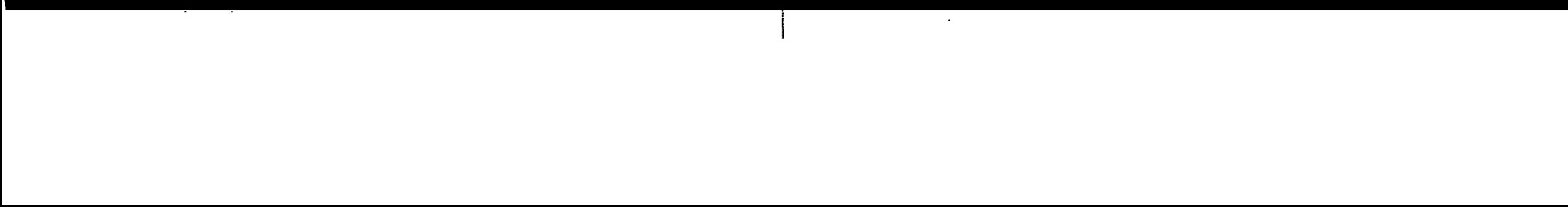
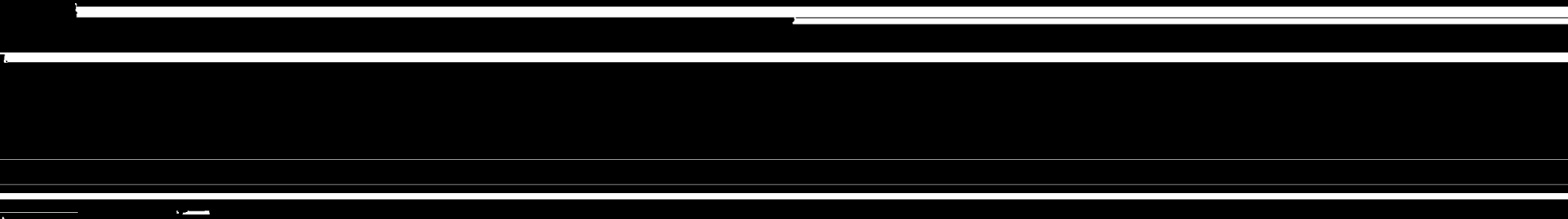




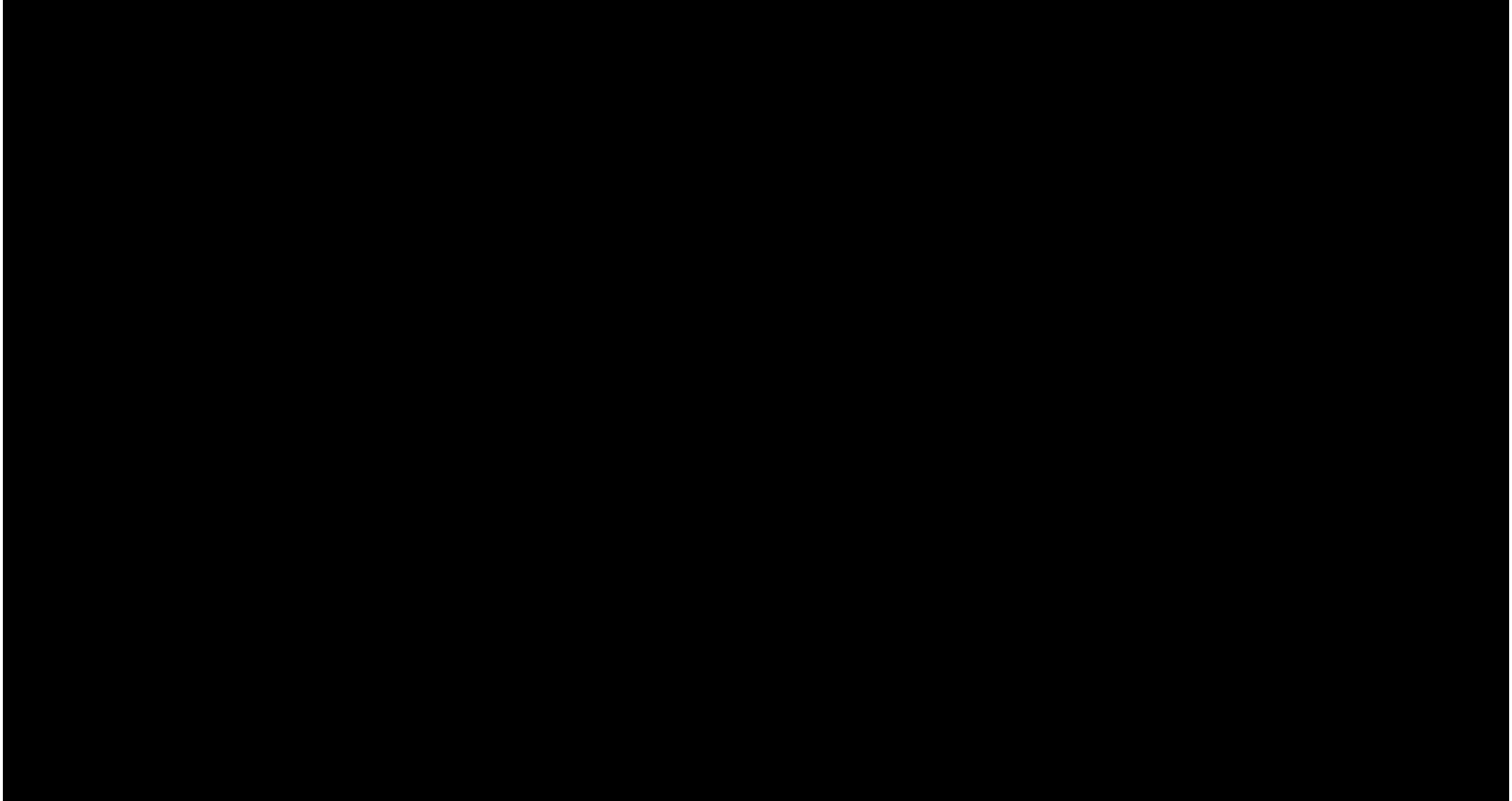
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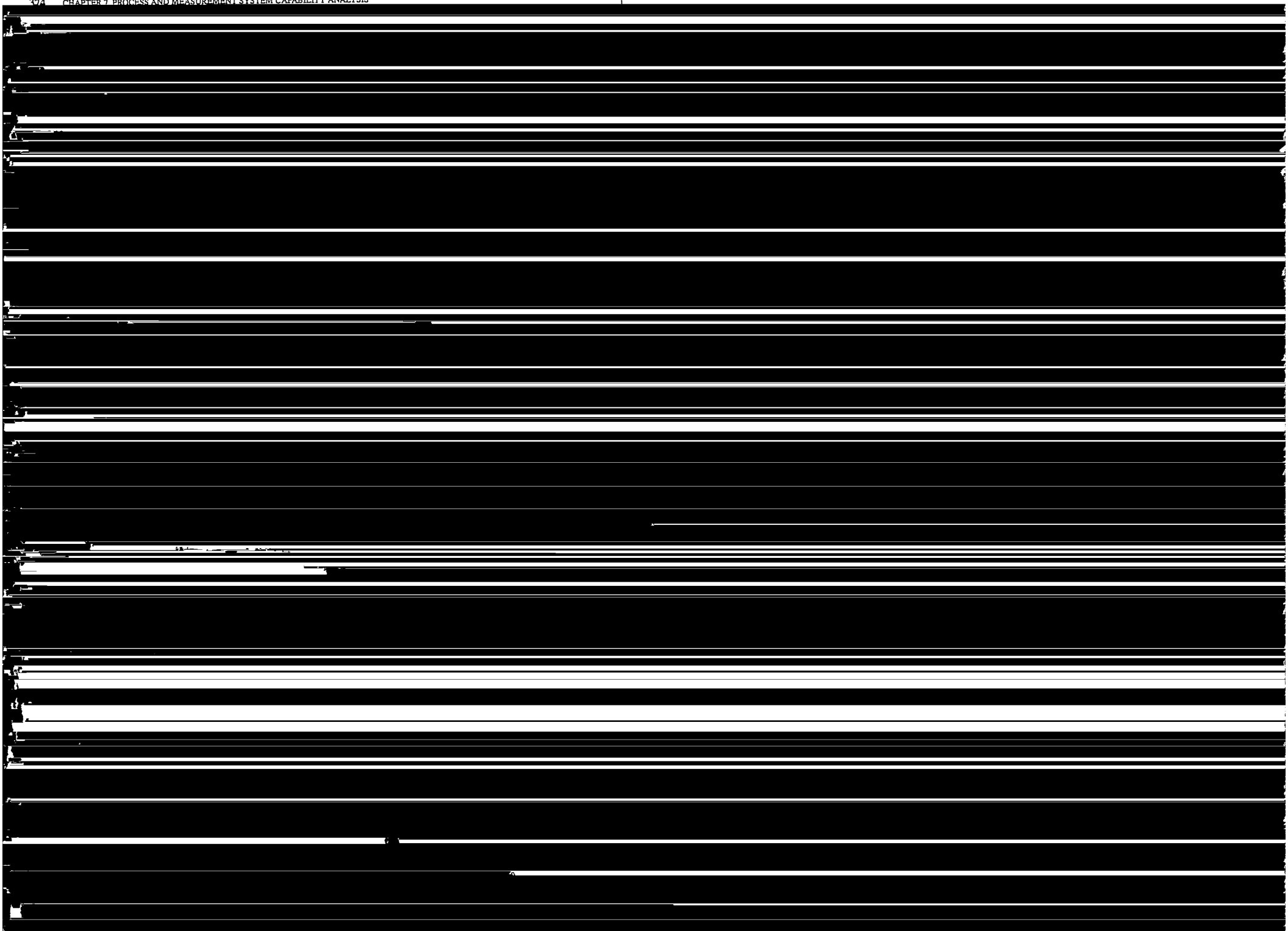
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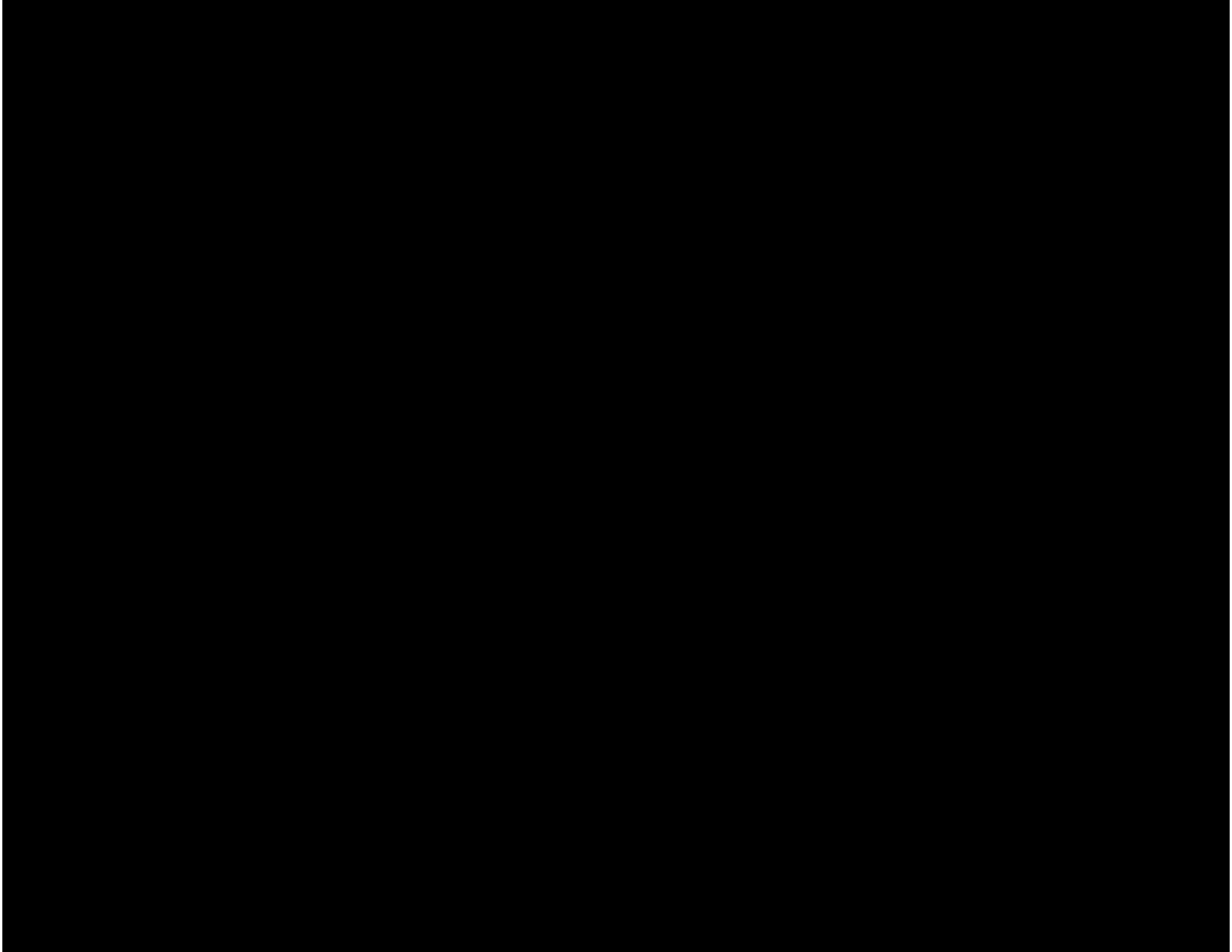




The table area is almost entirely obscured by black redaction. Only a few horizontal lines are visible, suggesting a table with multiple rows and columns. The content within the table is illegible.

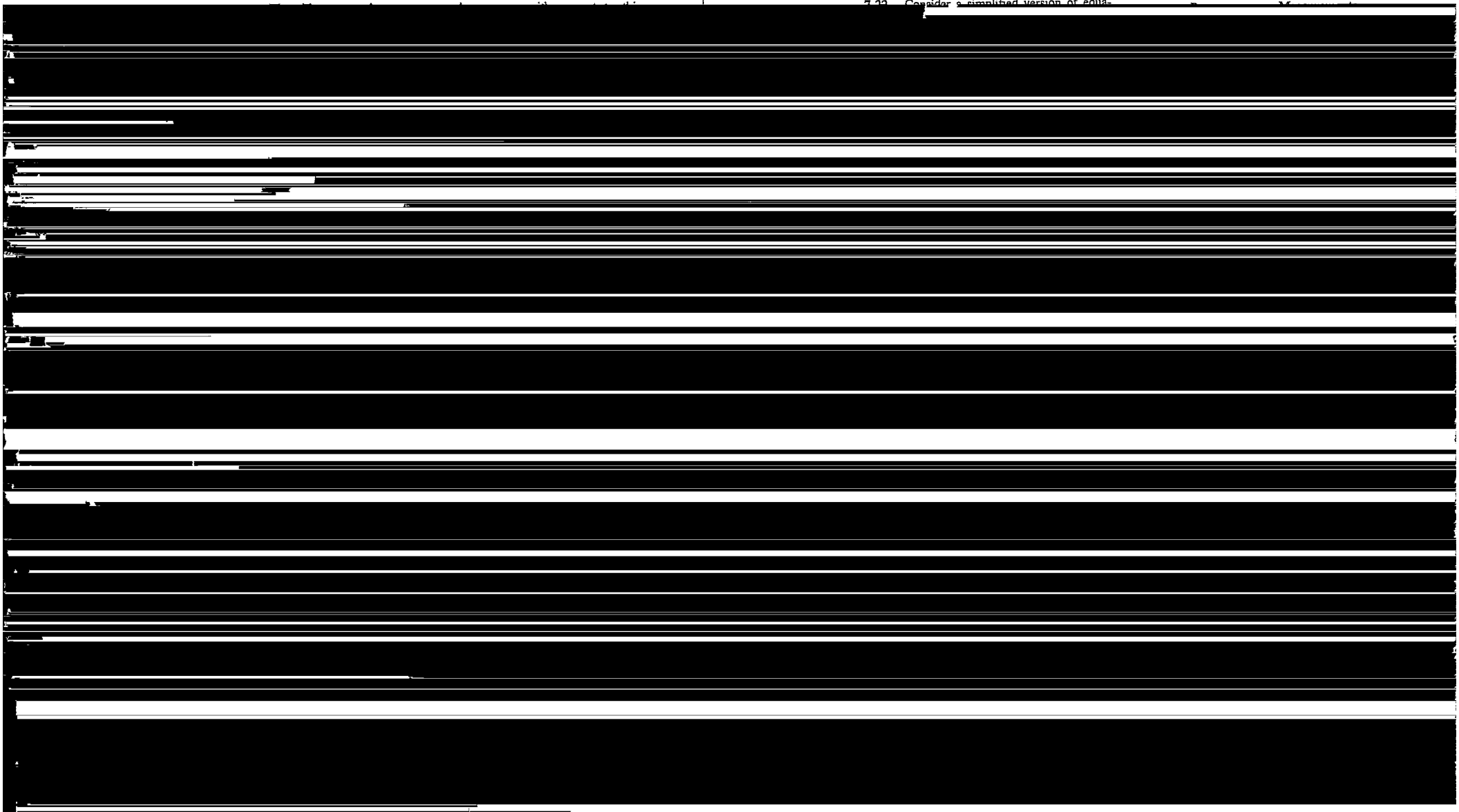


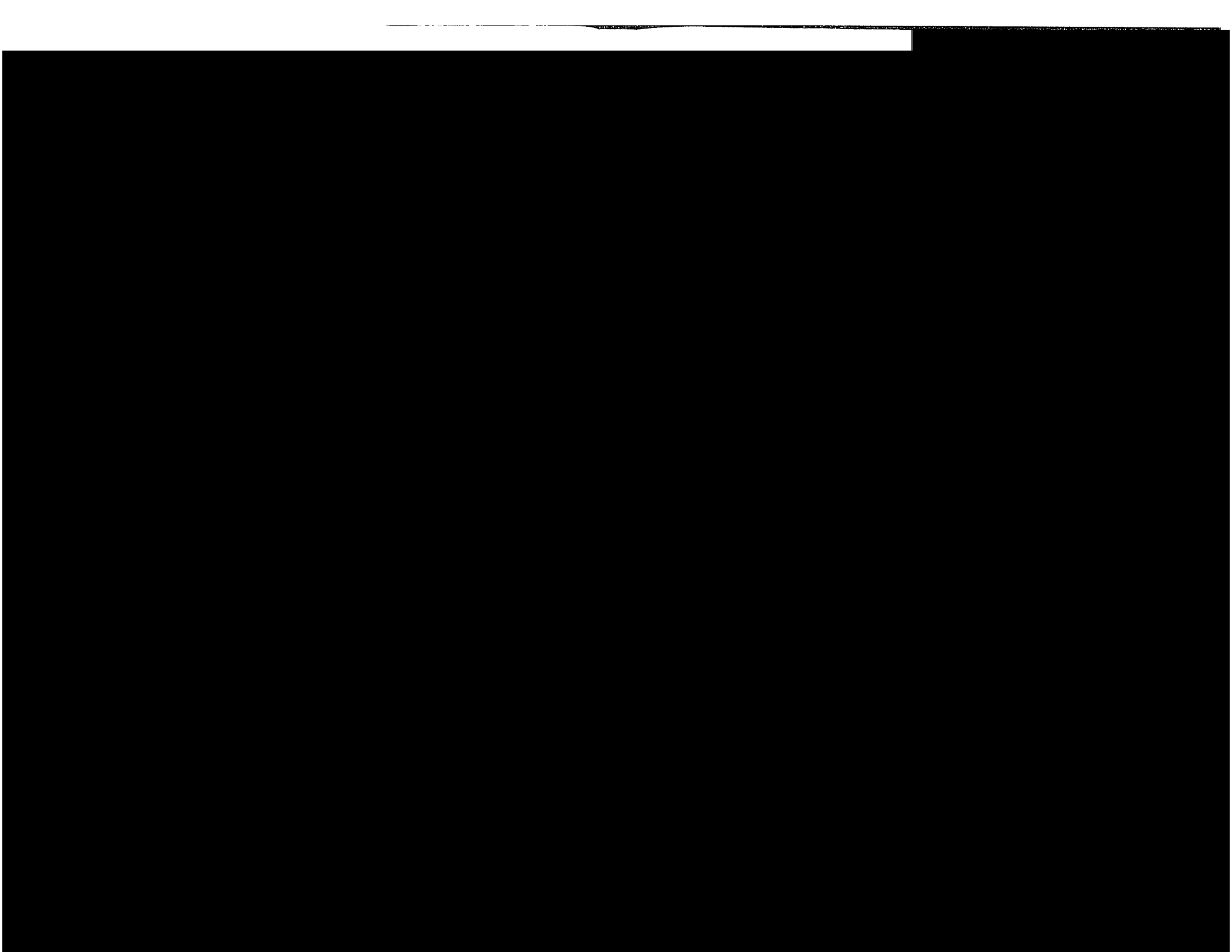




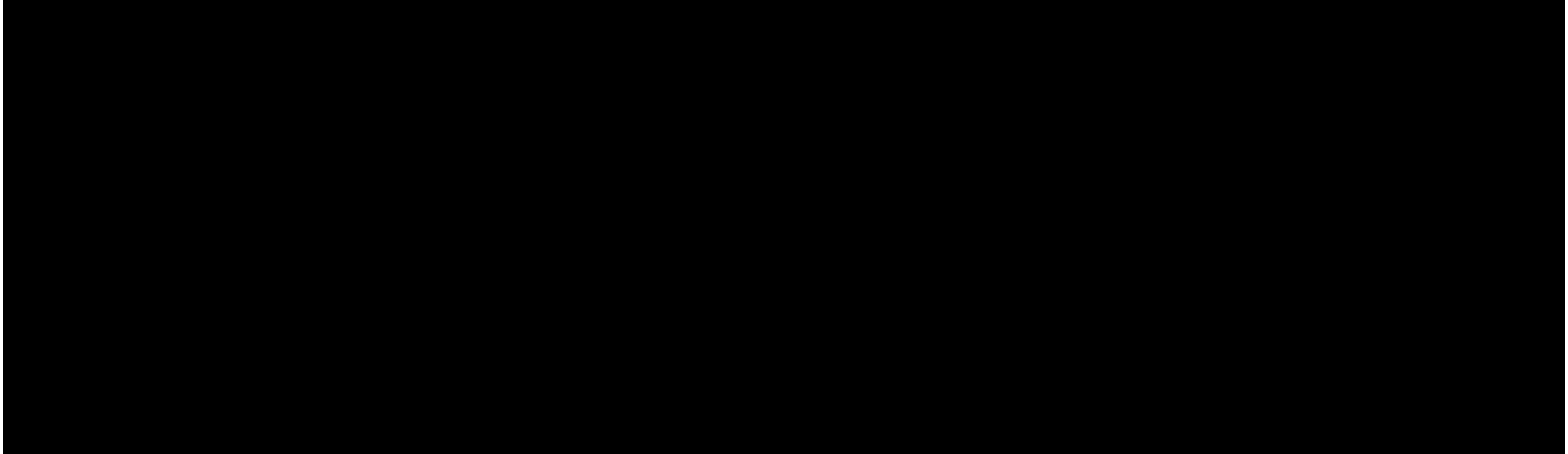
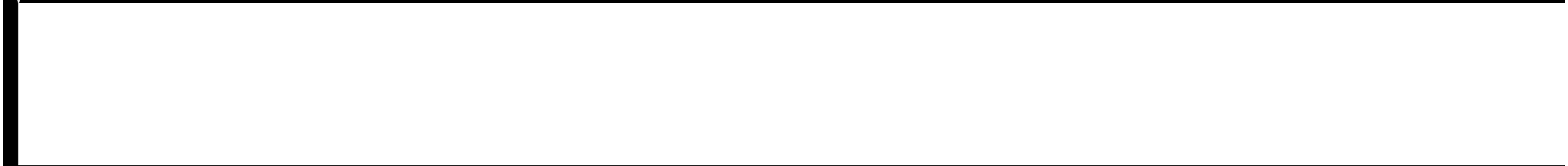
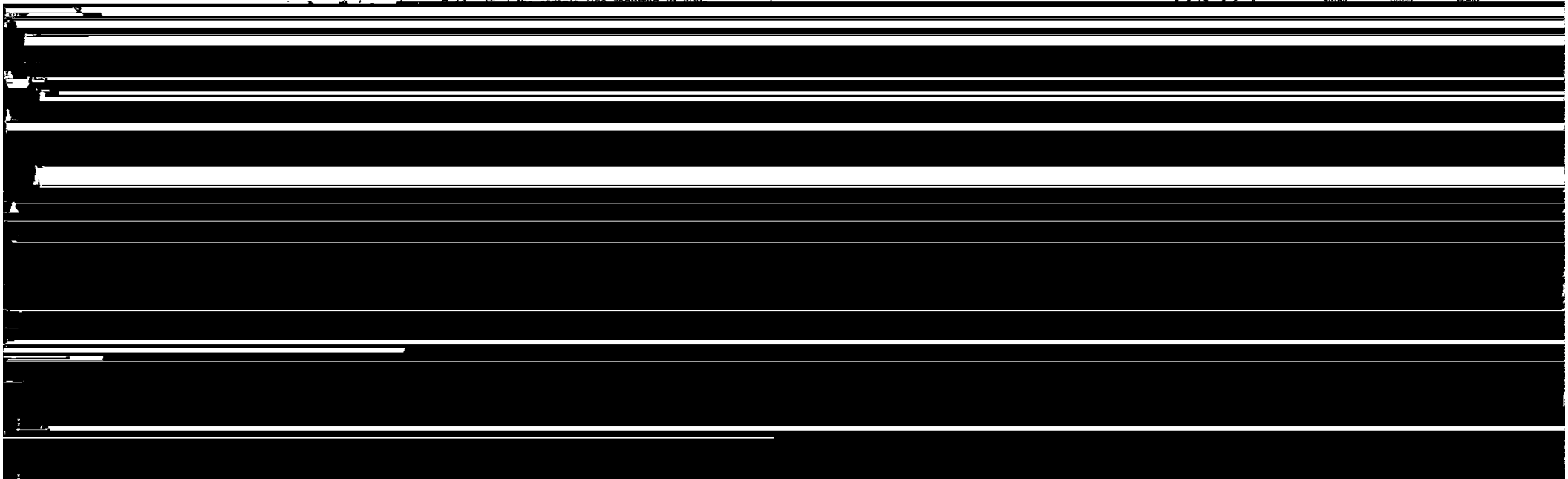


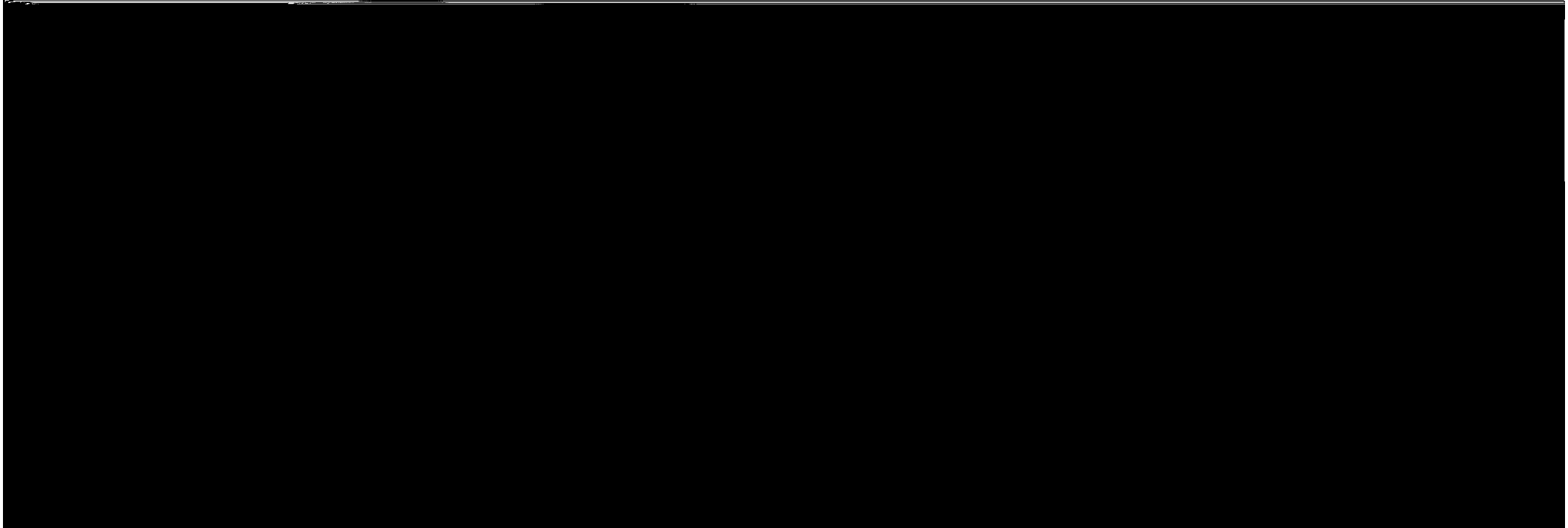
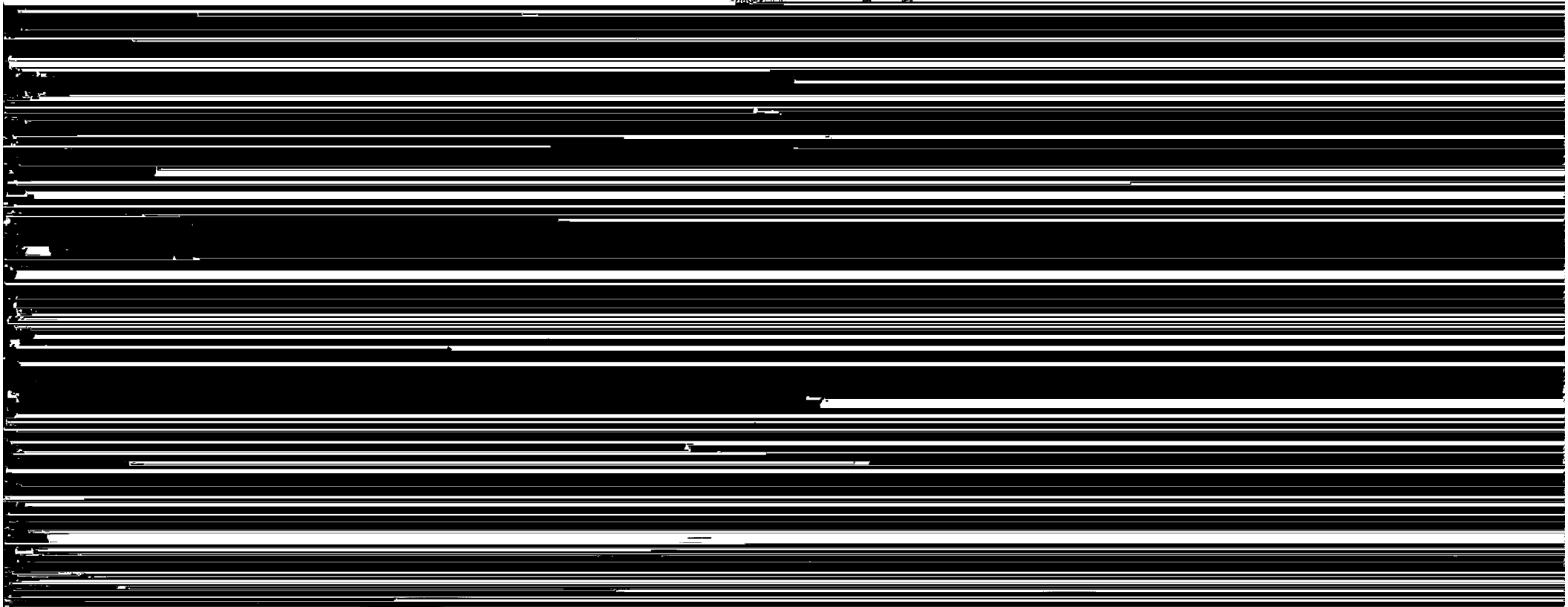
7.23 Consider a simplified version of equa-

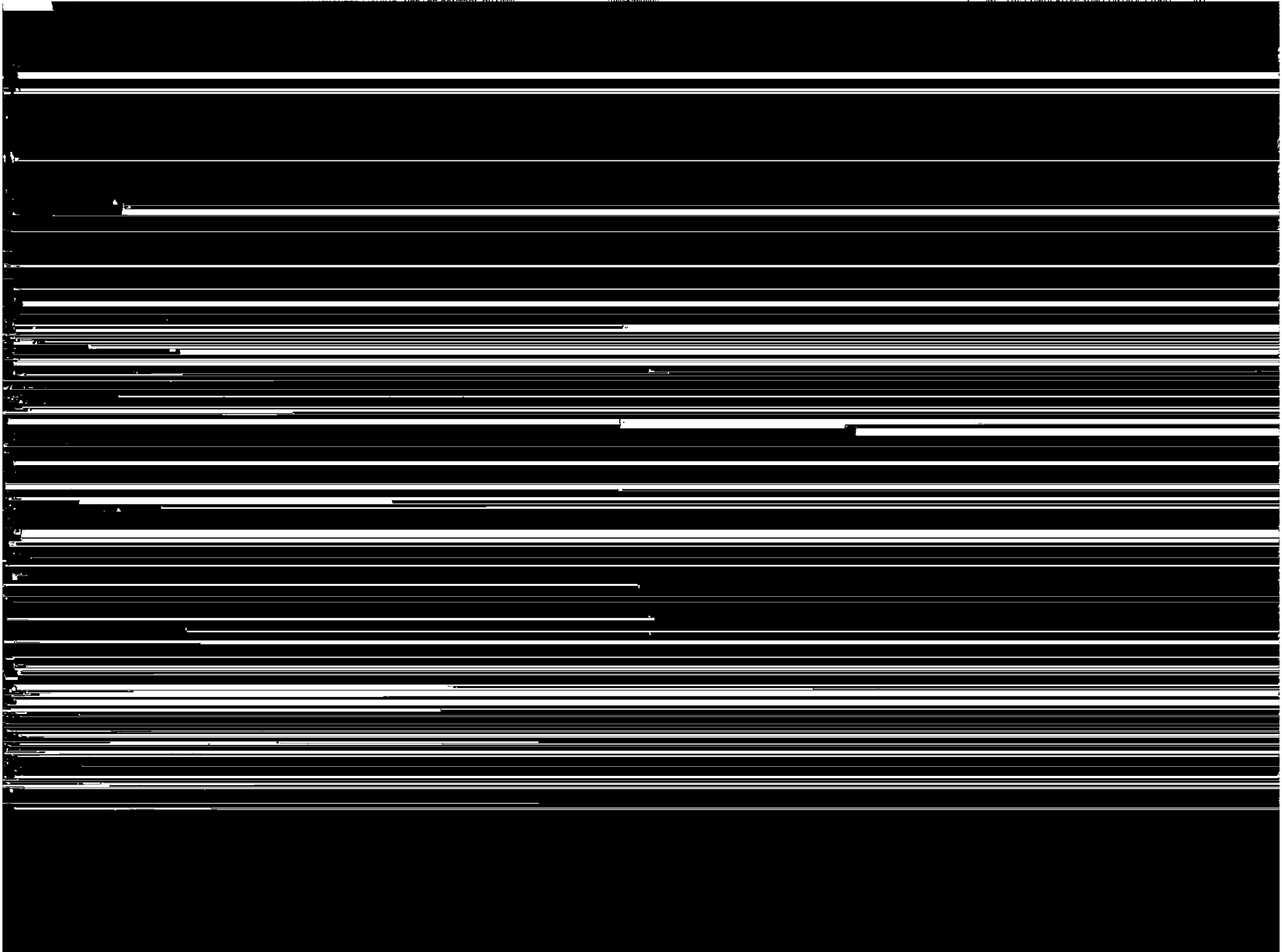




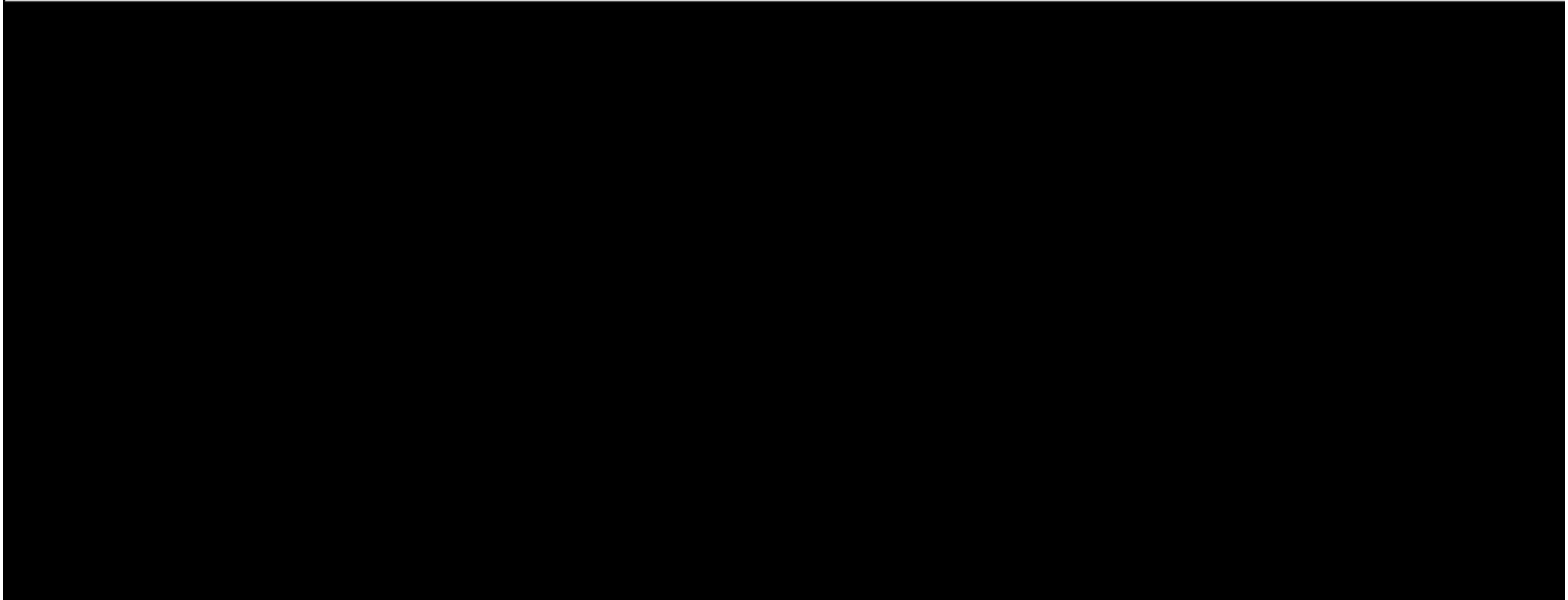
DAPT









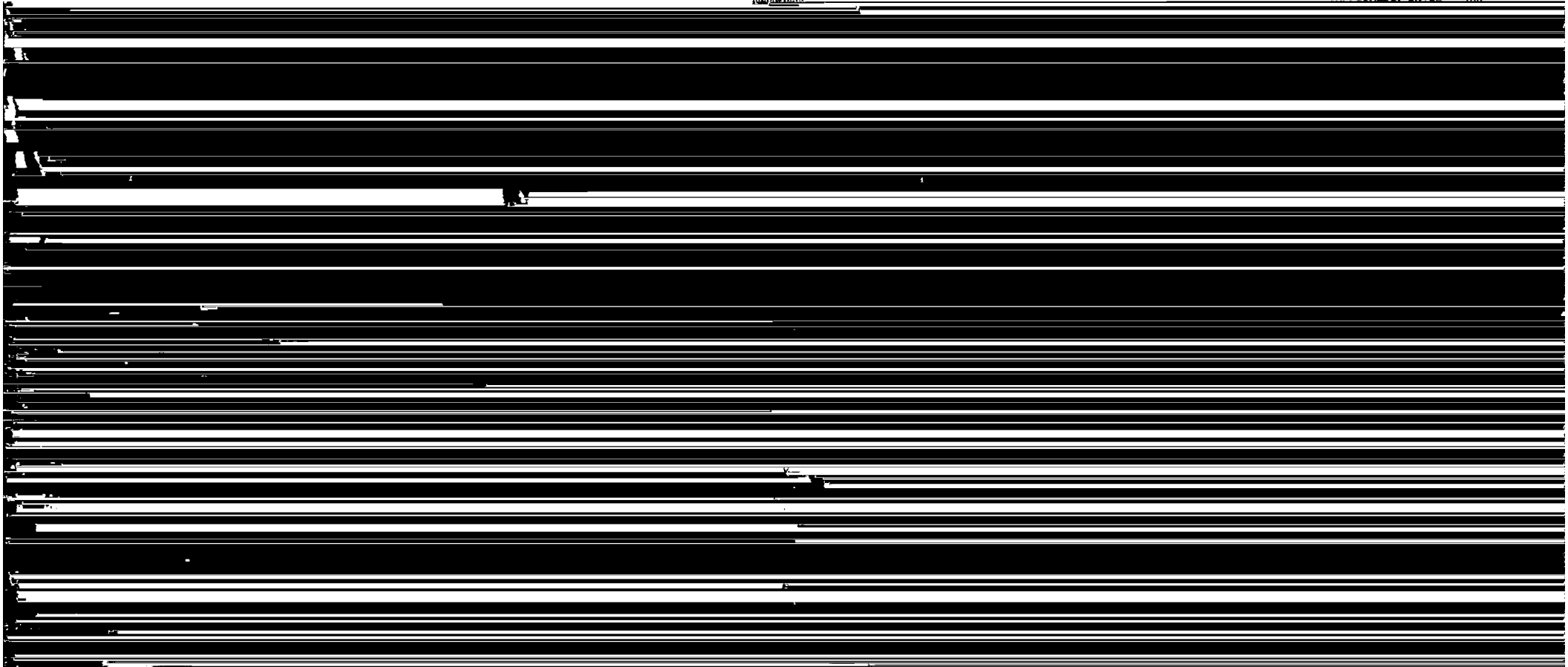


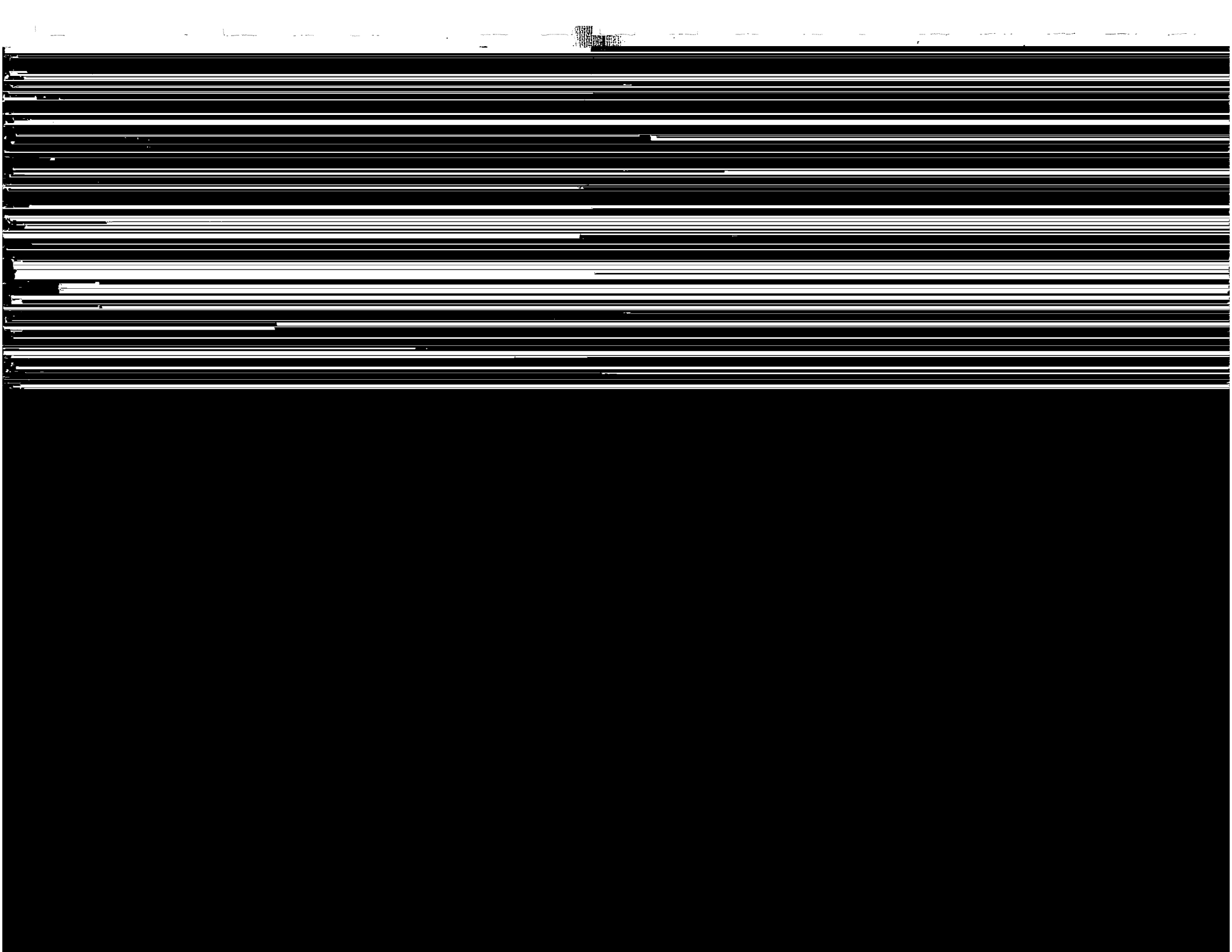


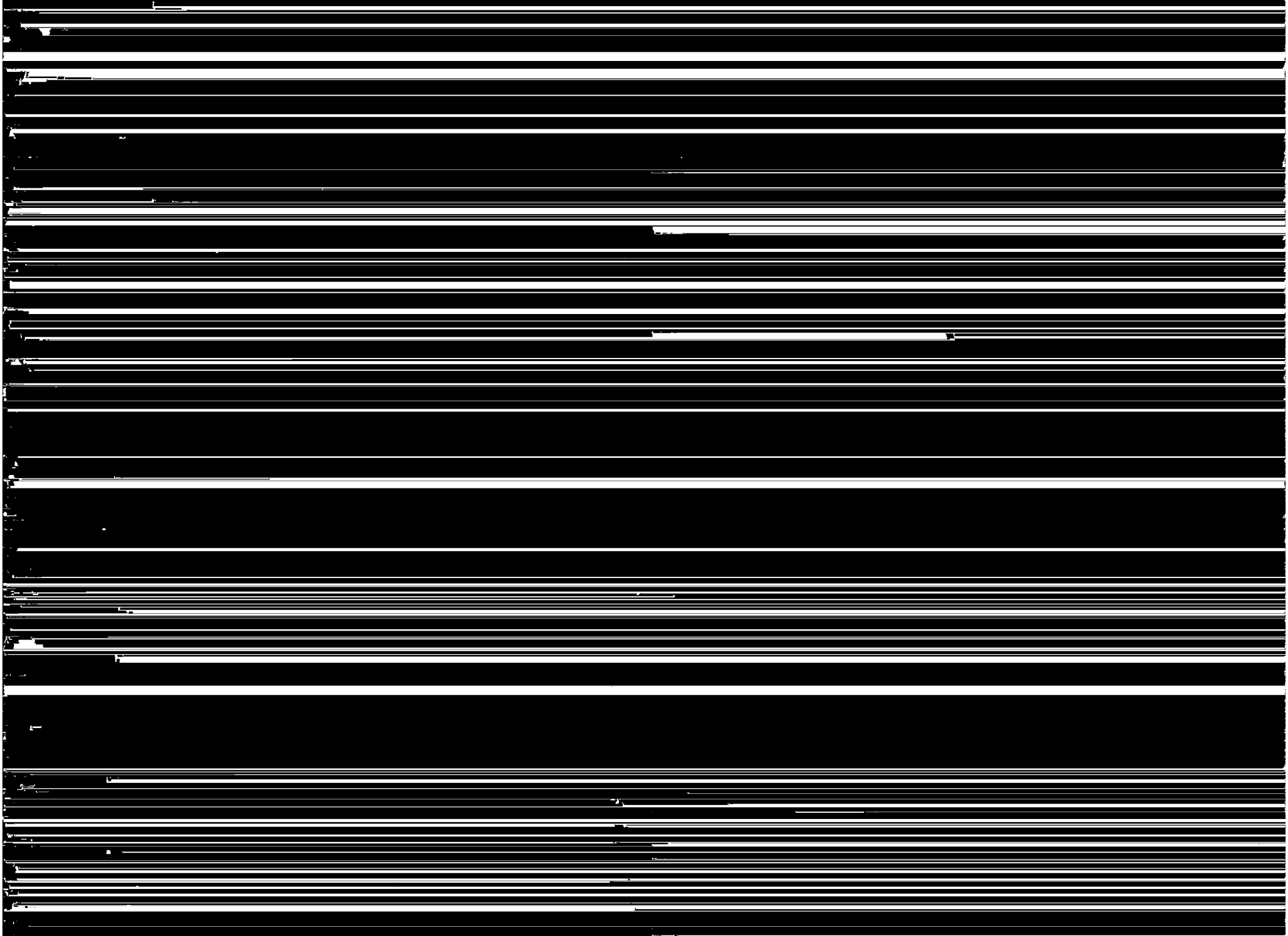


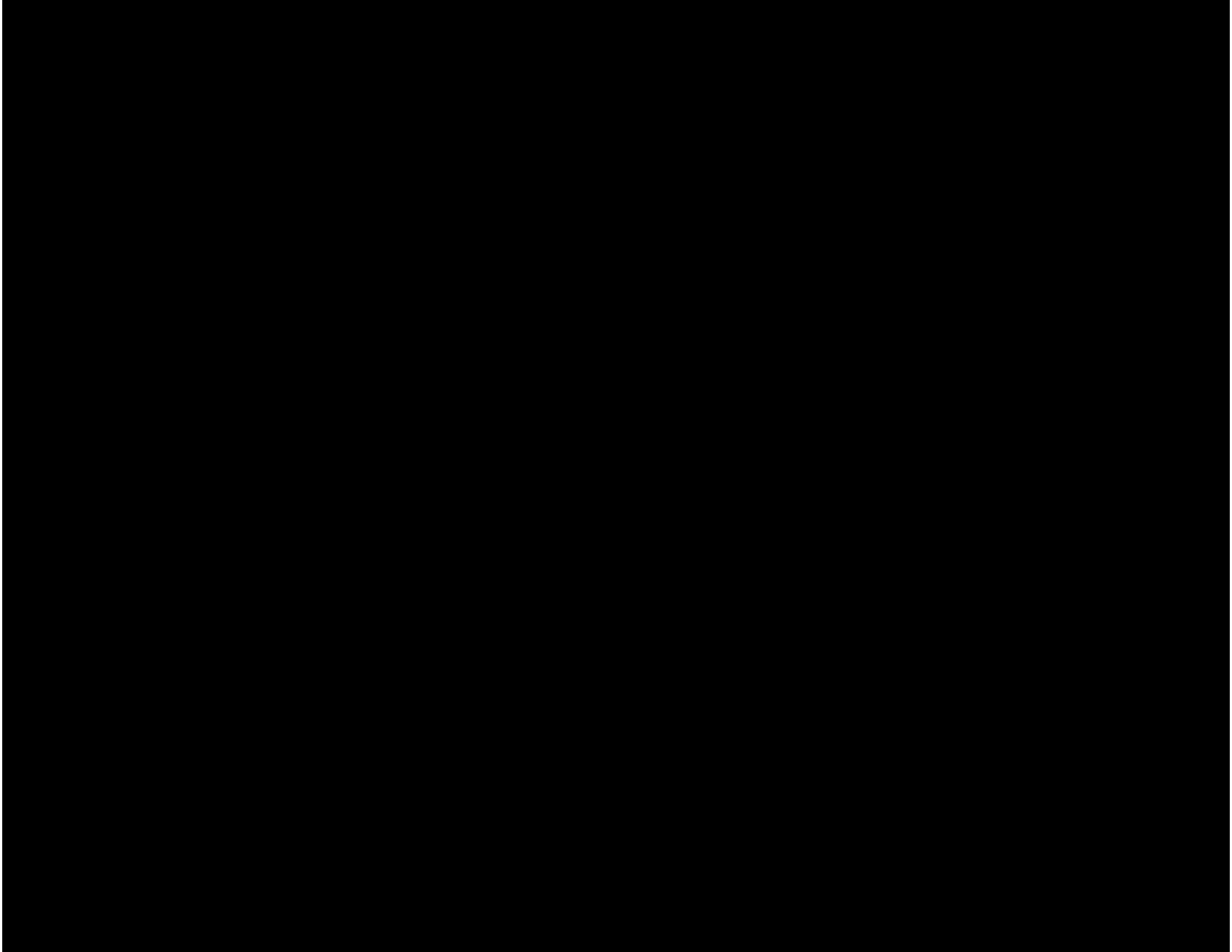


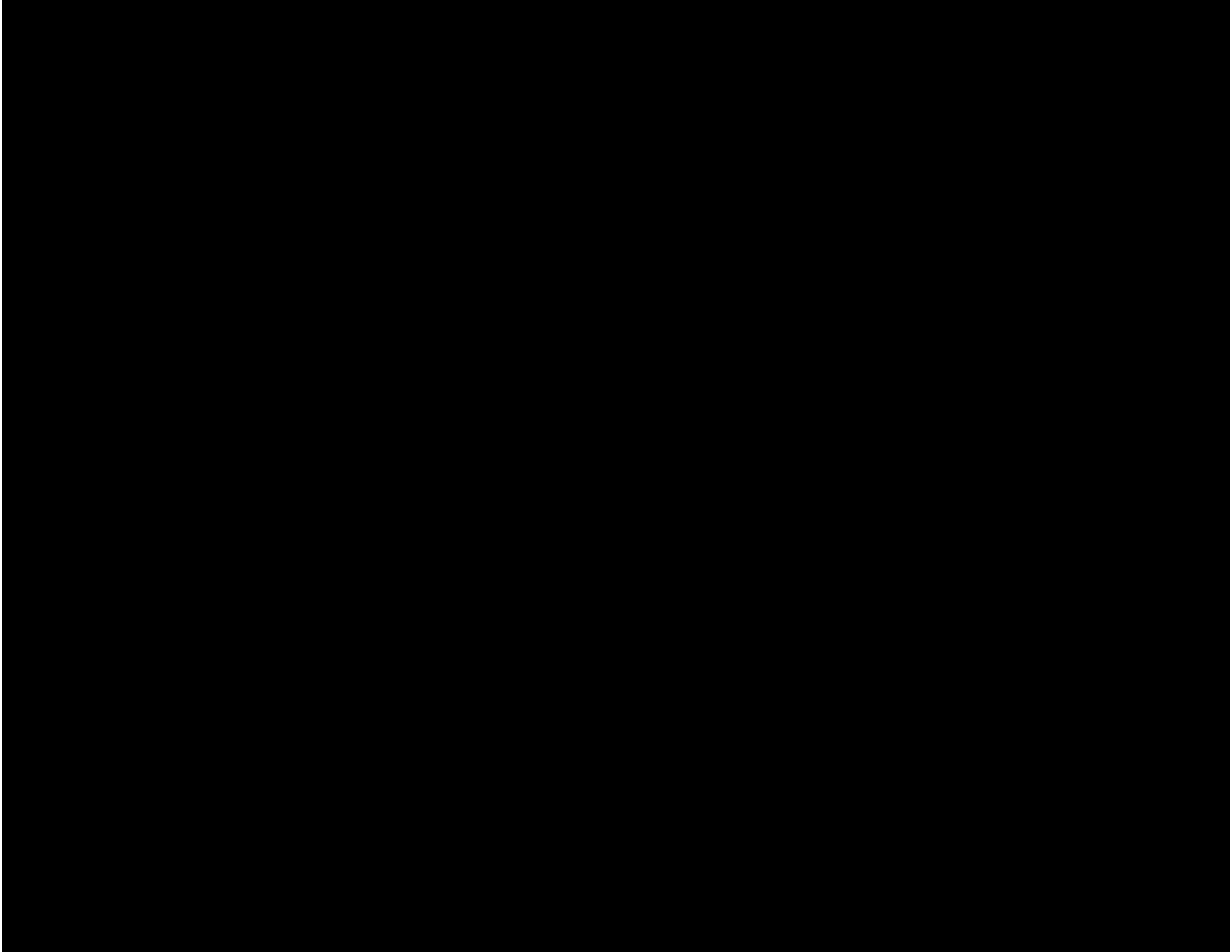


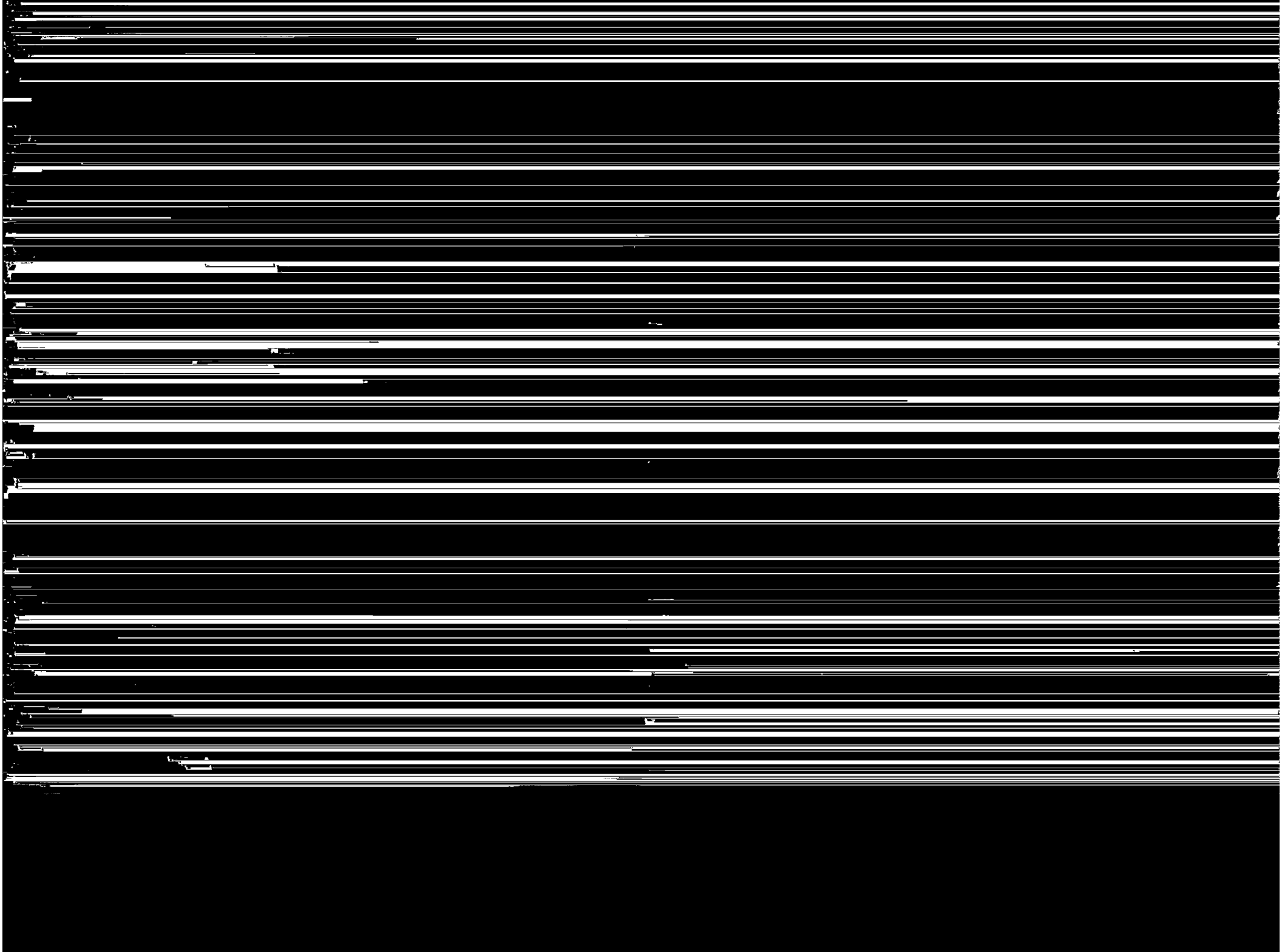






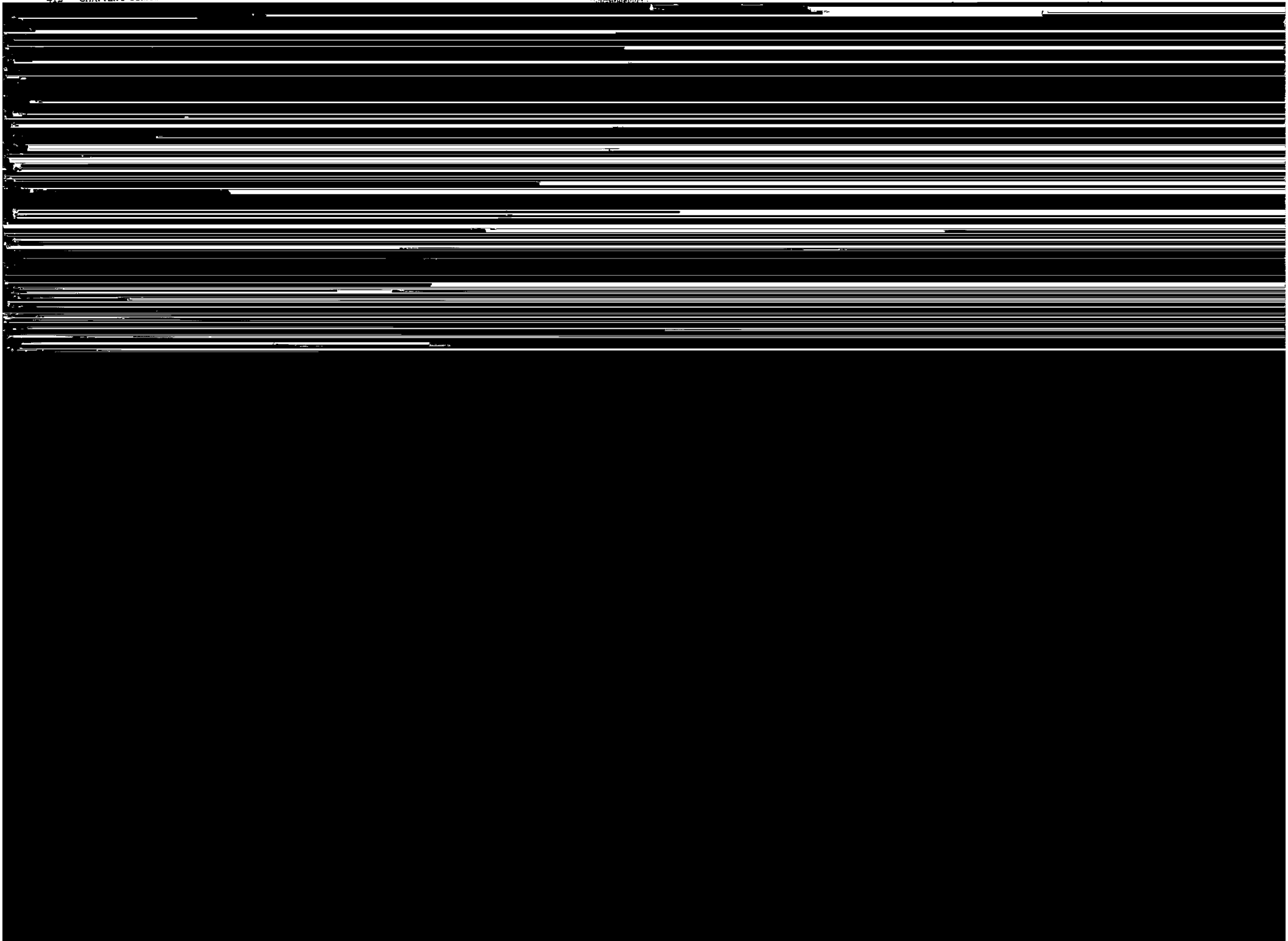


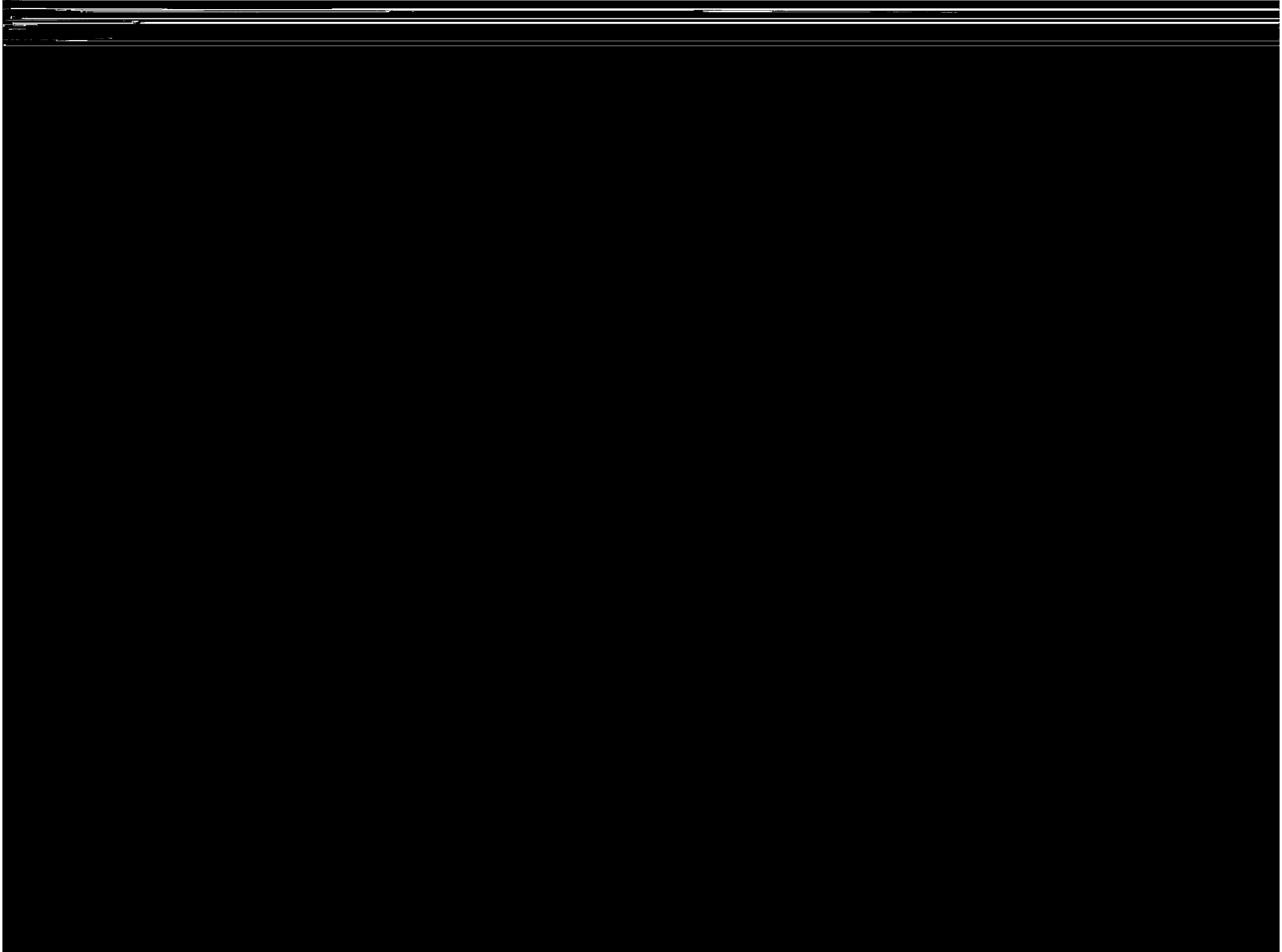


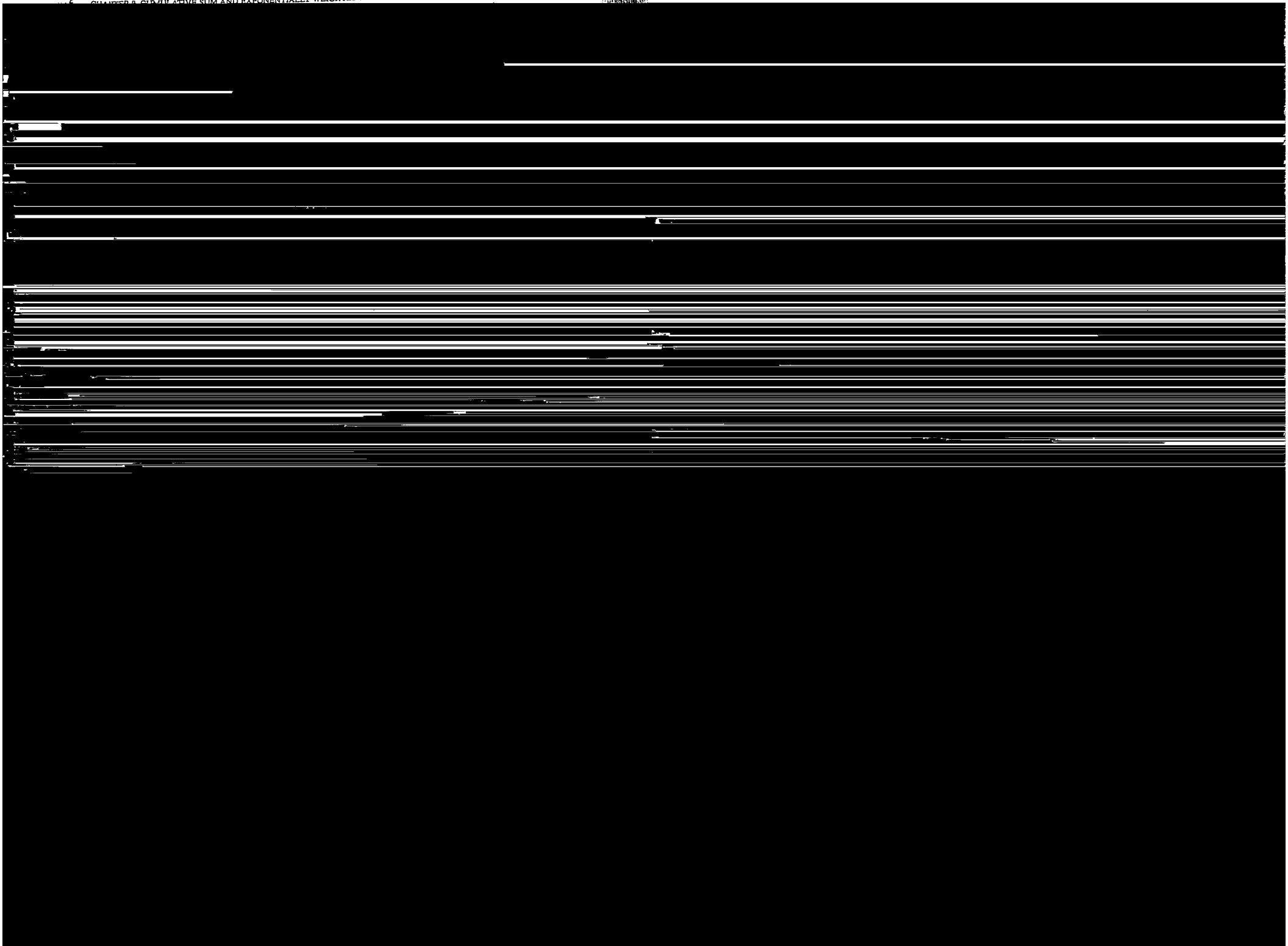


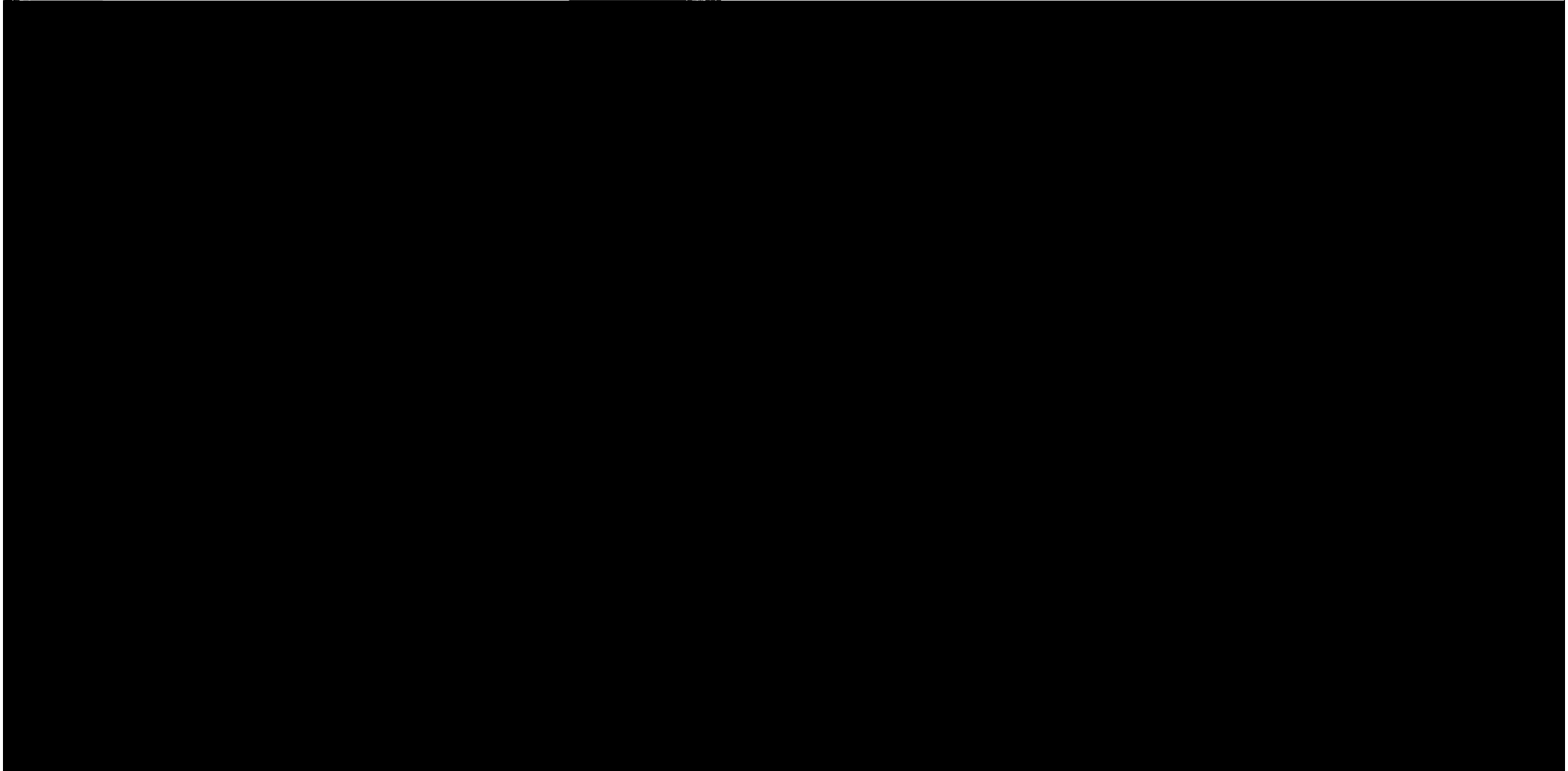
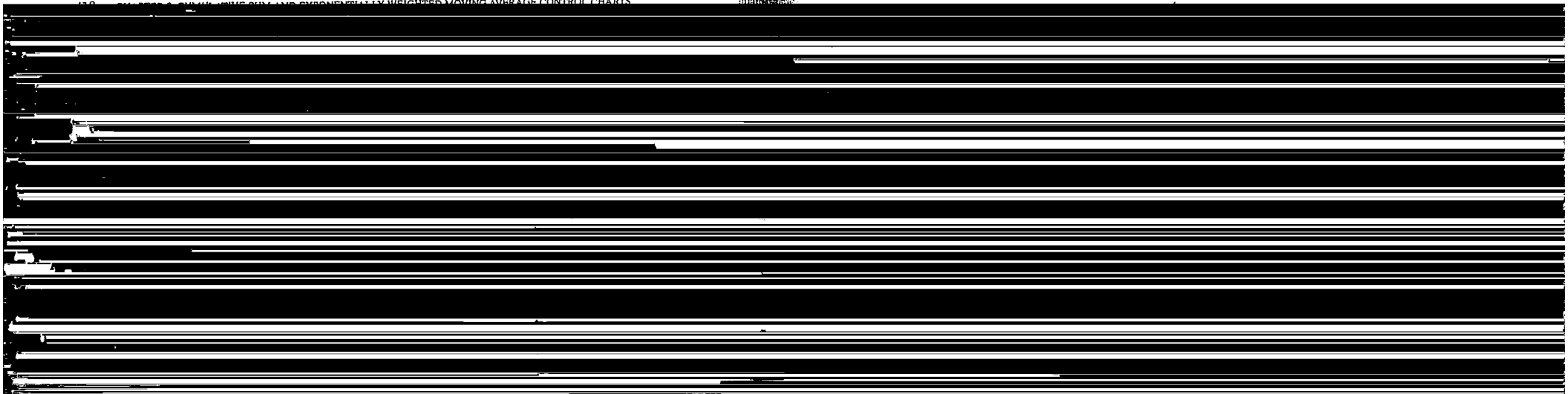




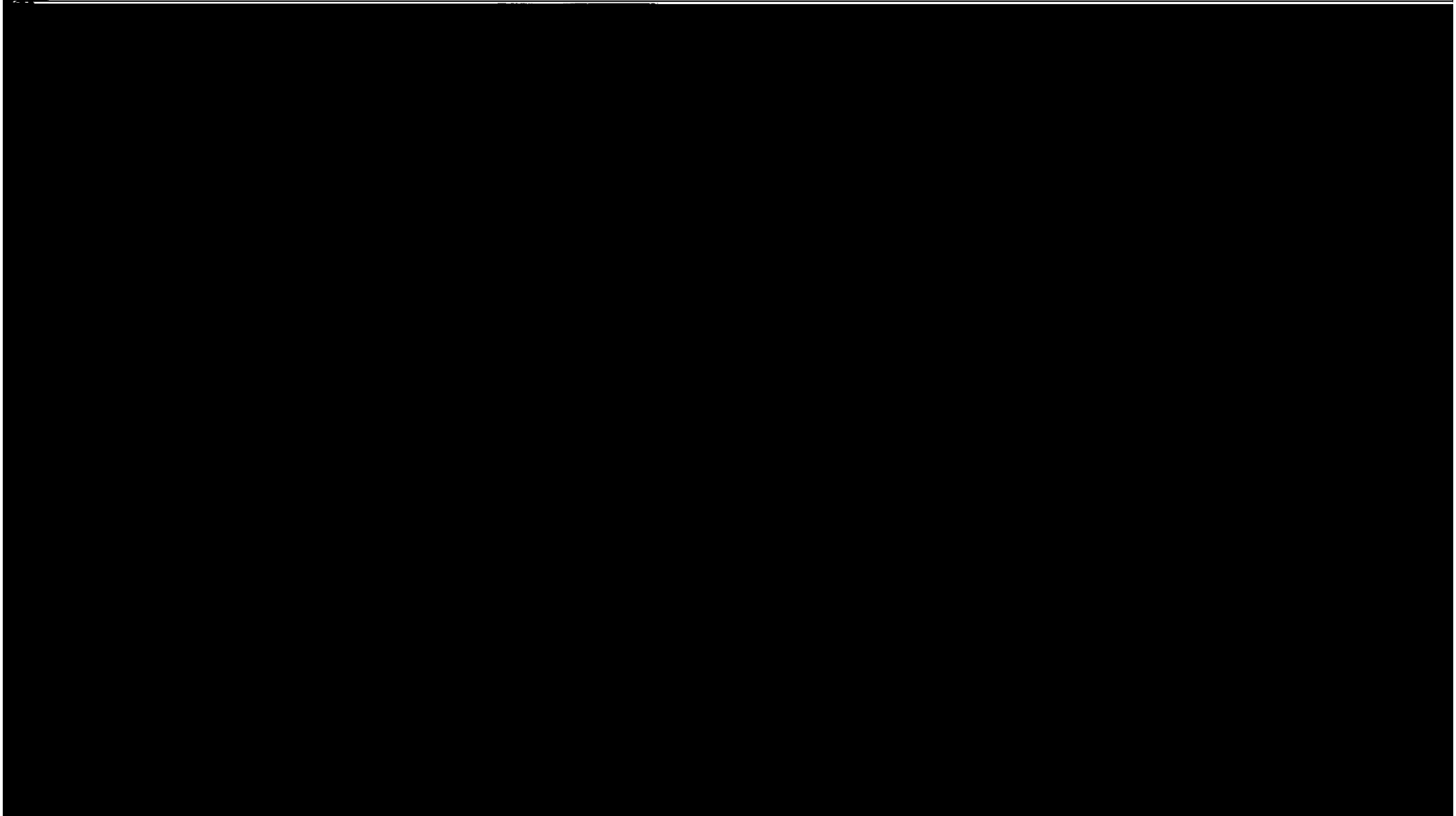


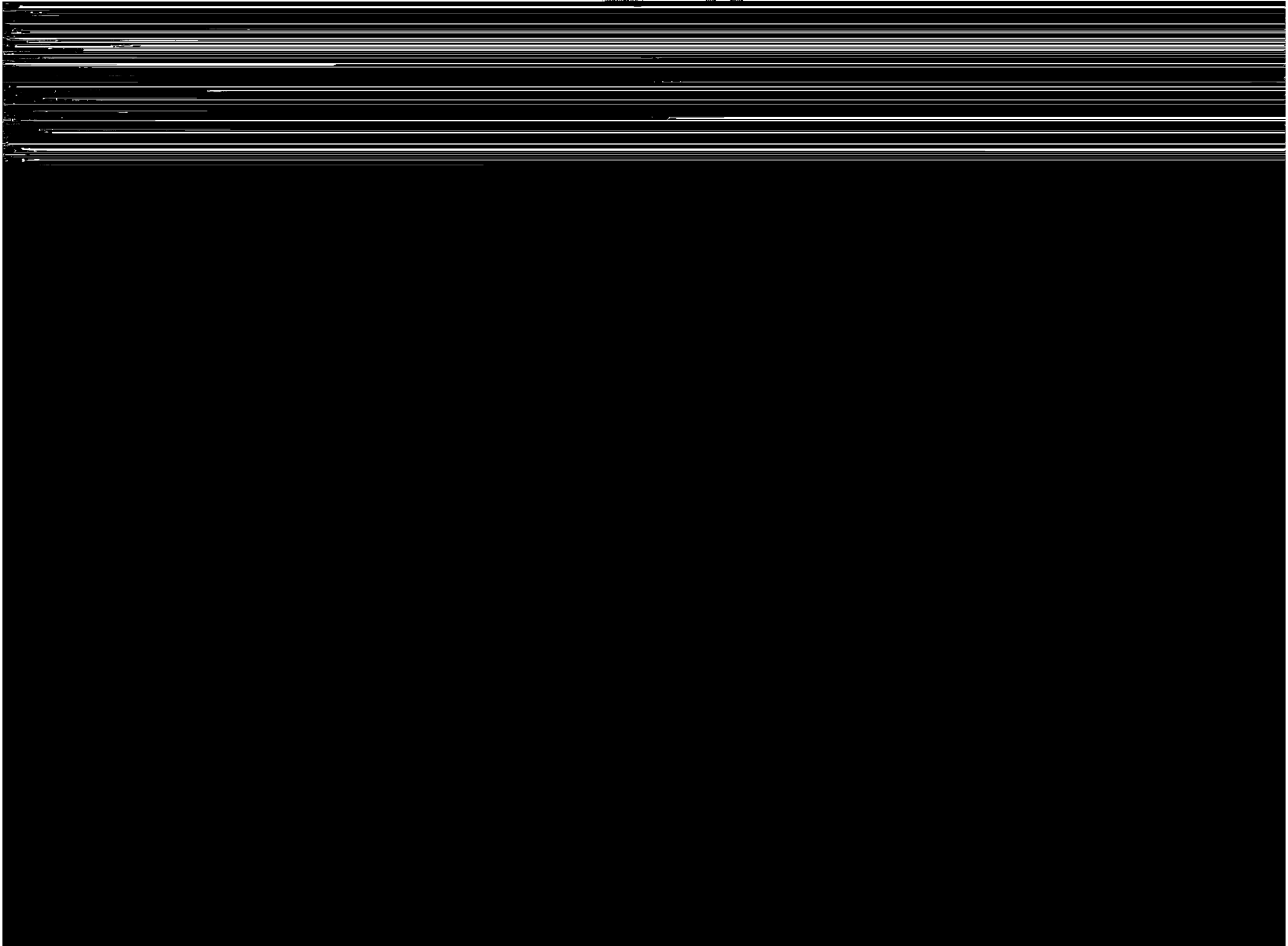






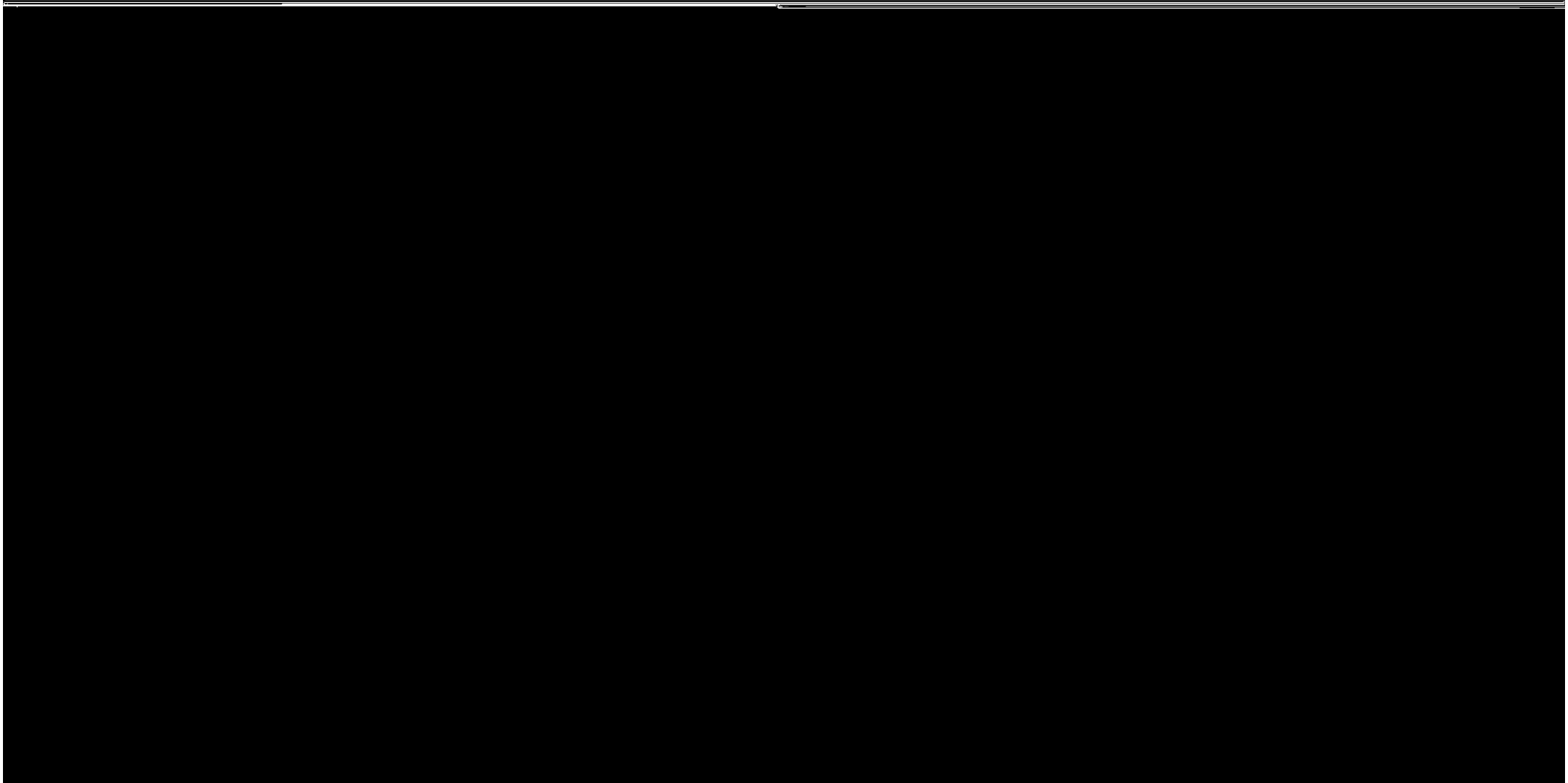
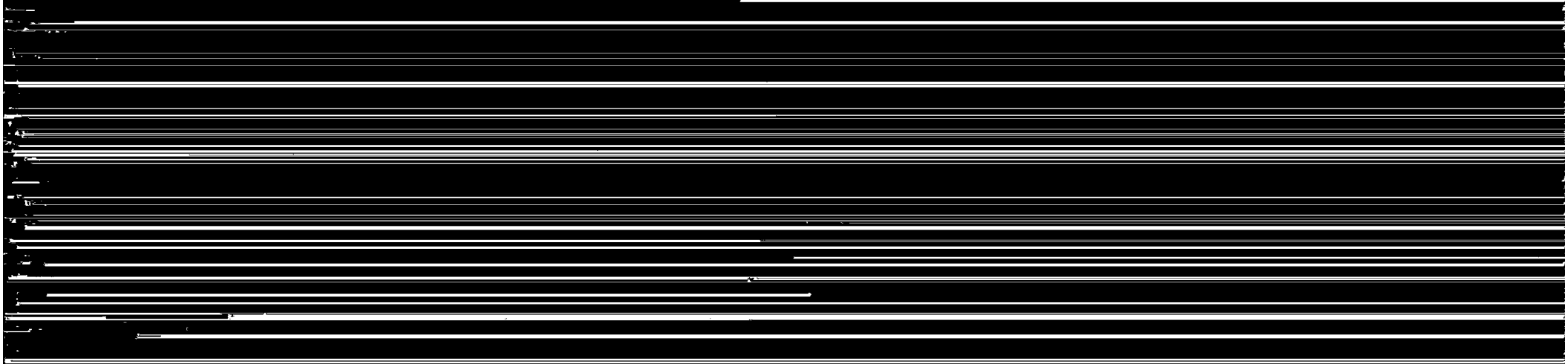
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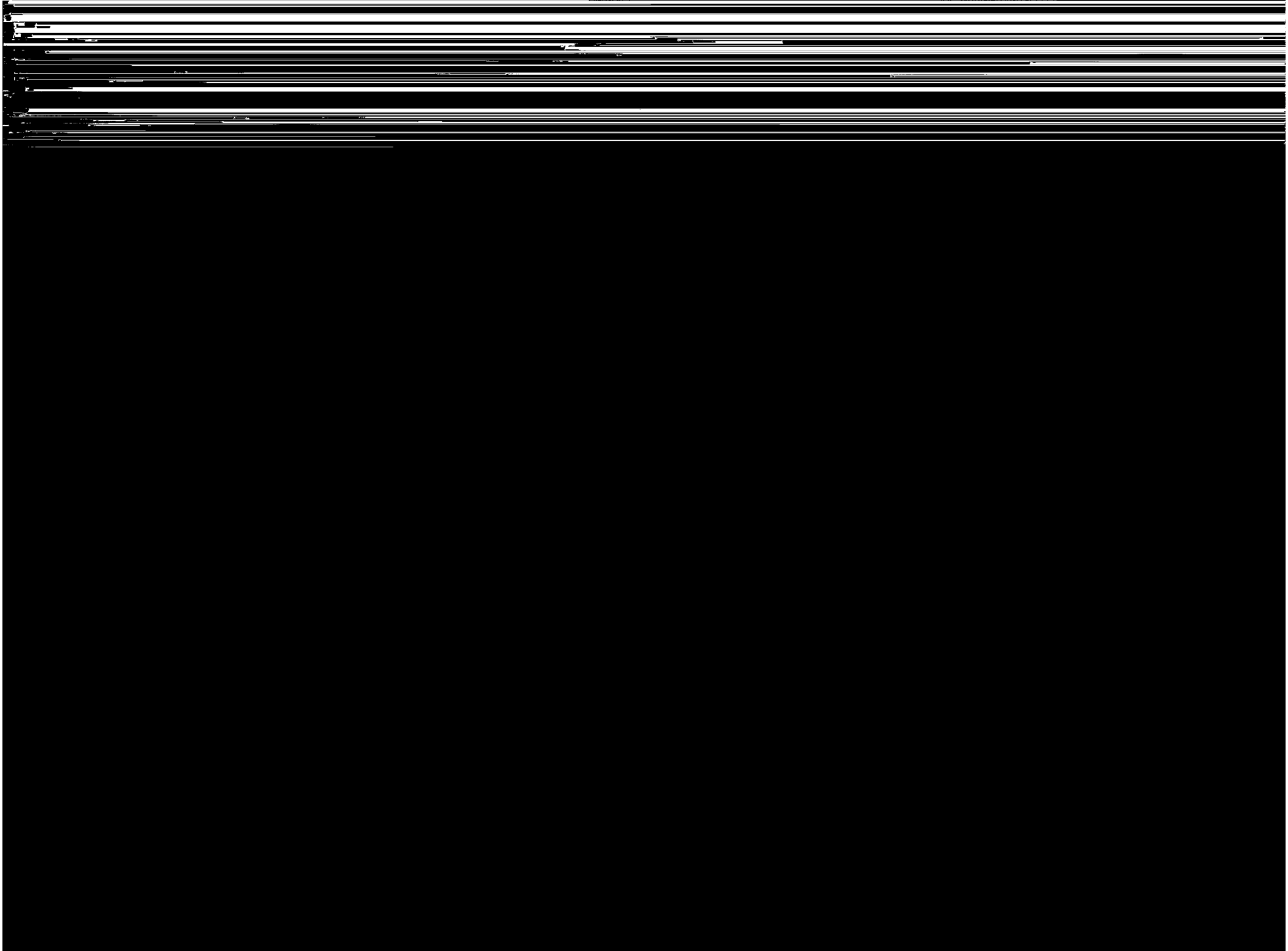


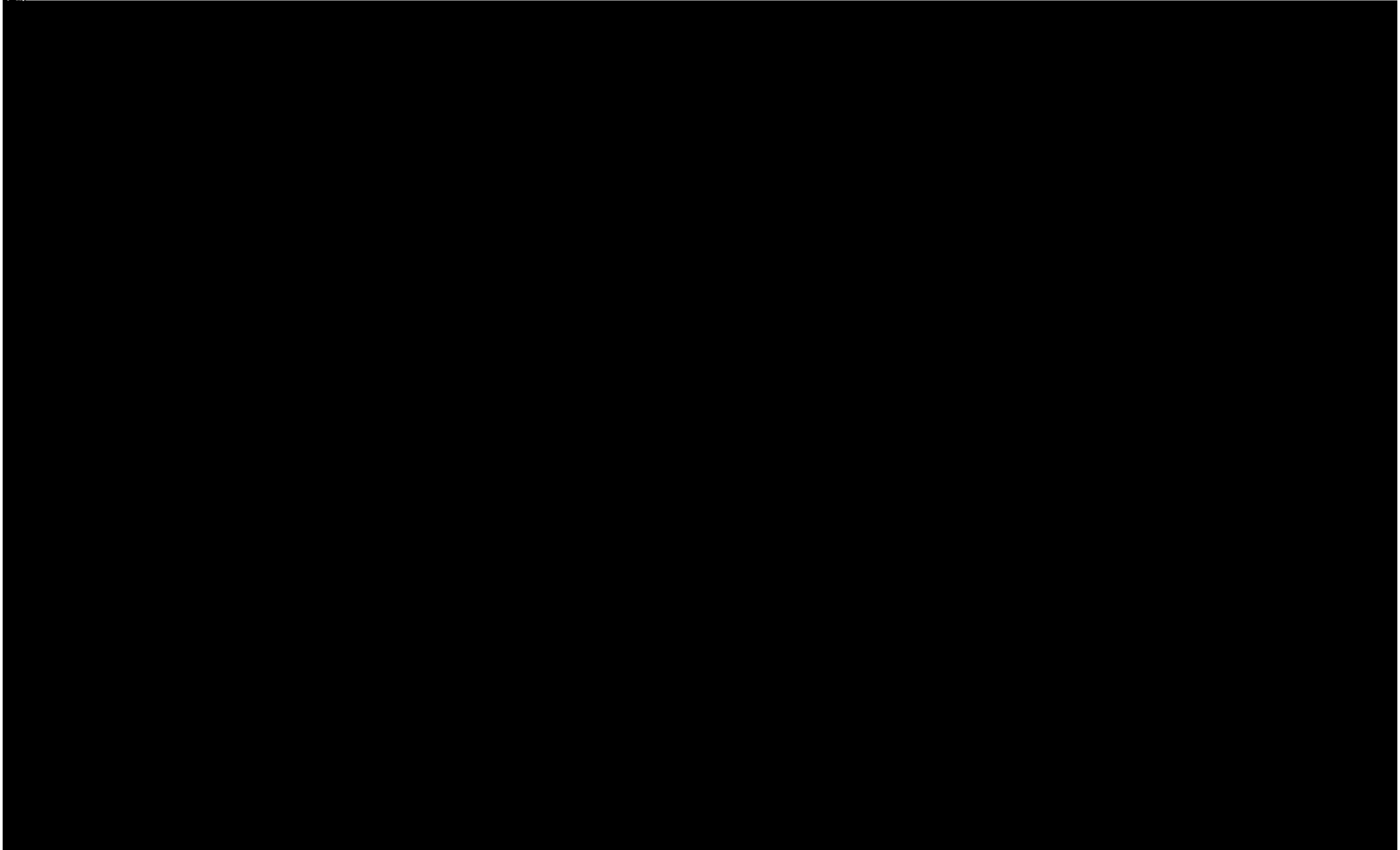
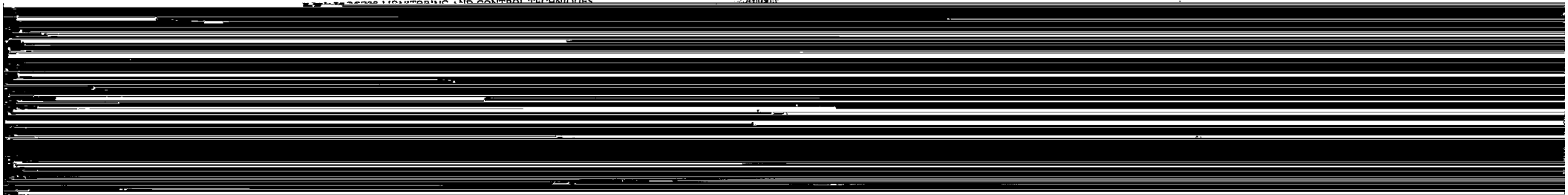


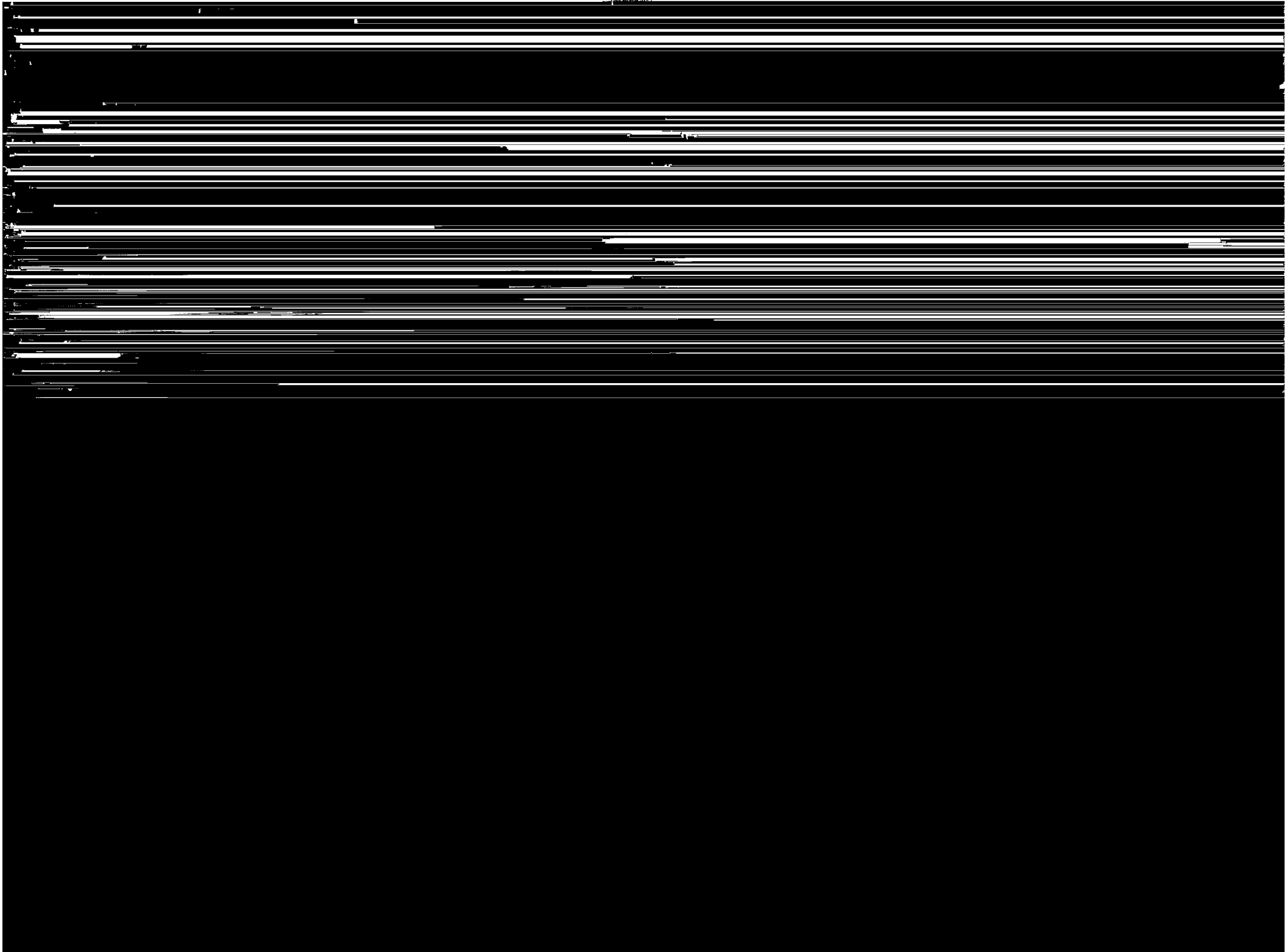


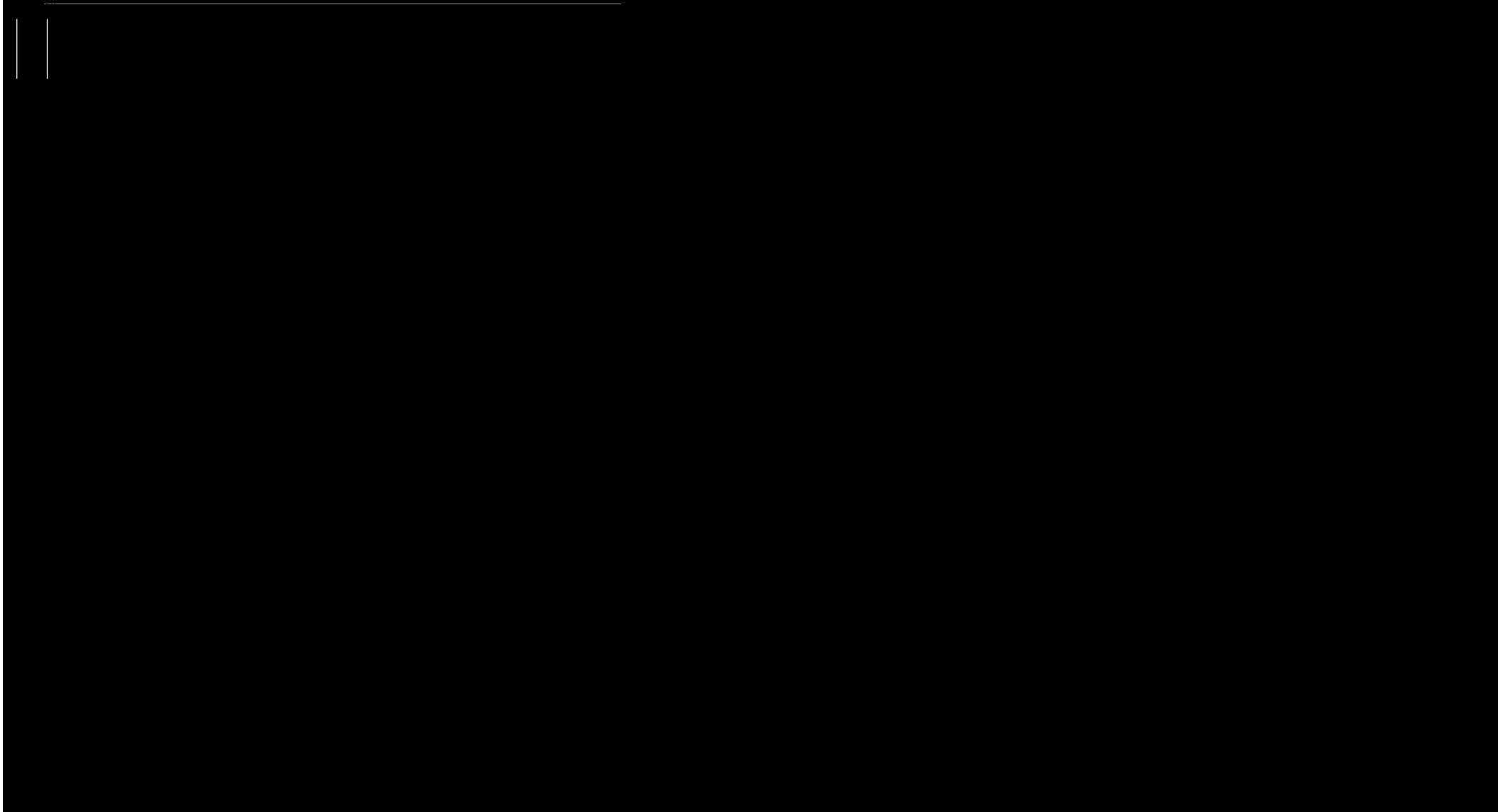
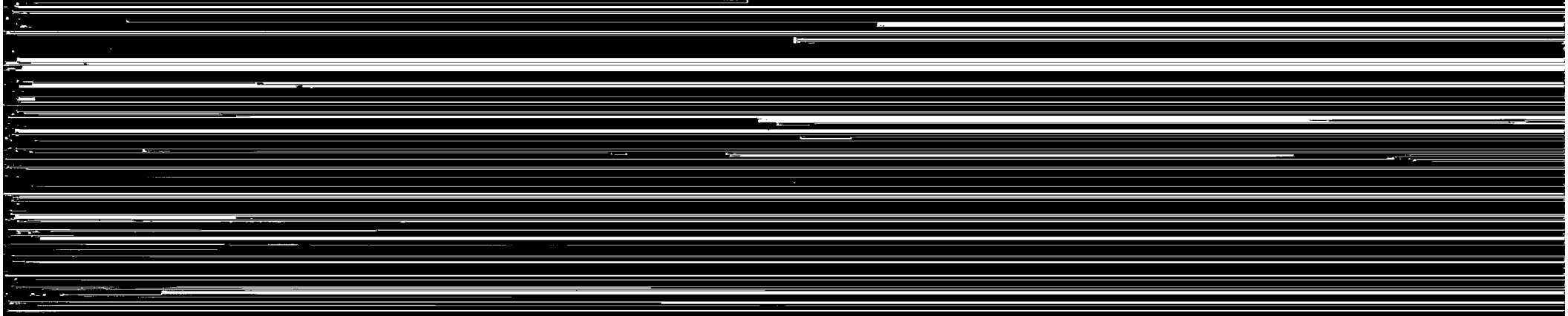


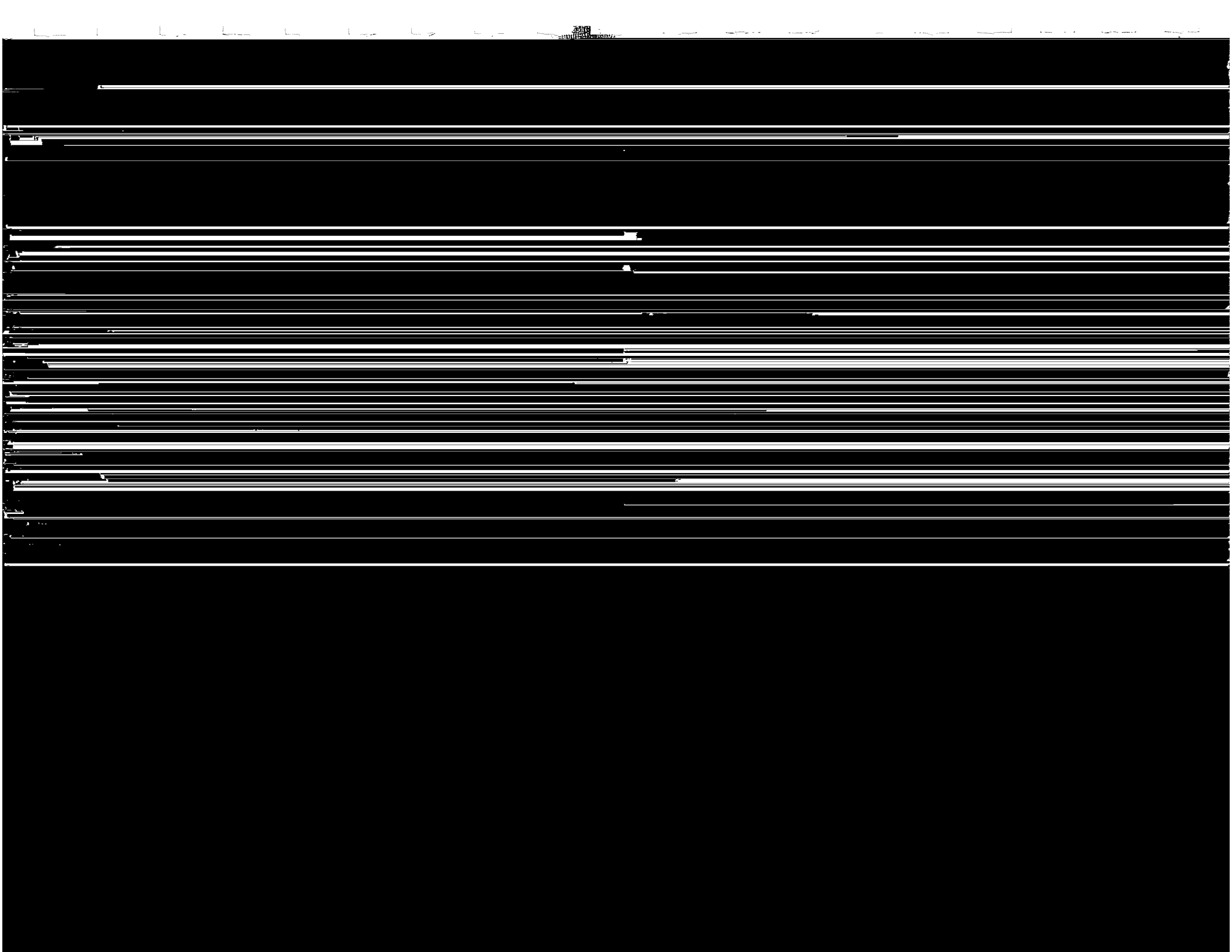


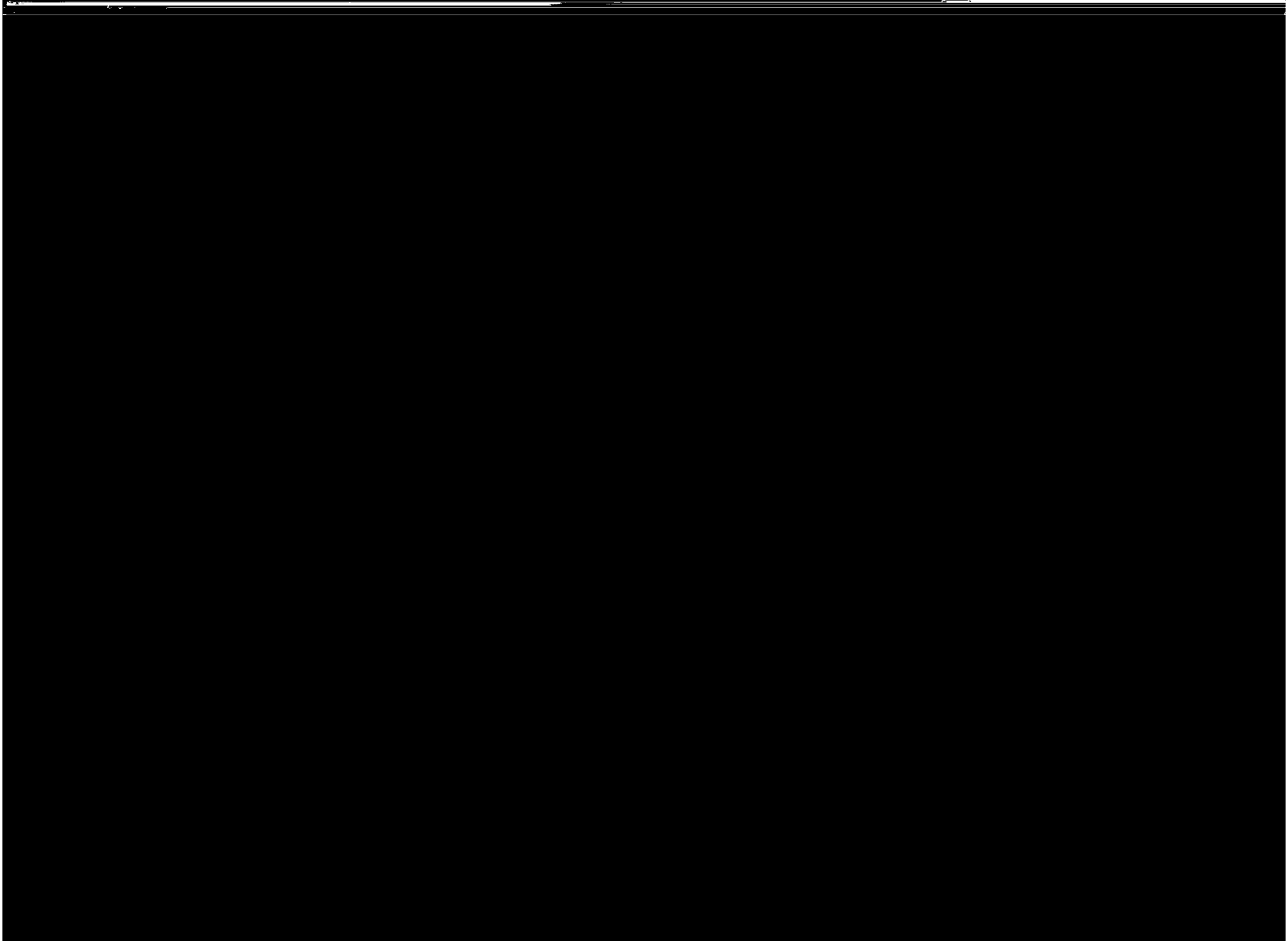


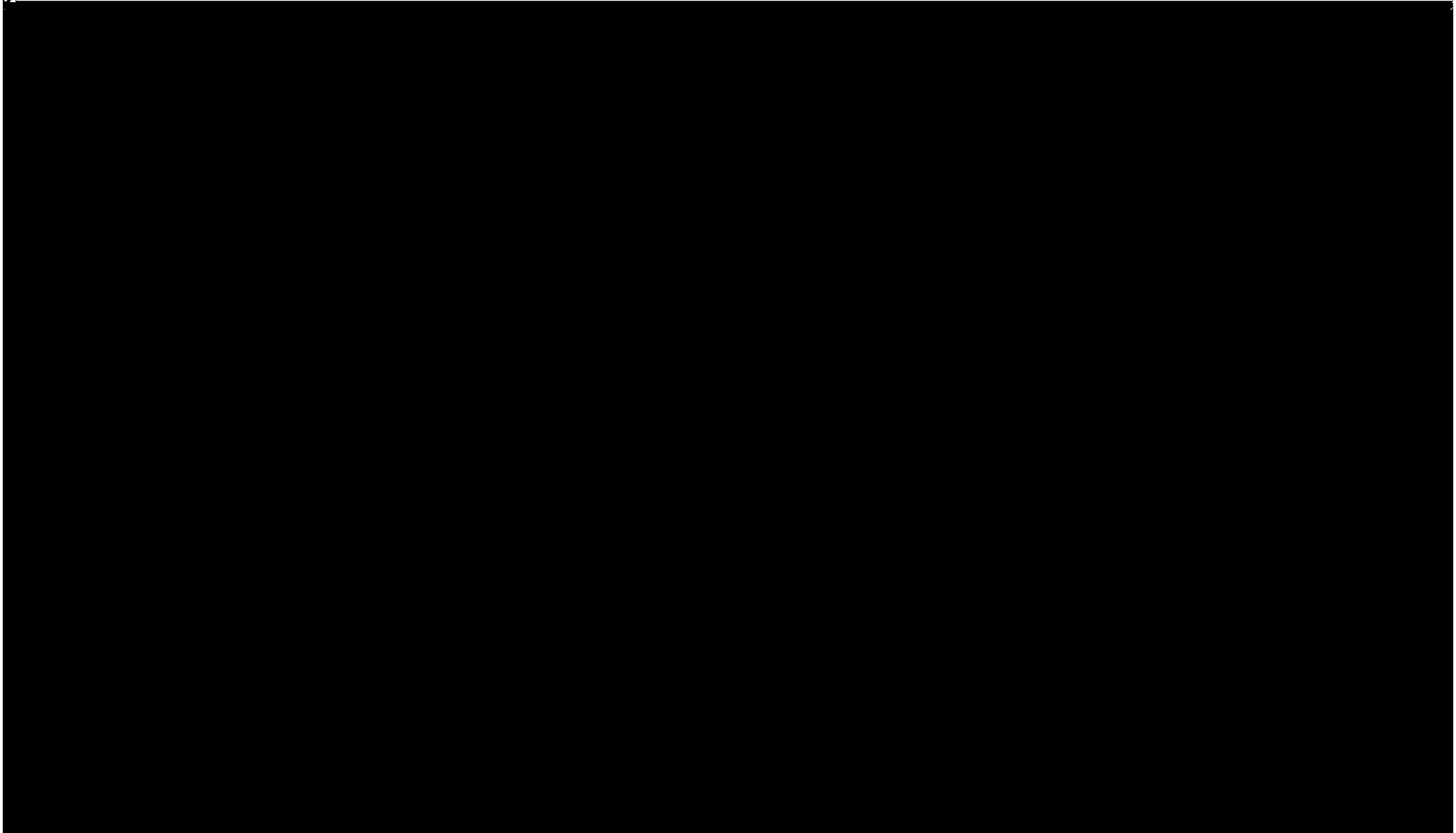
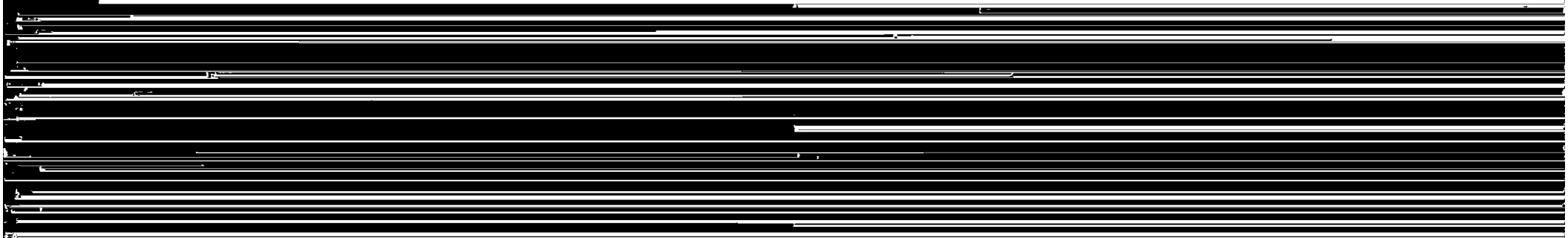




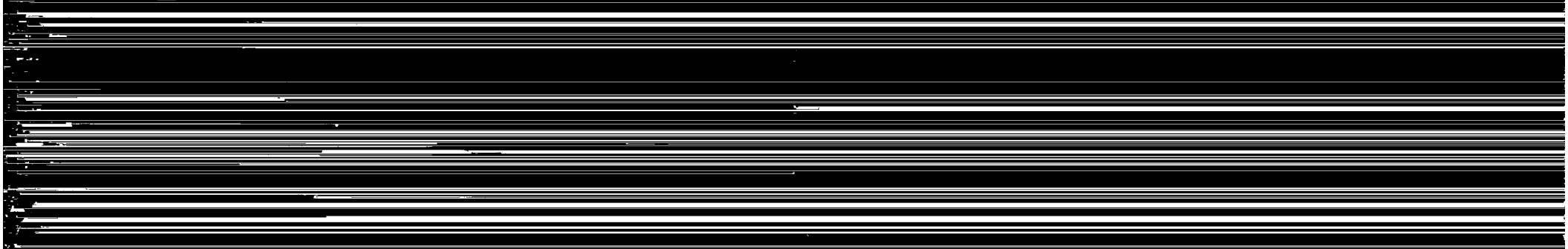




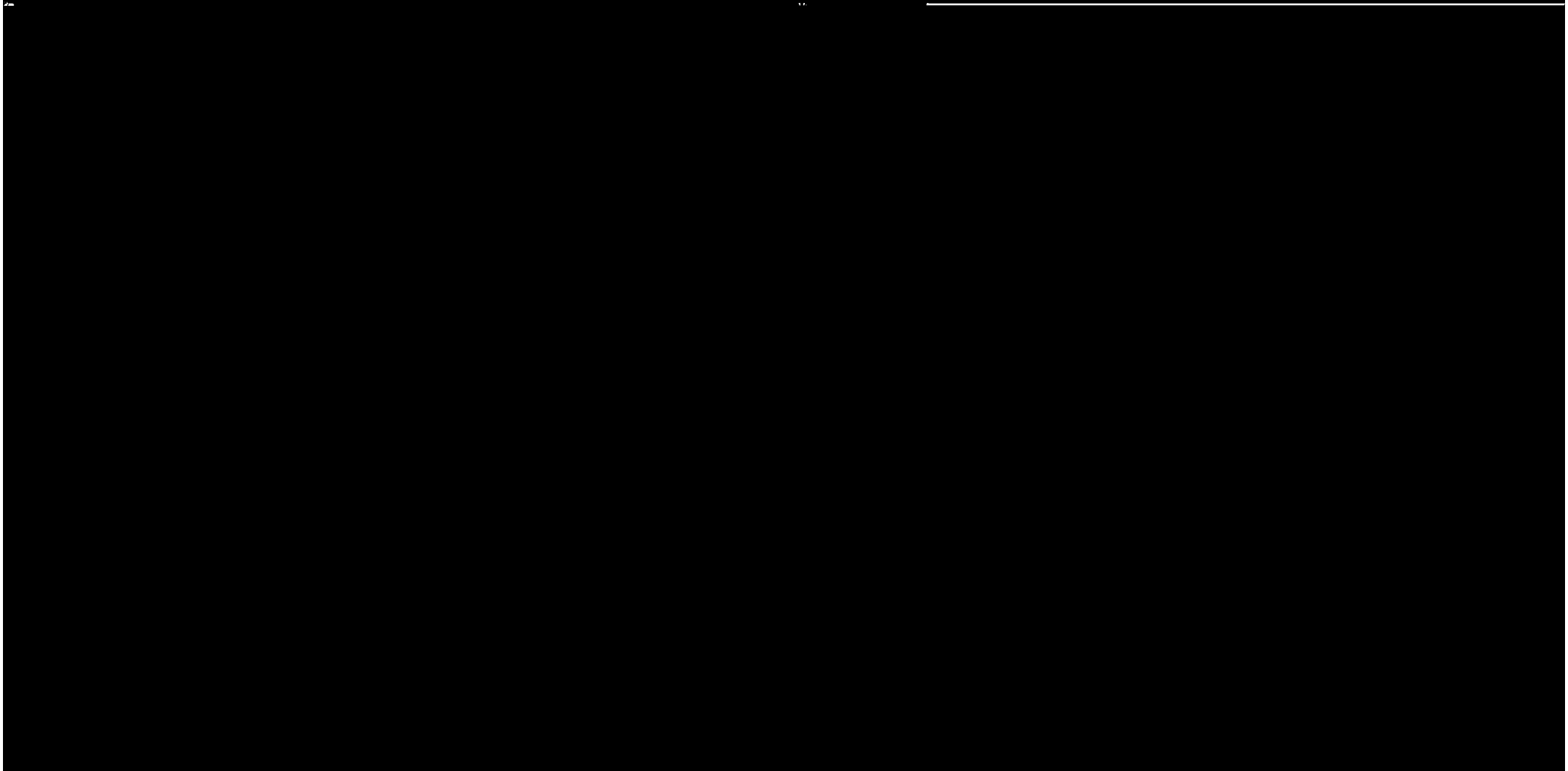


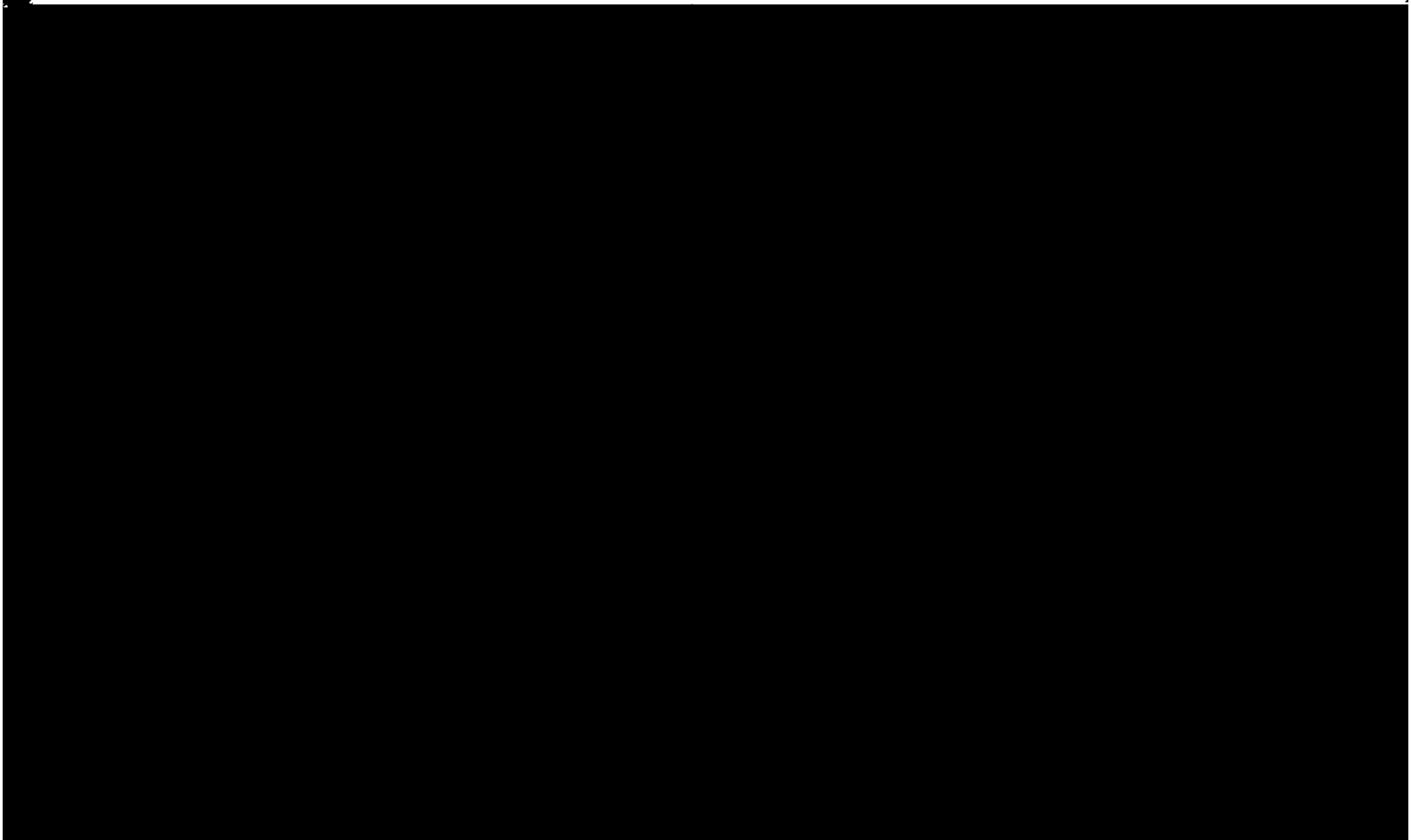
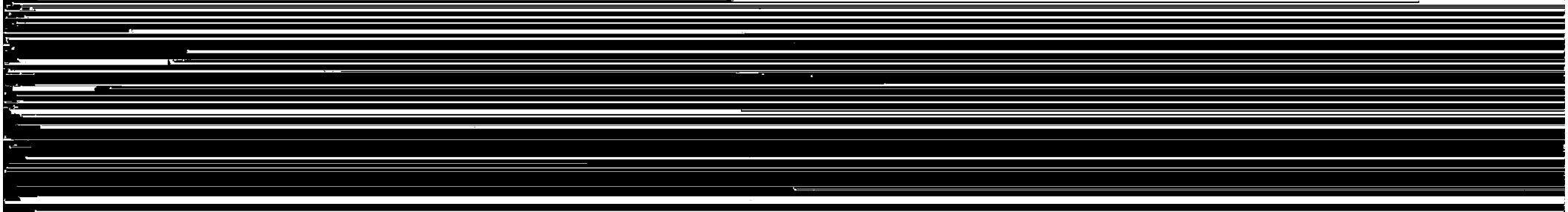


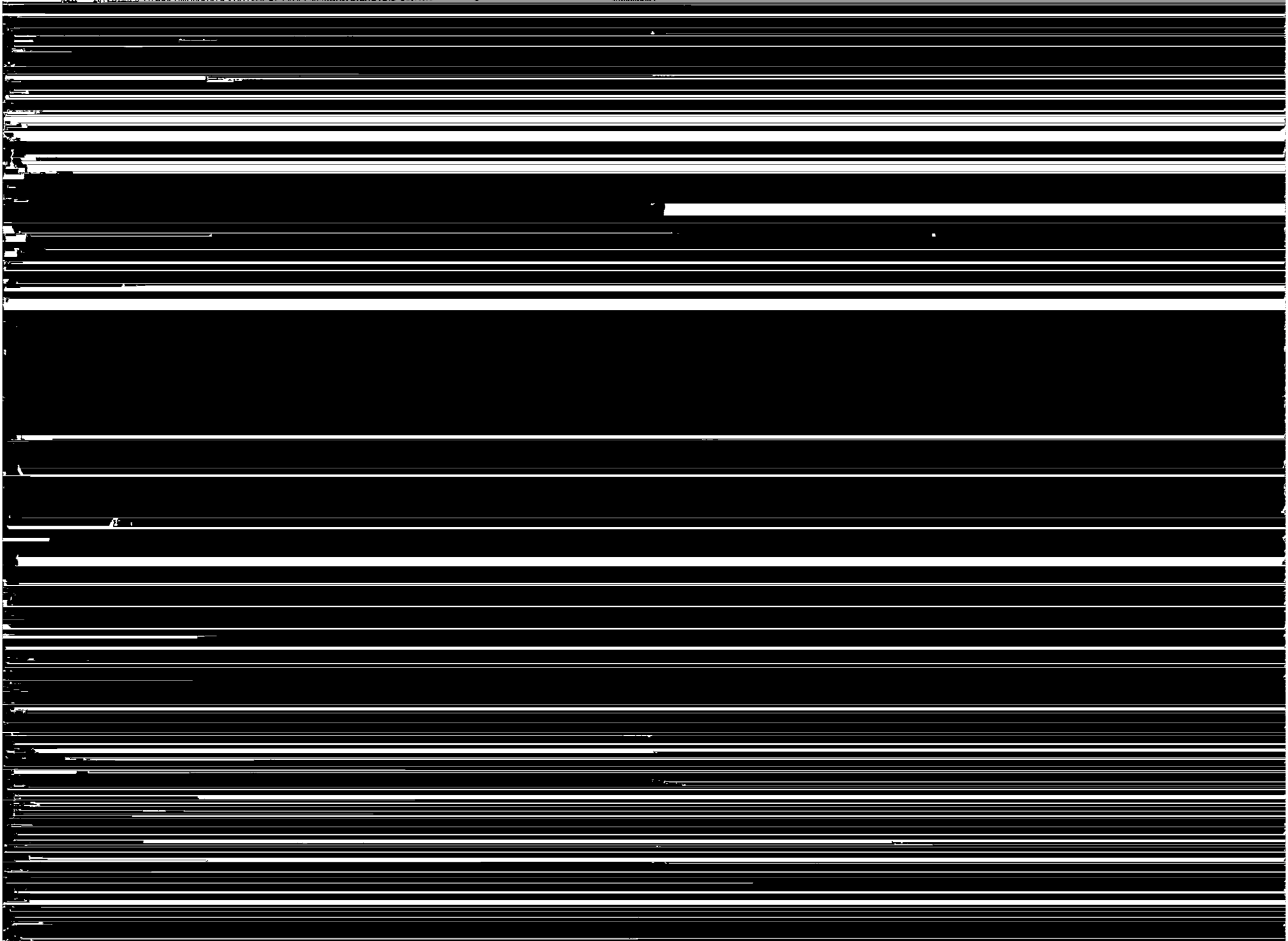




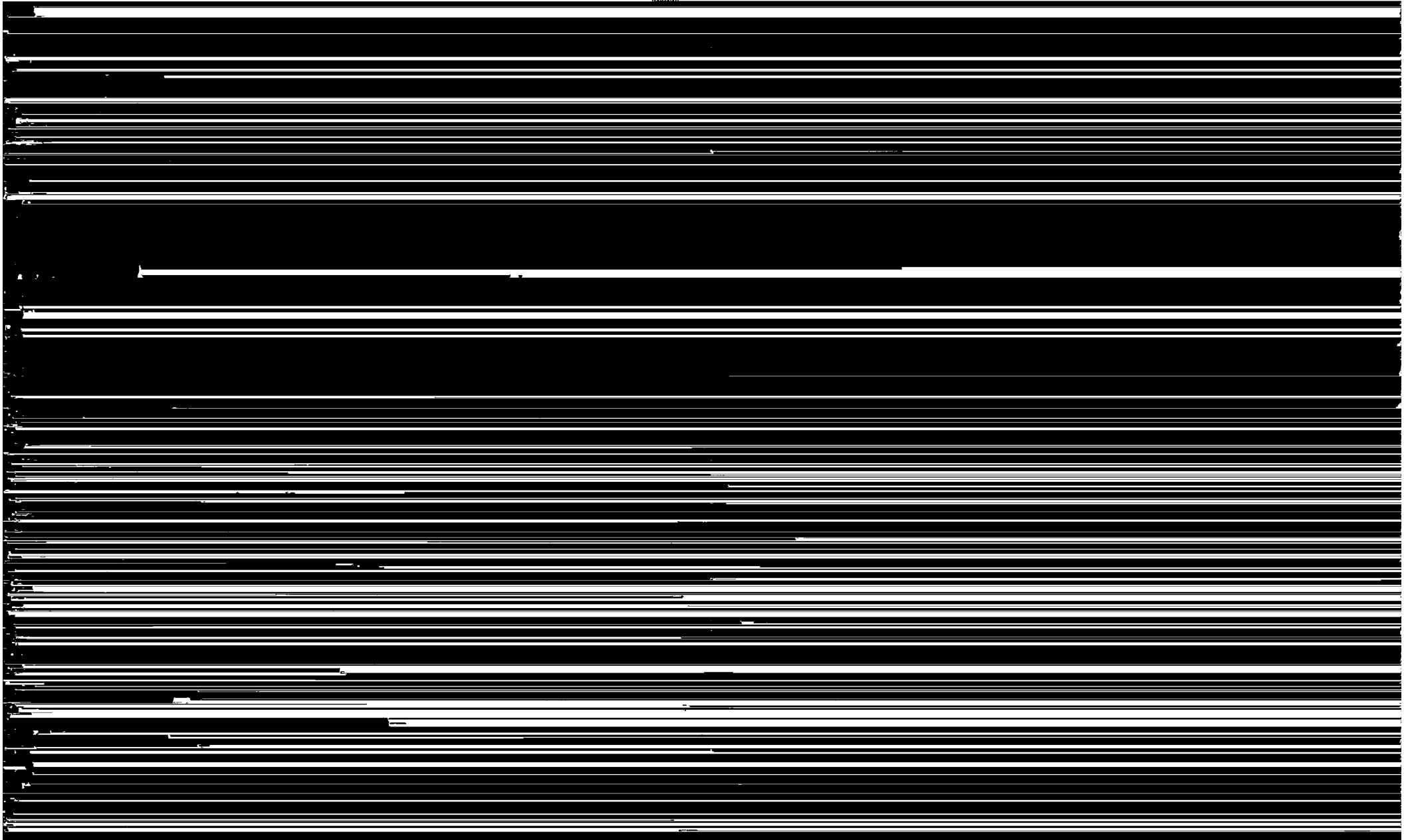
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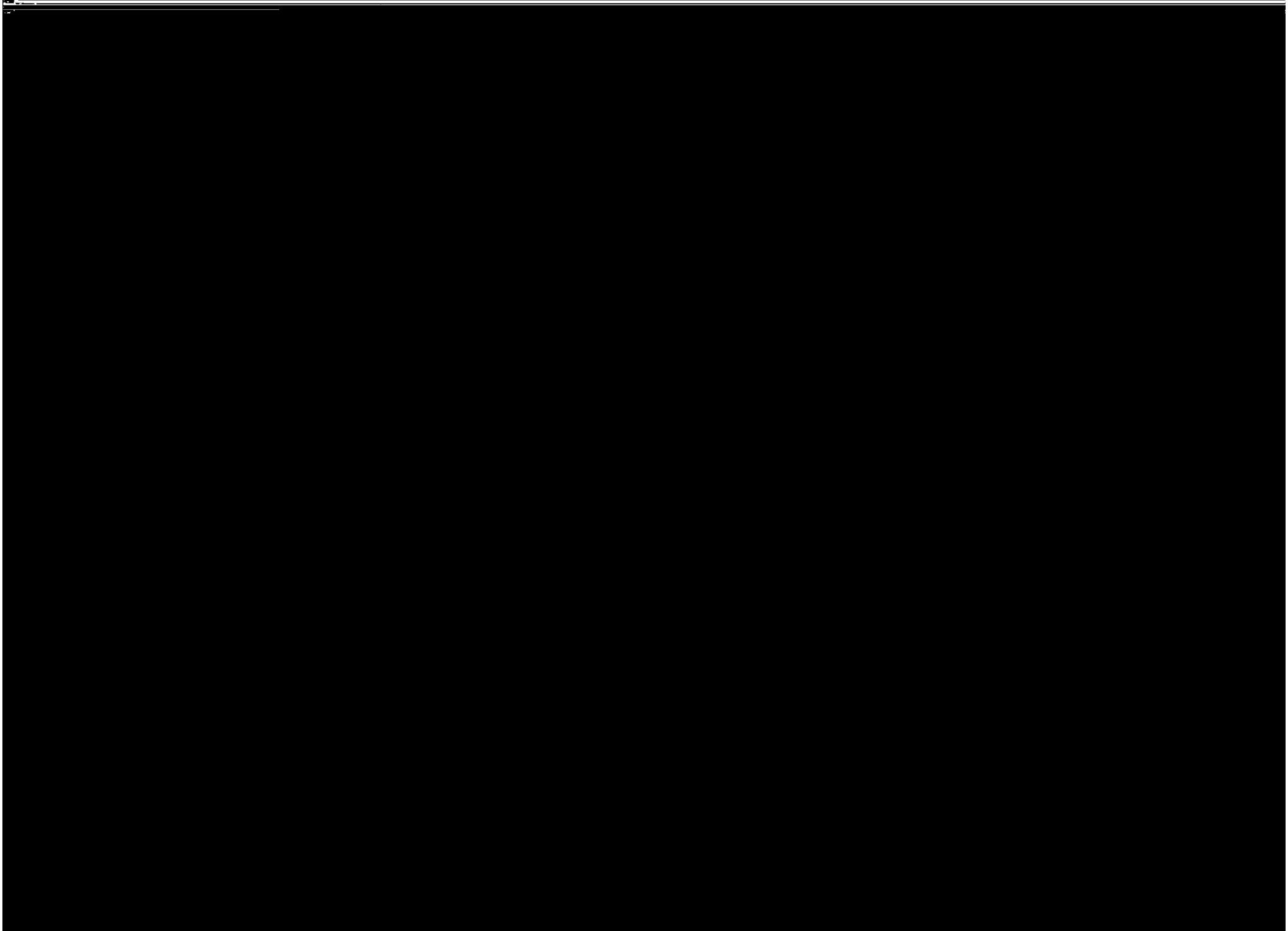


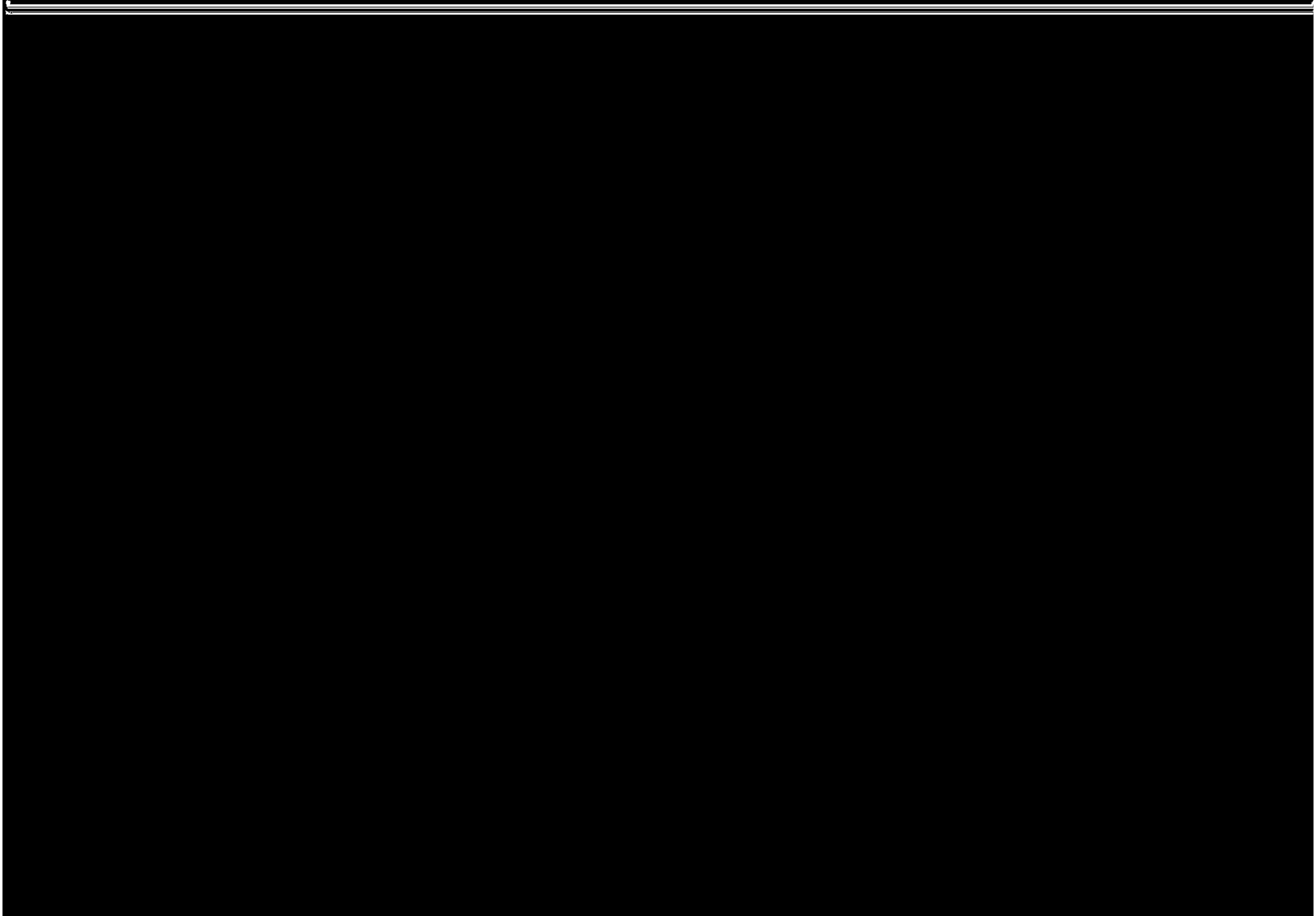


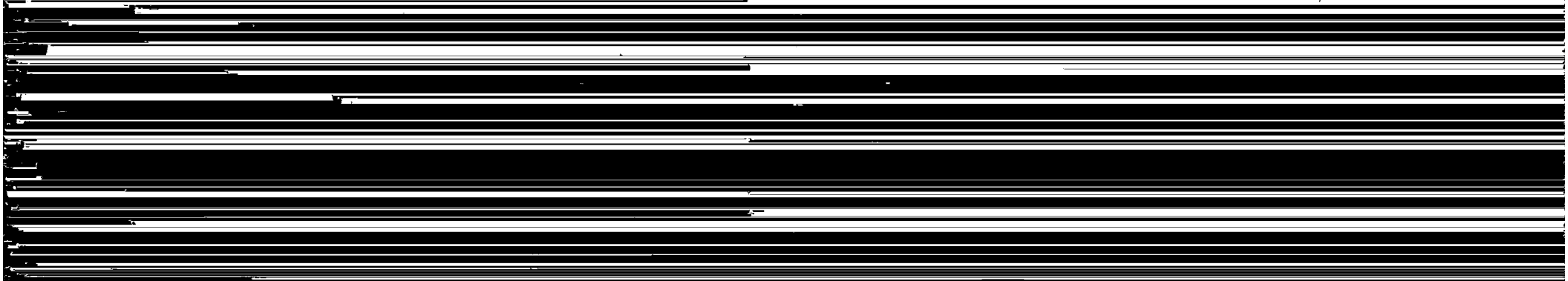


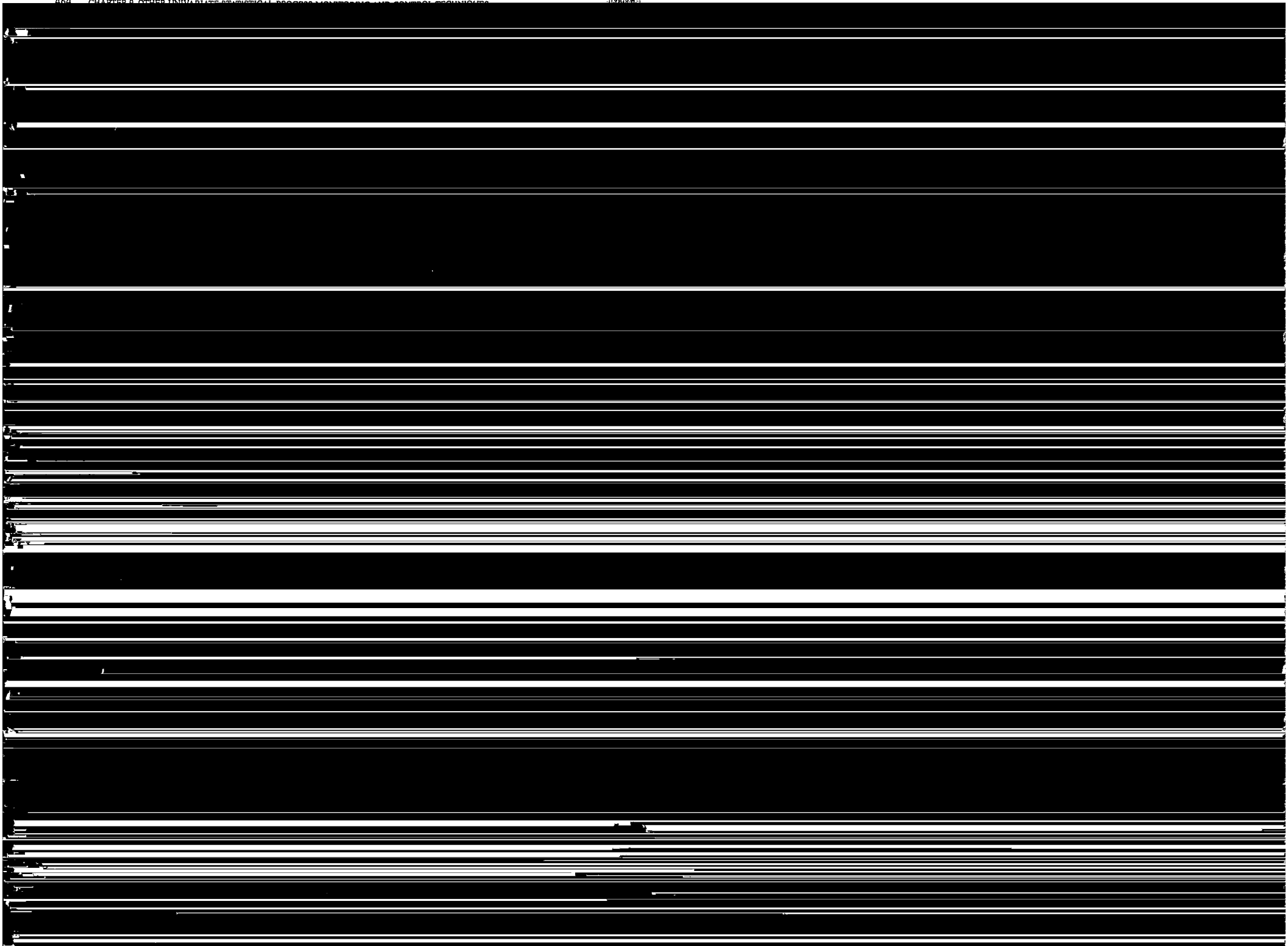






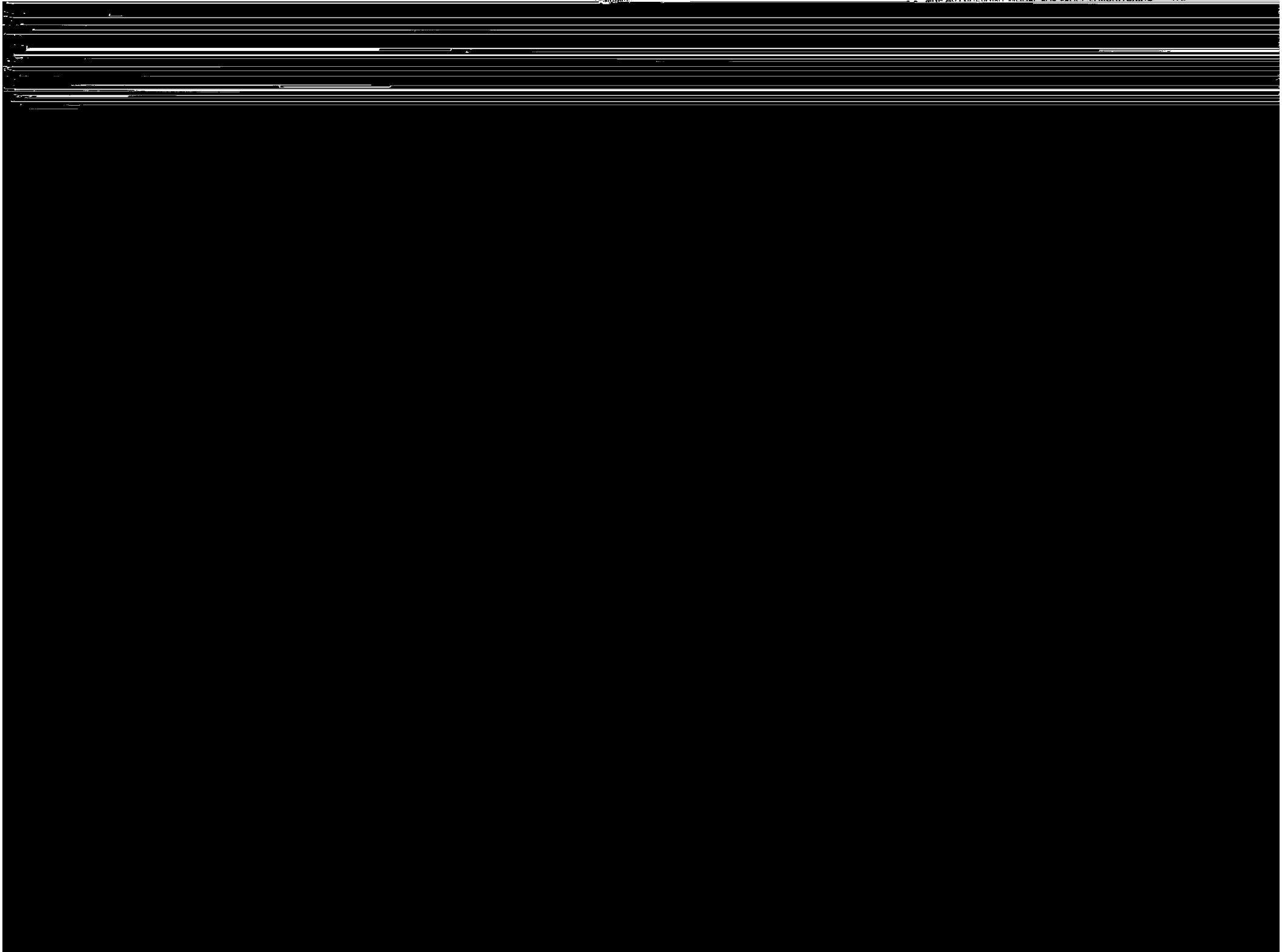






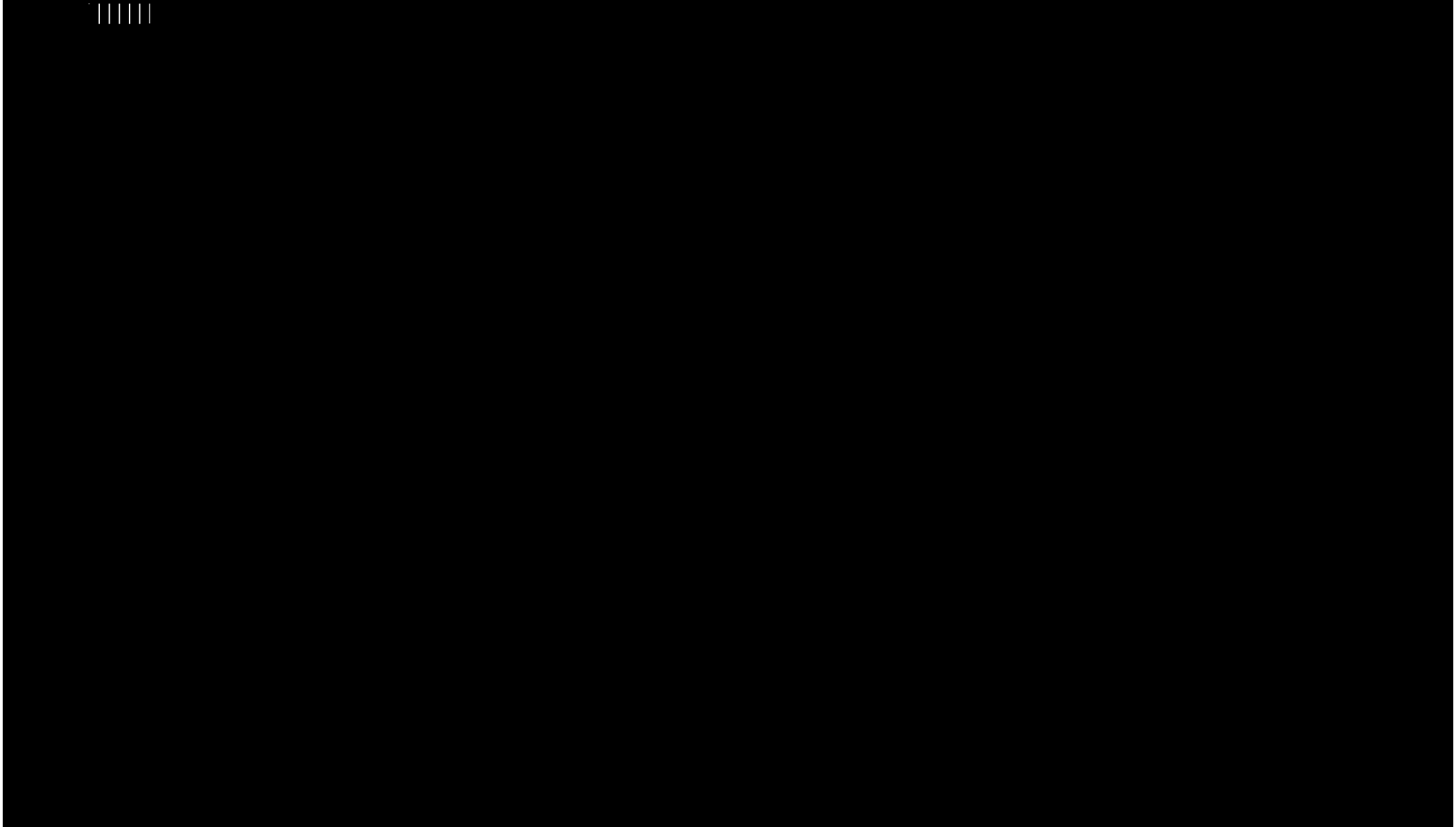
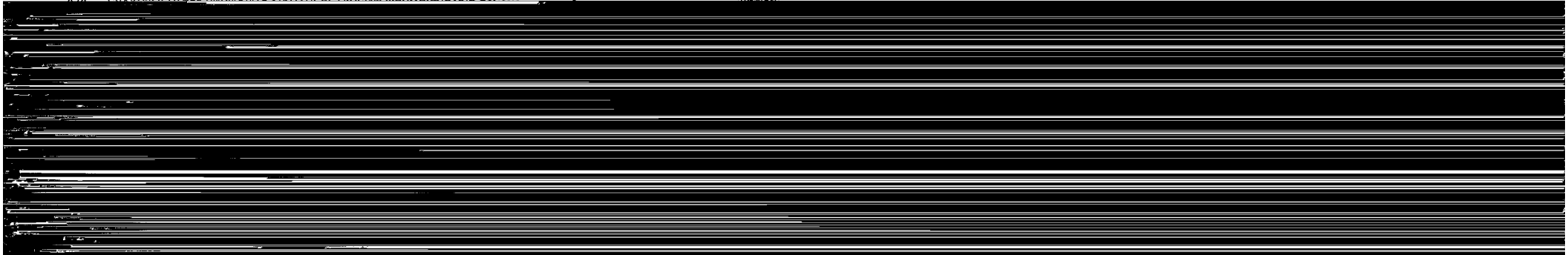


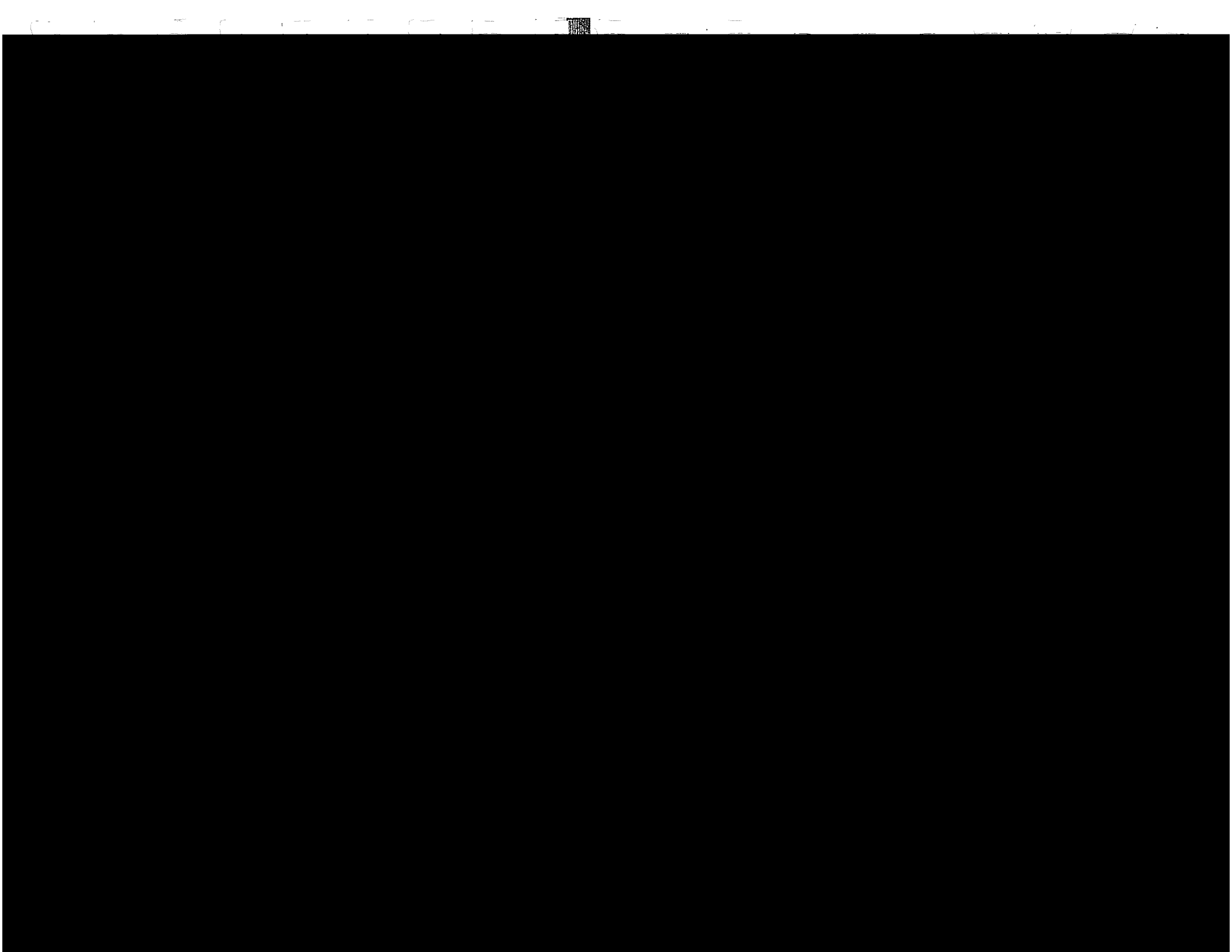


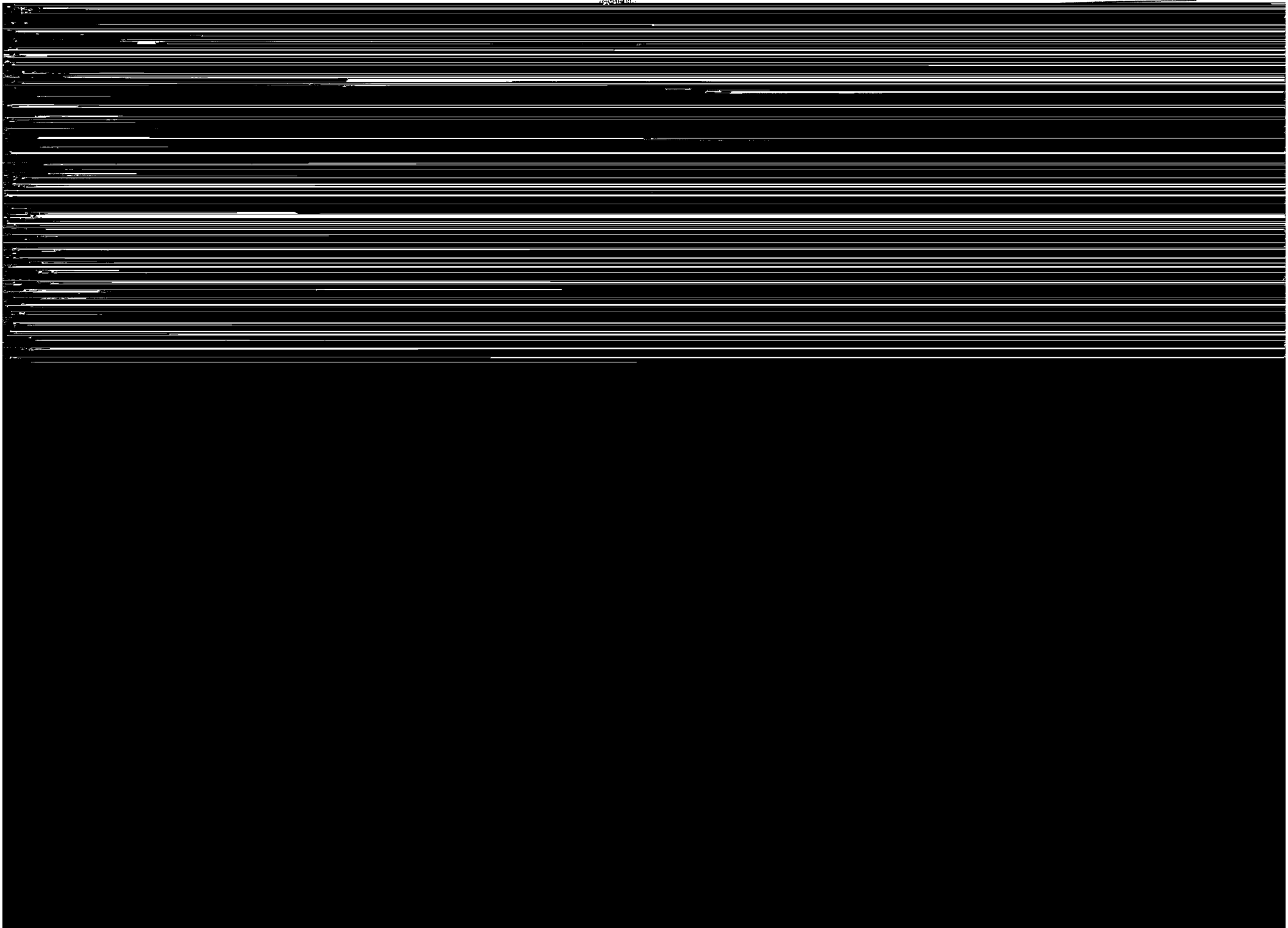


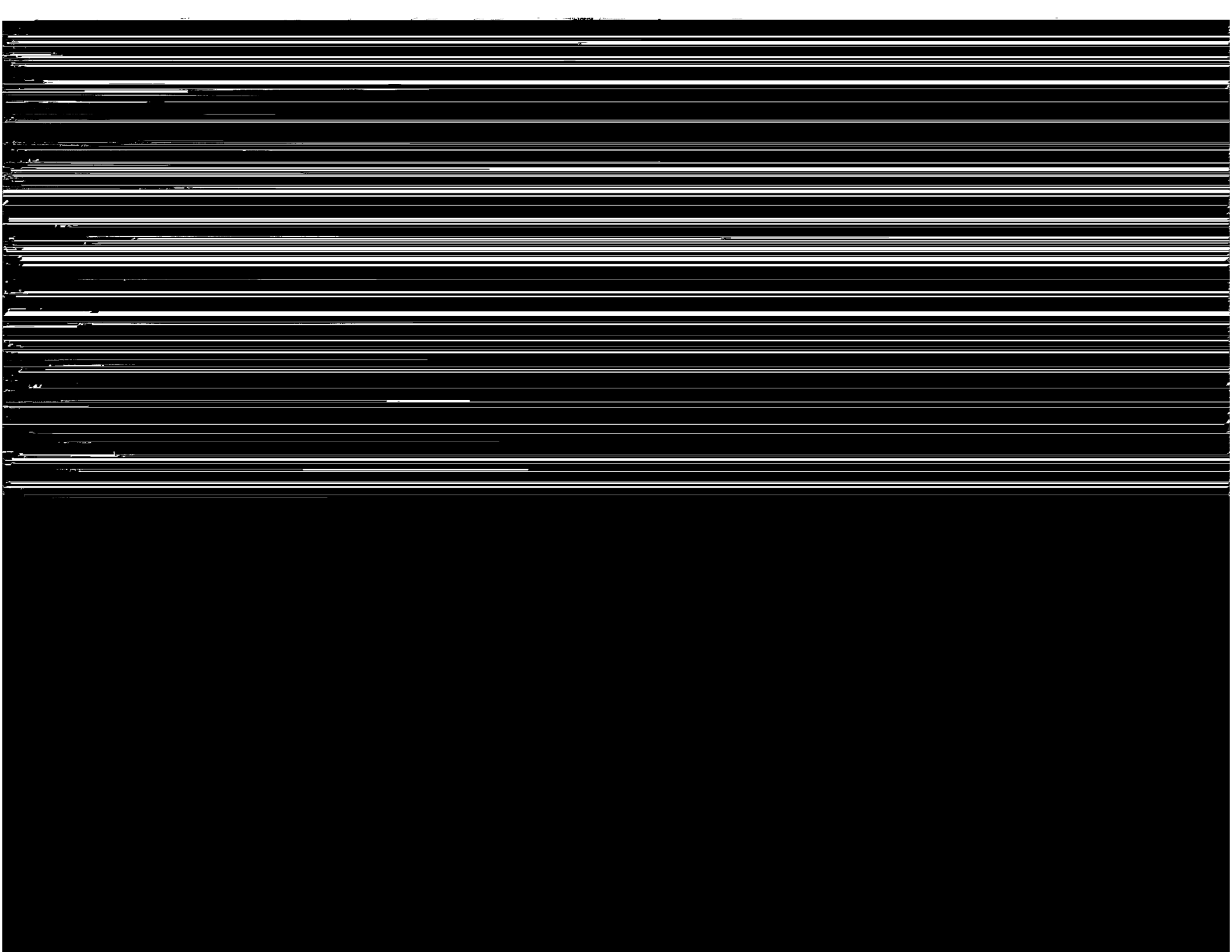




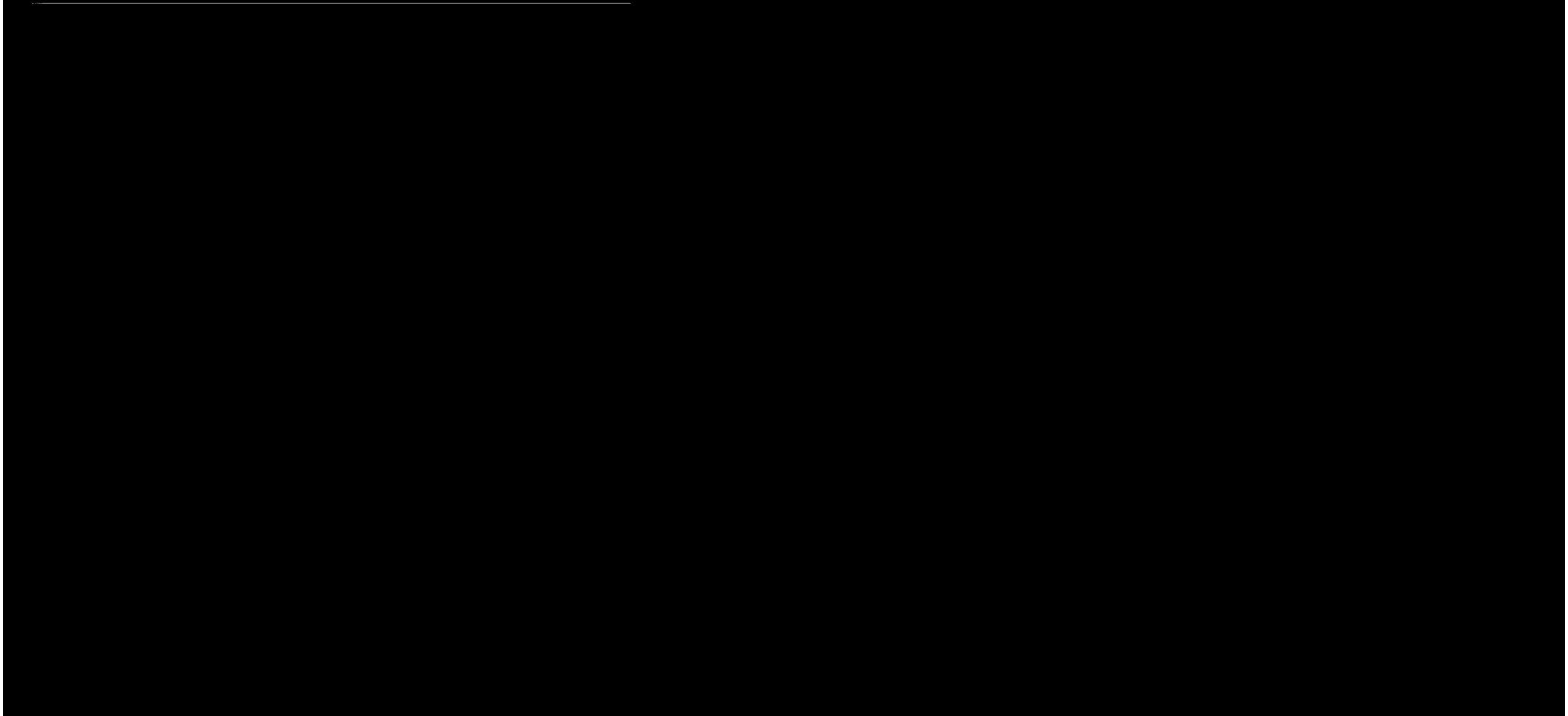






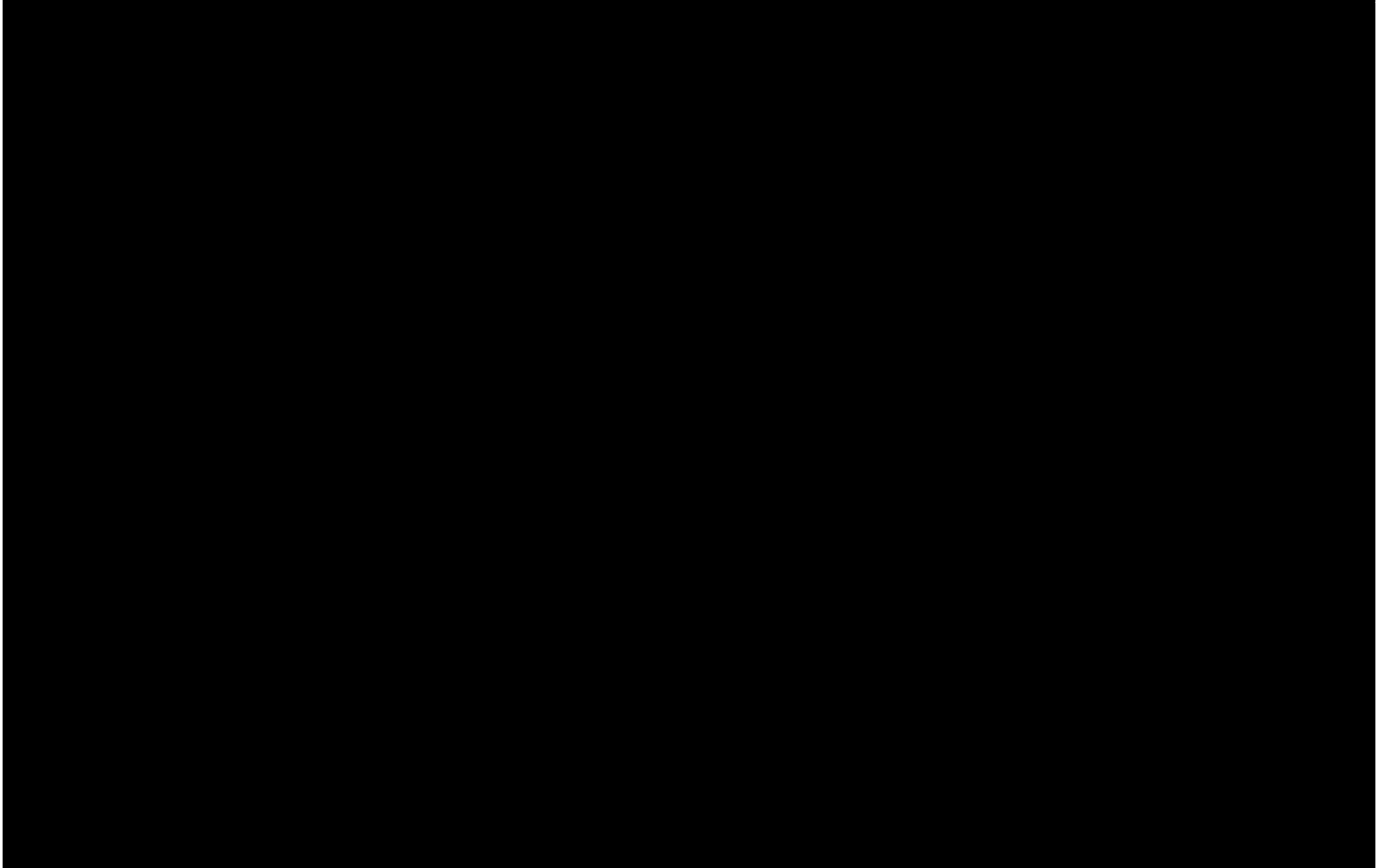
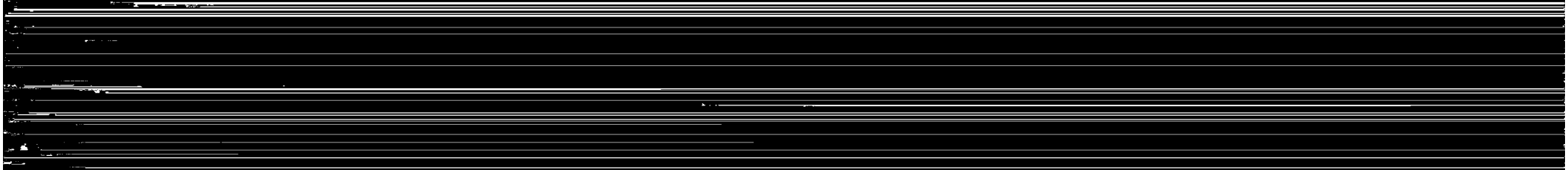






100

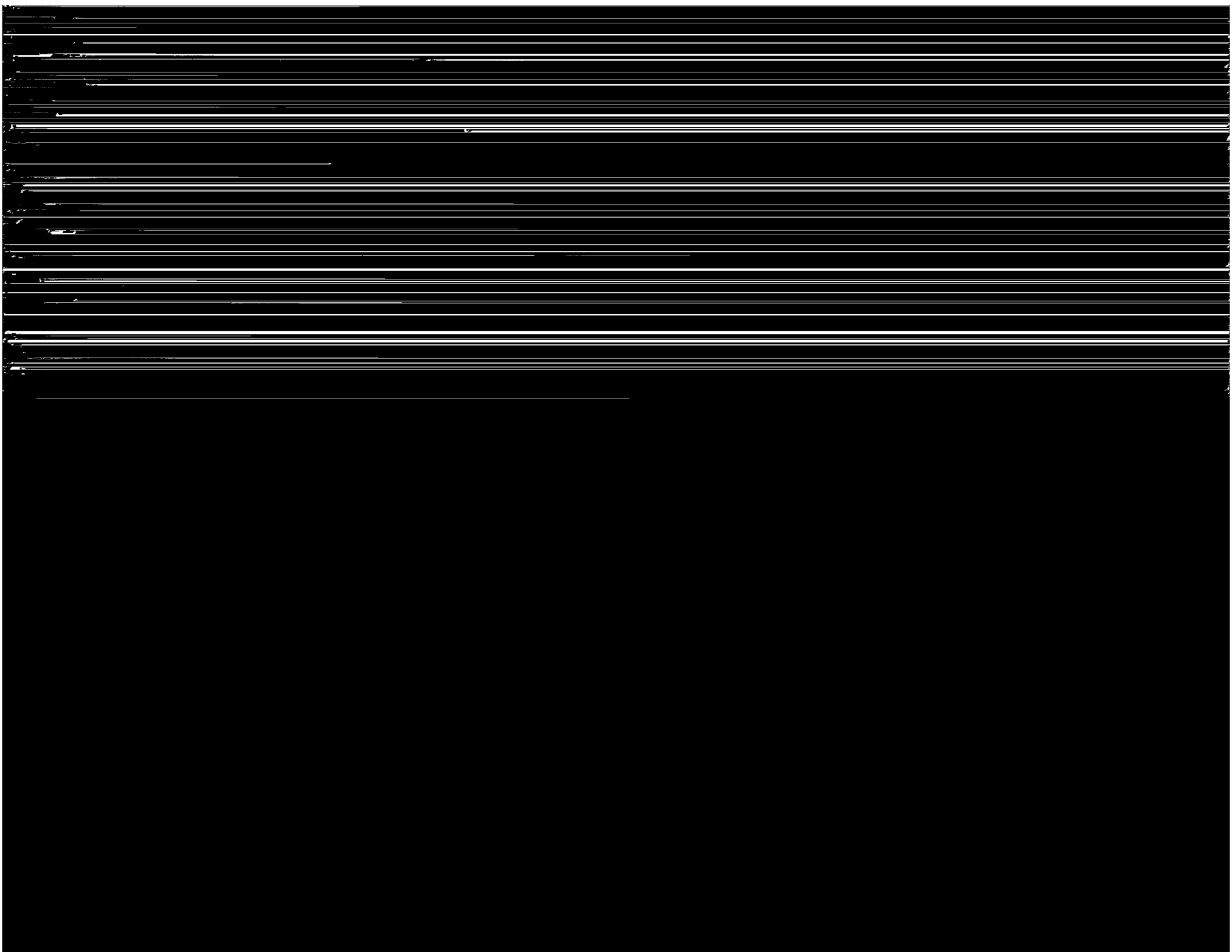
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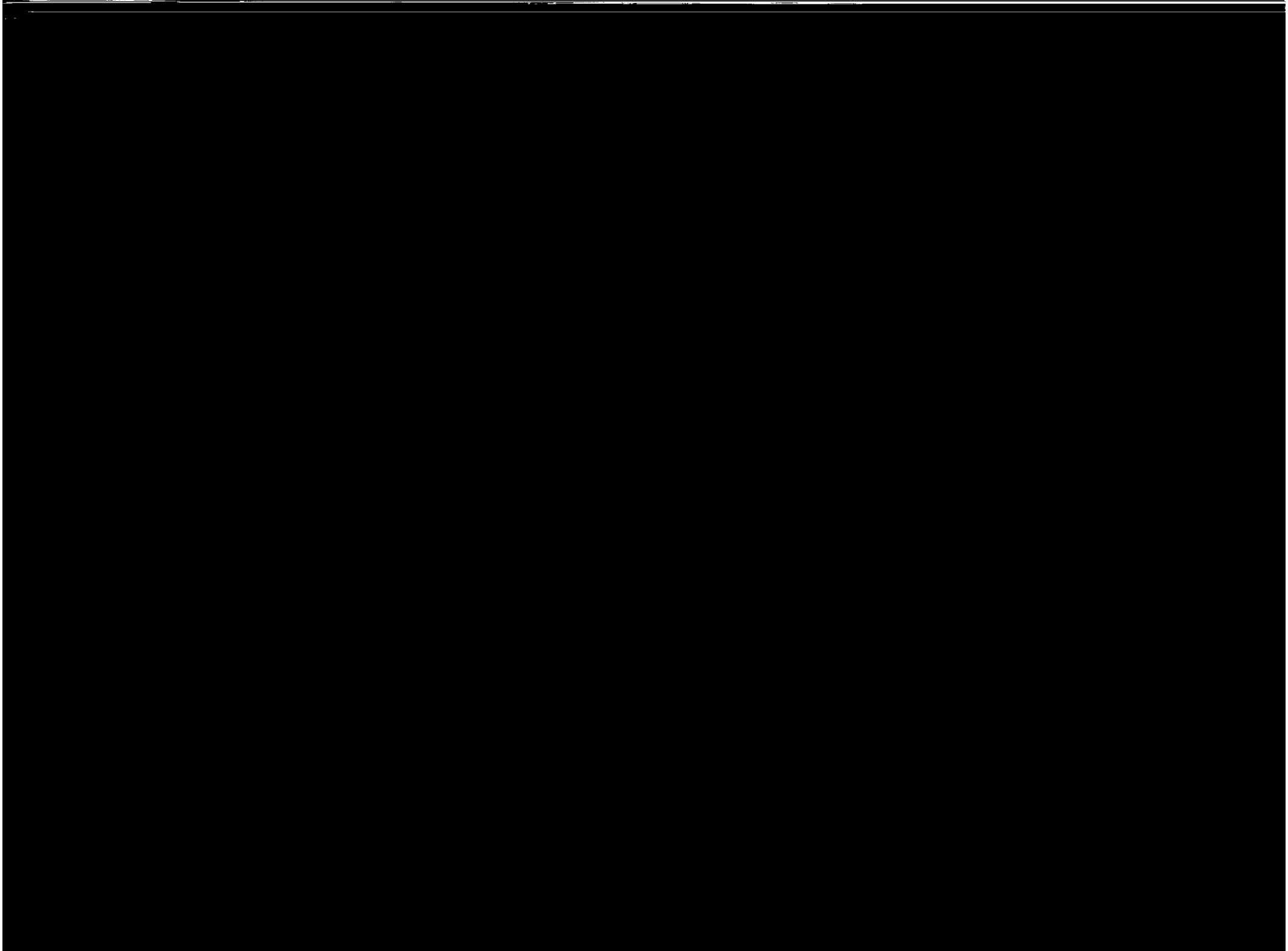


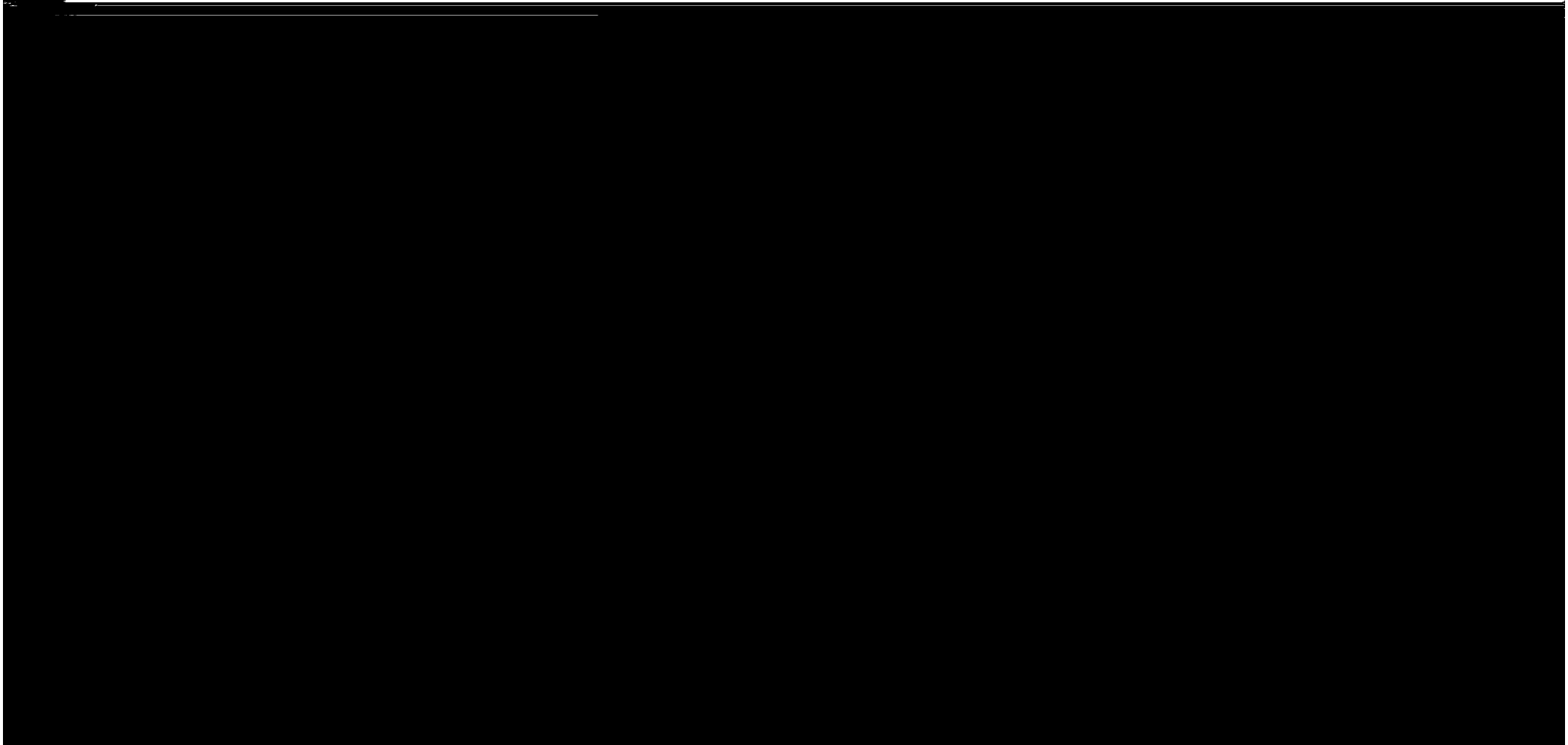
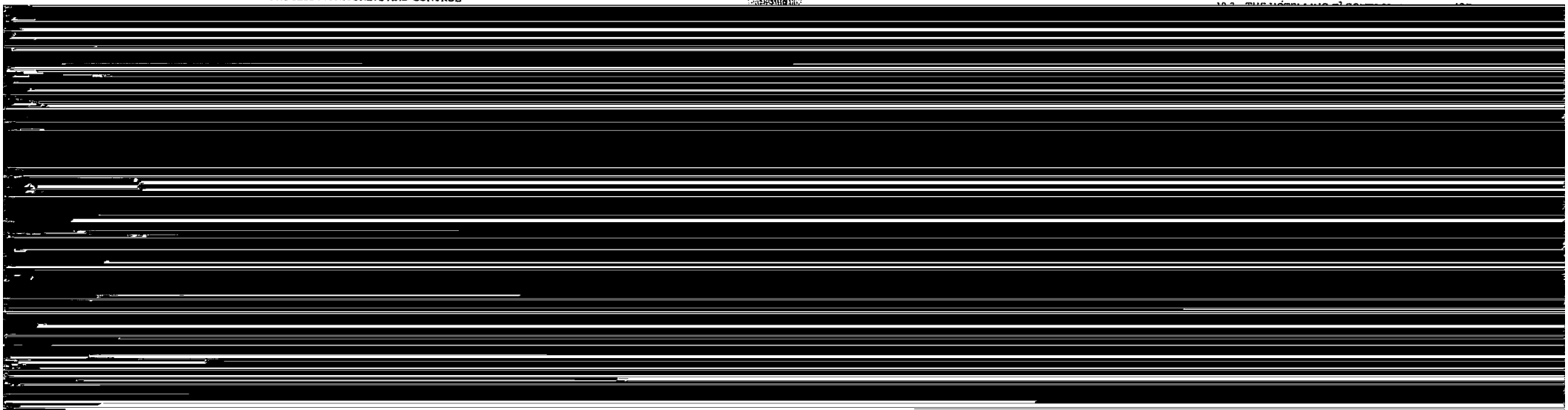
Variable	Mean	Standard Deviation	Minimum	Maximum
1	1.0	0.0	1.0	1.0
2	1.0	0.0	1.0	1.0
3	1.0	0.0	1.0	1.0
4	1.0	0.0	1.0	1.0
5	1.0	0.0	1.0	1.0
6	1.0	0.0	1.0	1.0
7	1.0	0.0	1.0	1.0
8	1.0	0.0	1.0	1.0
9	1.0	0.0	1.0	1.0
10	1.0	0.0	1.0	1.0
11	1.0	0.0	1.0	1.0
12	1.0	0.0	1.0	1.0
13	1.0	0.0	1.0	1.0
14	1.0	0.0	1.0	1.0
15	1.0	0.0	1.0	1.0
16	1.0	0.0	1.0	1.0
17	1.0	0.0	1.0	1.0
18	1.0	0.0	1.0	1.0
19	1.0	0.0	1.0	1.0
20	1.0	0.0	1.0	1.0
21	1.0	0.0	1.0	1.0
22	1.0	0.0	1.0	1.0
23	1.0	0.0	1.0	1.0
24	1.0	0.0	1.0	1.0
25	1.0	0.0	1.0	1.0
26	1.0	0.0	1.0	1.0
27	1.0	0.0	1.0	1.0
28	1.0	0.0	1.0	1.0
29	1.0	0.0	1.0	1.0
30	1.0	0.0	1.0	1.0
31	1.0	0.0	1.0	1.0
32	1.0	0.0	1.0	1.0
33	1.0	0.0	1.0	1.0
34	1.0	0.0	1.0	1.0
35	1.0	0.0	1.0	1.0
36	1.0	0.0	1.0	1.0
37	1.0	0.0	1.0	1.0
38	1.0	0.0	1.0	1.0
39	1.0	0.0	1.0	1.0
40	1.0	0.0	1.0	1.0
41	1.0	0.0	1.0	1.0
42	1.0	0.0	1.0	1.0
43	1.0	0.0	1.0	1.0
44	1.0	0.0	1.0	1.0
45	1.0	0.0	1.0	1.0
46	1.0	0.0	1.0	1.0
47	1.0	0.0	1.0	1.0
48	1.0	0.0	1.0	1.0
49	1.0	0.0	1.0	1.0
50	1.0	0.0	1.0	1.0
51	1.0	0.0	1.0	1.0
52	1.0	0.0	1.0	1.0
53	1.0	0.0	1.0	1.0
54	1.0	0.0	1.0	1.0
55	1.0	0.0	1.0	1.0
56	1.0	0.0	1.0	1.0
57	1.0	0.0	1.0	1.0
58	1.0	0.0	1.0	1.0
59	1.0	0.0	1.0	1.0
60	1.0	0.0	1.0	1.0
61	1.0	0.0	1.0	1.0
62	1.0	0.0	1.0	1.0
63	1.0	0.0	1.0	1.0
64	1.0	0.0	1.0	1.0
65	1.0	0.0	1.0	1.0
66	1.0	0.0	1.0	1.0
67	1.0	0.0	1.0	1.0
68	1.0	0.0	1.0	1.0
69	1.0	0.0	1.0	1.0
70	1.0	0.0	1.0	1.0
71	1.0	0.0	1.0	1.0
72	1.0	0.0	1.0	1.0
73	1.0	0.0	1.0	1.0
74	1.0	0.0	1.0	1.0
75	1.0	0.0	1.0	1.0
76	1.0	0.0	1.0	1.0
77	1.0	0.0	1.0	1.0
78	1.0	0.0	1.0	1.0
79	1.0	0.0	1.0	1.0
80	1.0	0.0	1.0	1.0
81	1.0	0.0	1.0	1.0
82	1.0	0.0	1.0	1.0
83	1.0	0.0	1.0	1.0
84	1.0	0.0	1.0	1.0
85	1.0	0.0	1.0	1.0
86	1.0	0.0	1.0	1.0
87	1.0	0.0	1.0	1.0
88	1.0	0.0	1.0	1.0
89	1.0	0.0	1.0	1.0
90	1.0	0.0	1.0	1.0
91	1.0	0.0	1.0	1.0
92	1.0	0.0	1.0	1.0
93	1.0	0.0	1.0	1.0
94	1.0	0.0	1.0	1.0
95	1.0	0.0	1.0	1.0
96	1.0	0.0	1.0	1.0
97	1.0	0.0	1.0	1.0
98	1.0	0.0	1.0	1.0
99	1.0	0.0	1.0	1.0
100	1.0	0.0	1.0	1.0



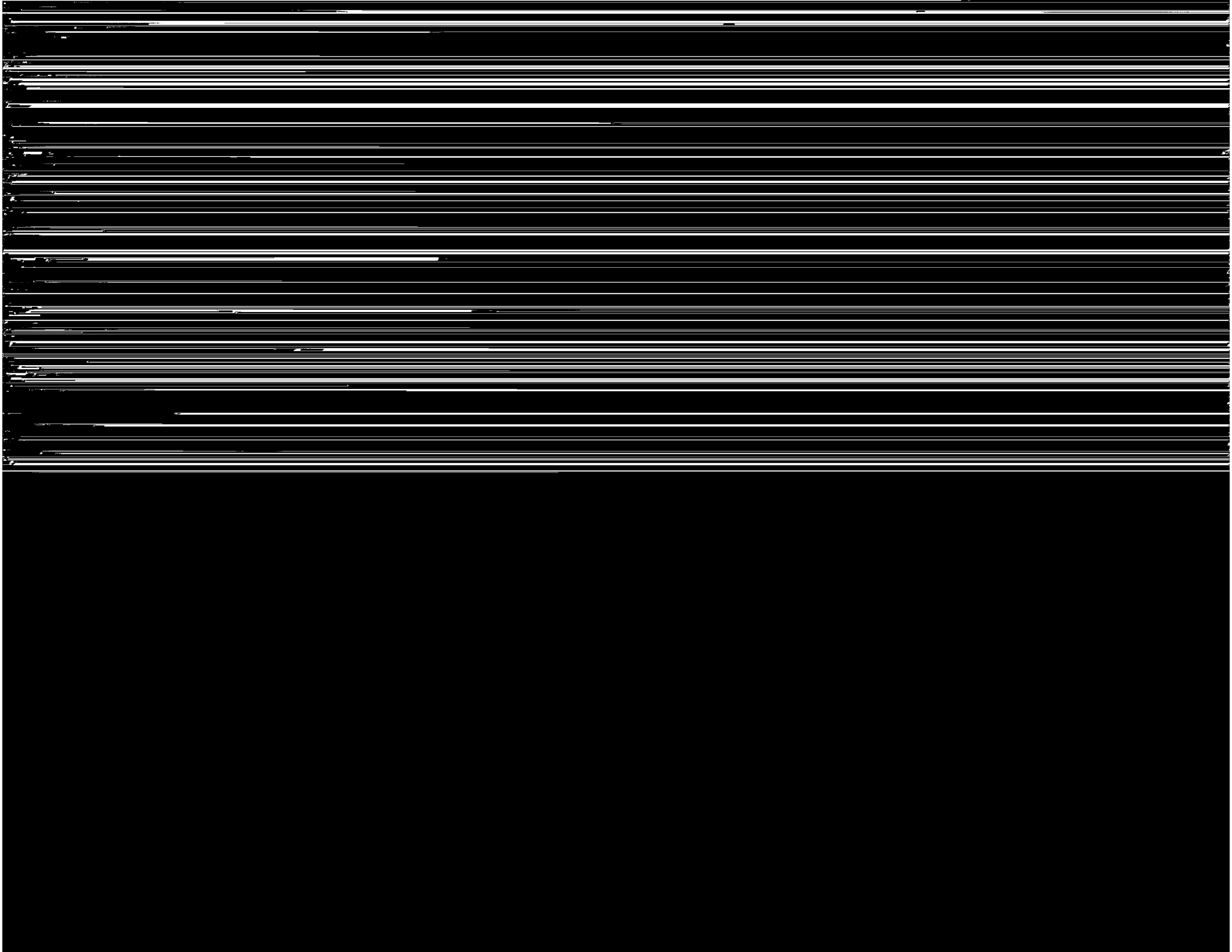


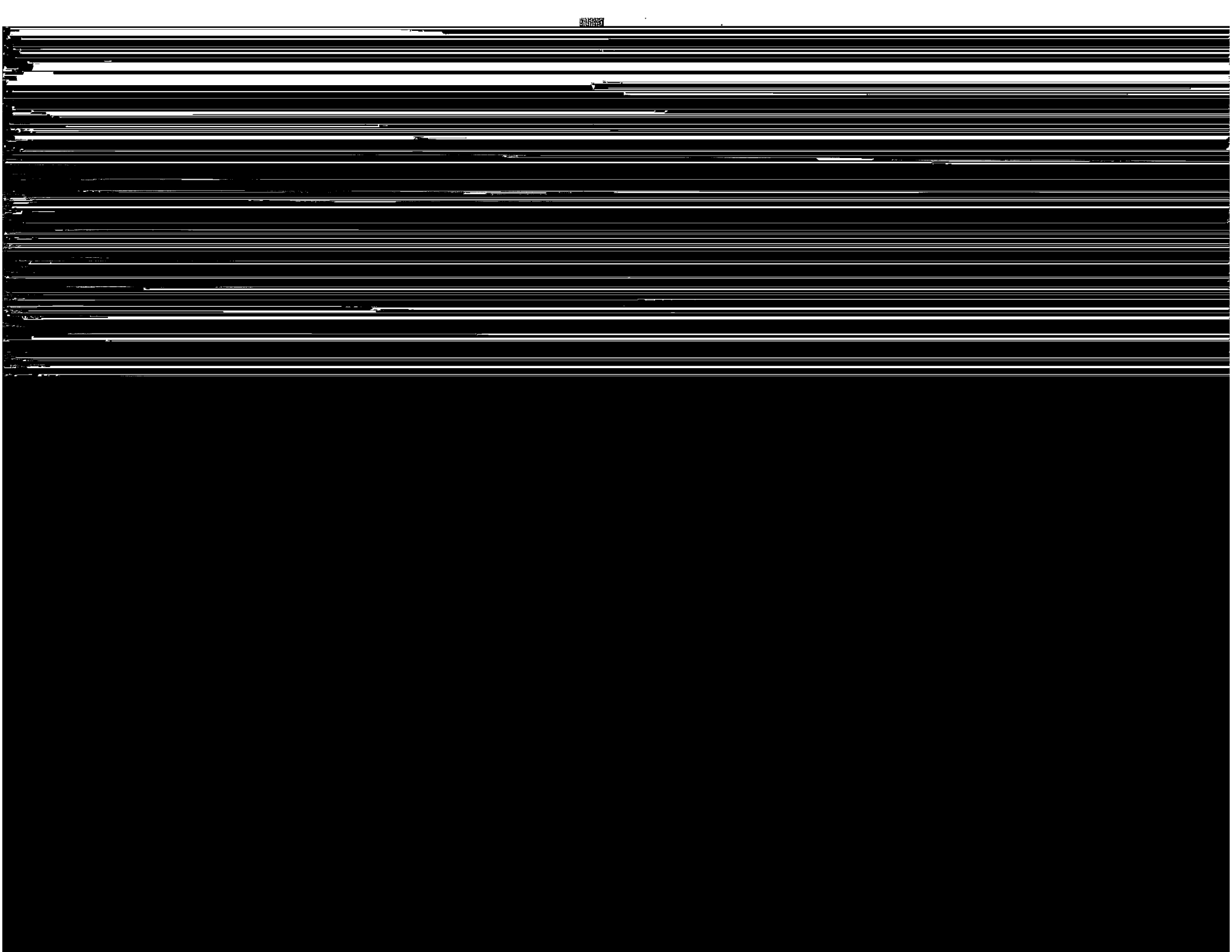


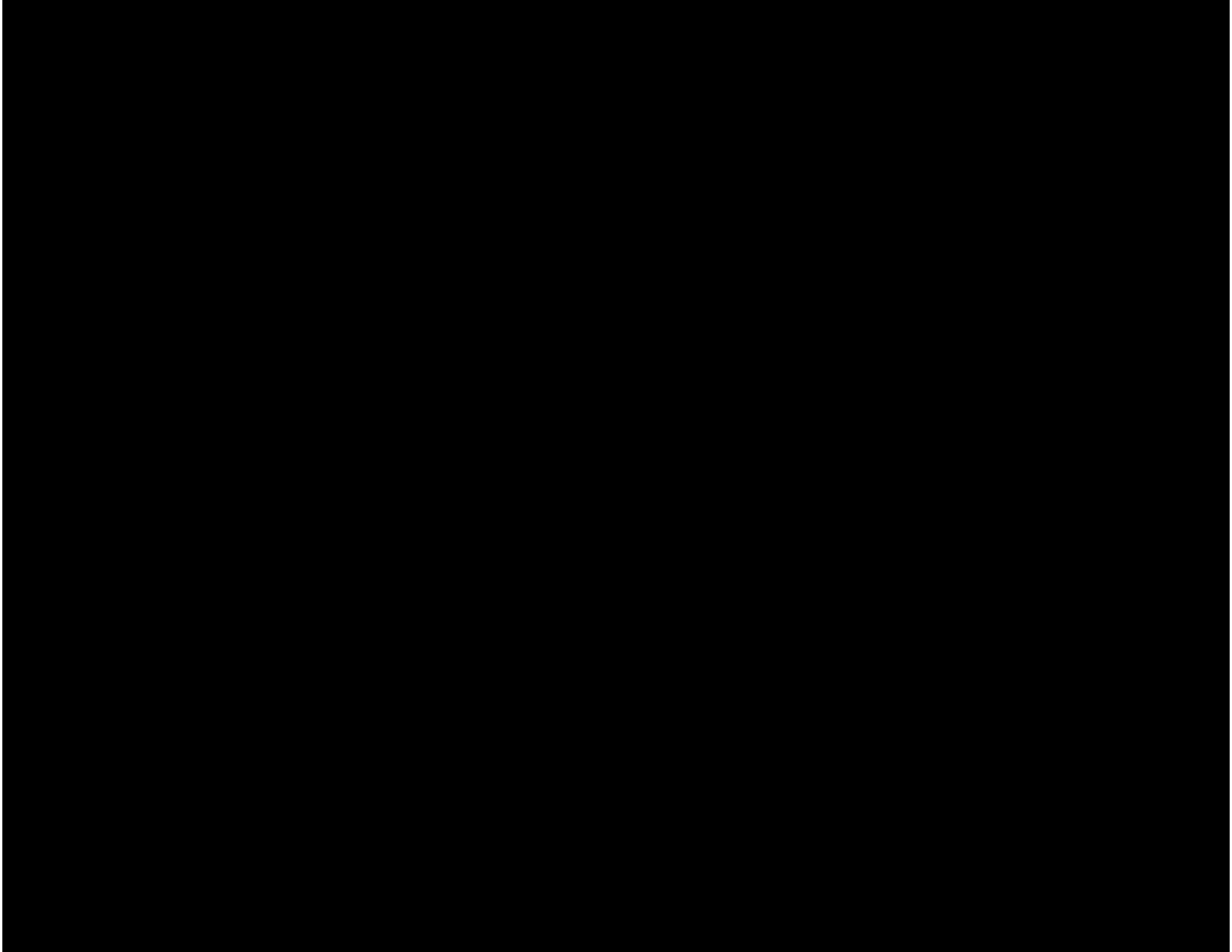




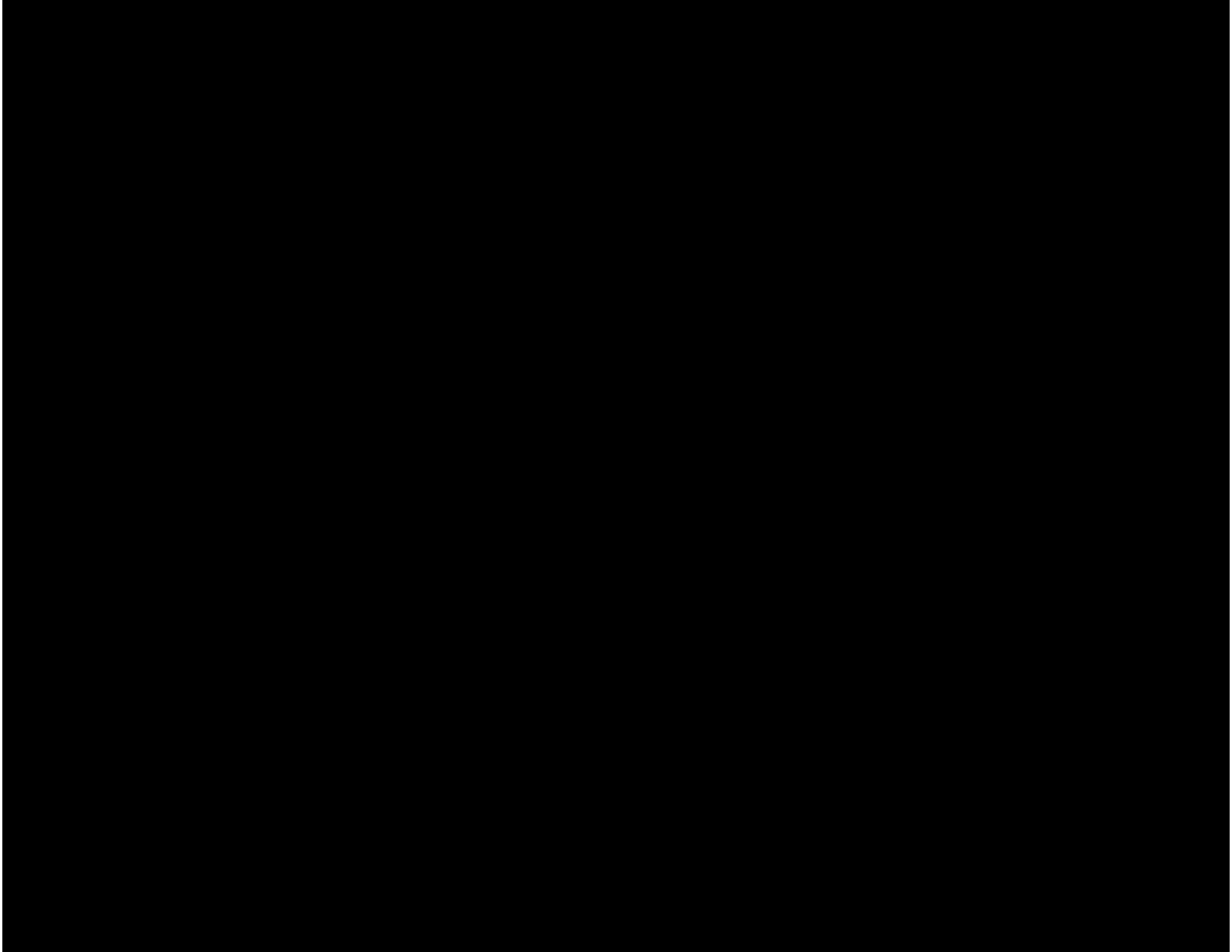


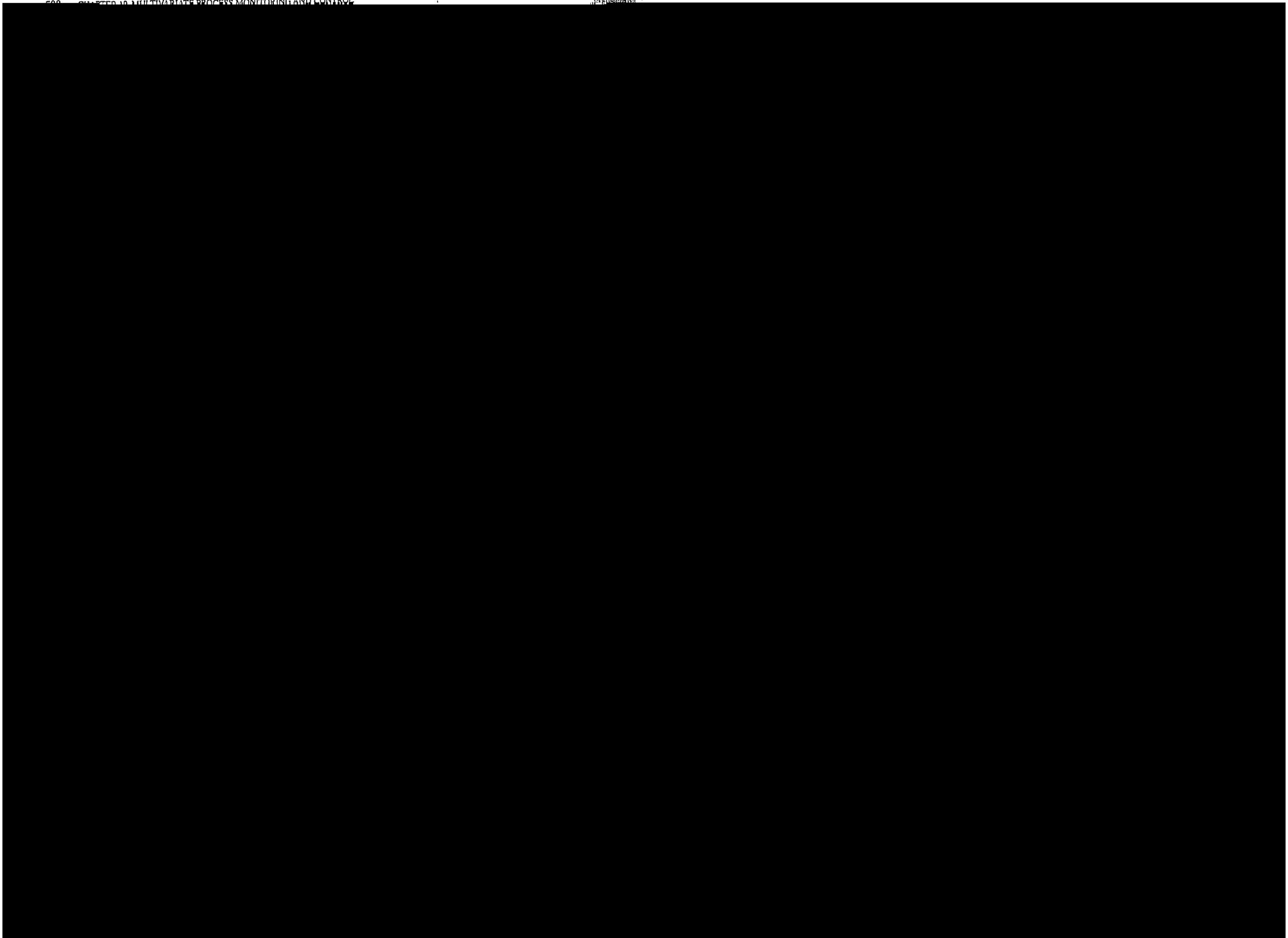


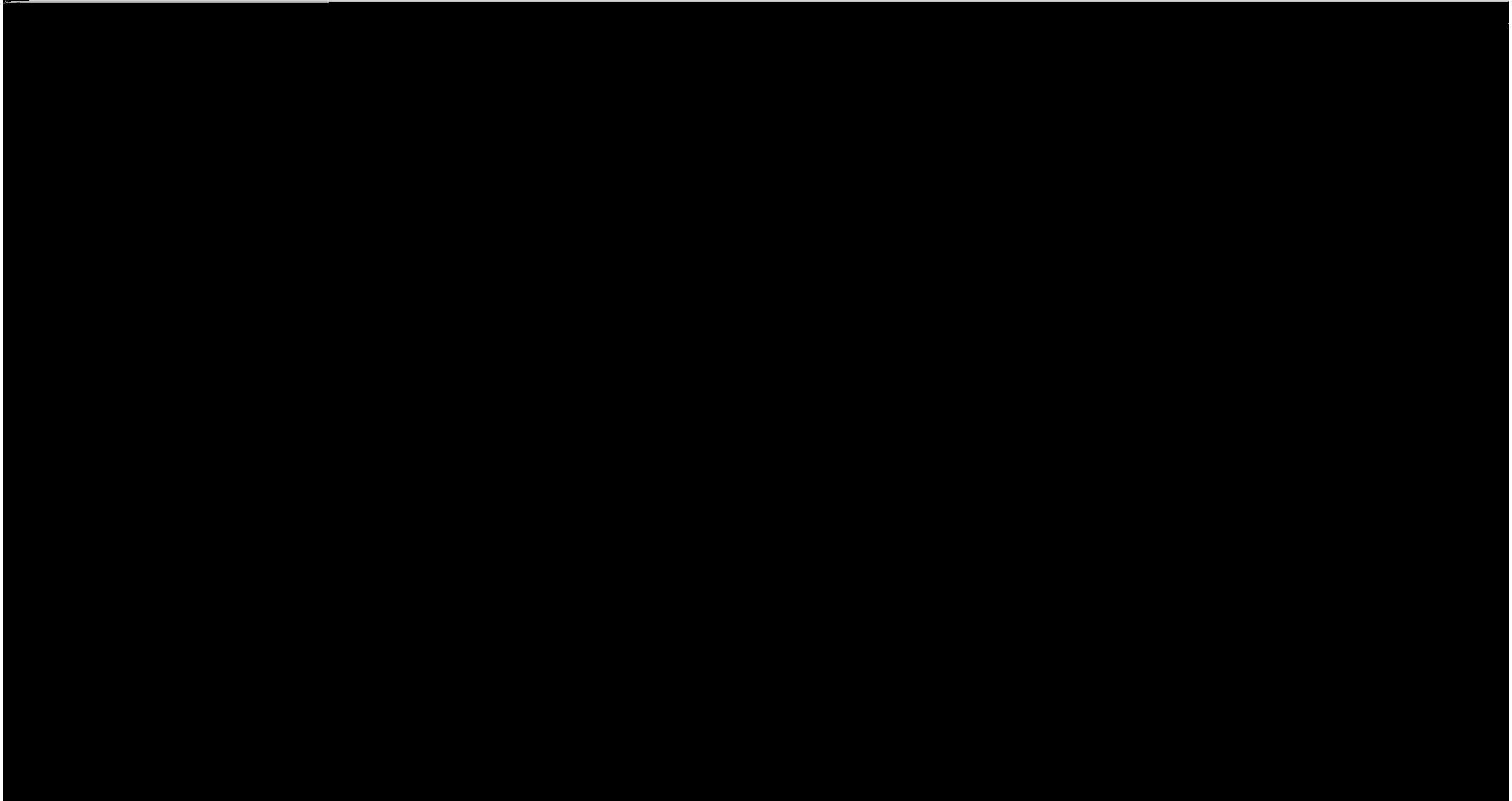
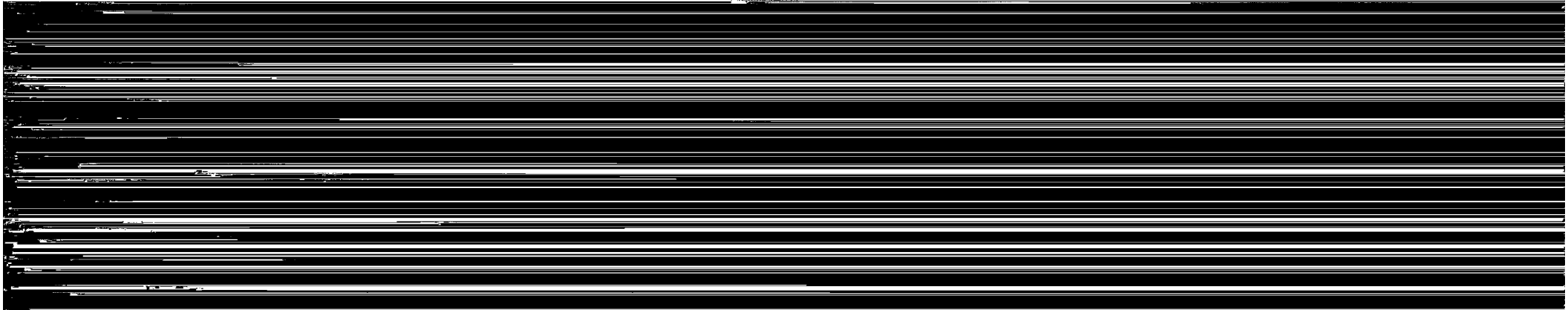


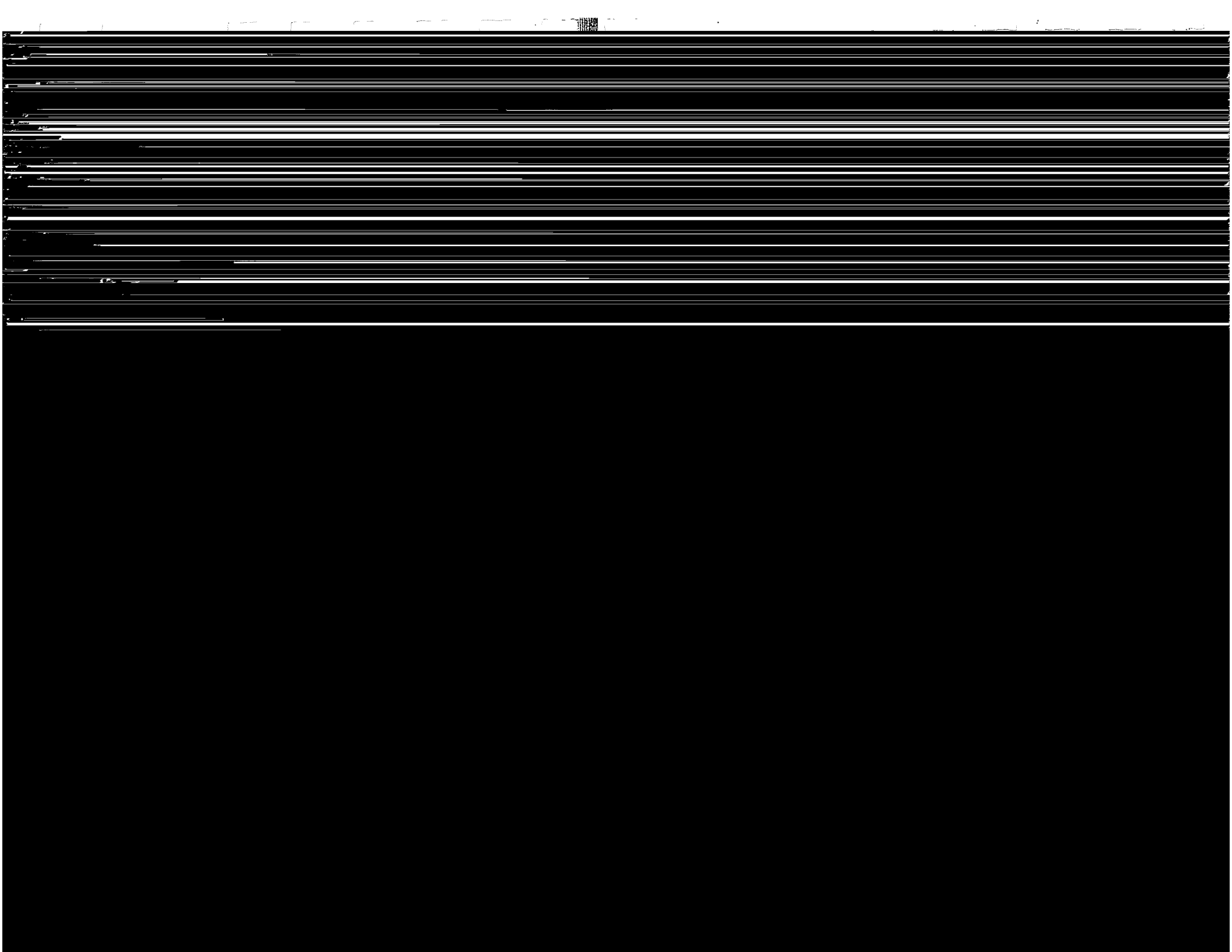


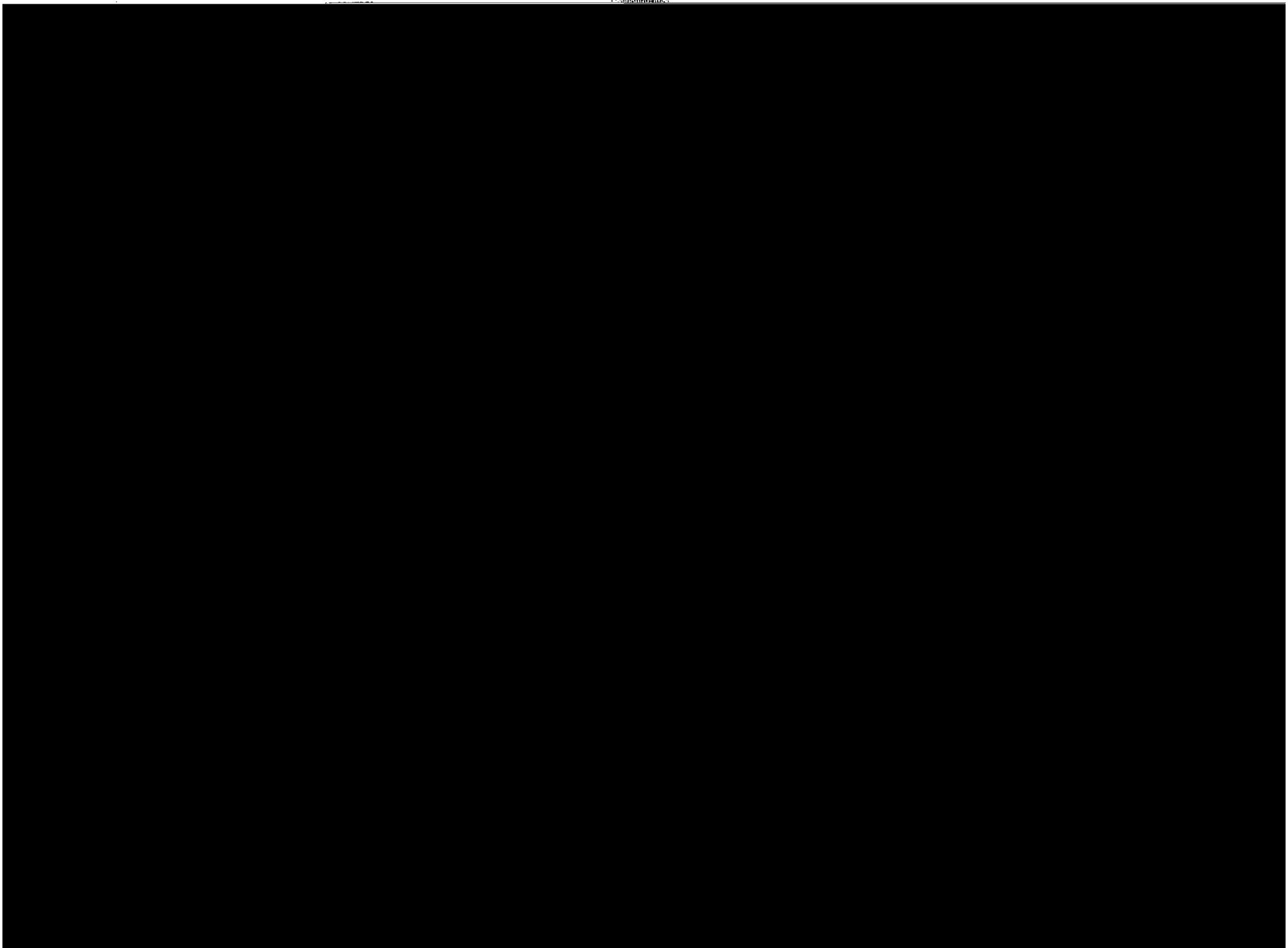












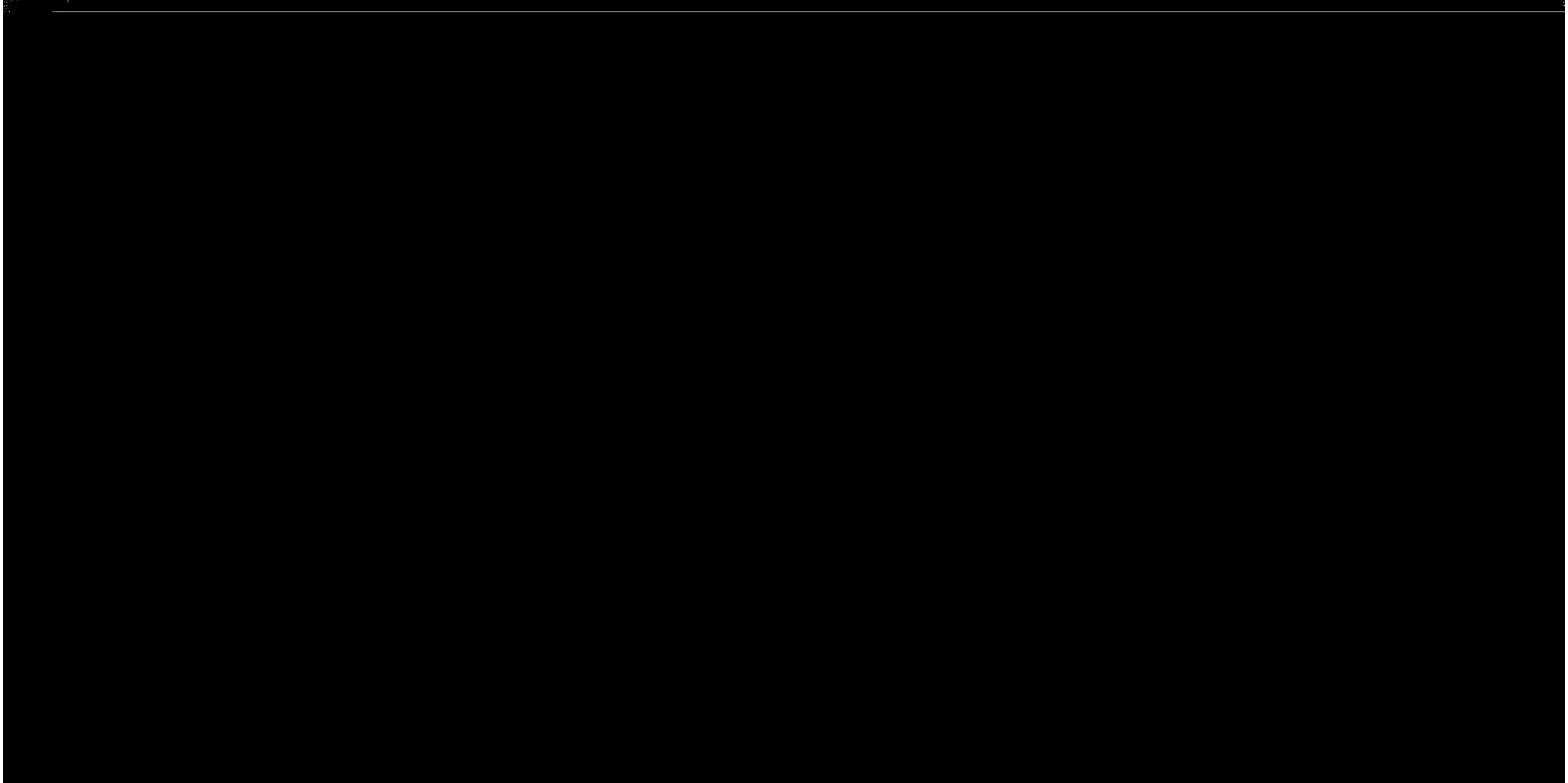
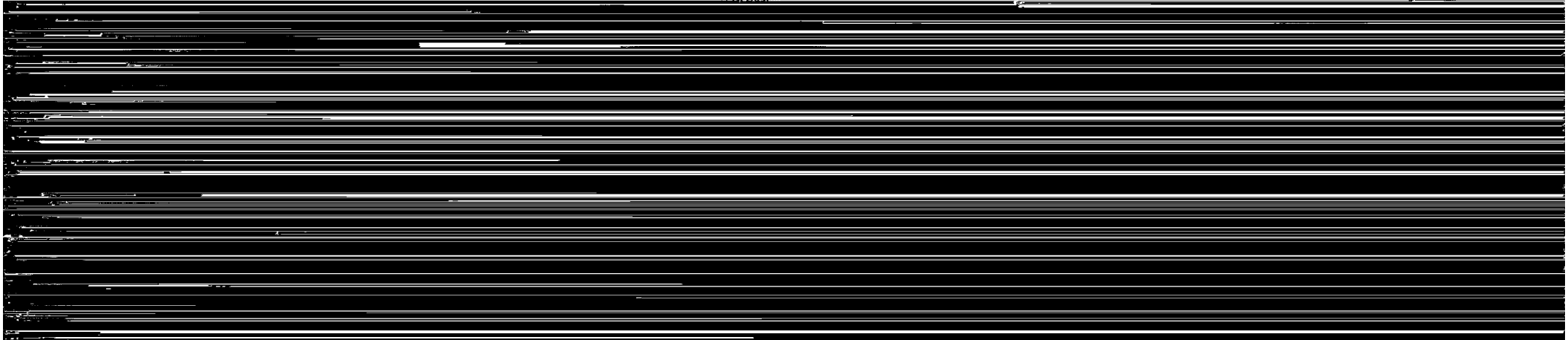




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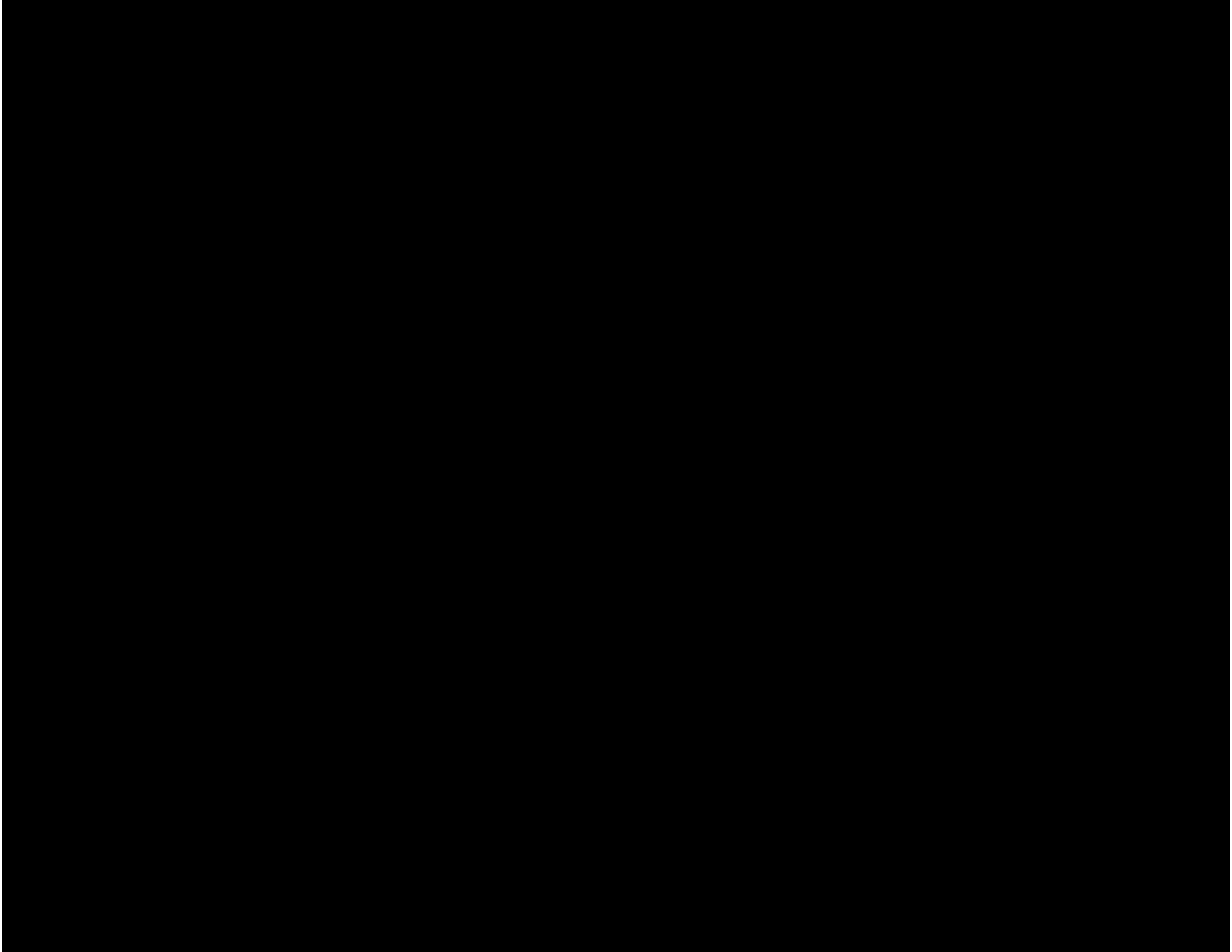
















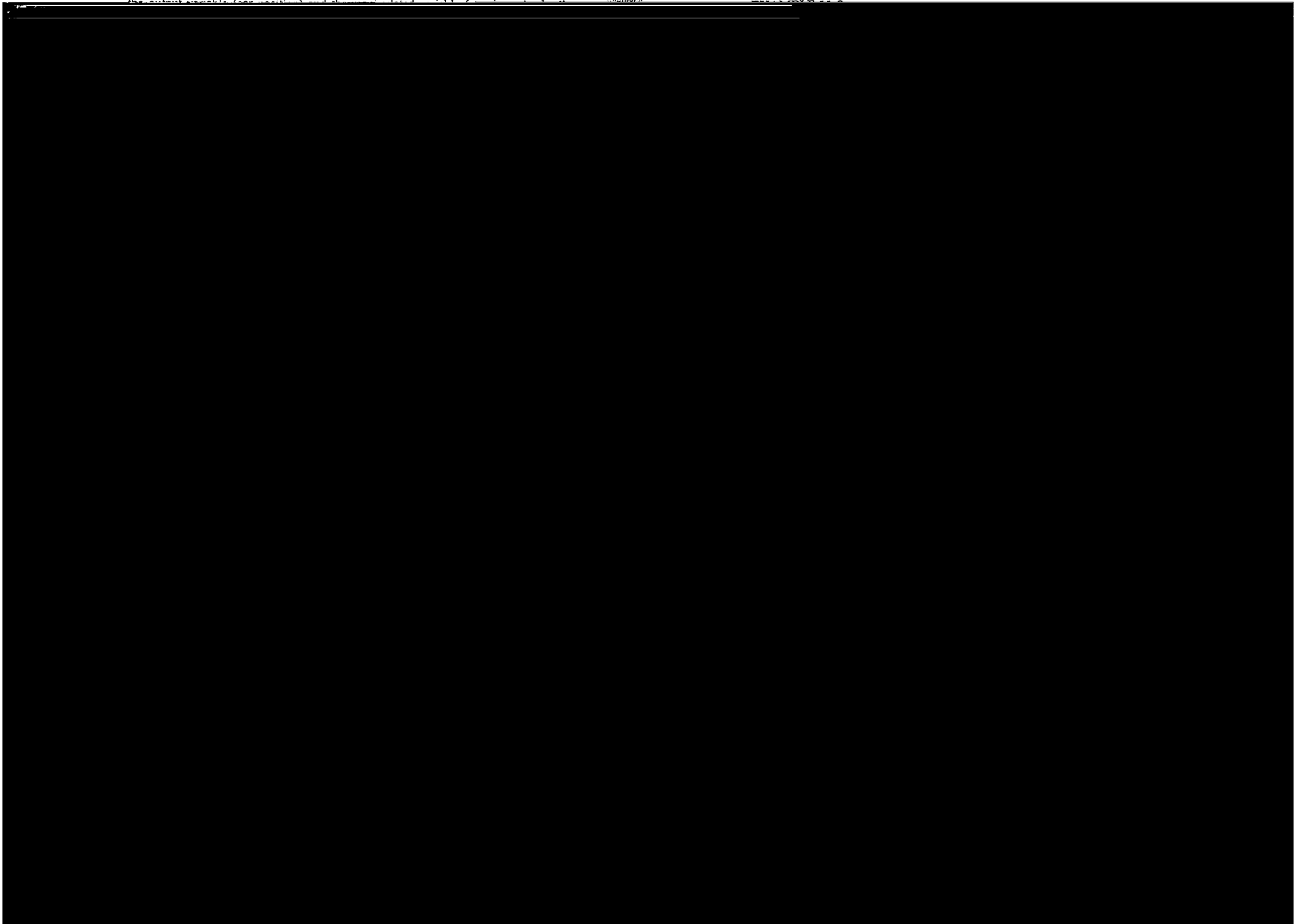


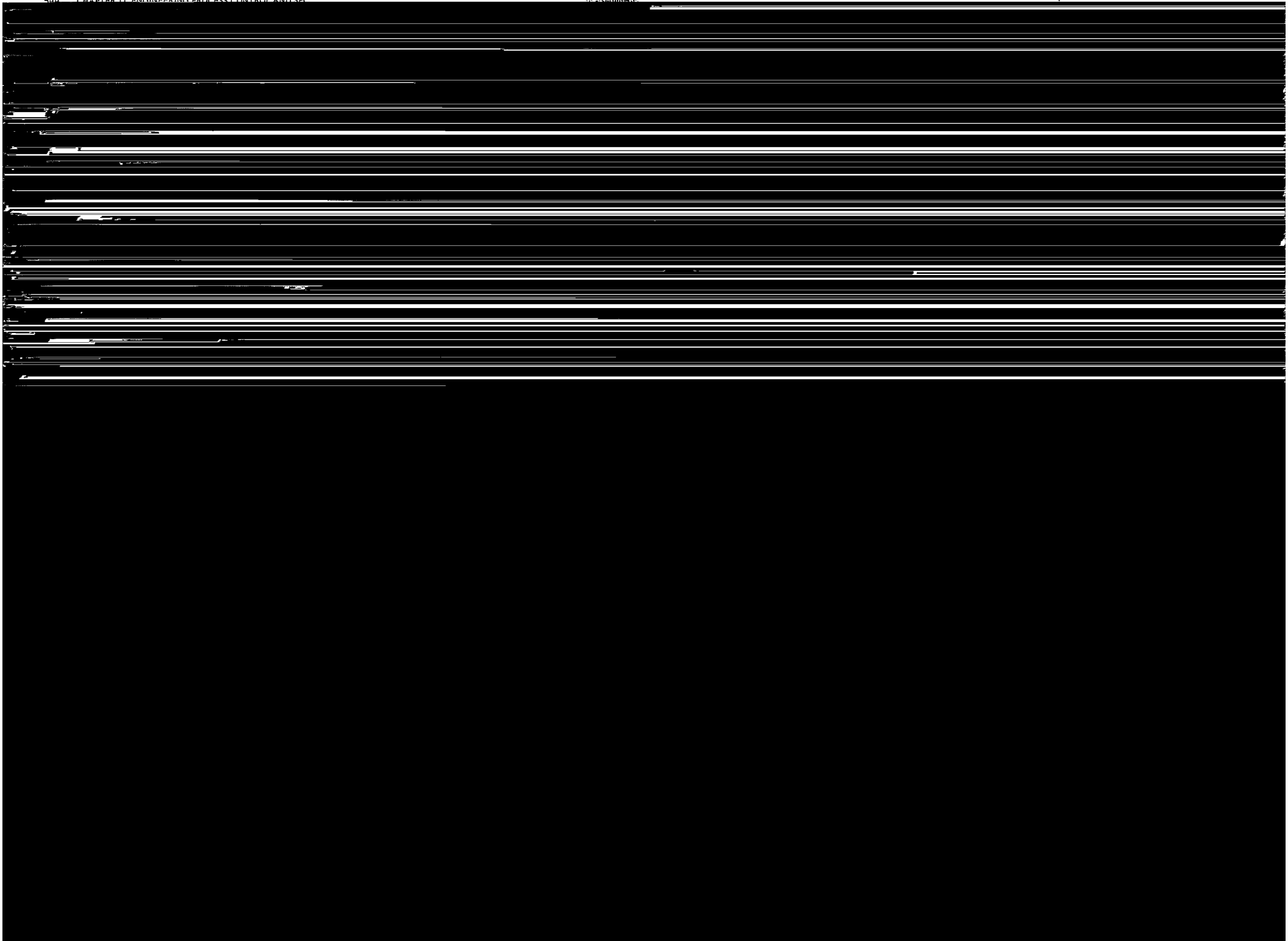


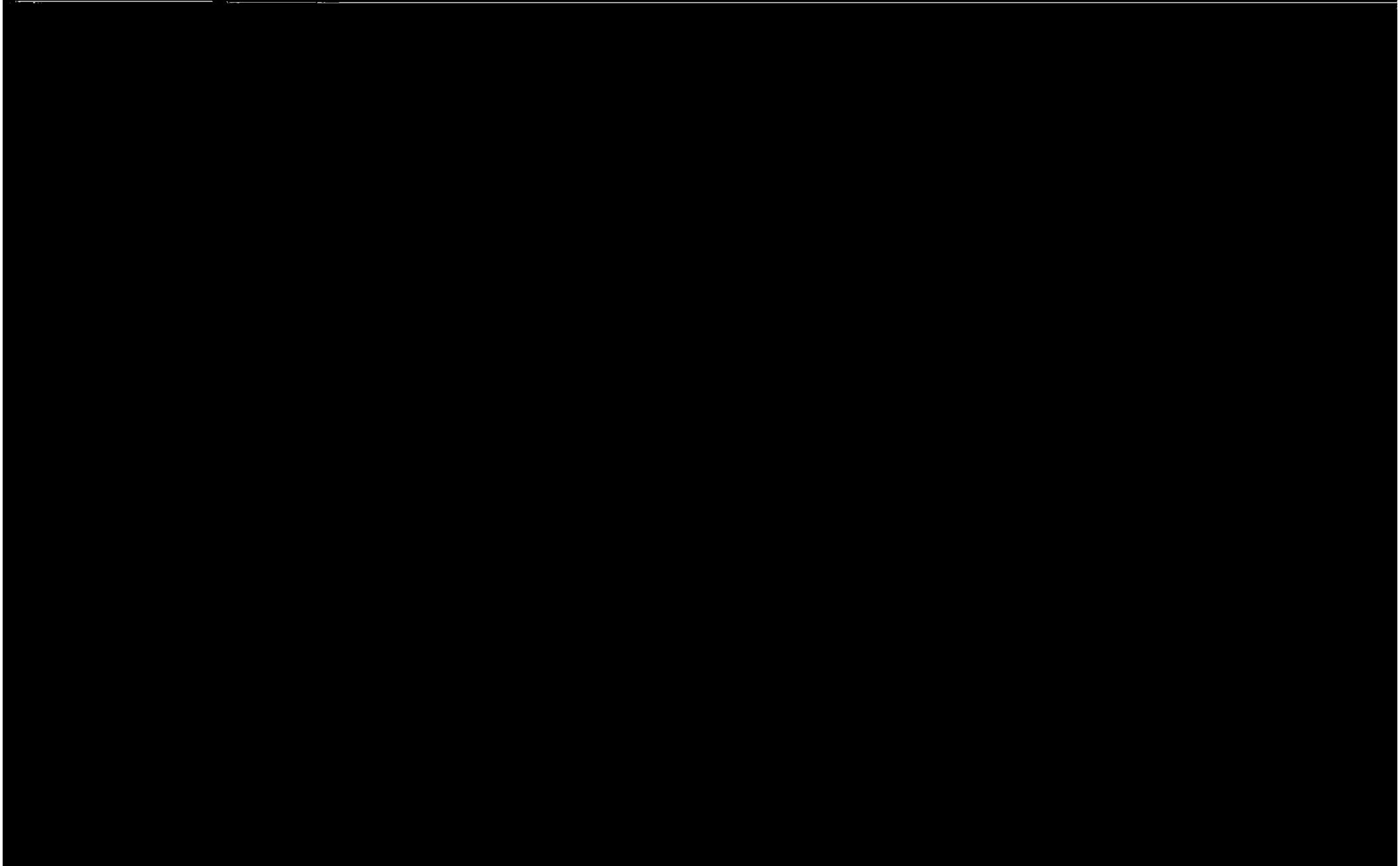
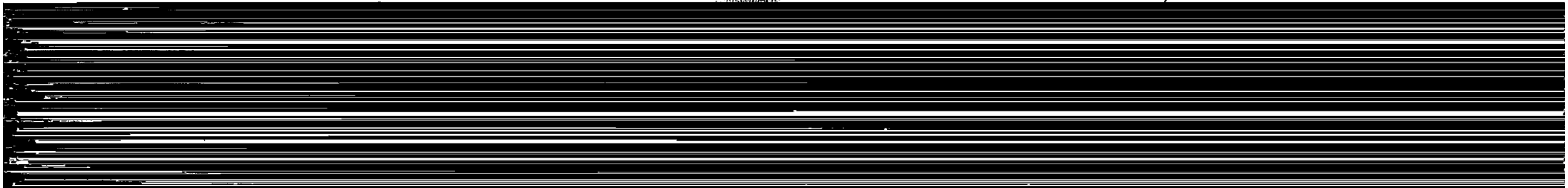
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[REDACTED]

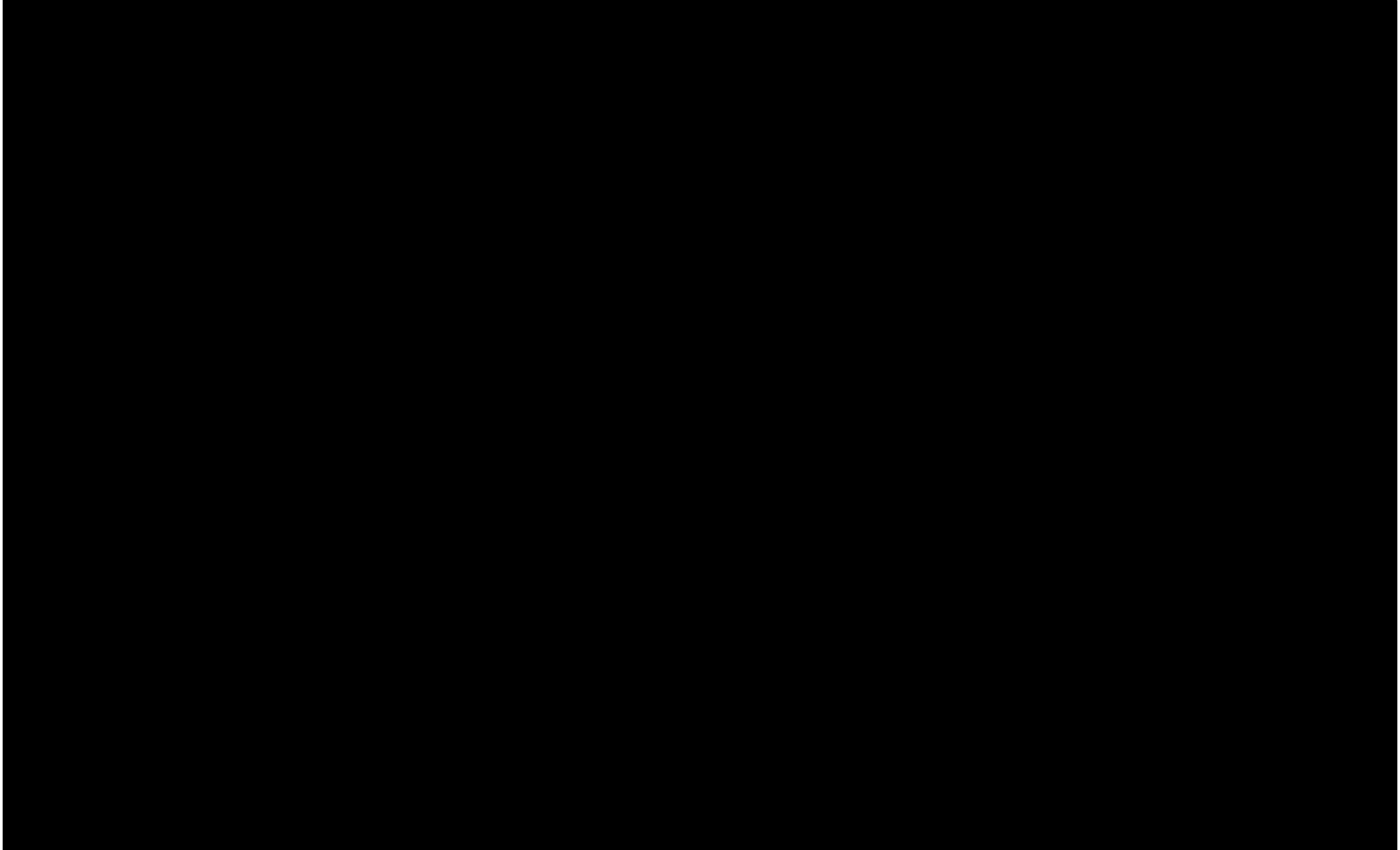
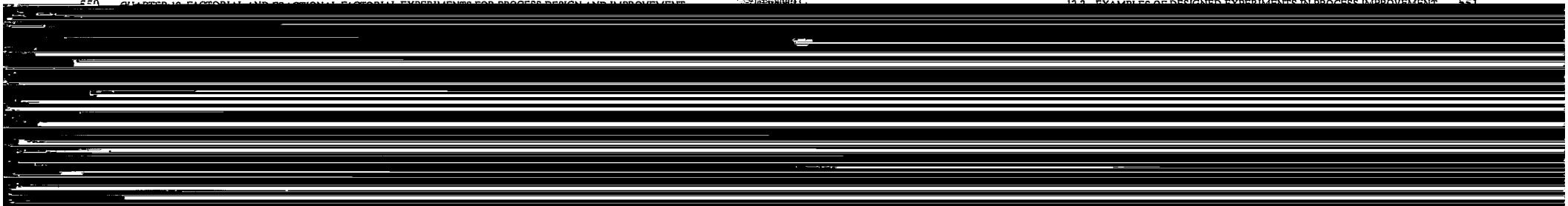






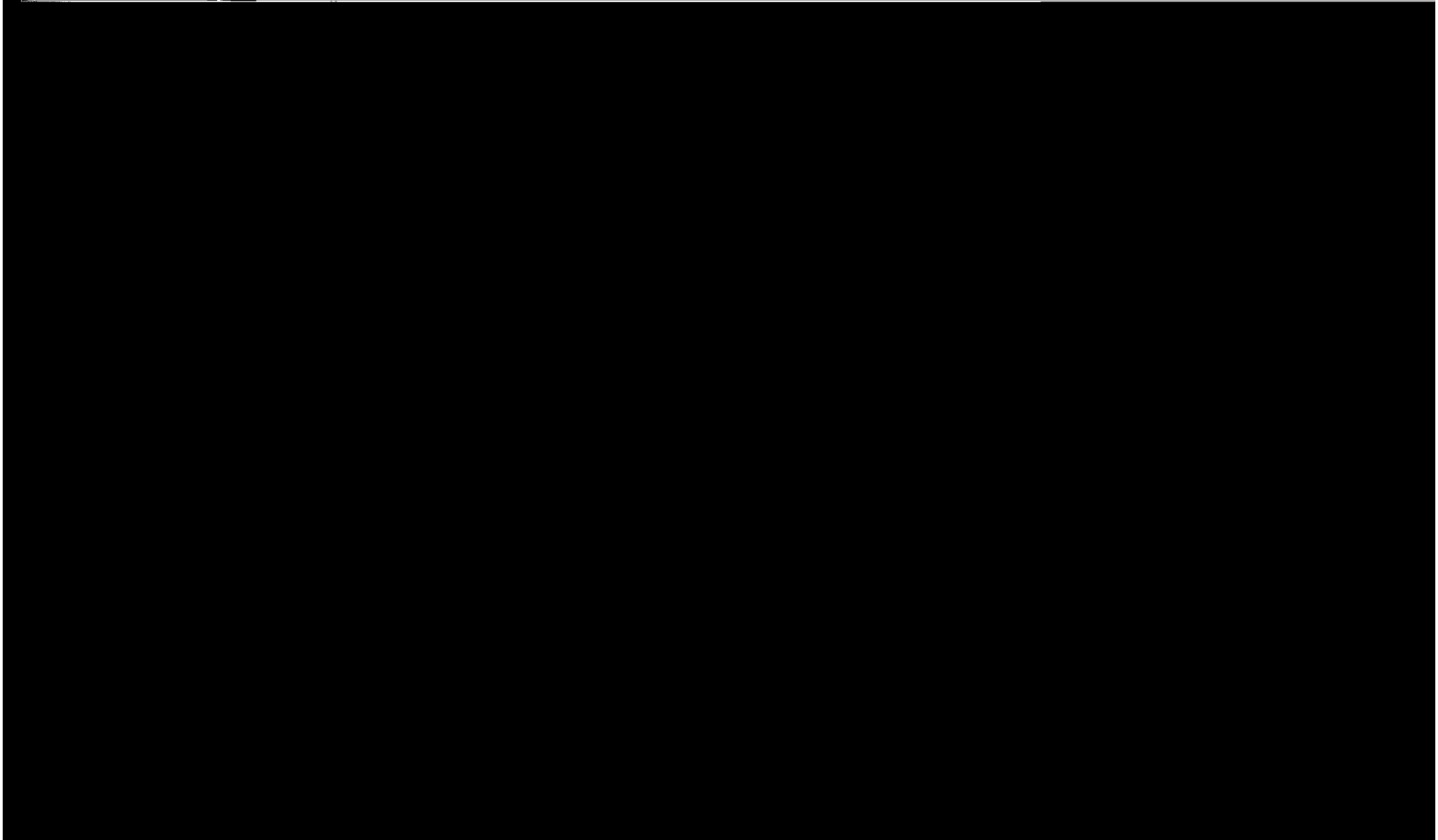


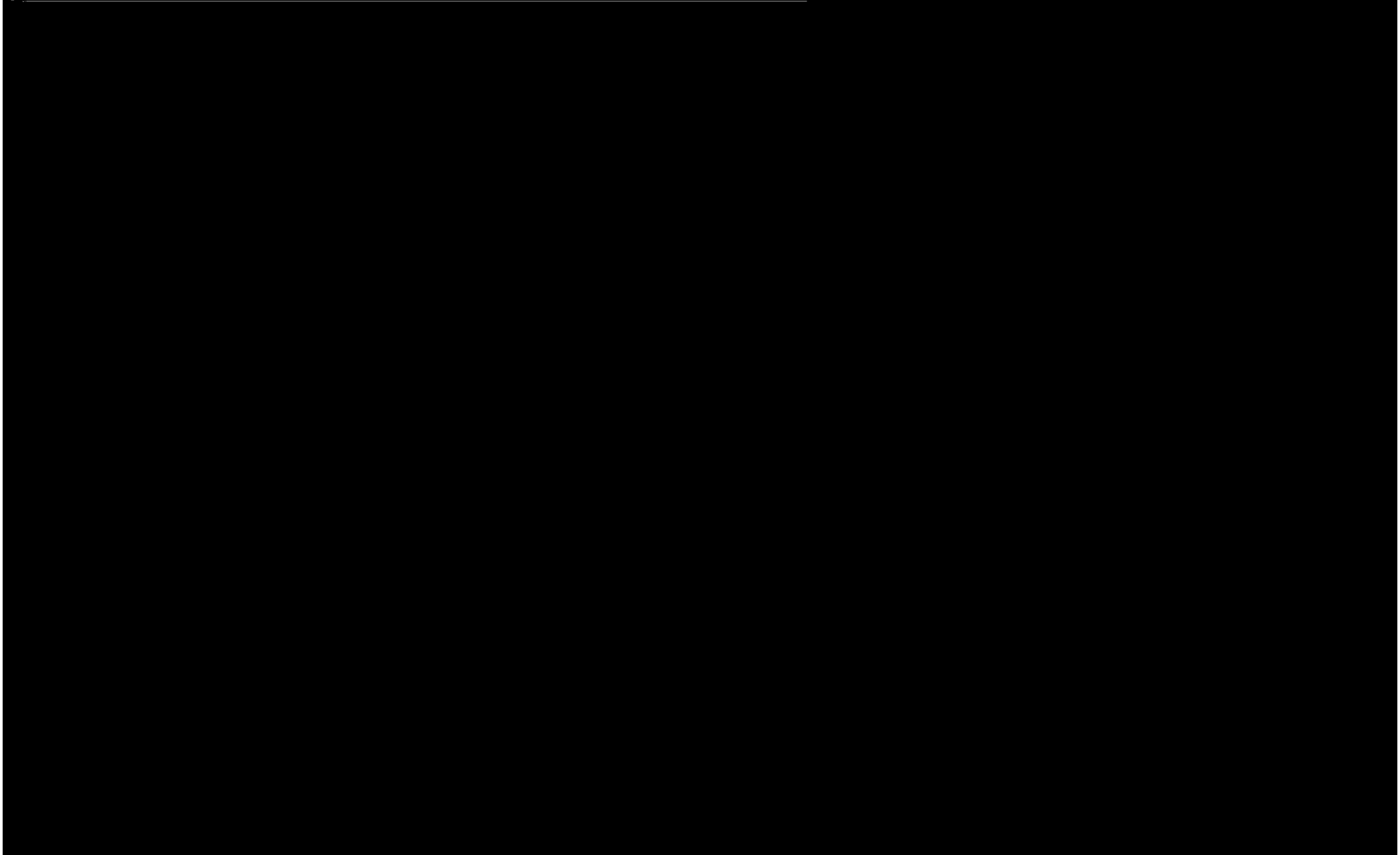
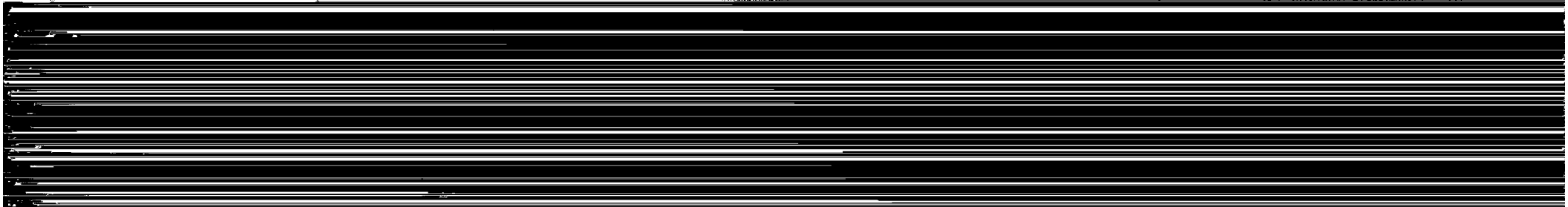


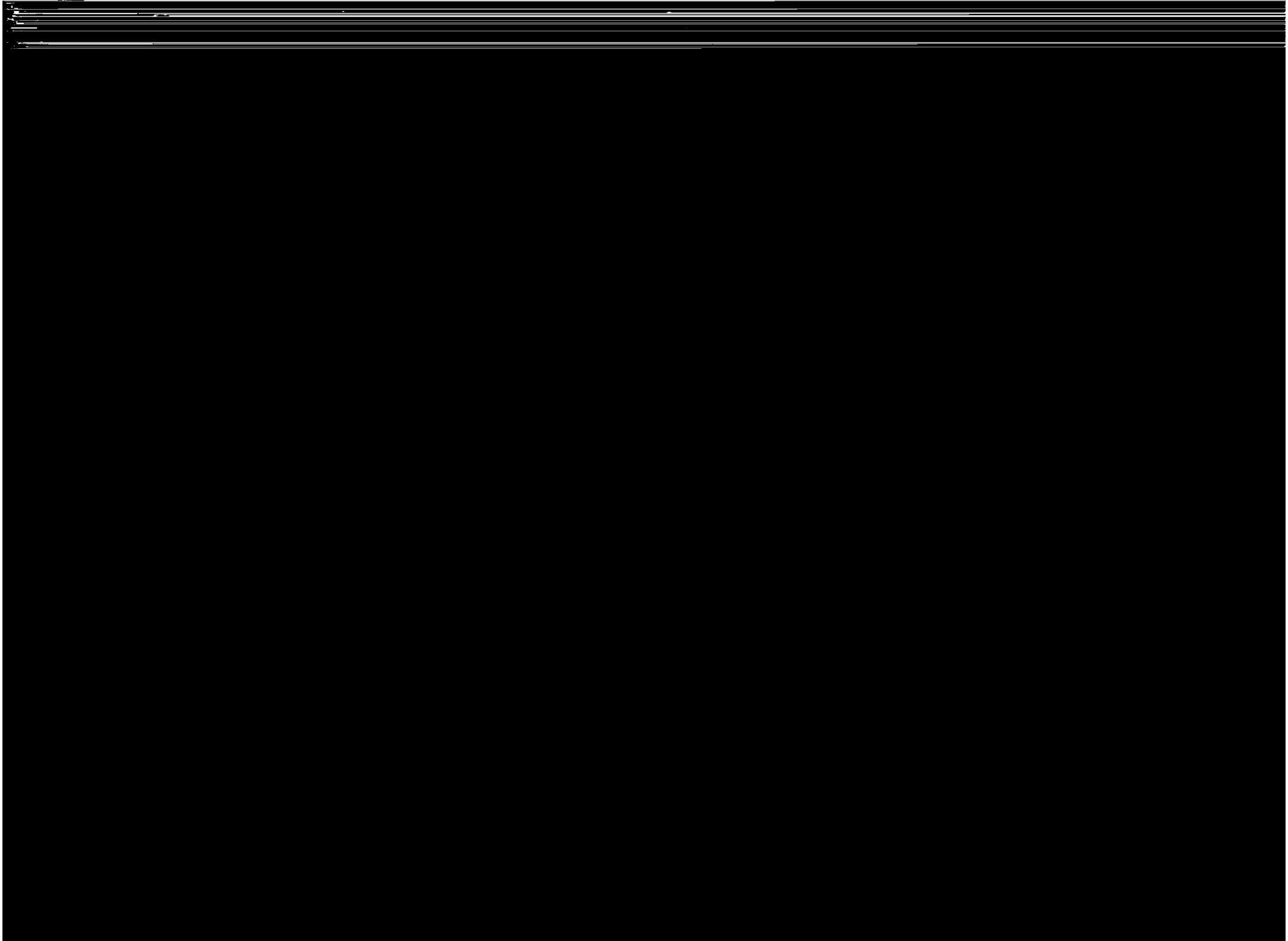






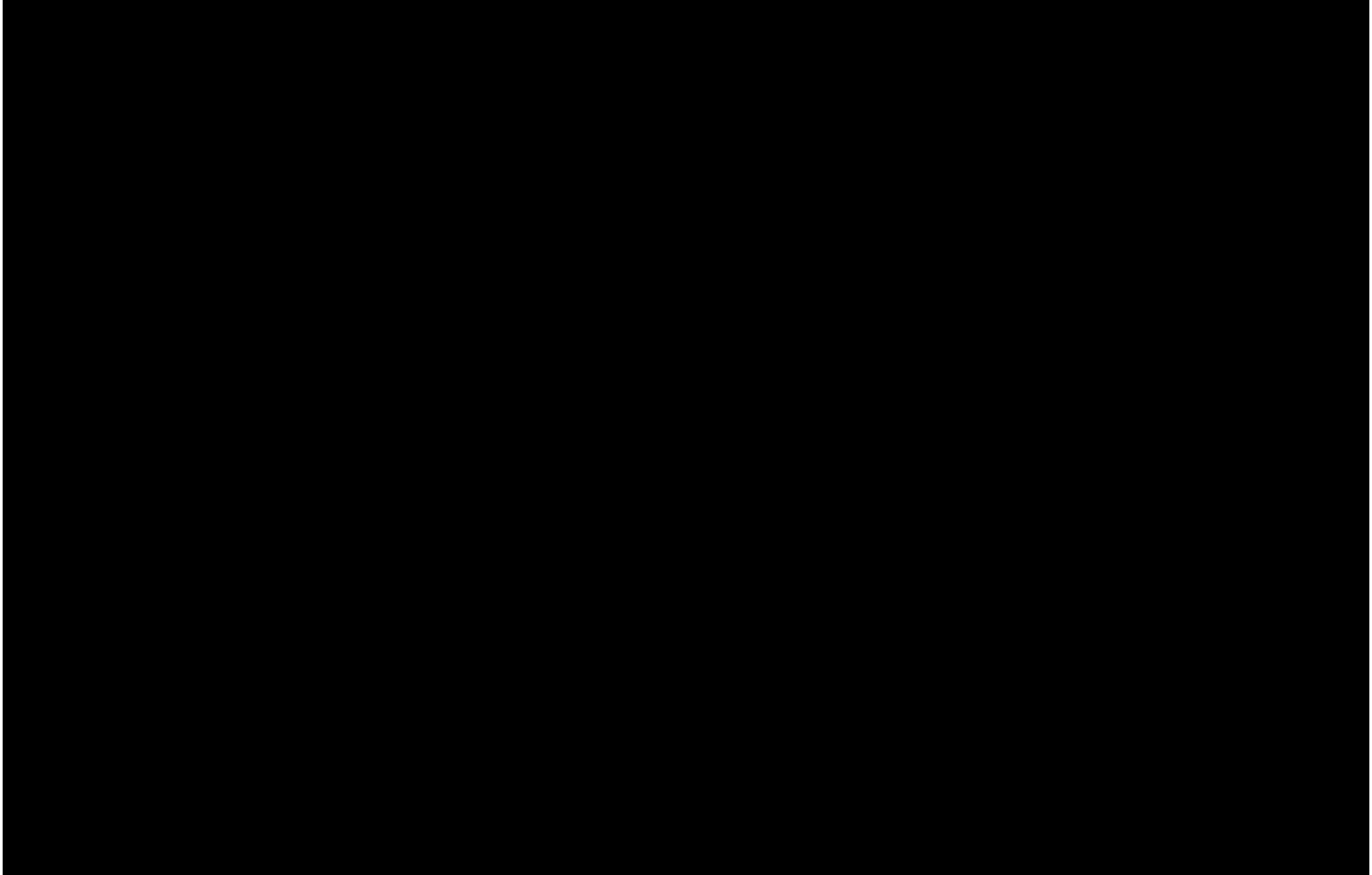
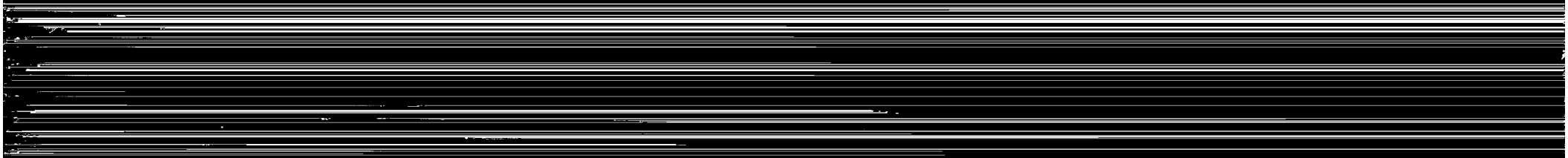


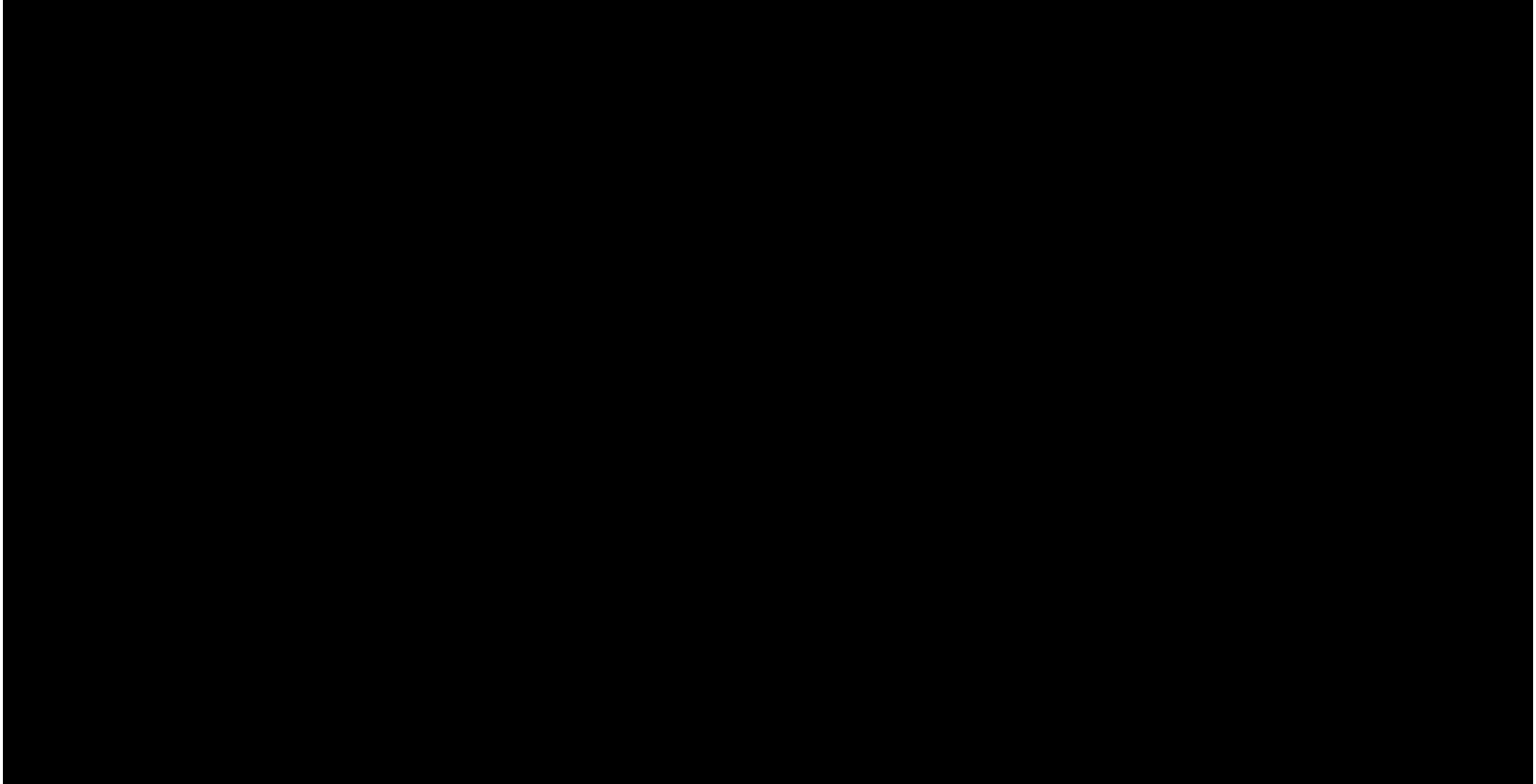


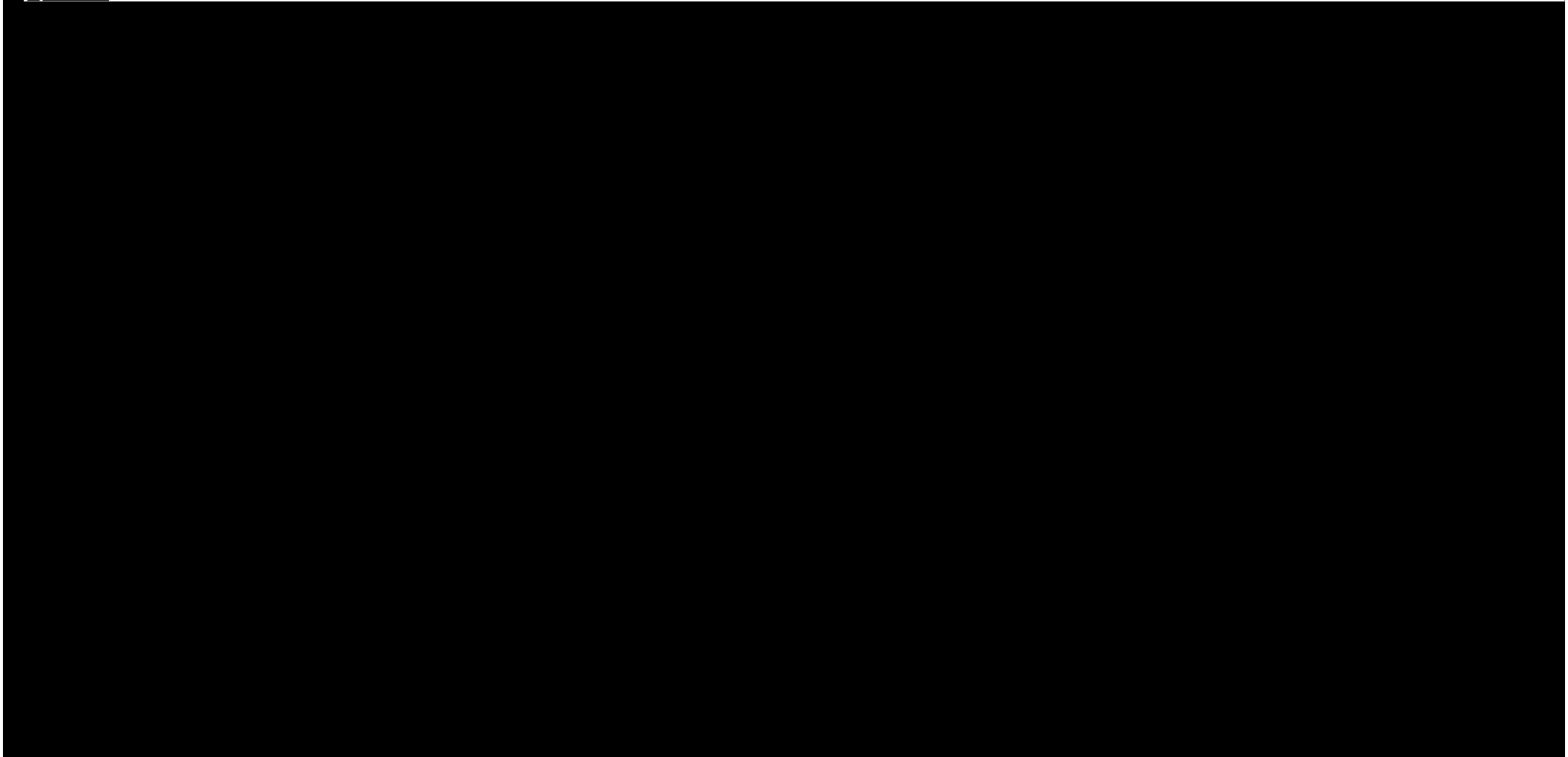




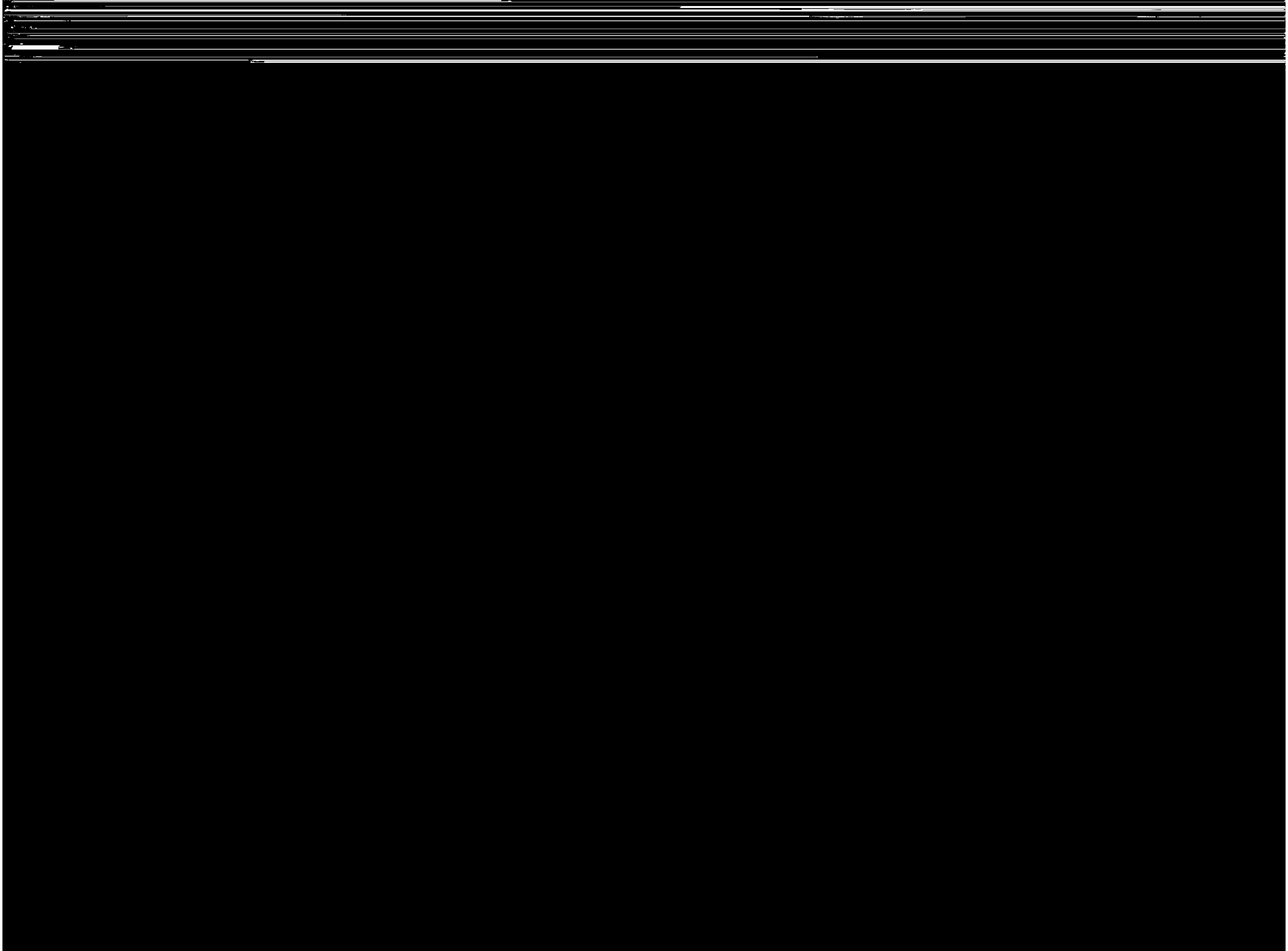




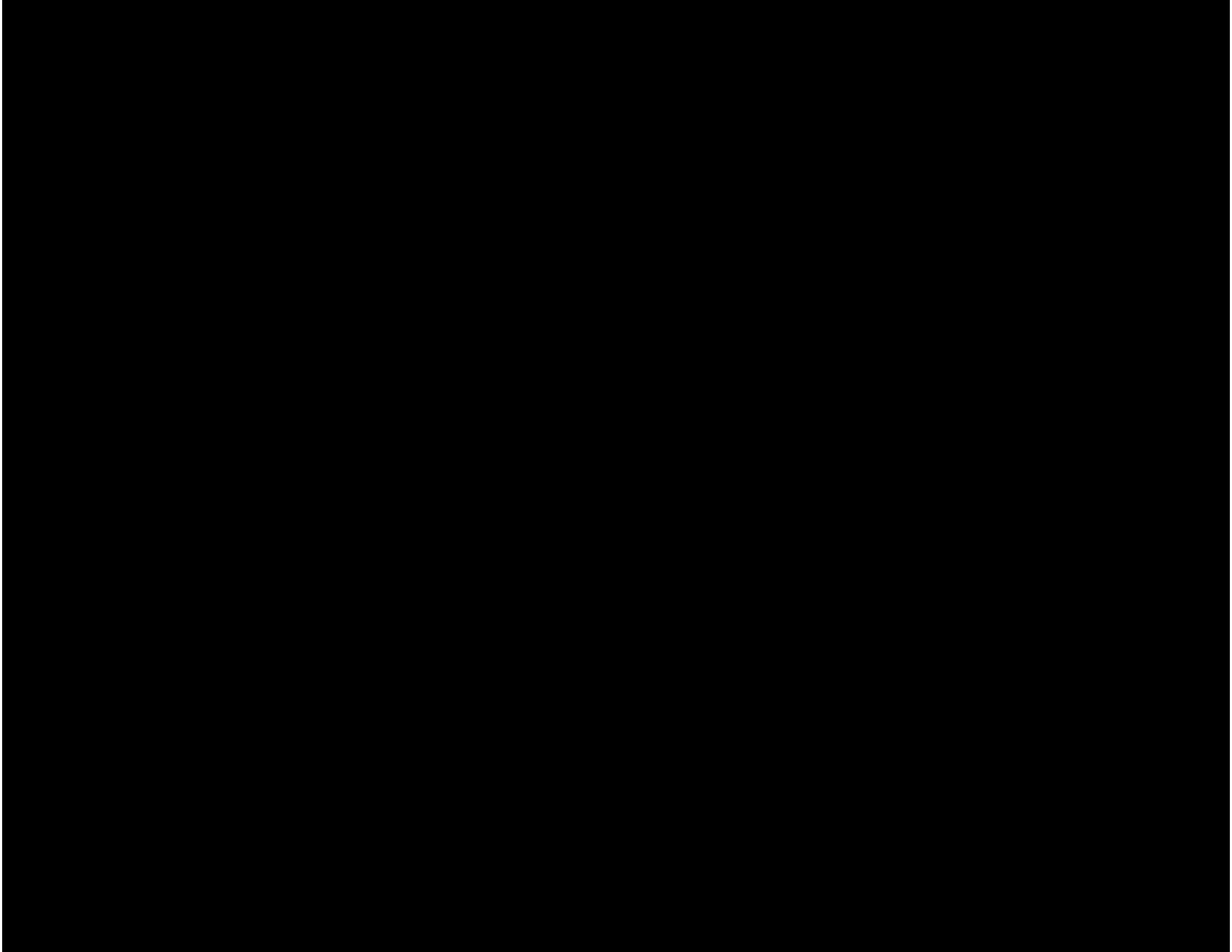


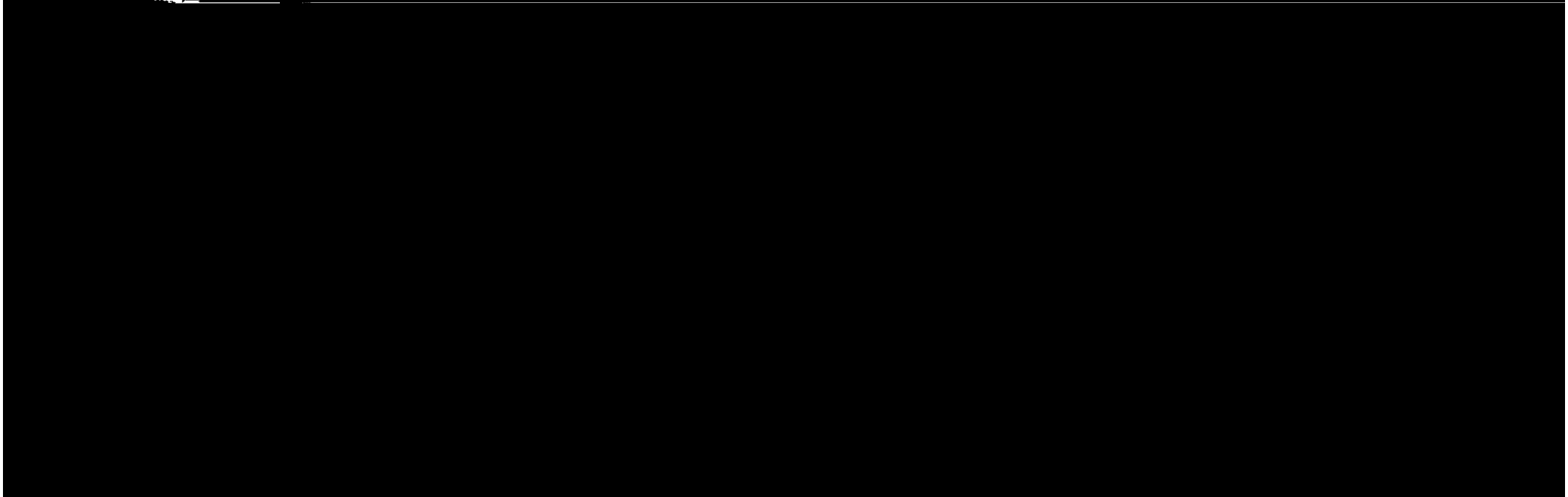
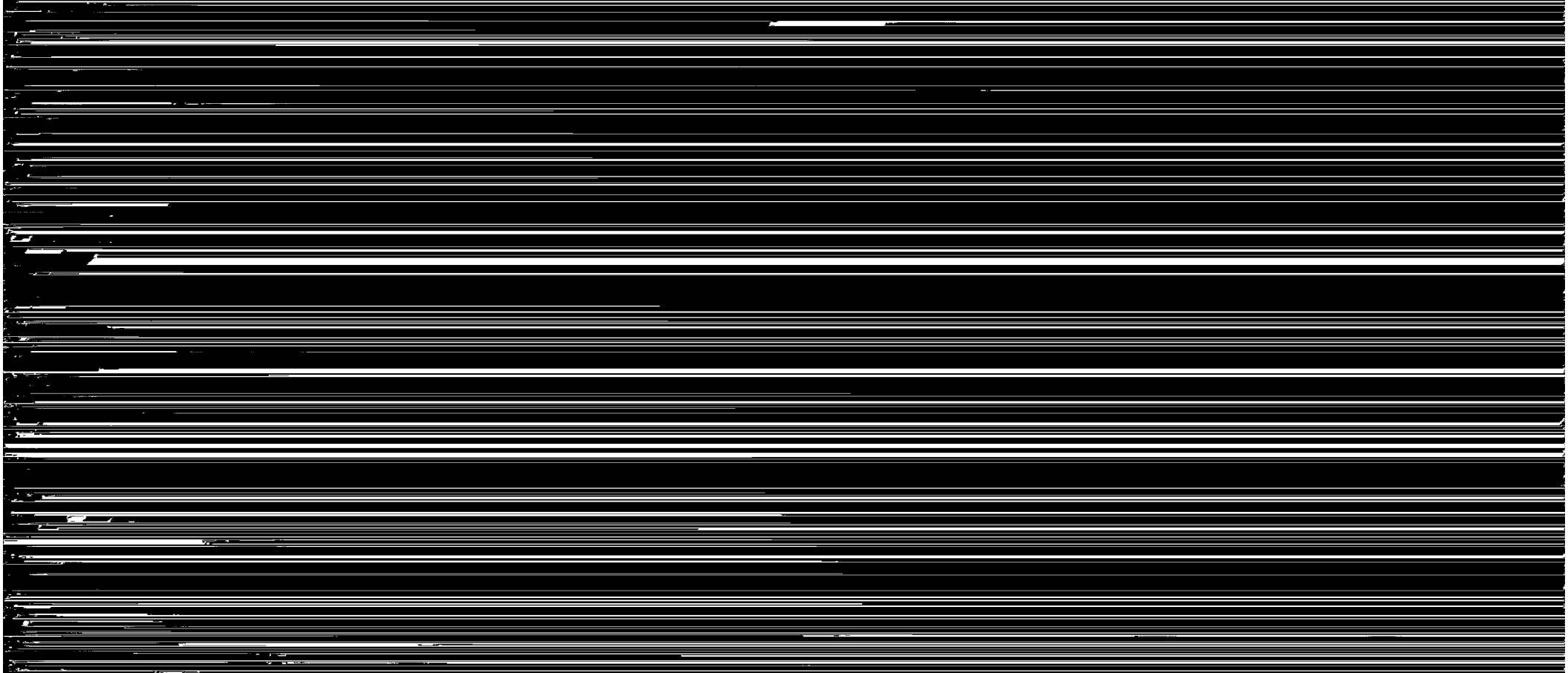


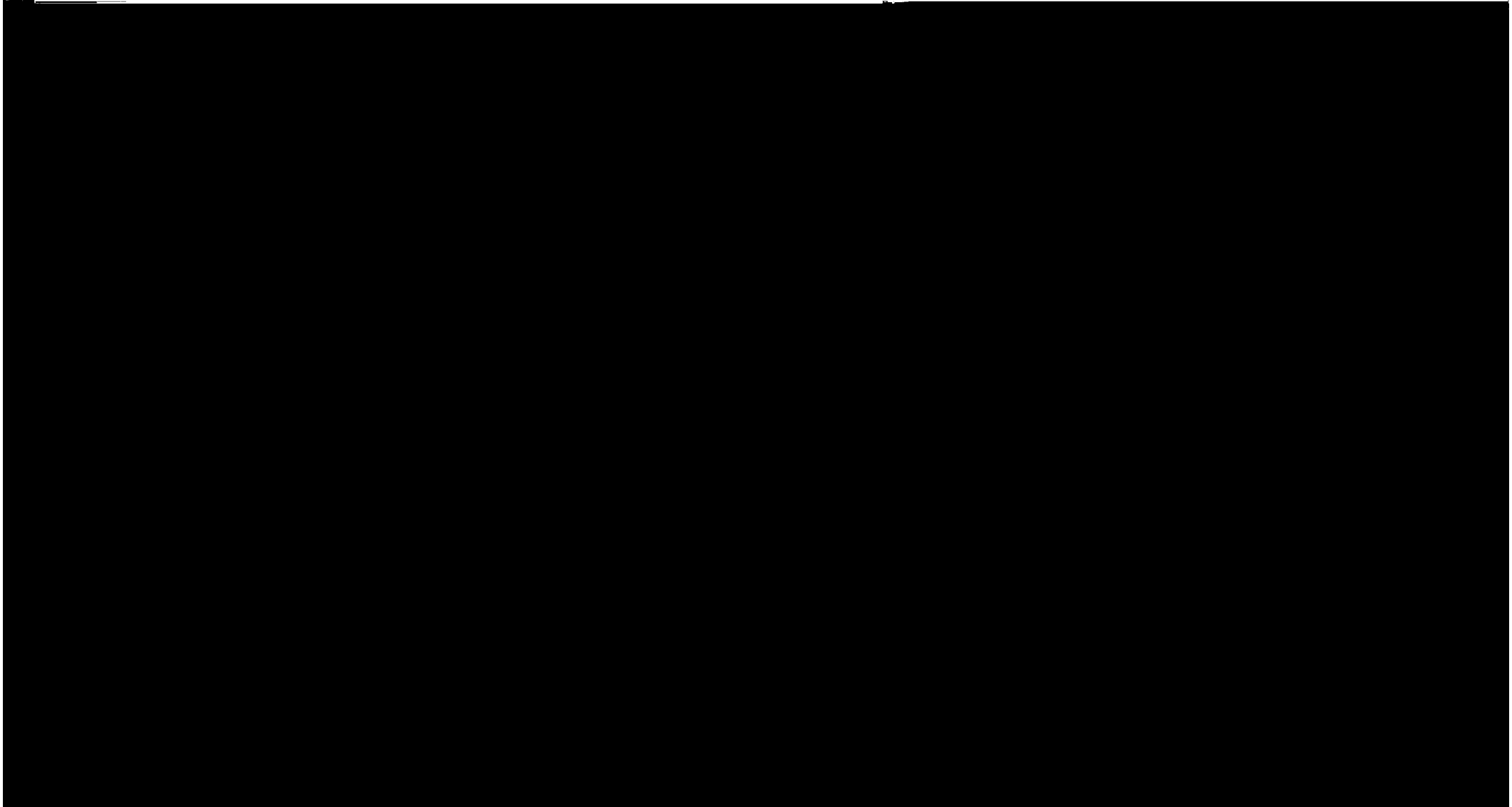


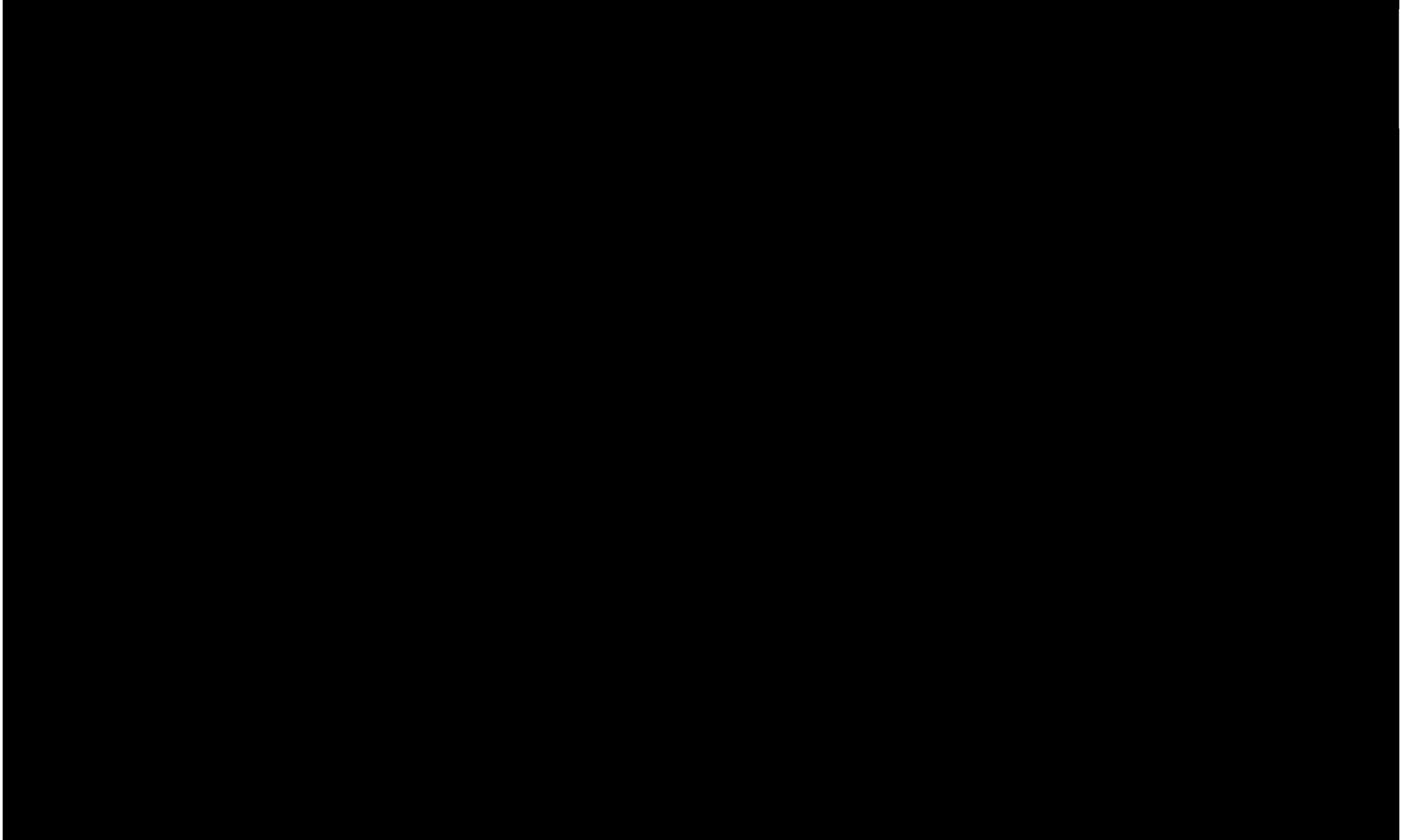


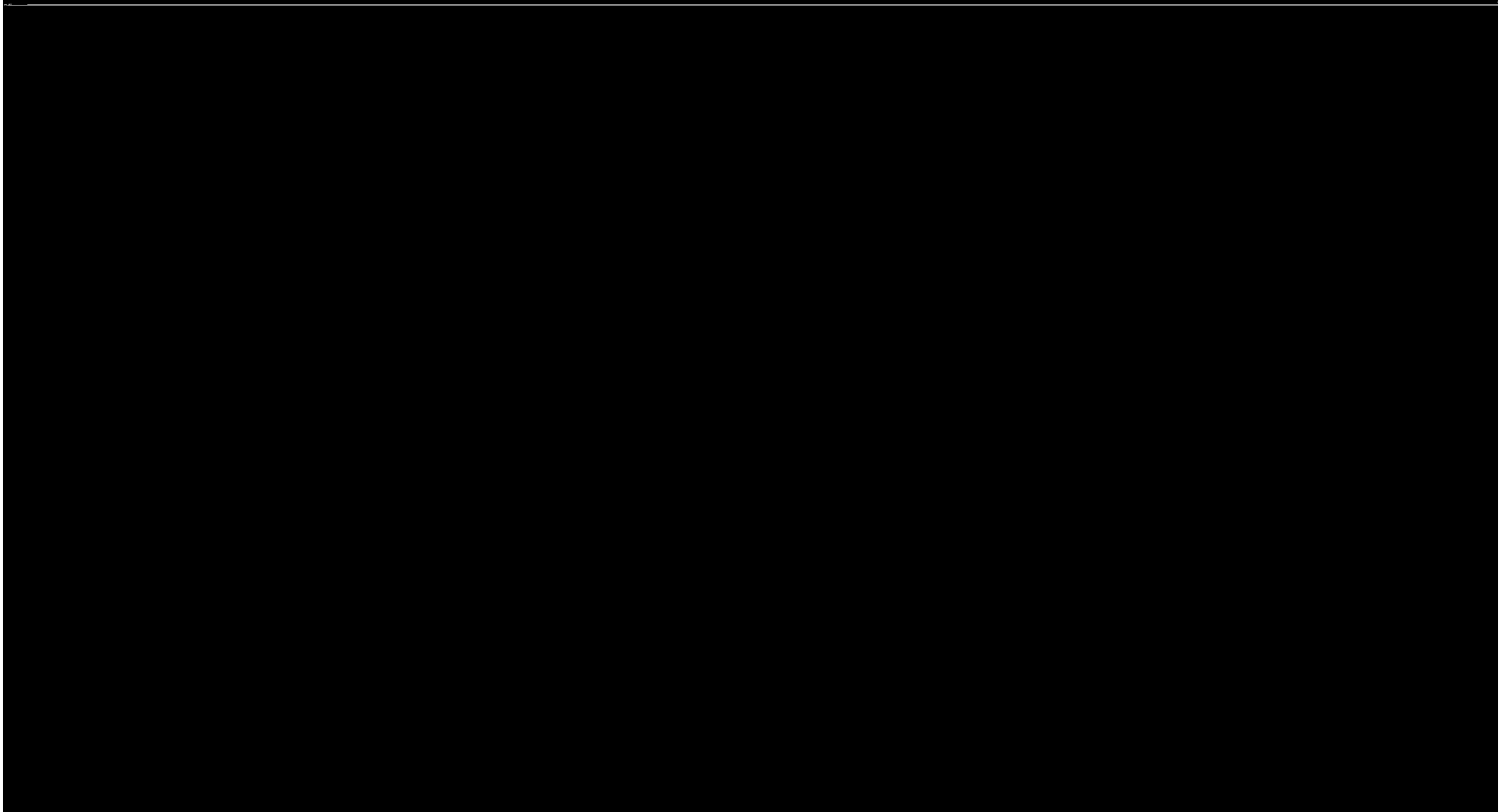
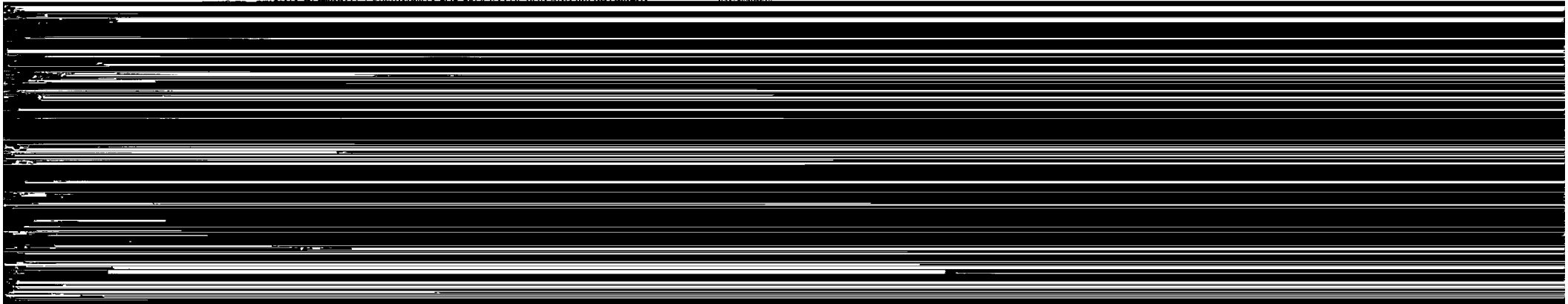


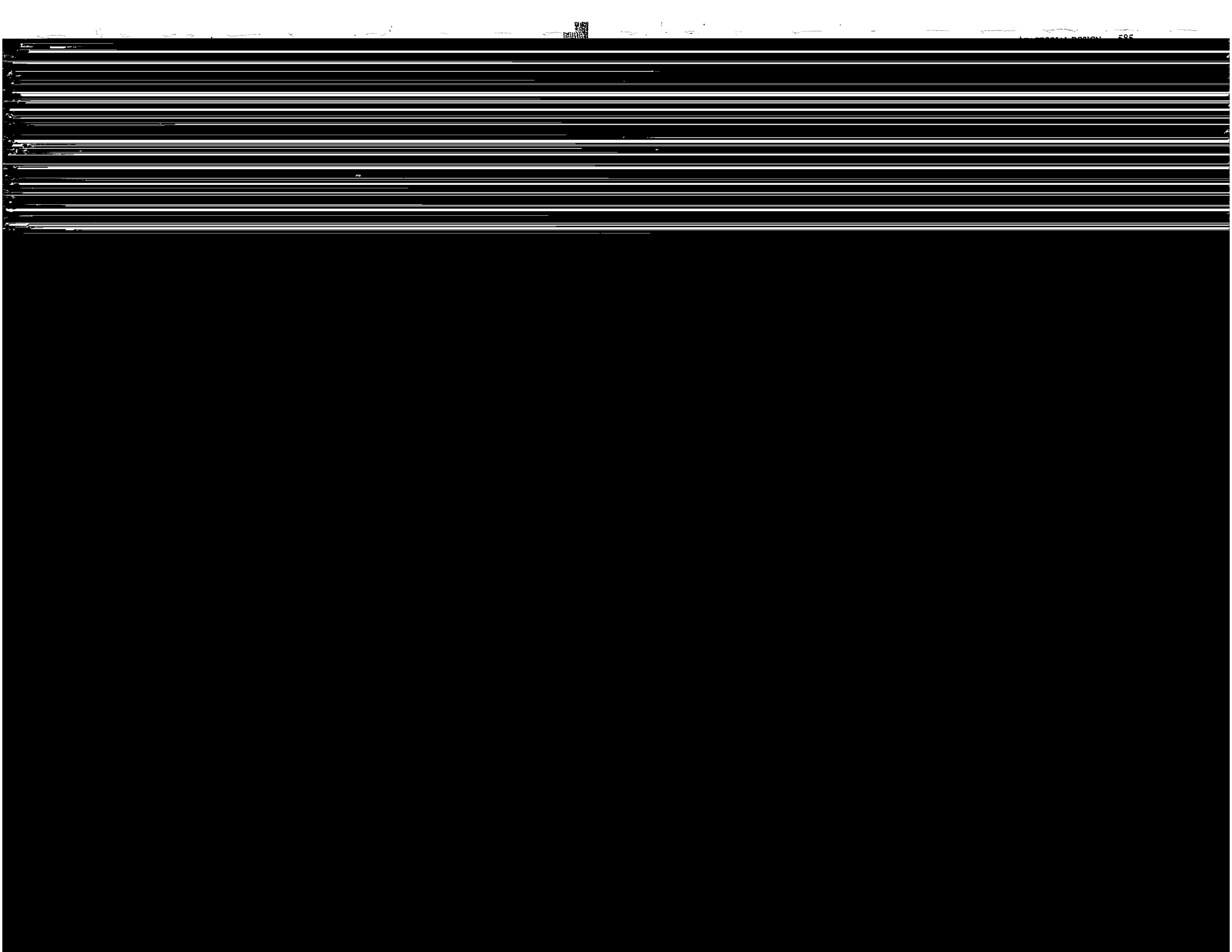






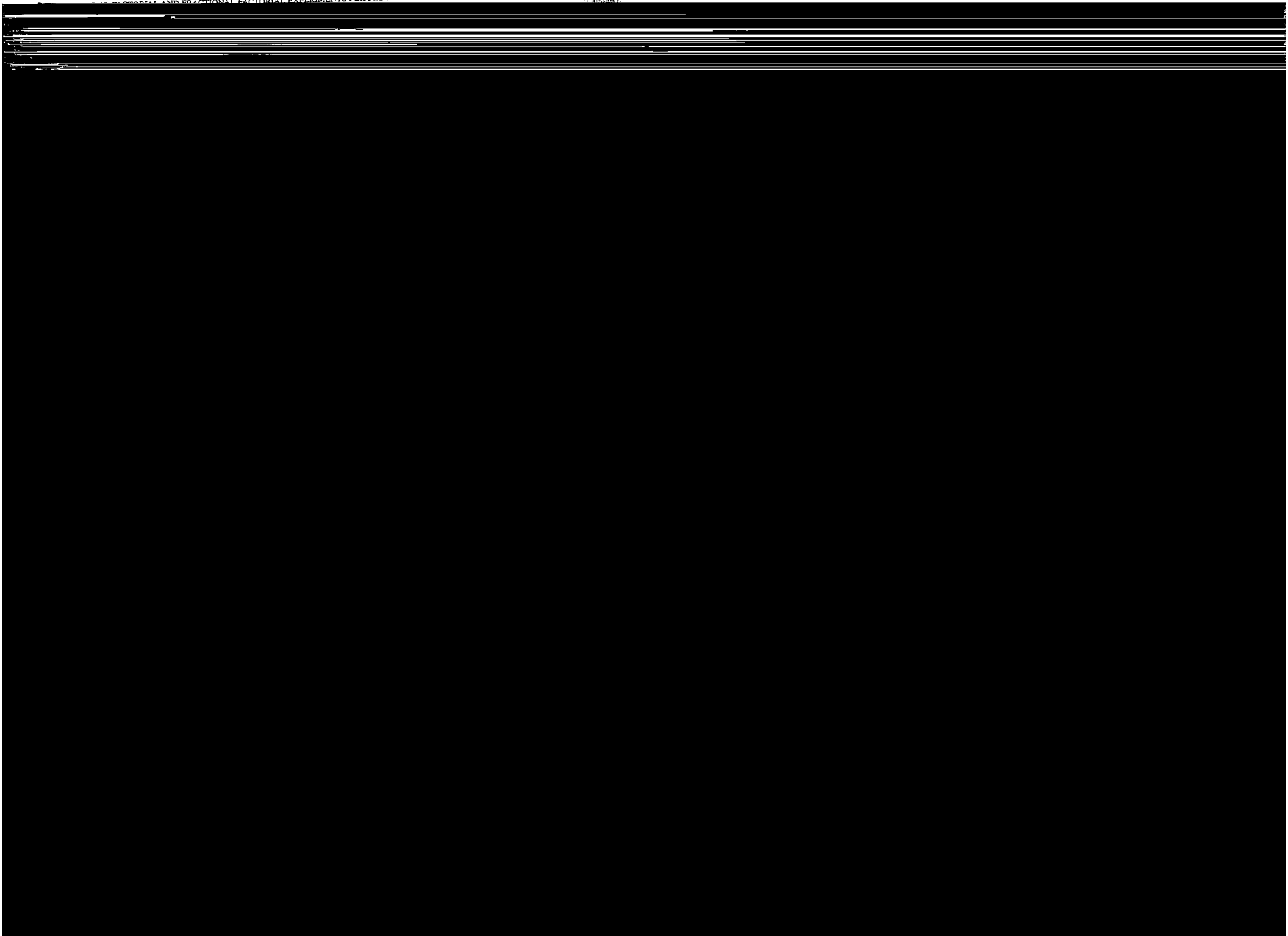


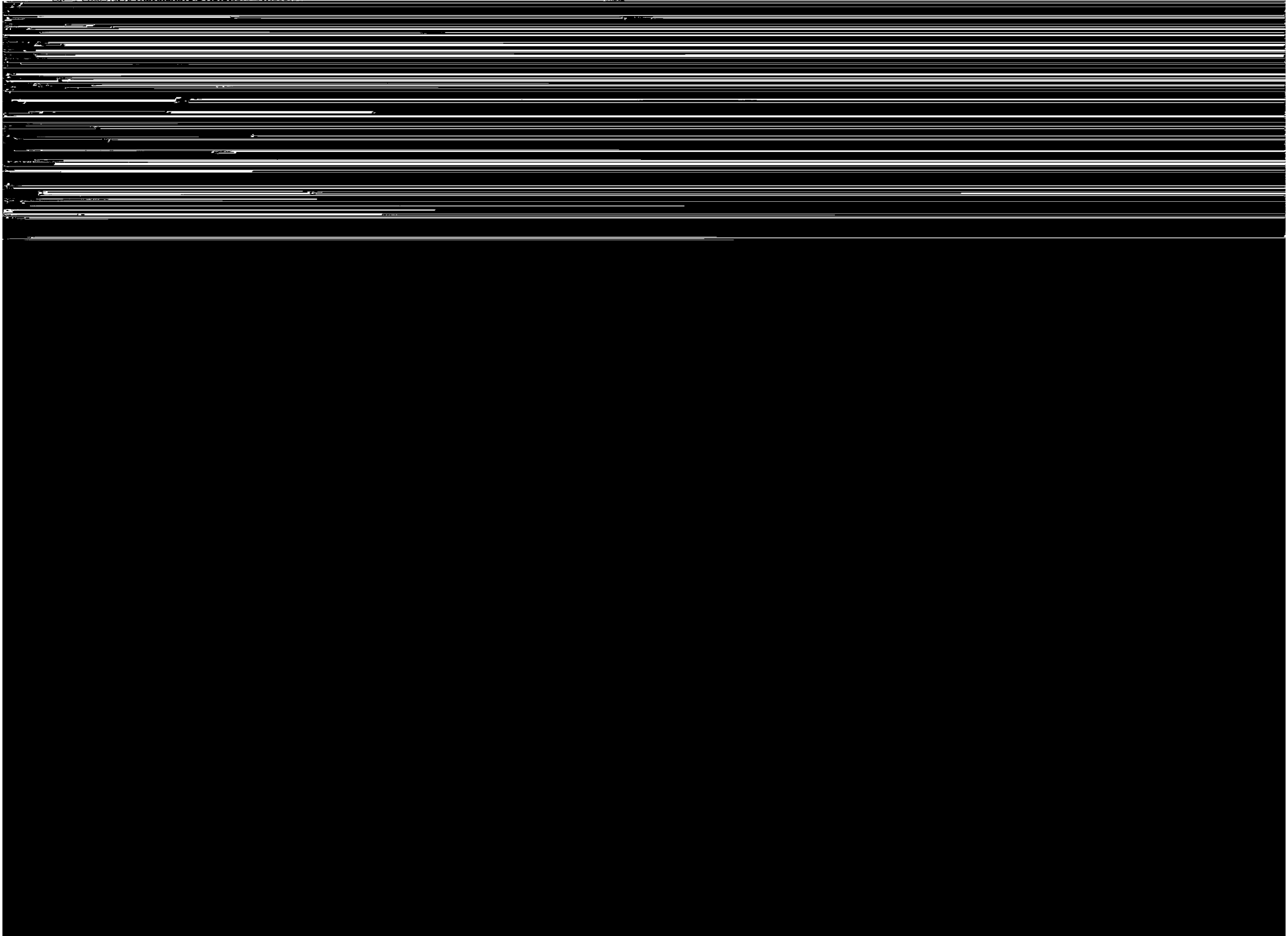


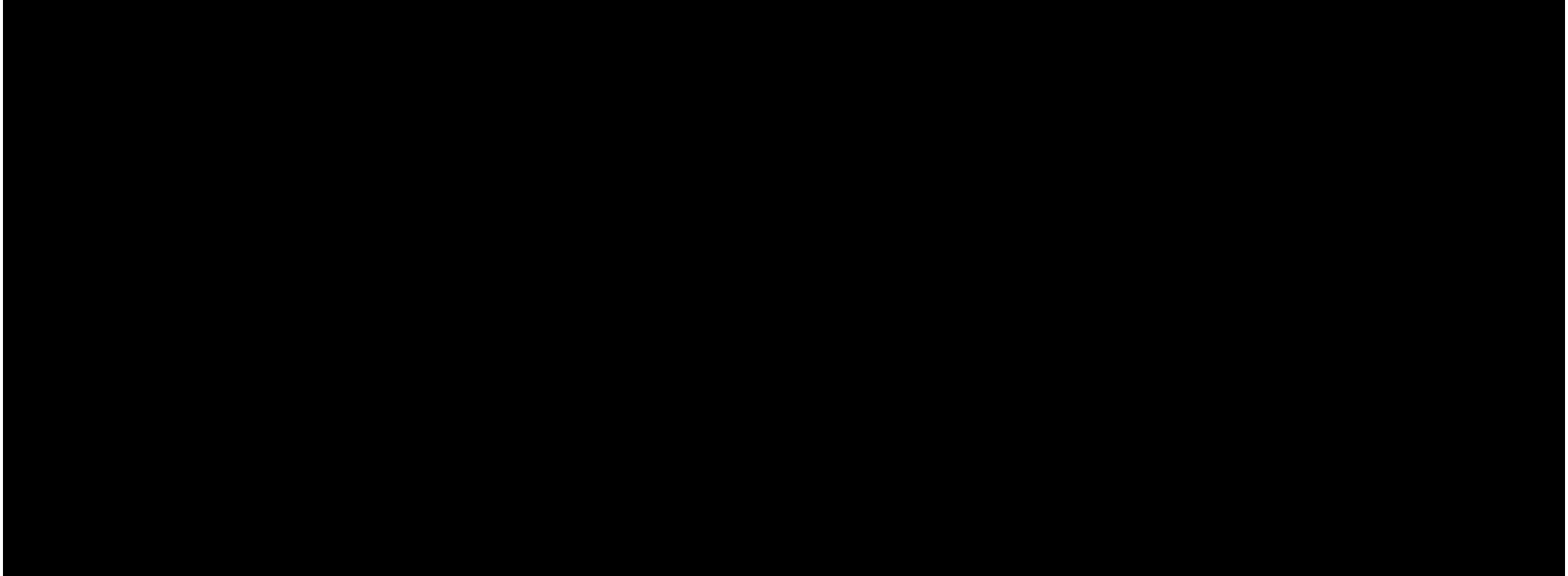


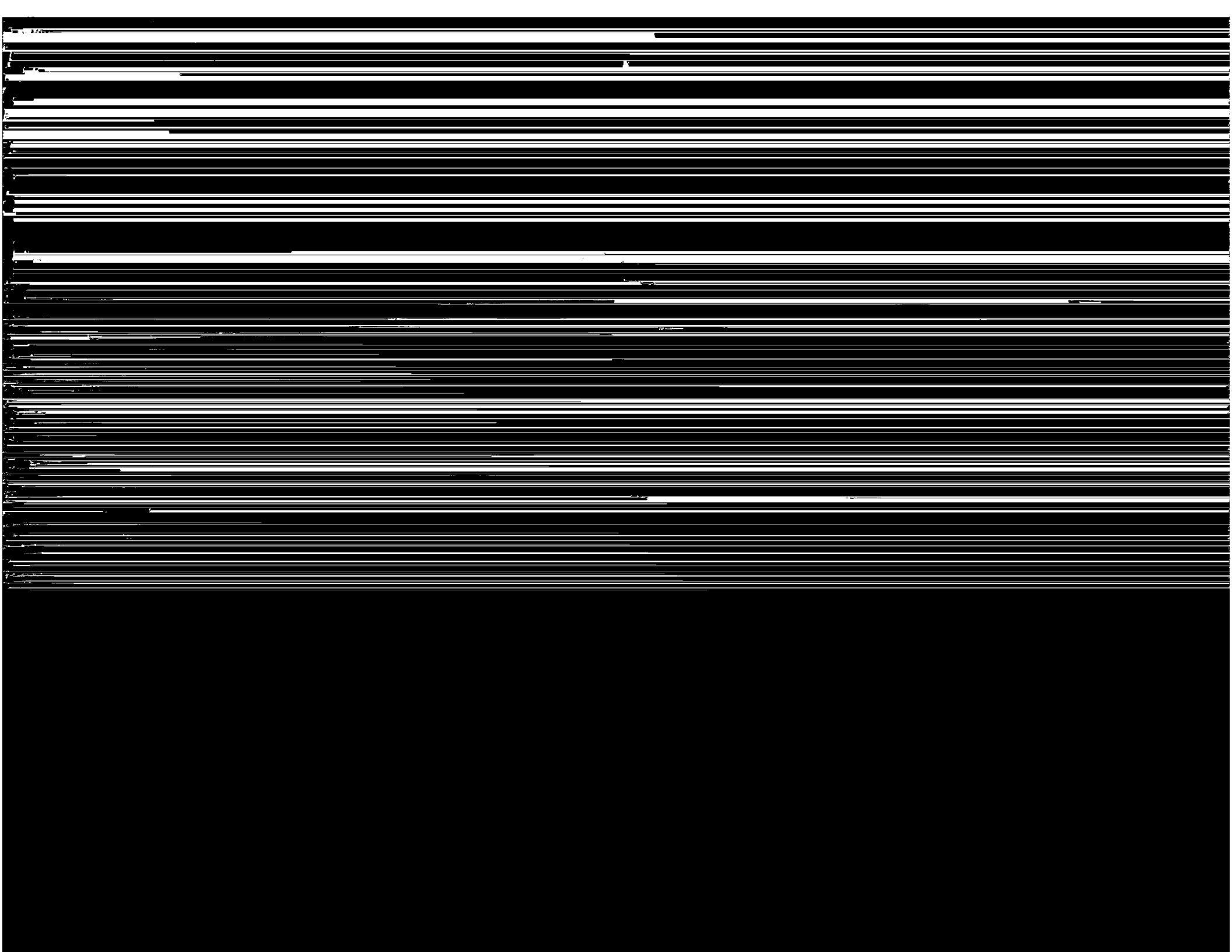


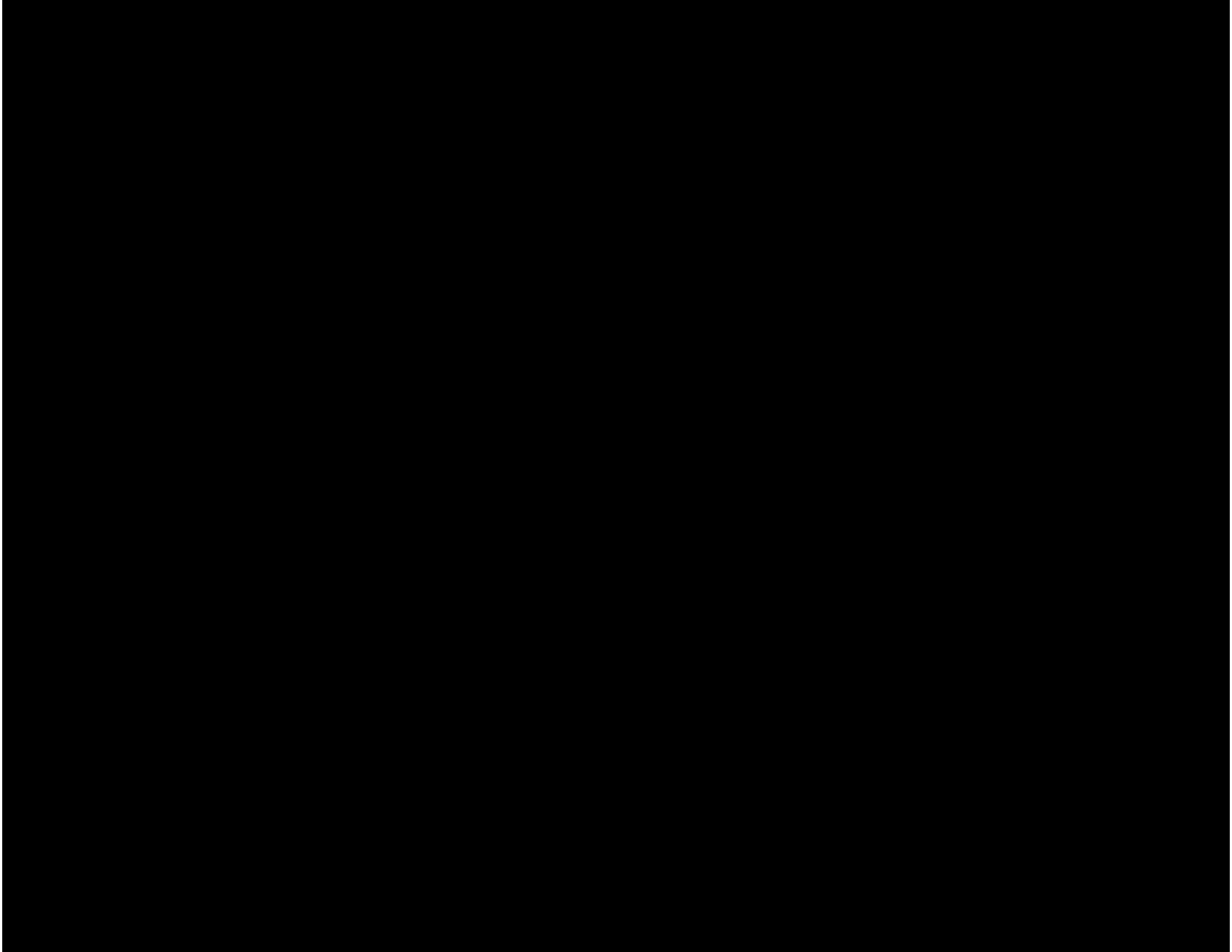


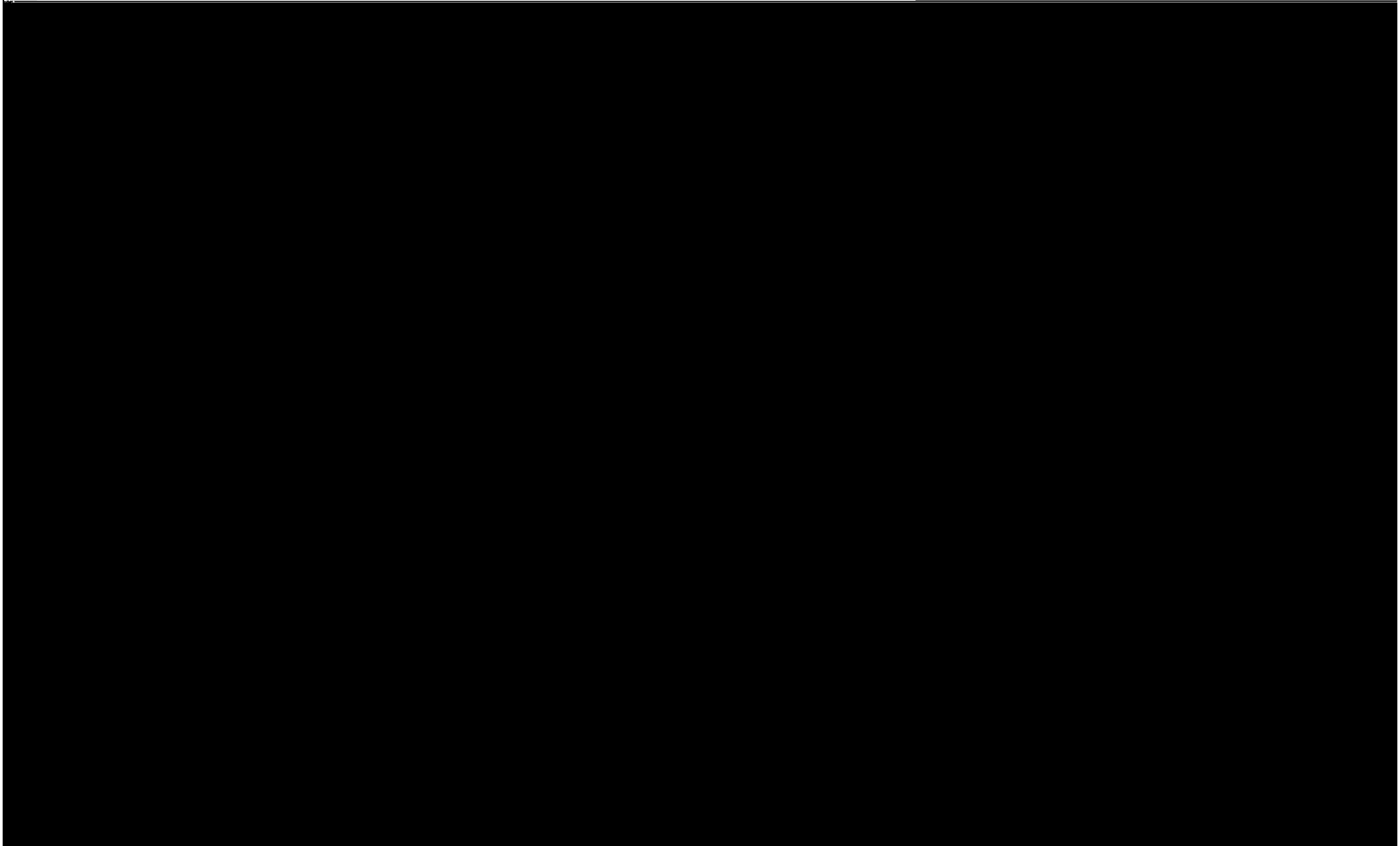
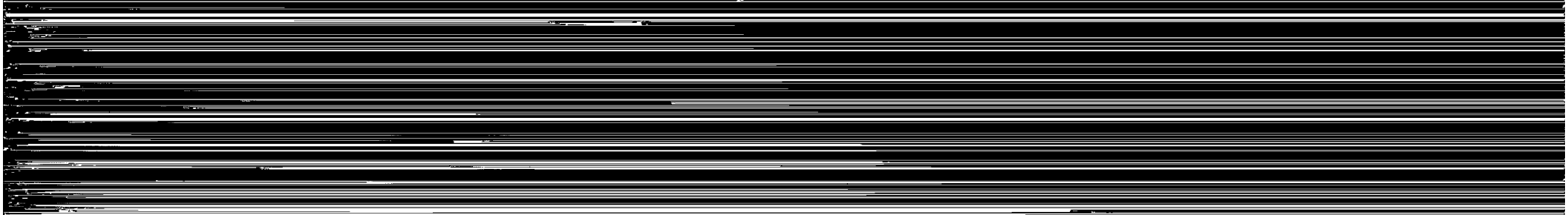








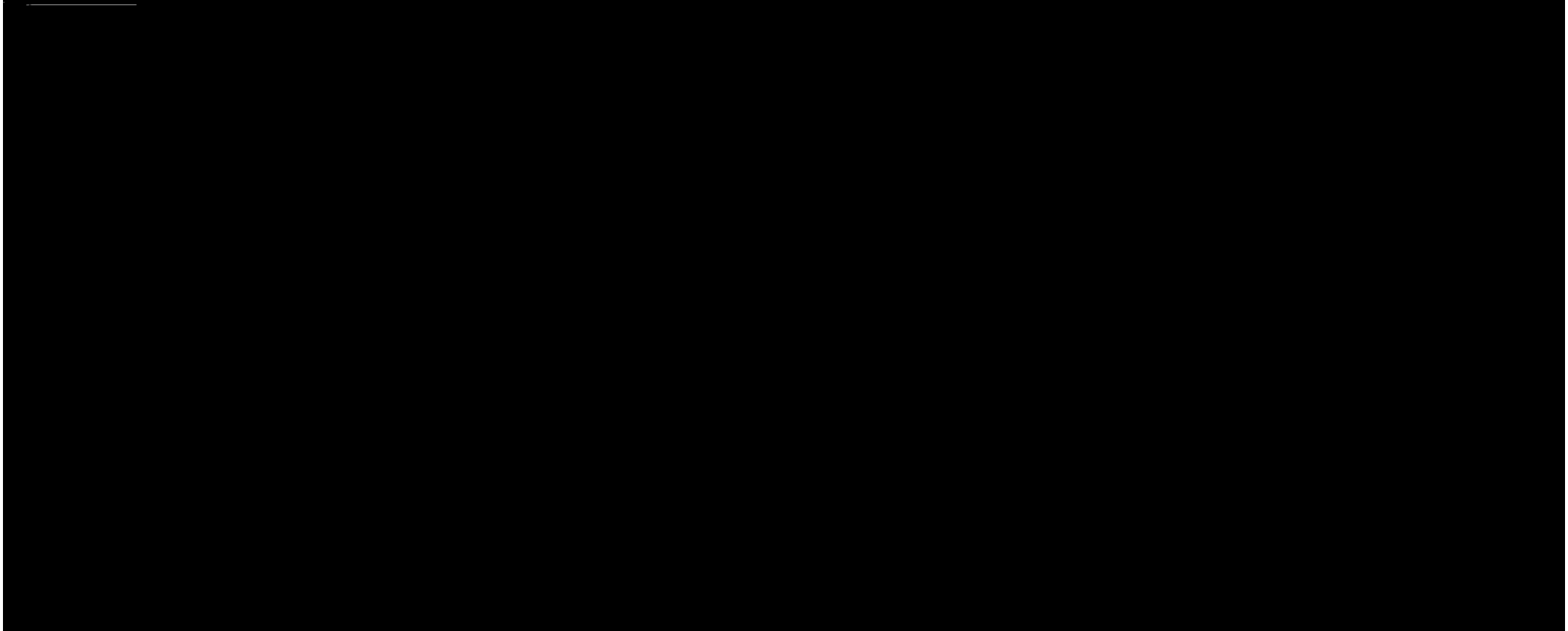


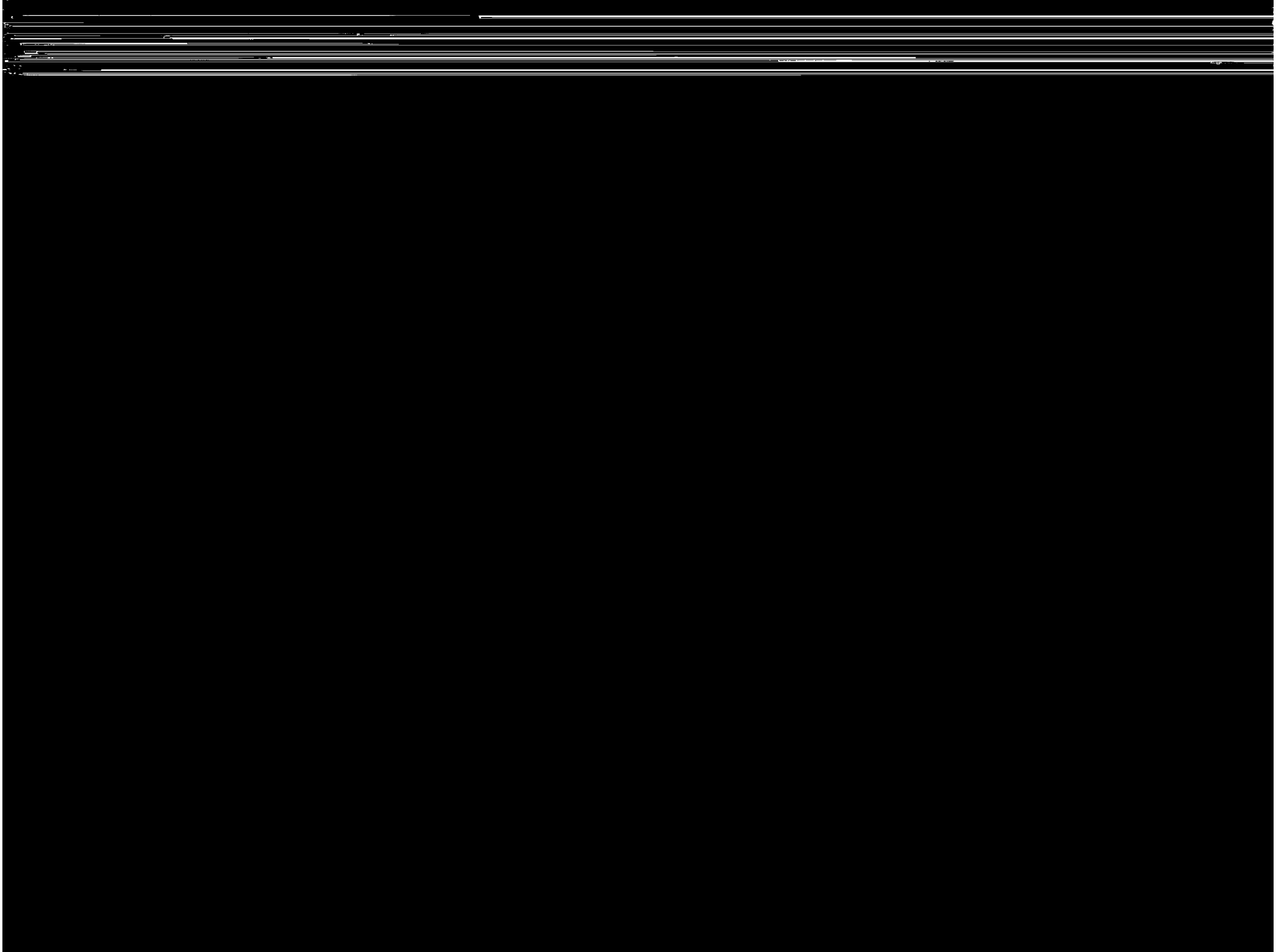




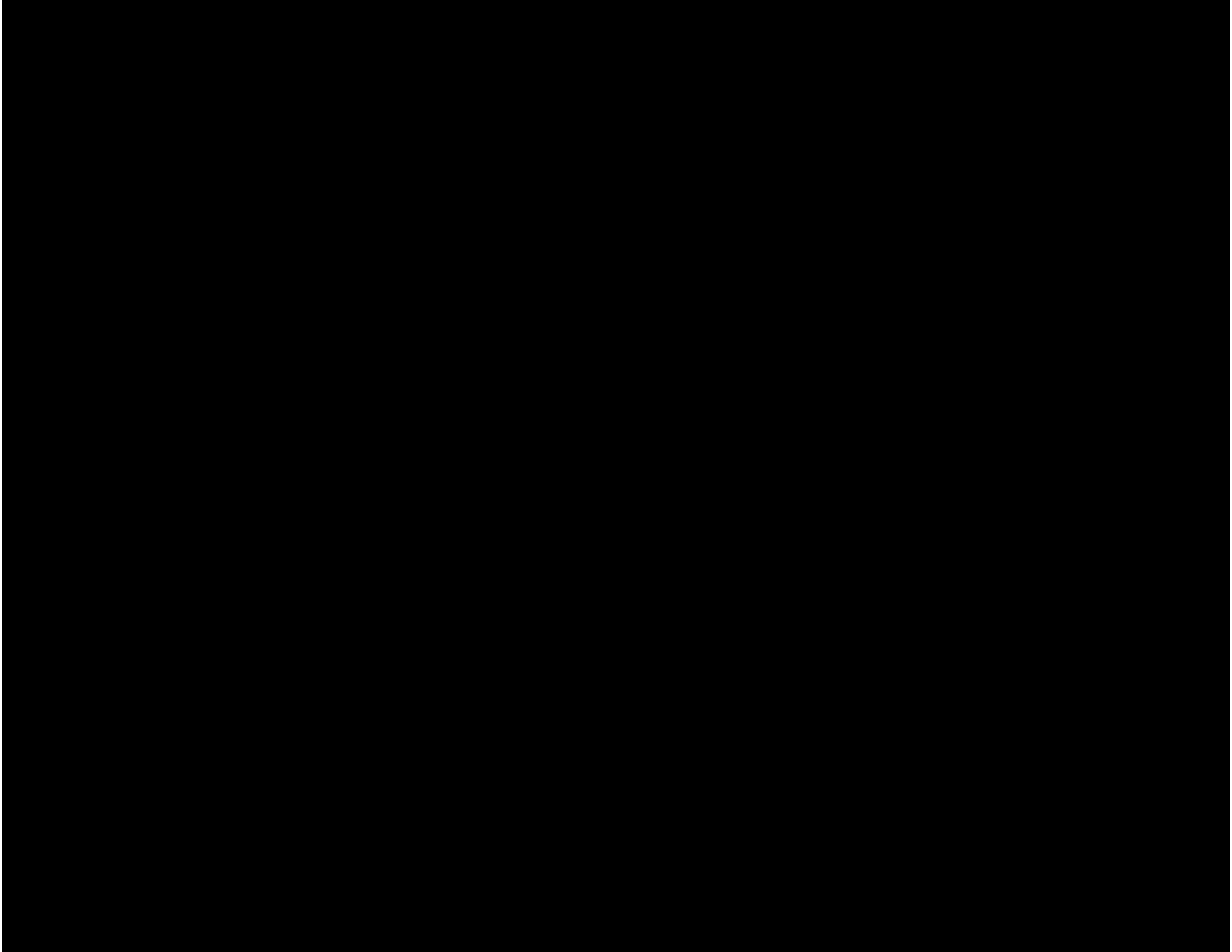


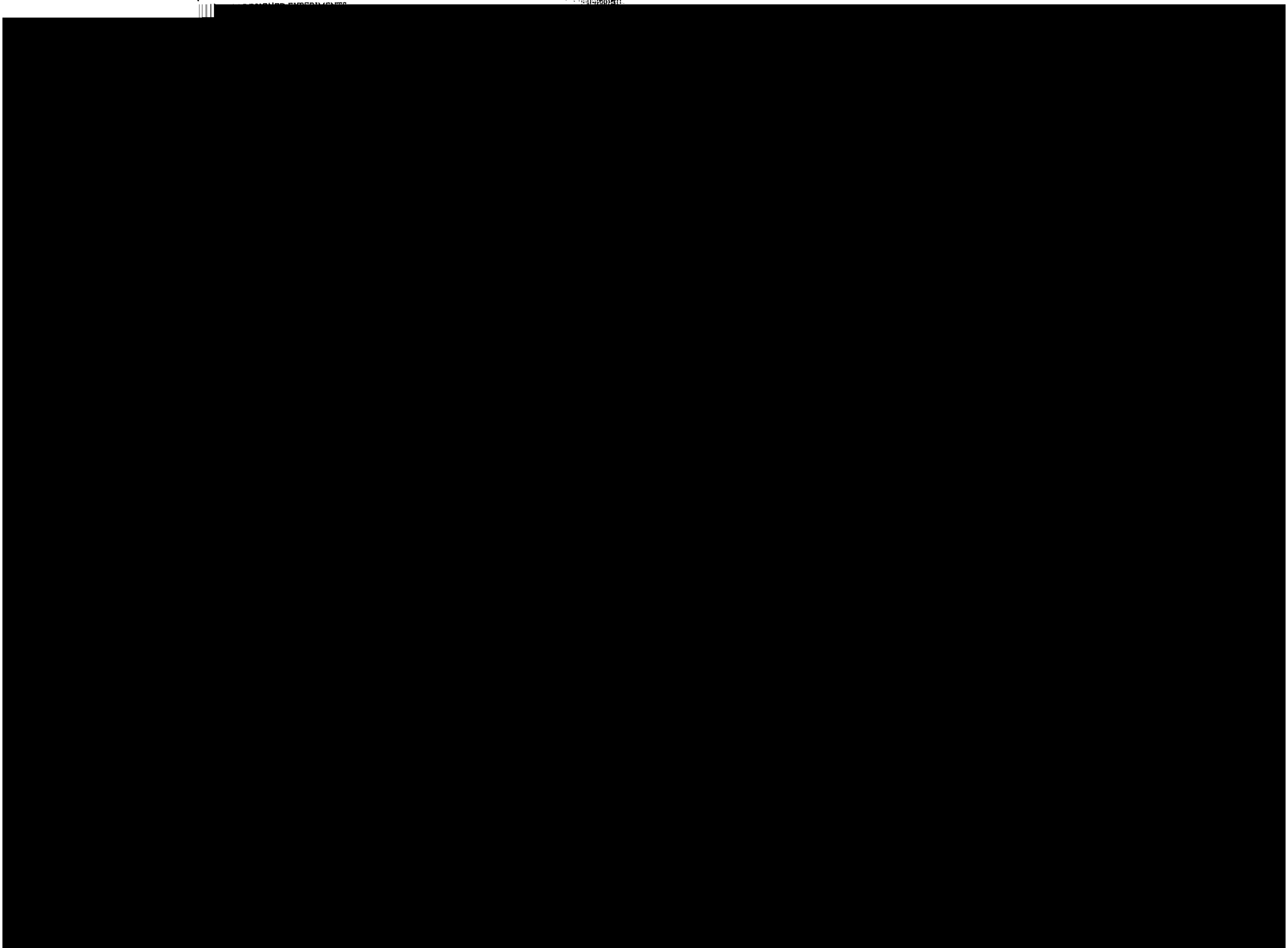


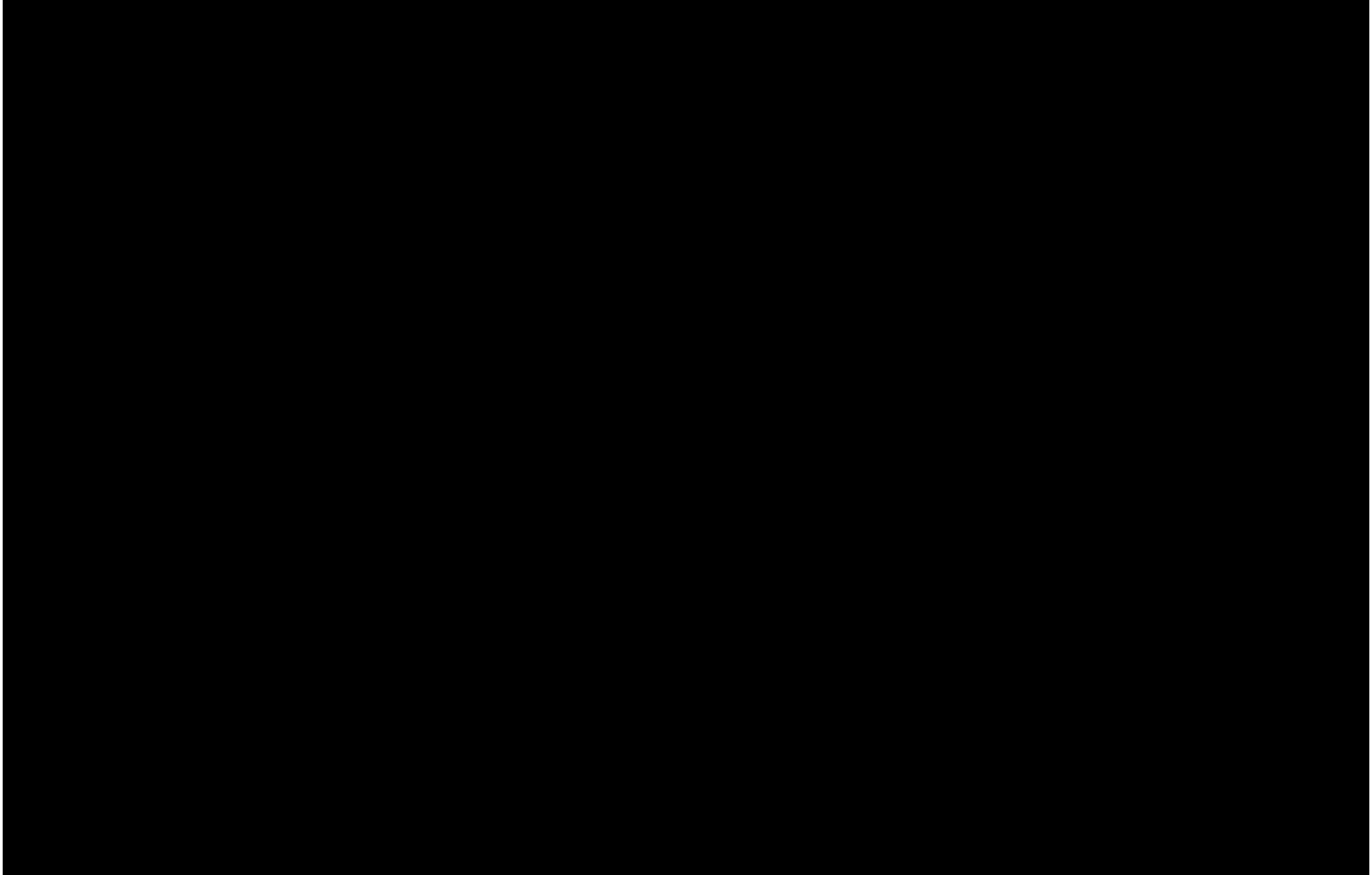
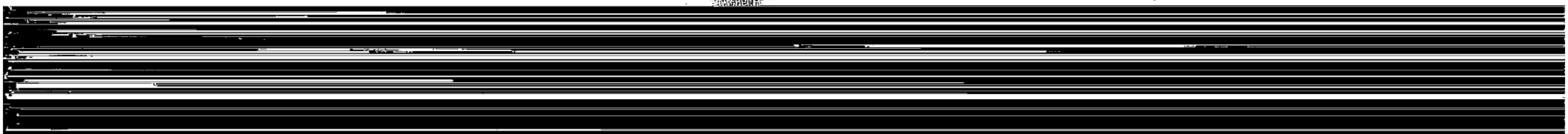






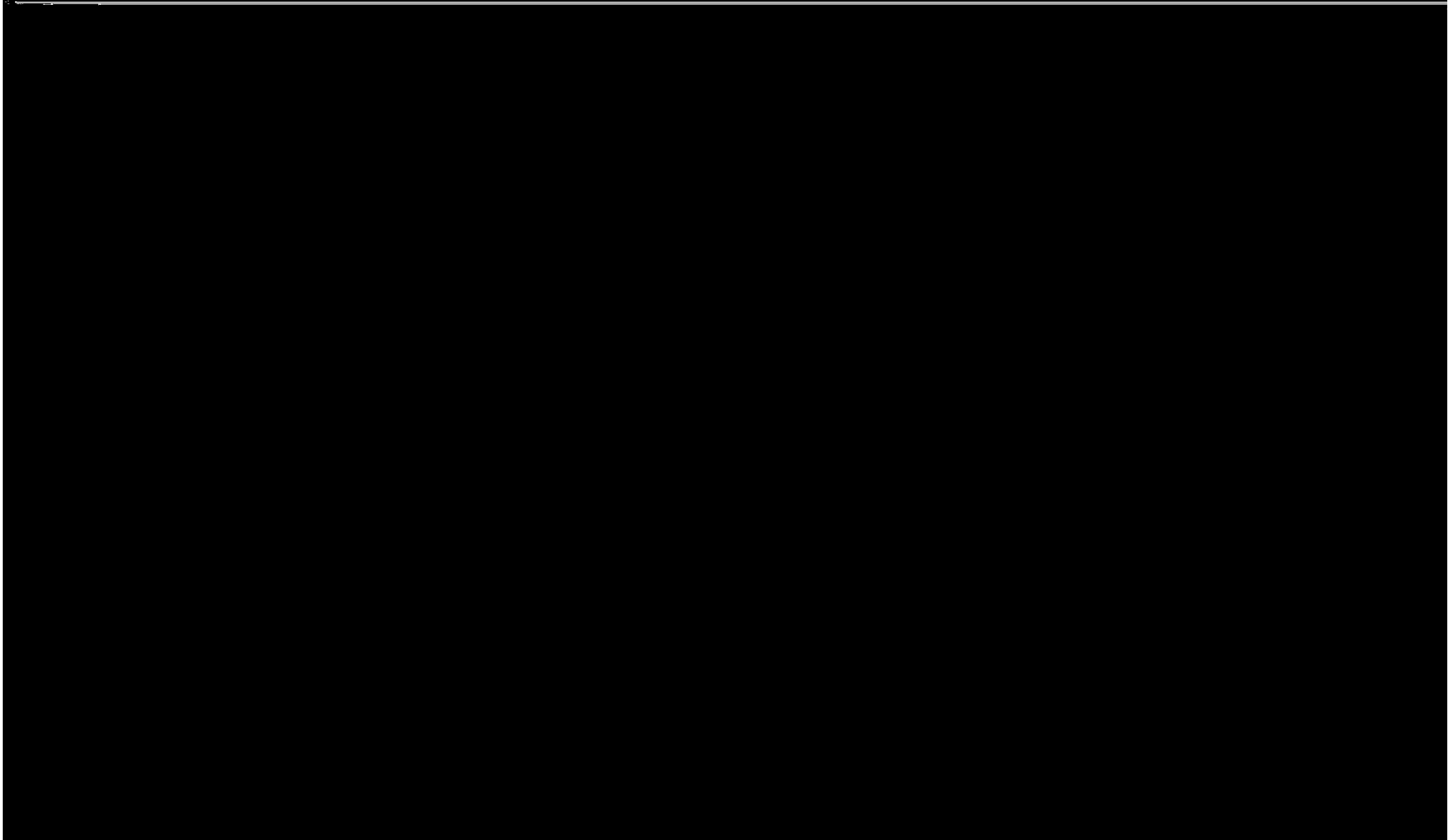
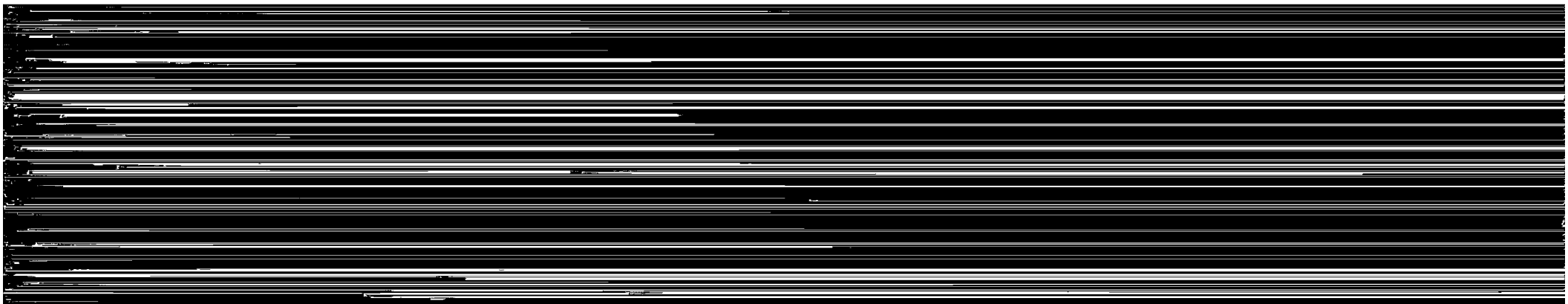




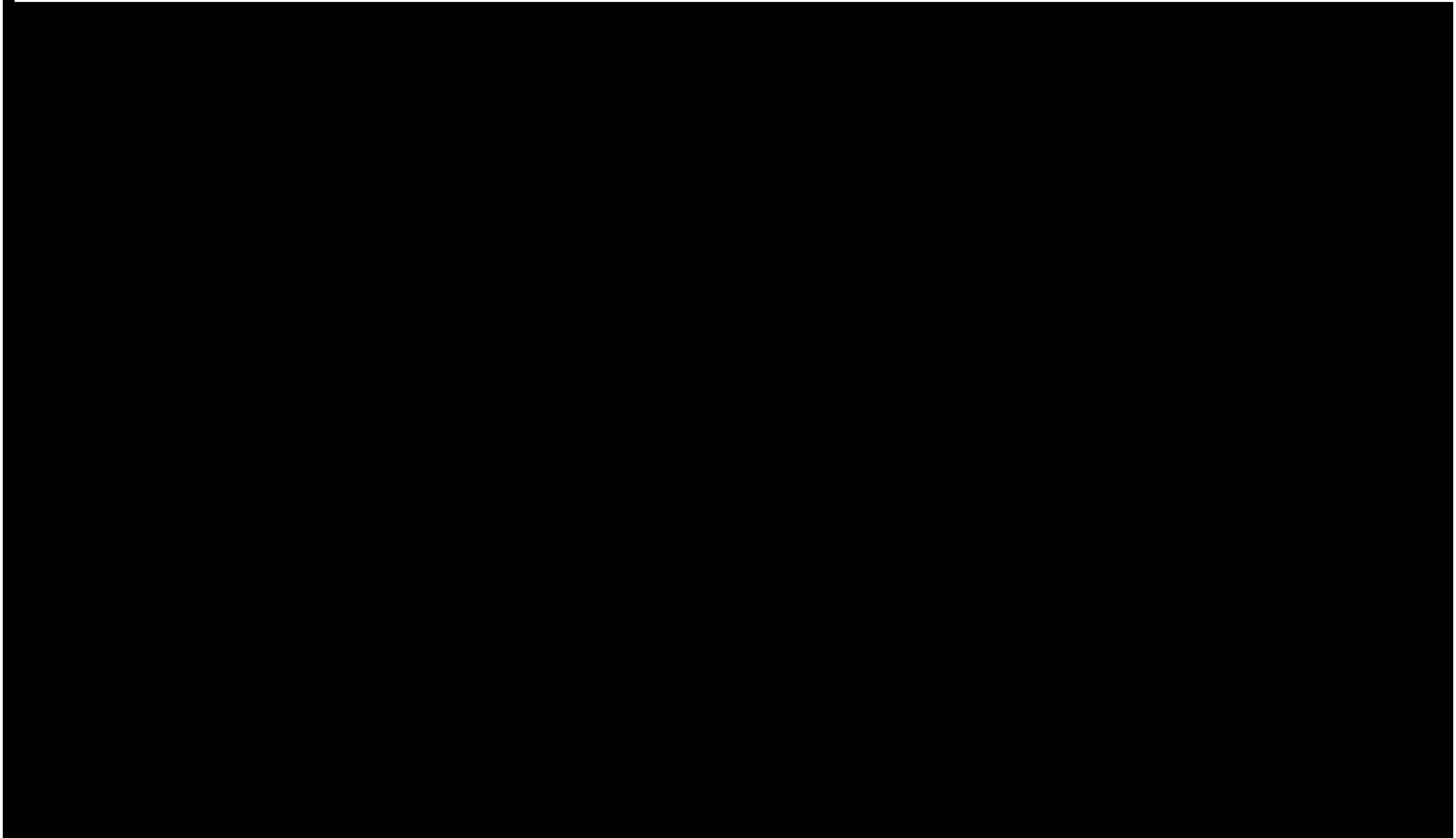
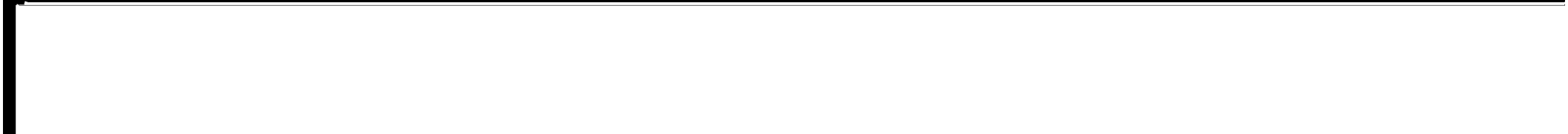


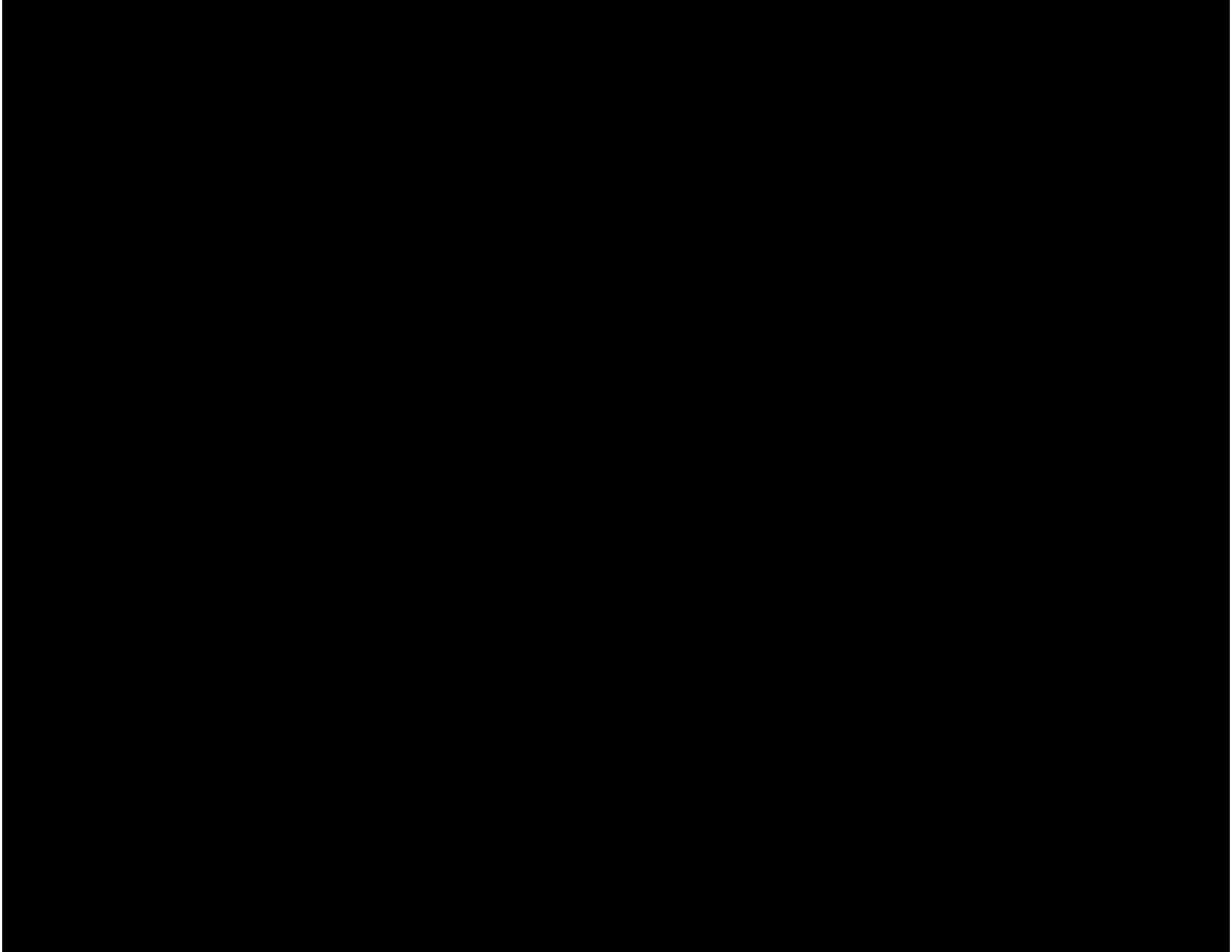






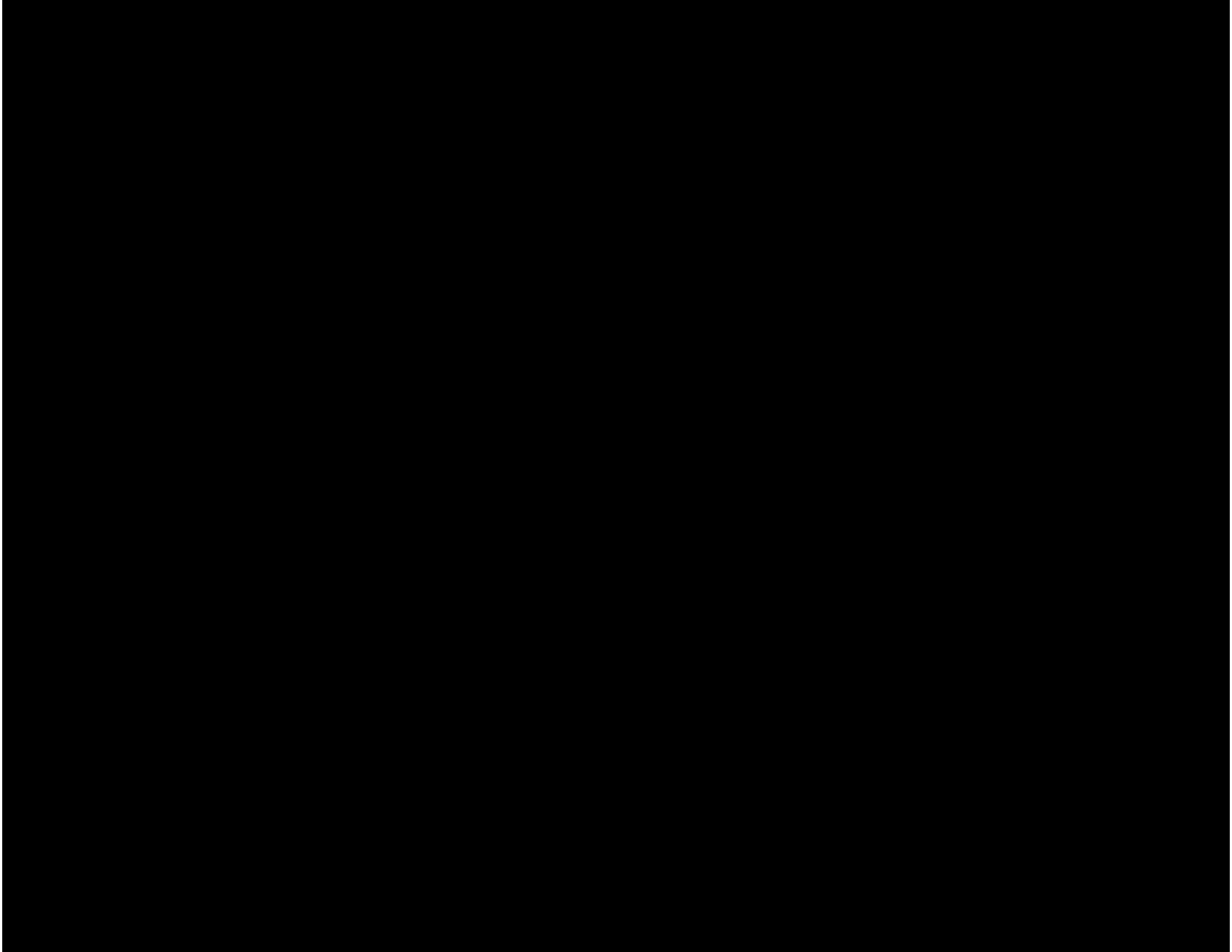




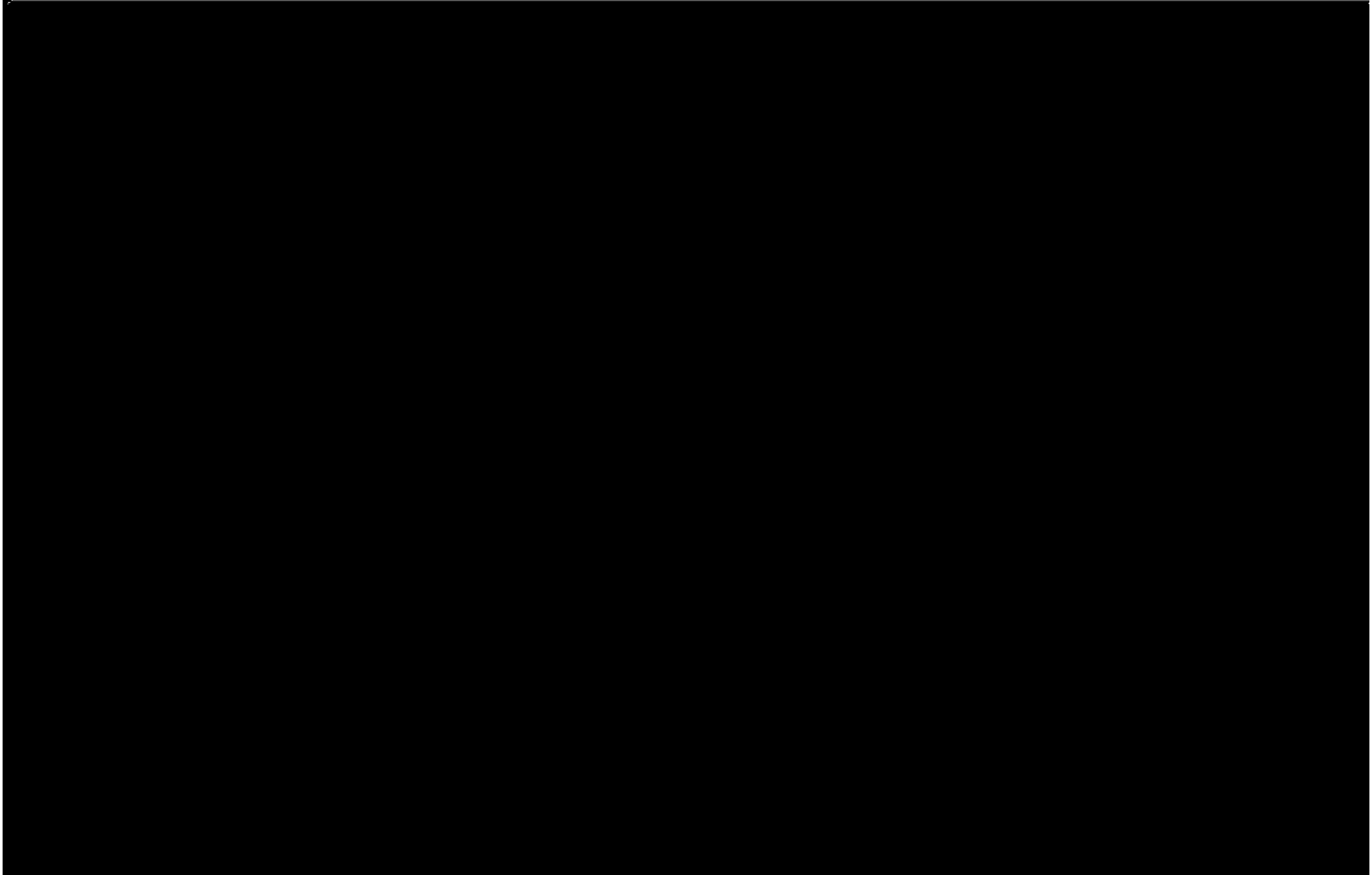


$$y = \mu + \sigma \sqrt{10.81 - 0.06x + 8.31x^2} + \sigma^2$$





1.00



...DESIGNED EXPERIMENTS



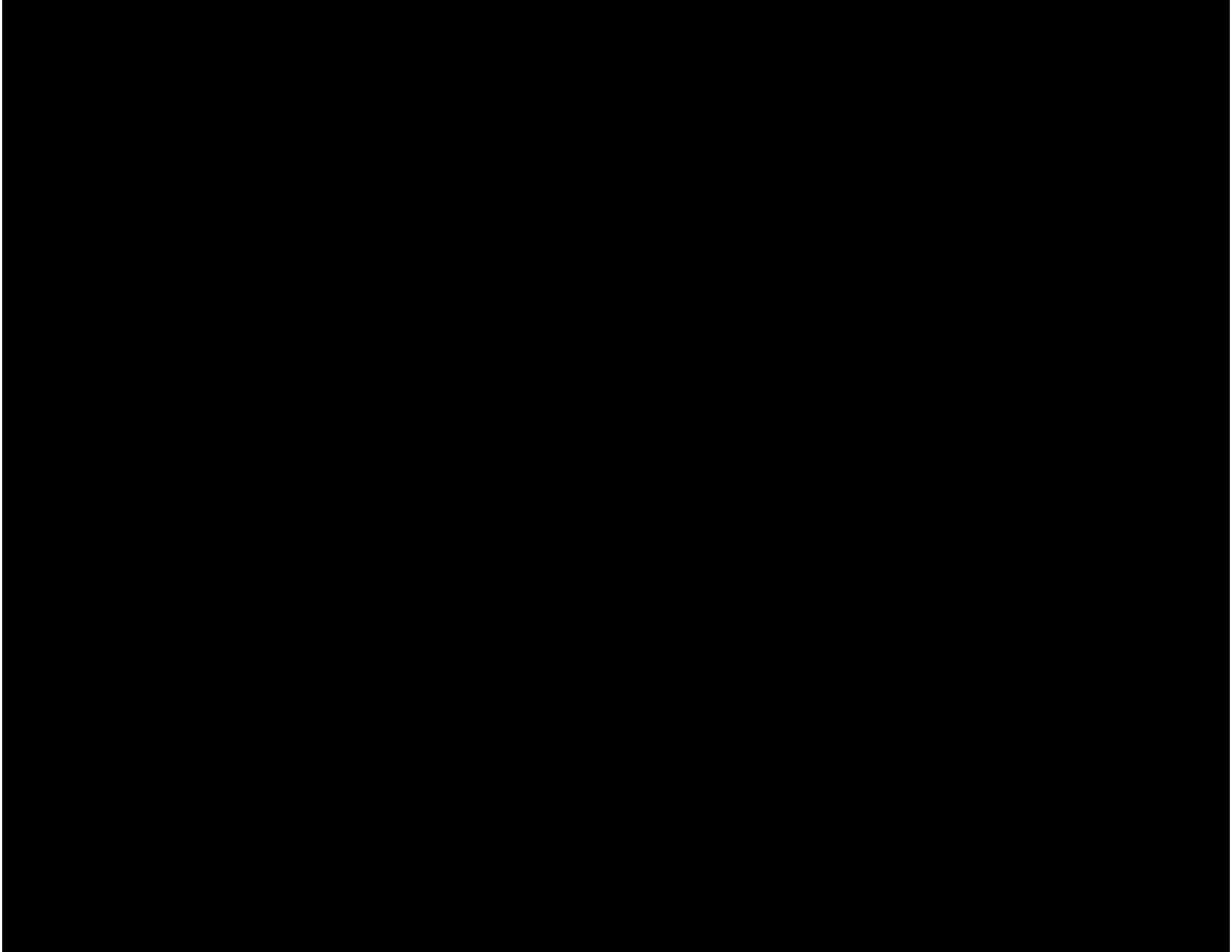






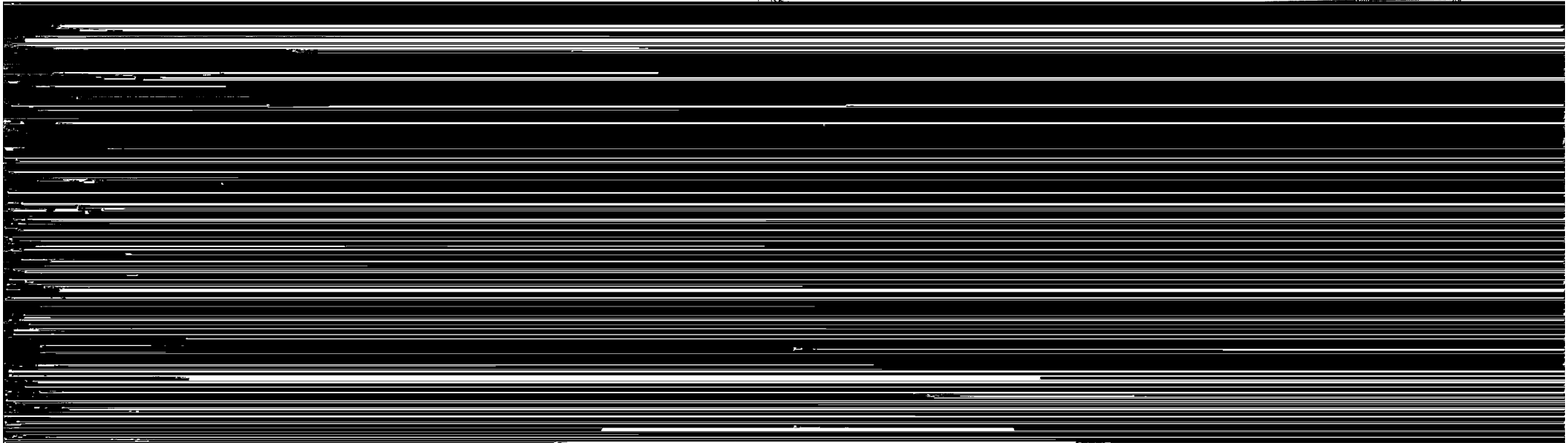
UNDESIGNED EXPERIMENTS

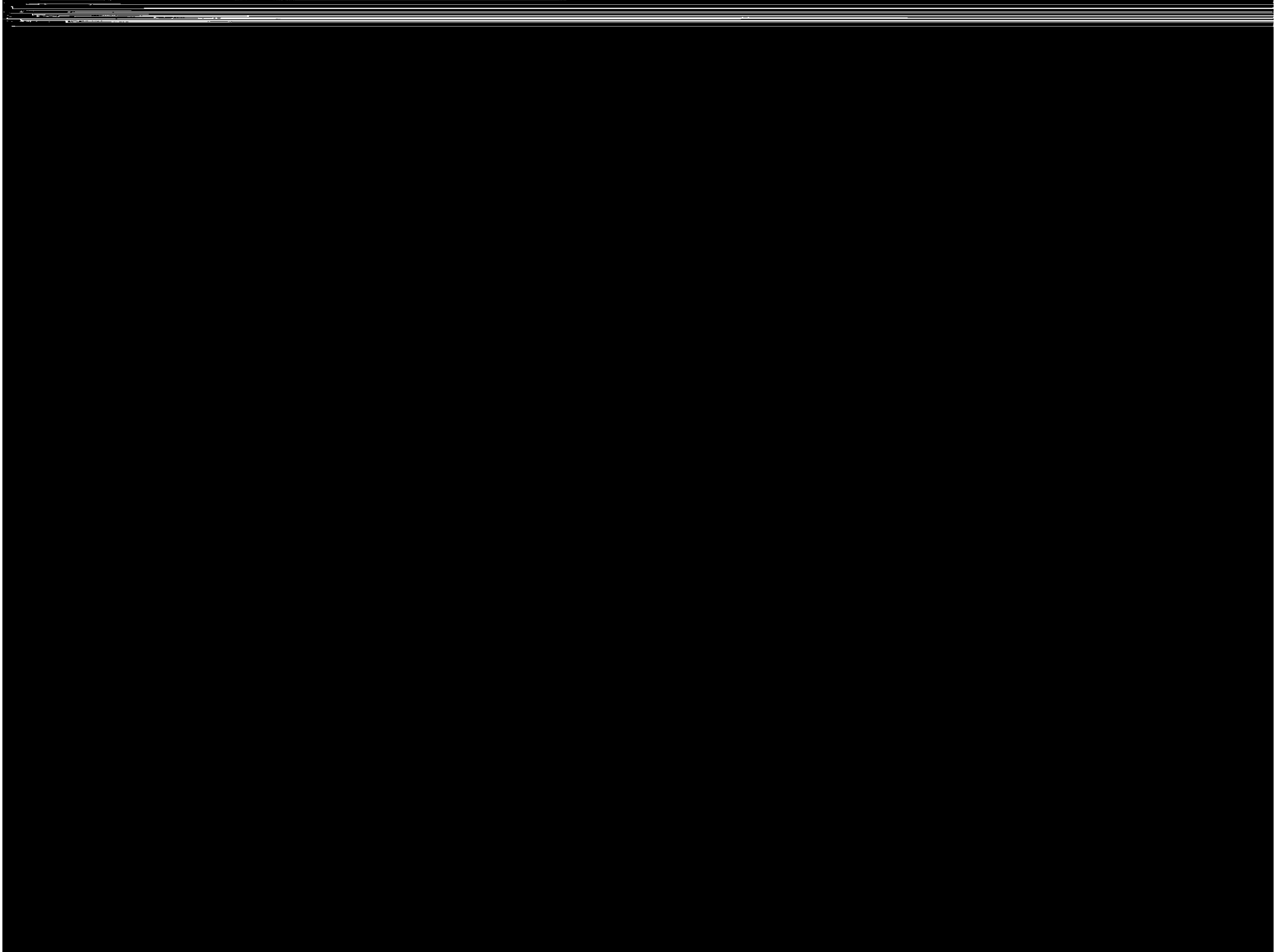


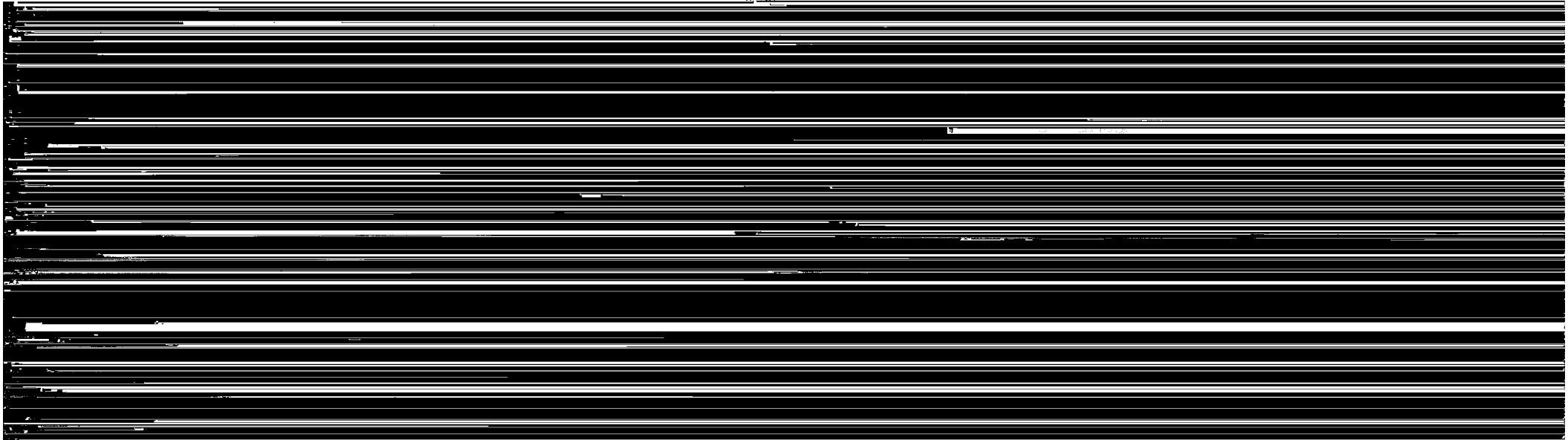


PART

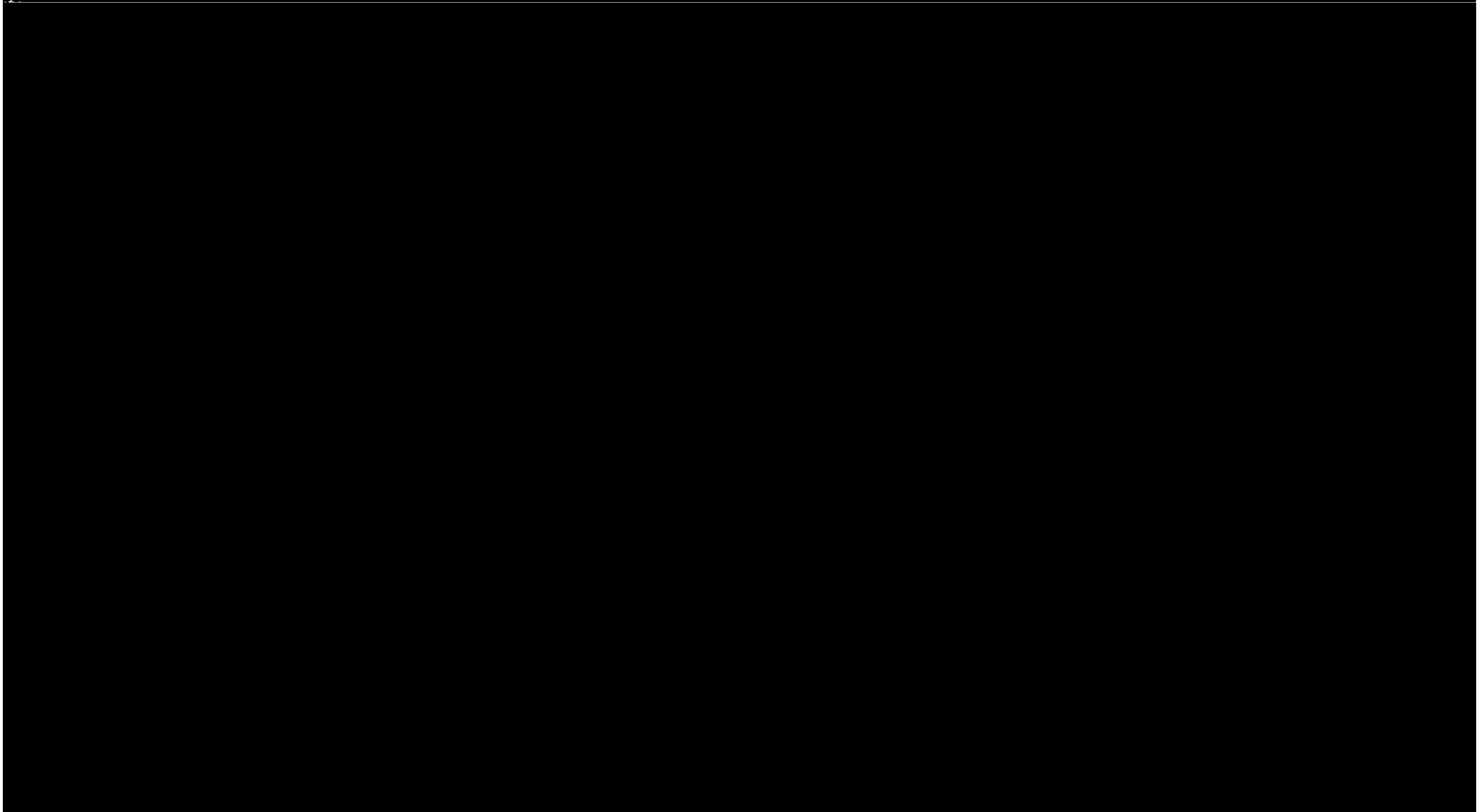
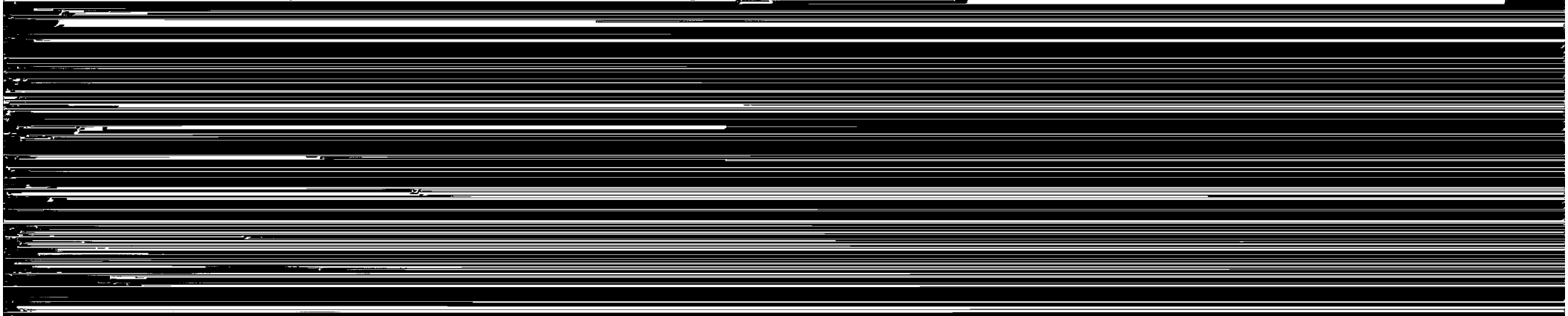
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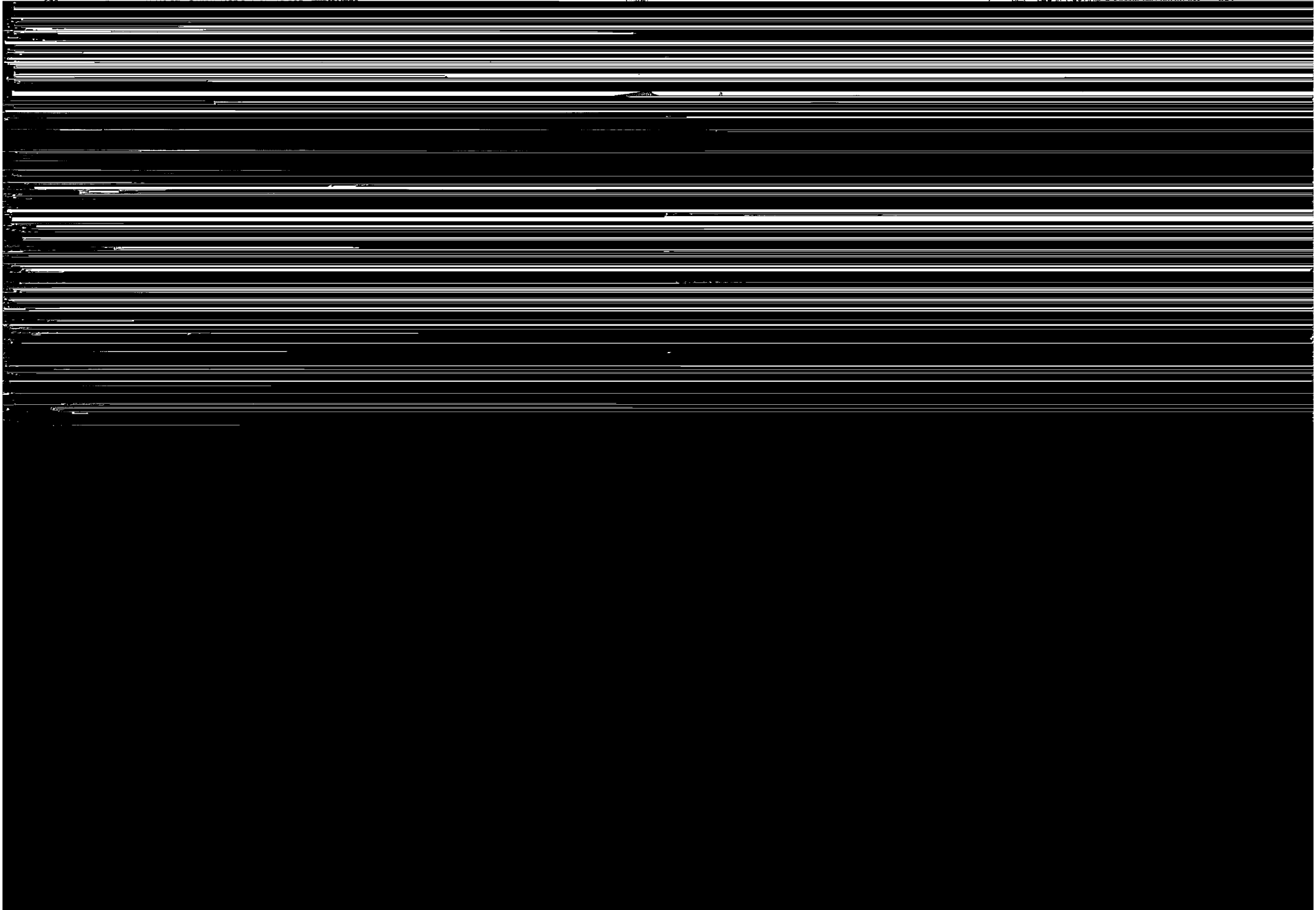


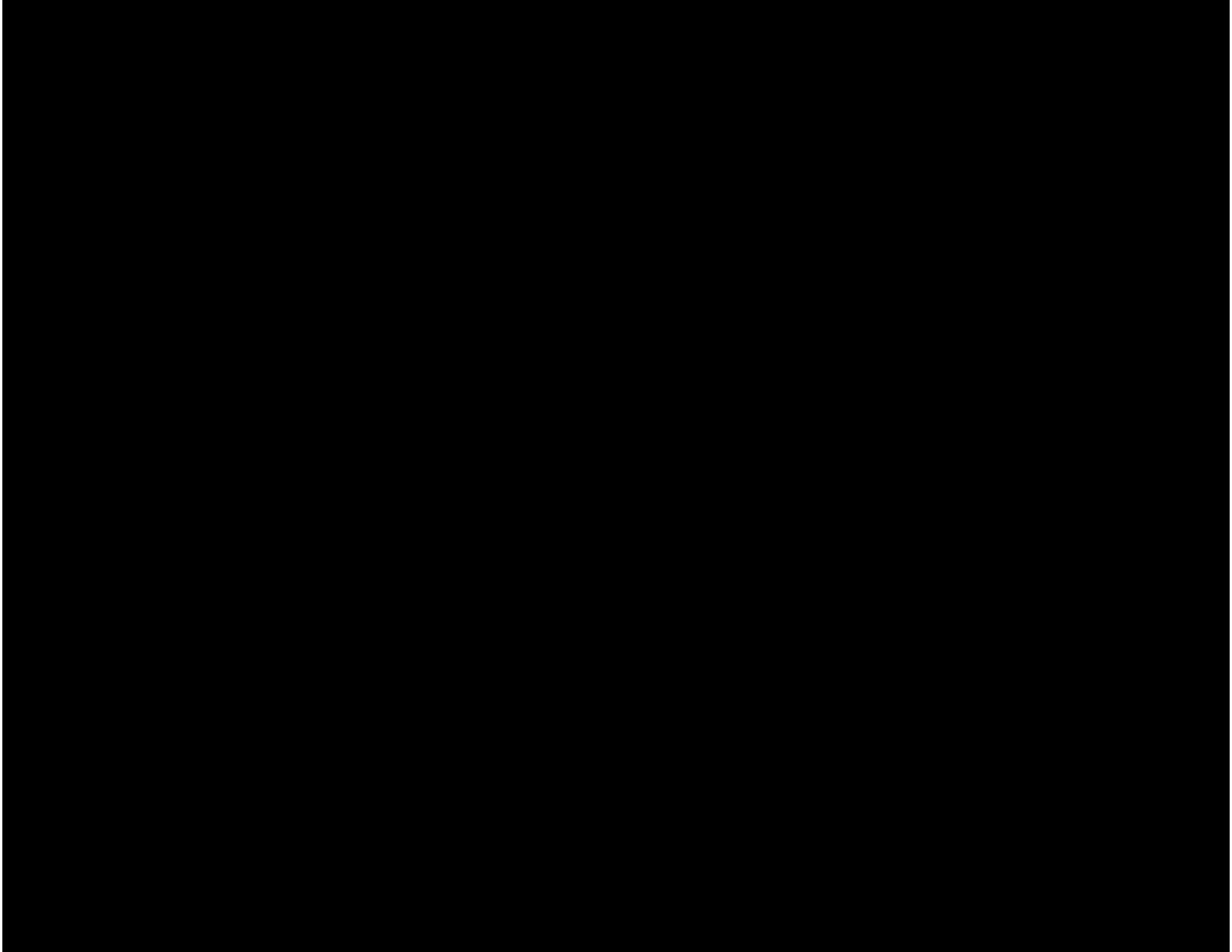


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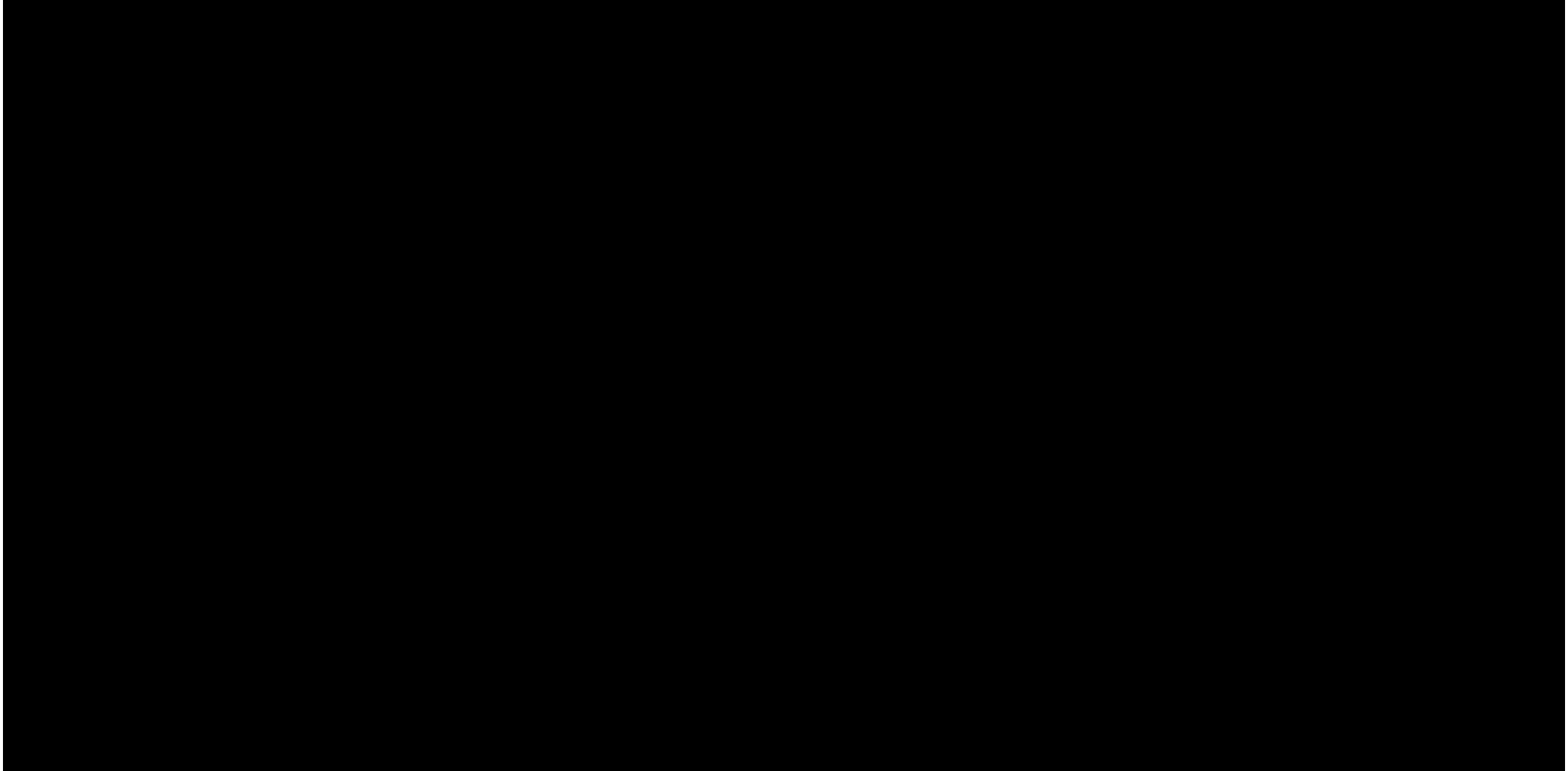
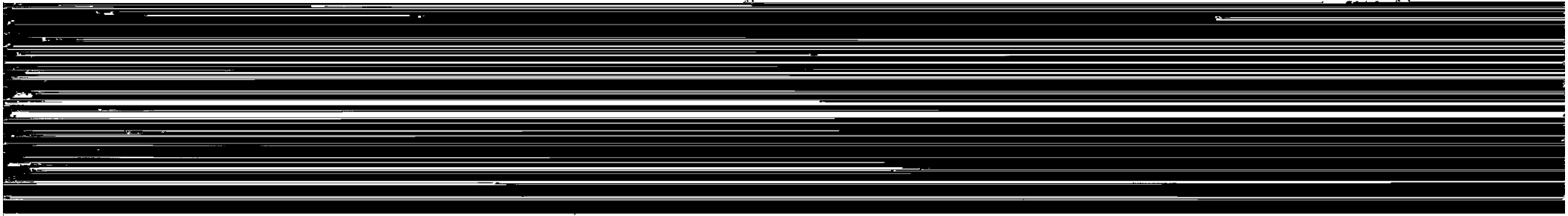




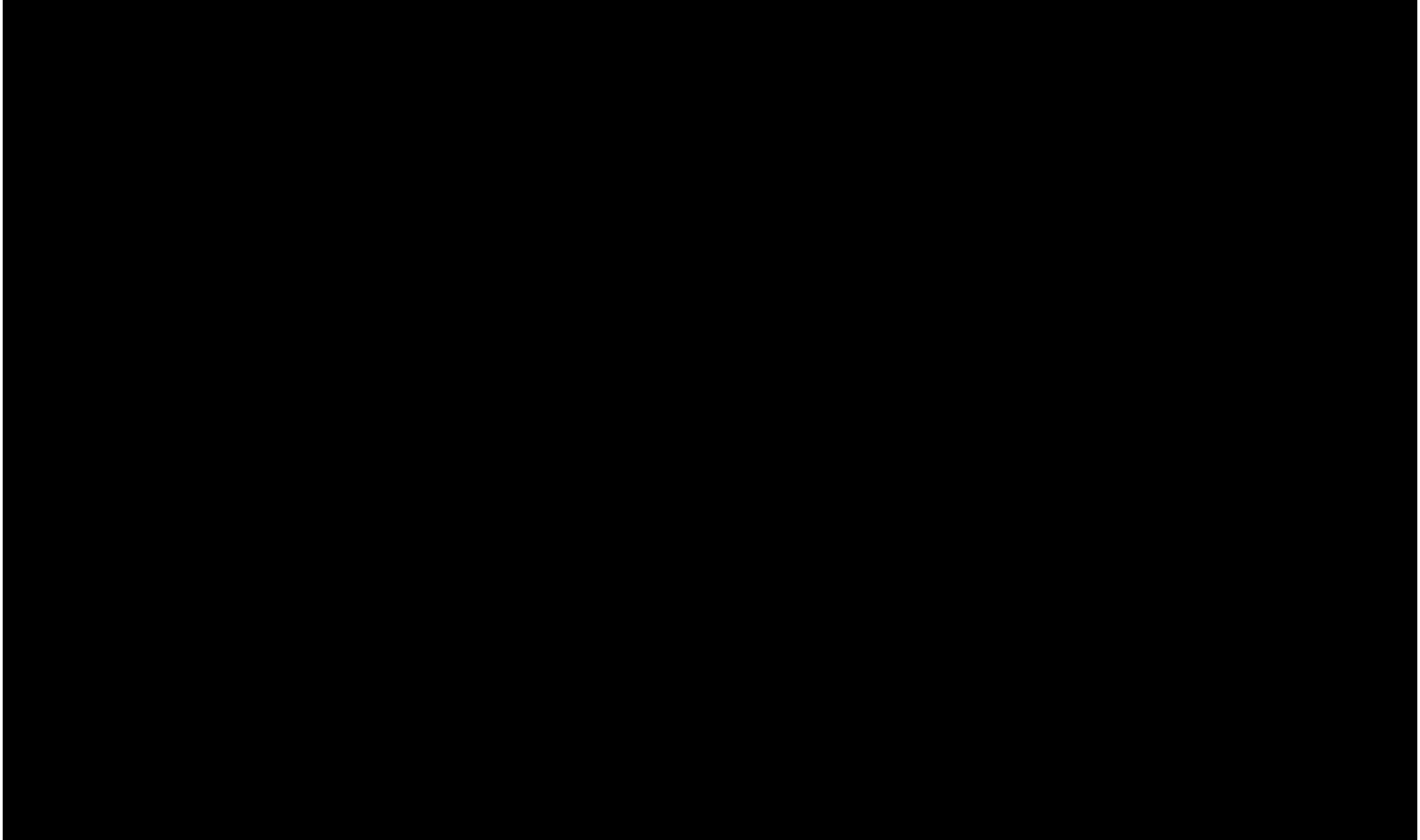


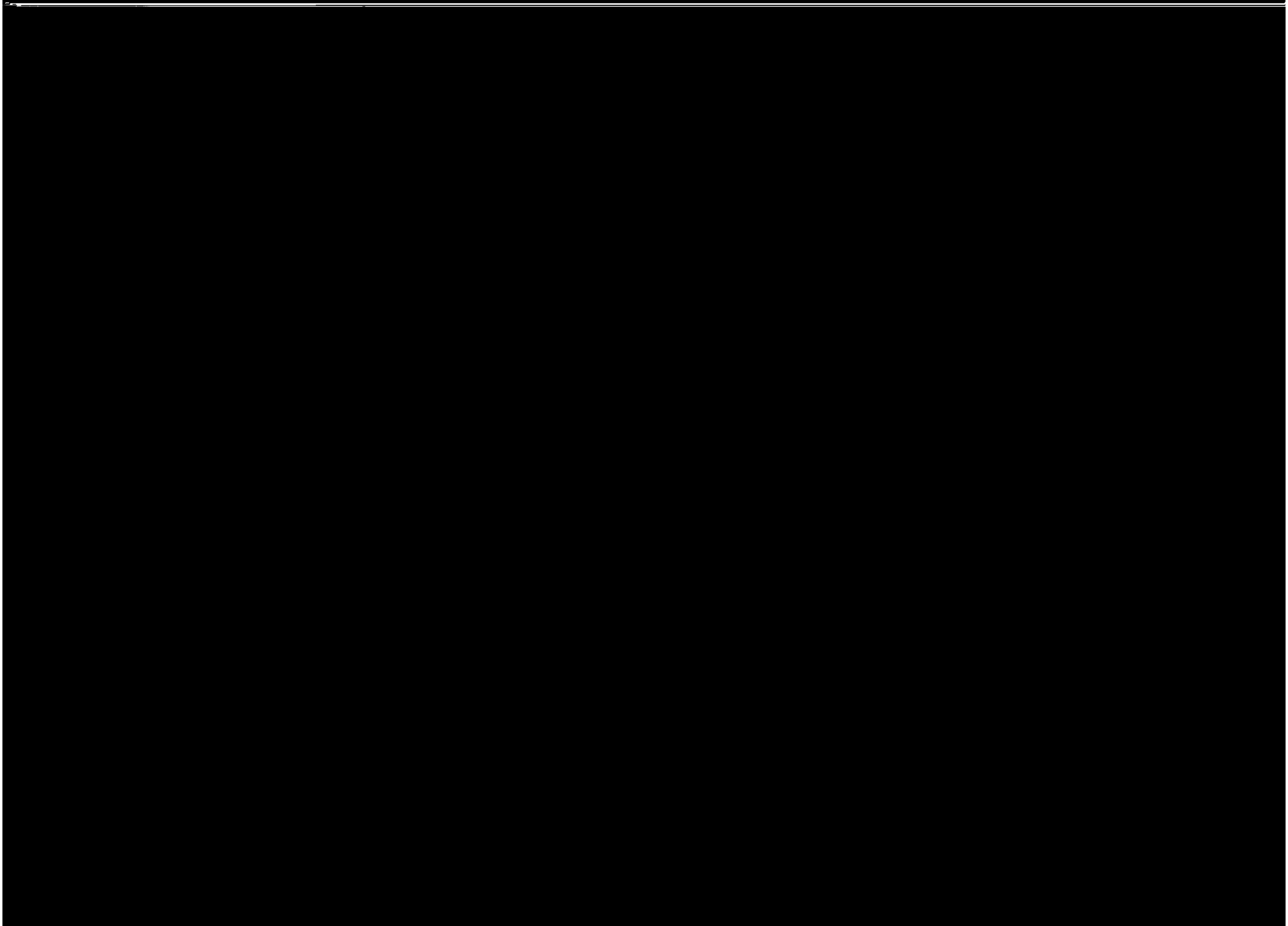






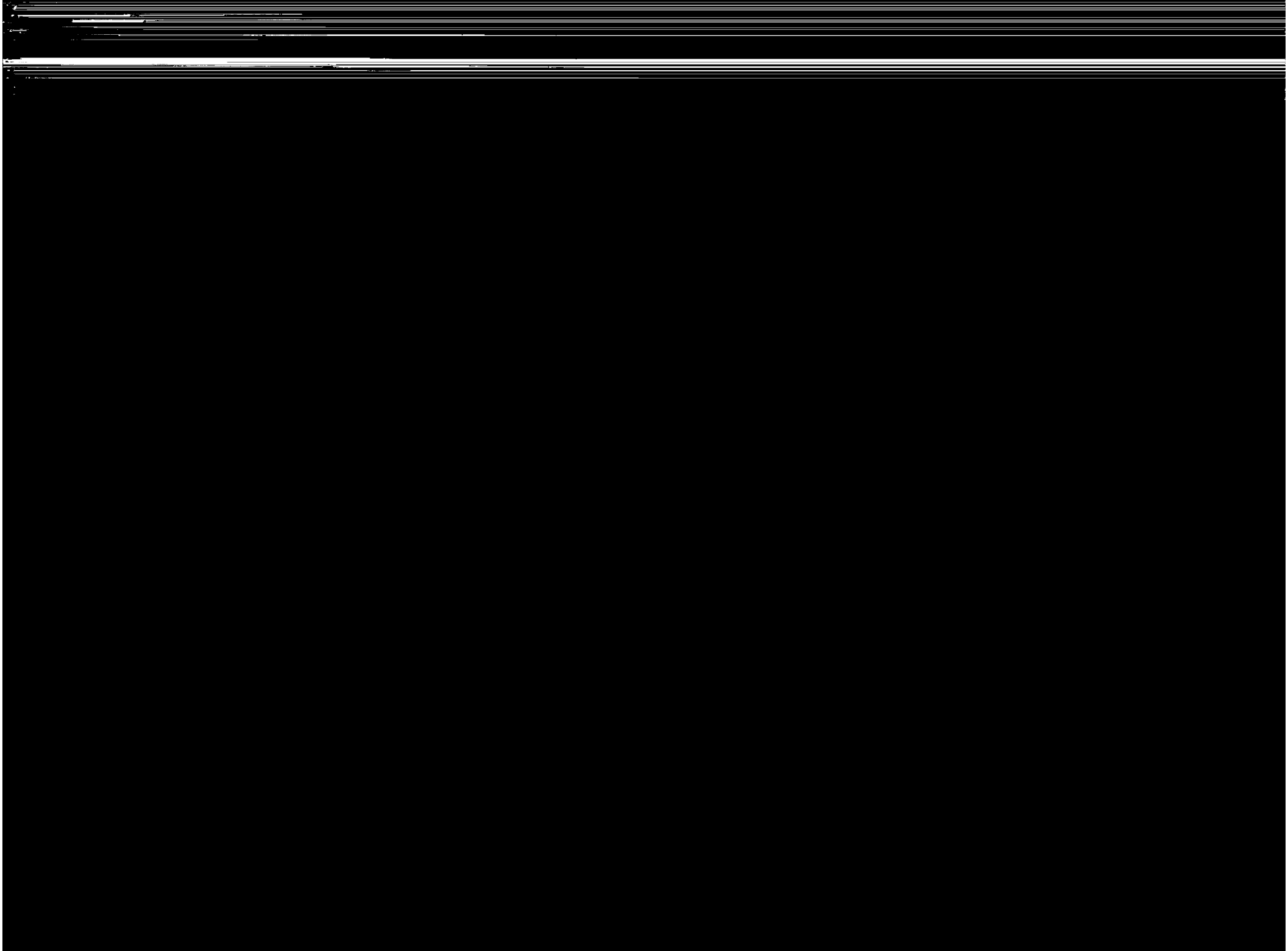


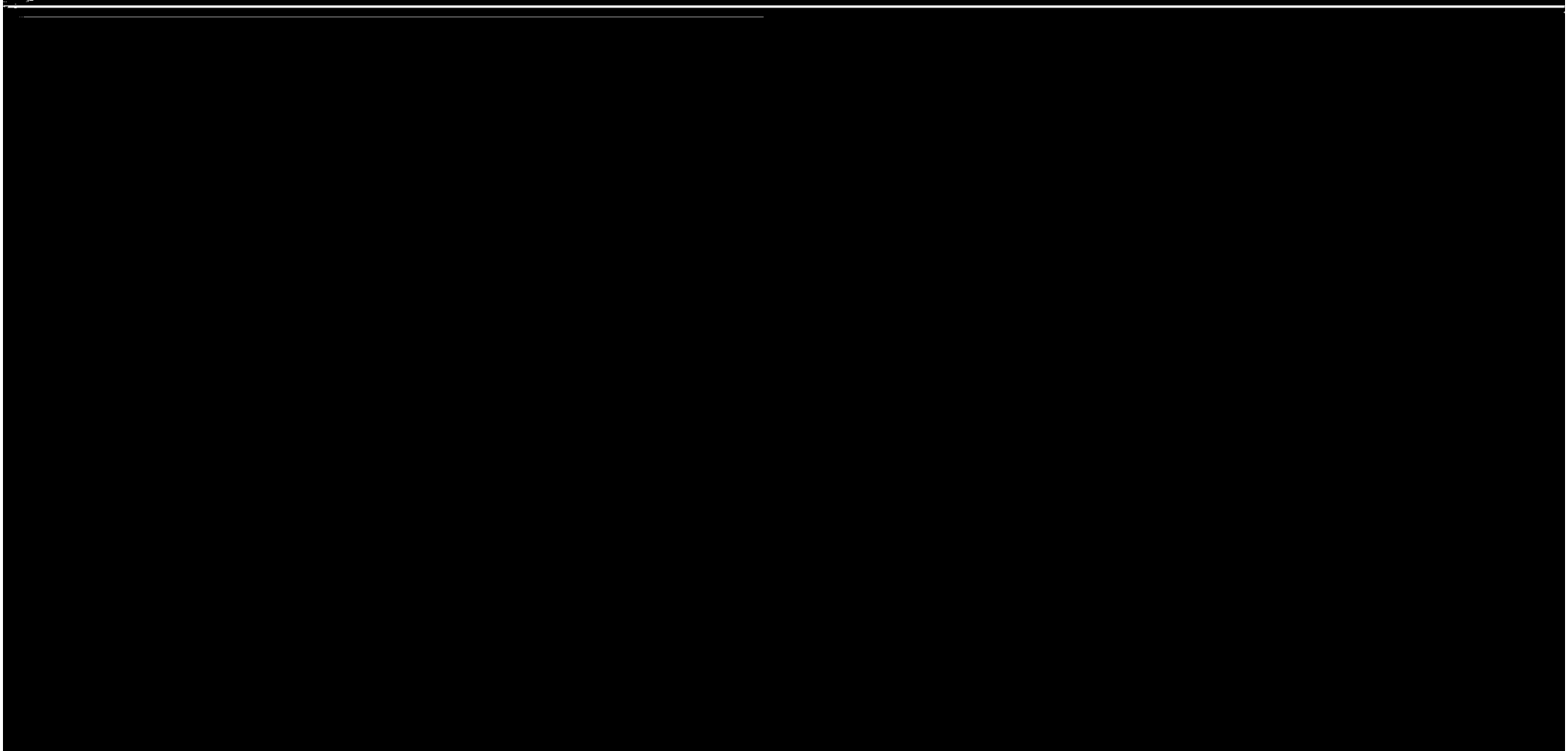














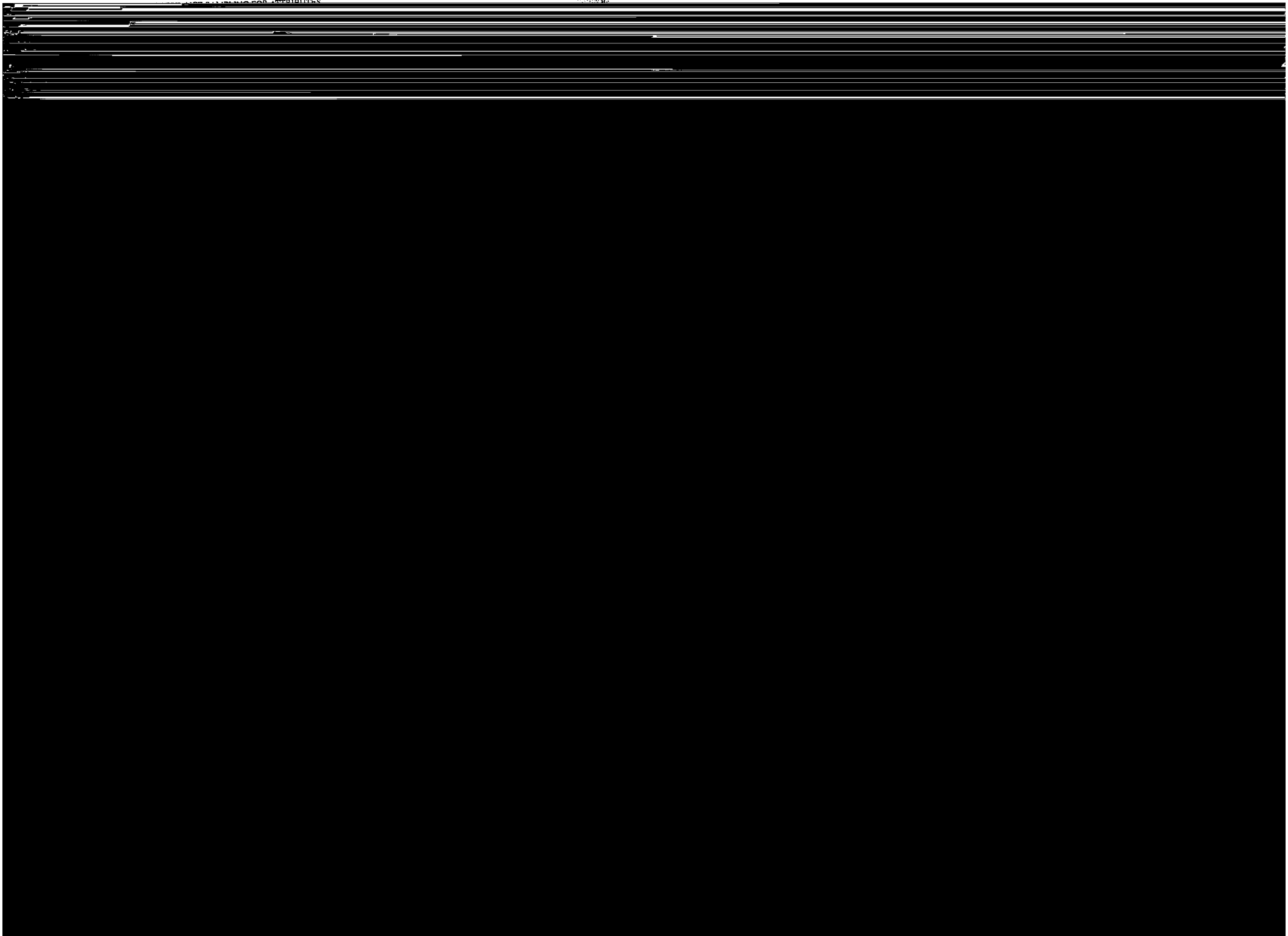
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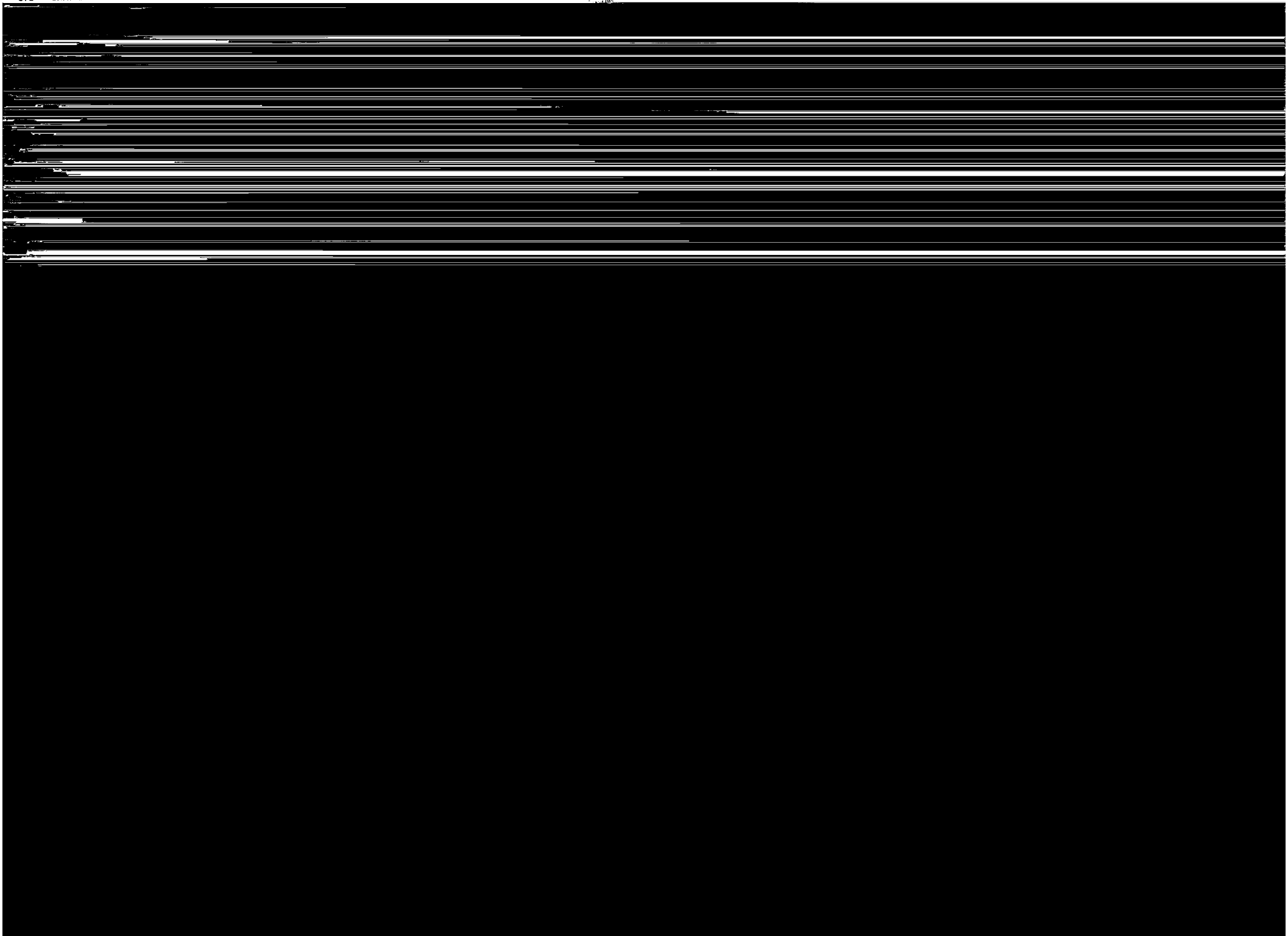
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USE ONLY FOR ATTRIBUTES





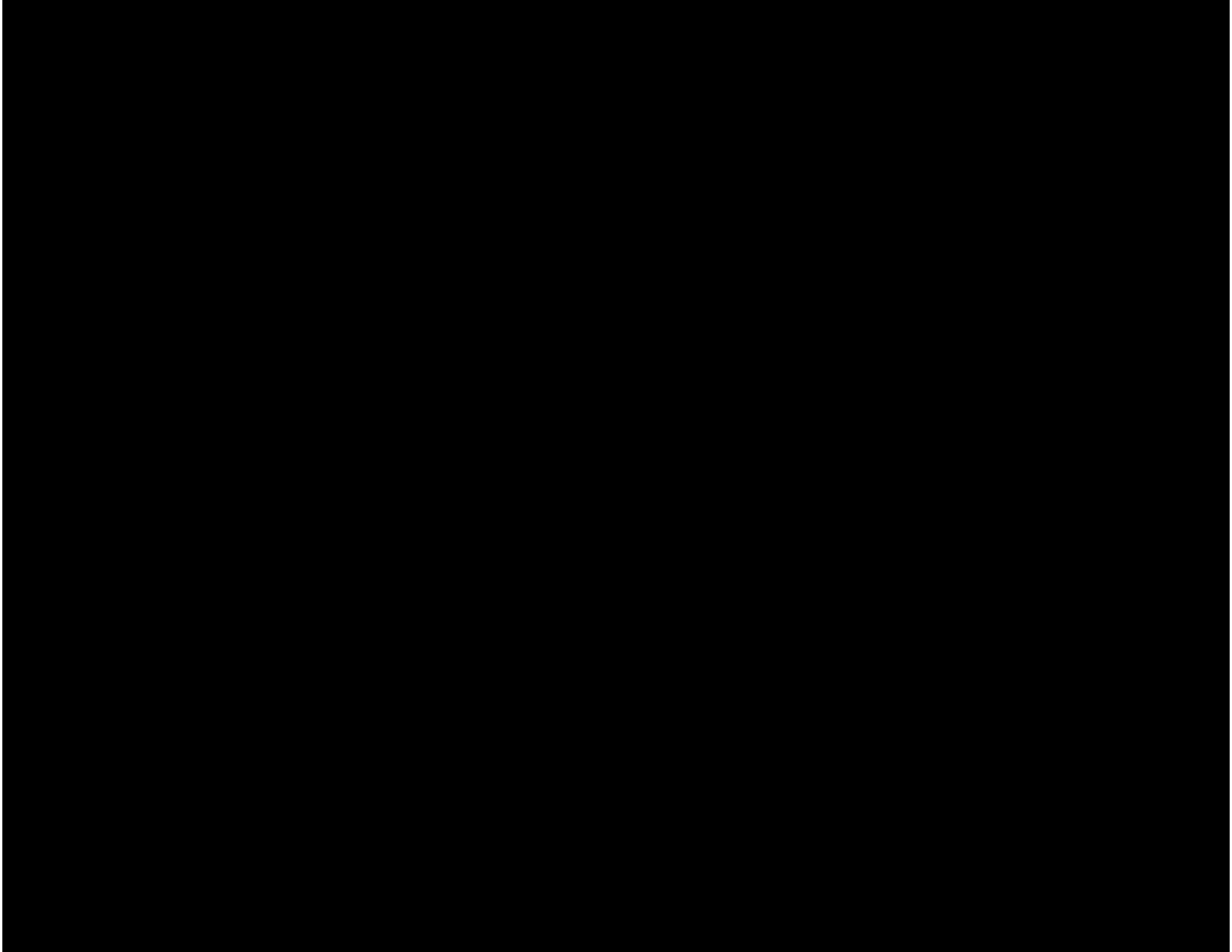
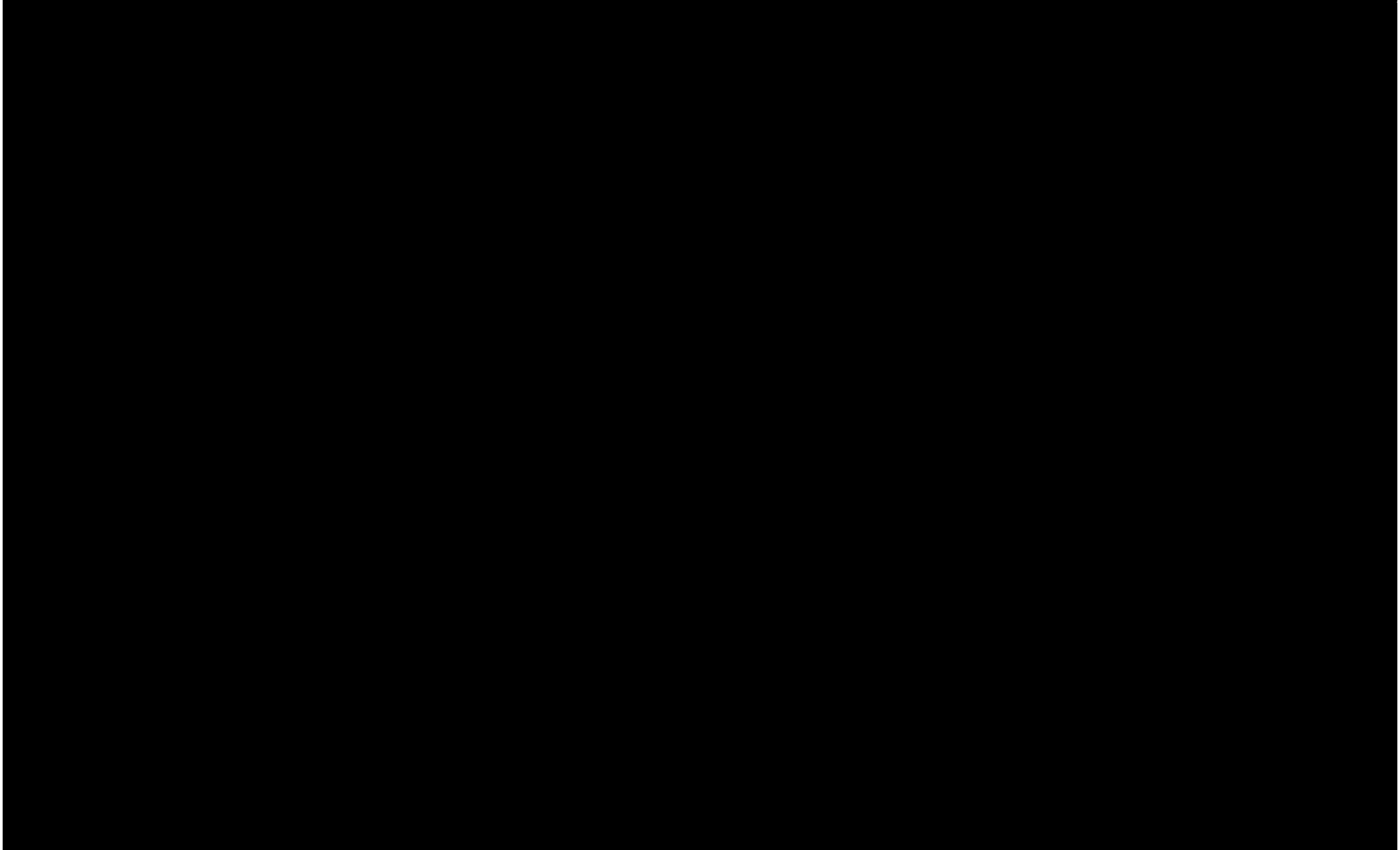
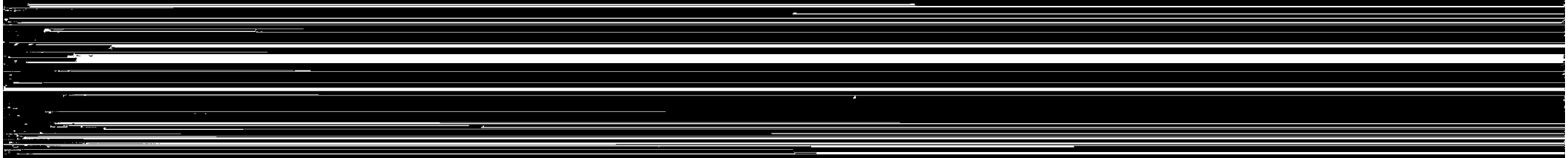




FIGURE 14-5 Dodge-Romig Sampling Plans

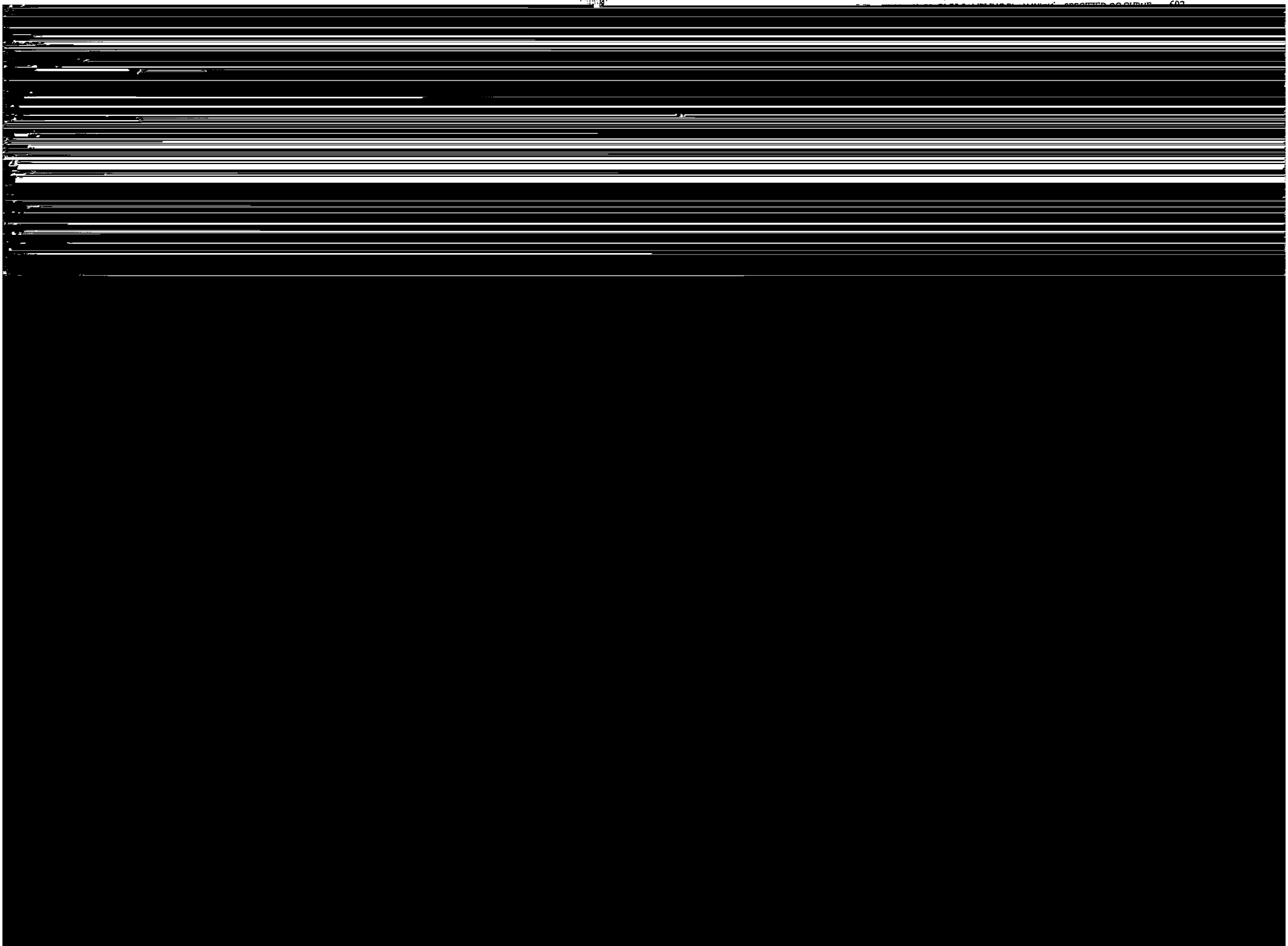




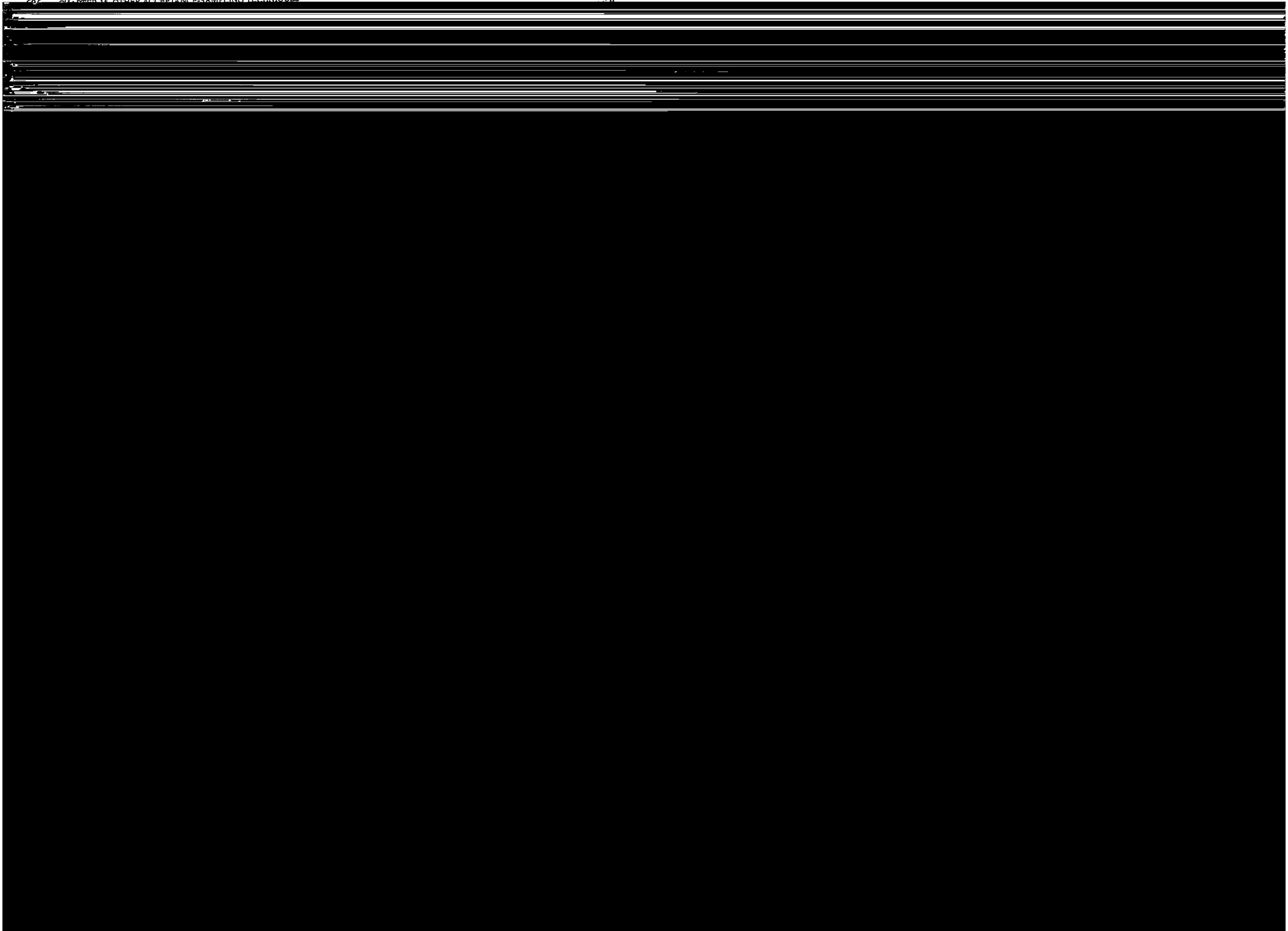




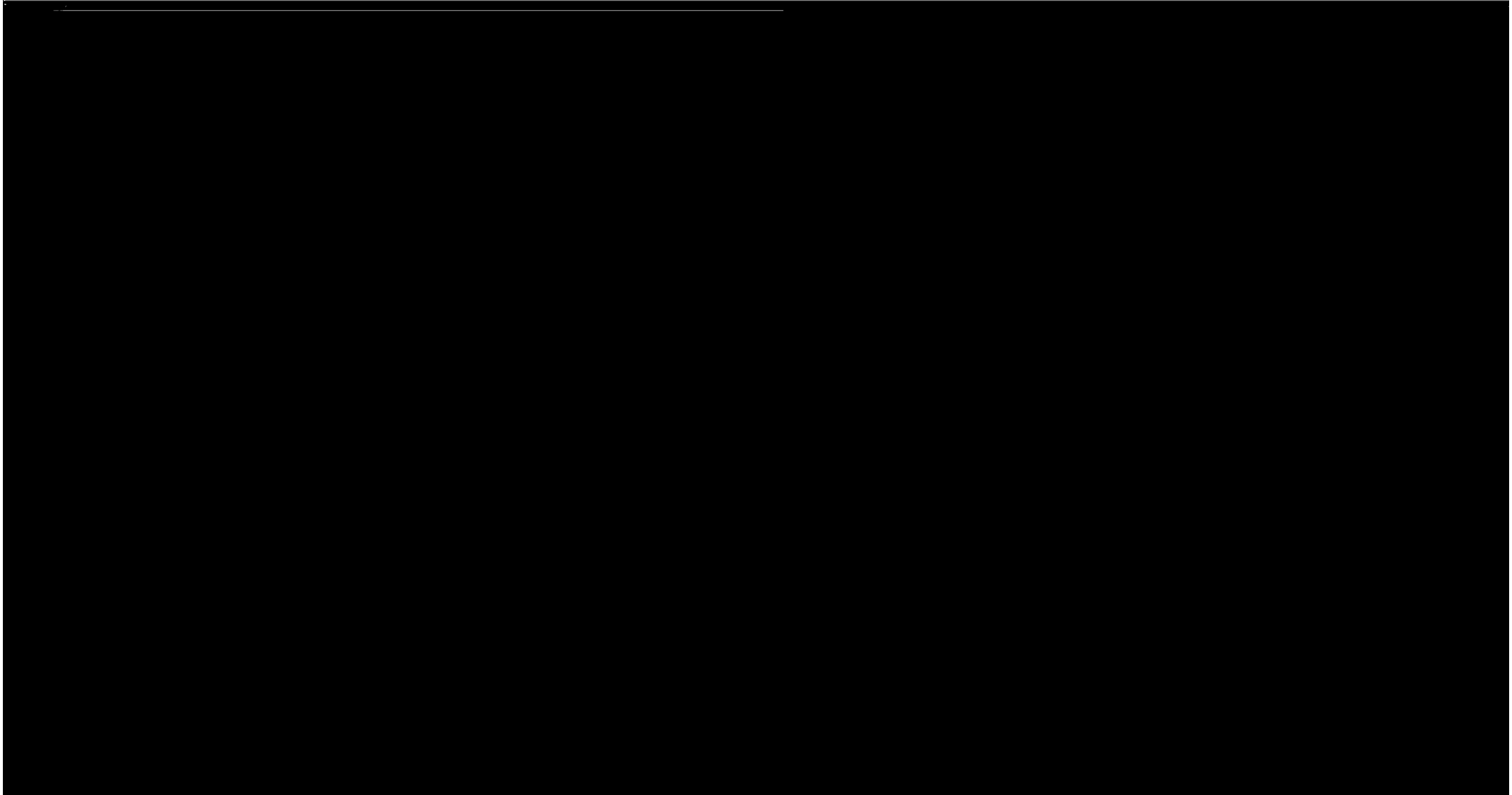
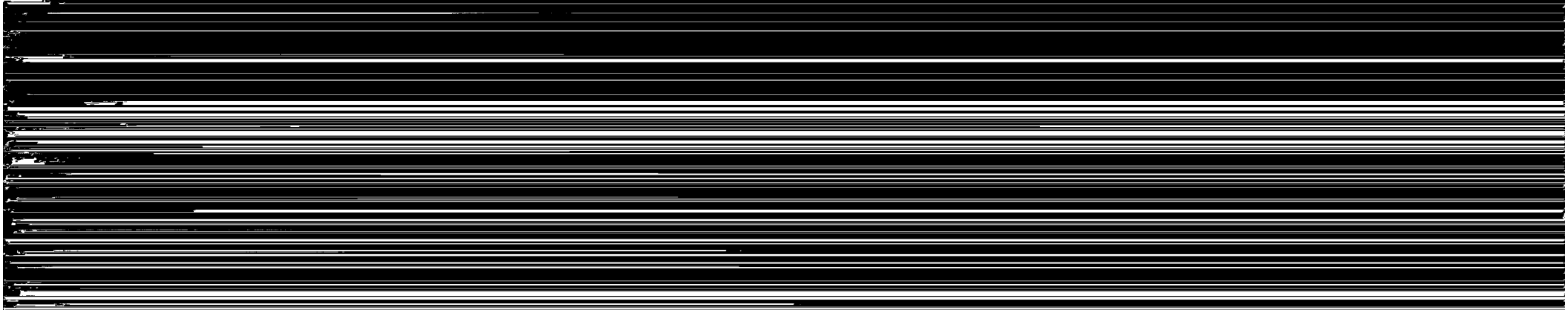
the area under the standard normal curve below  $Z_{1-\alpha}$ . (Actually, using  $O_{1-\alpha} =$

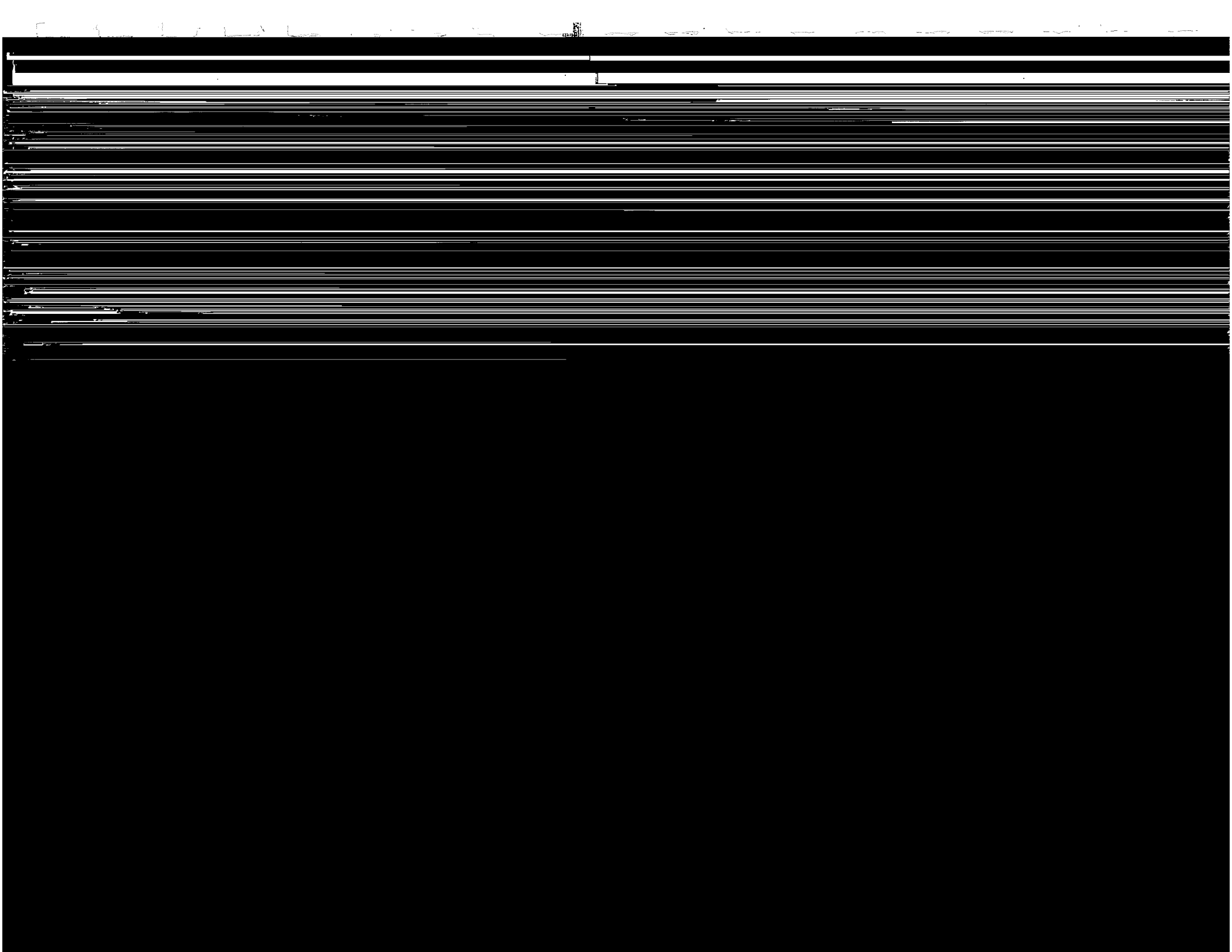


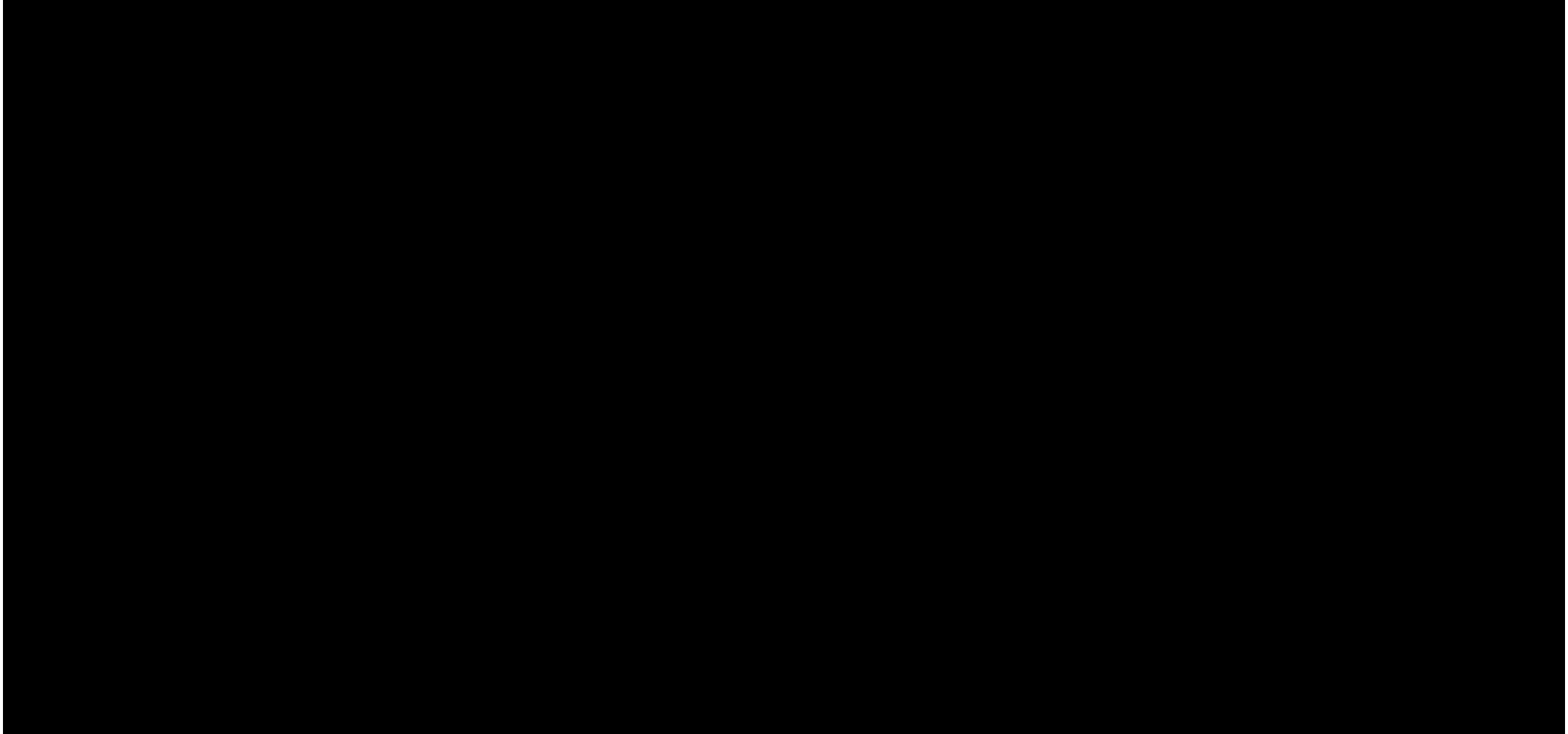


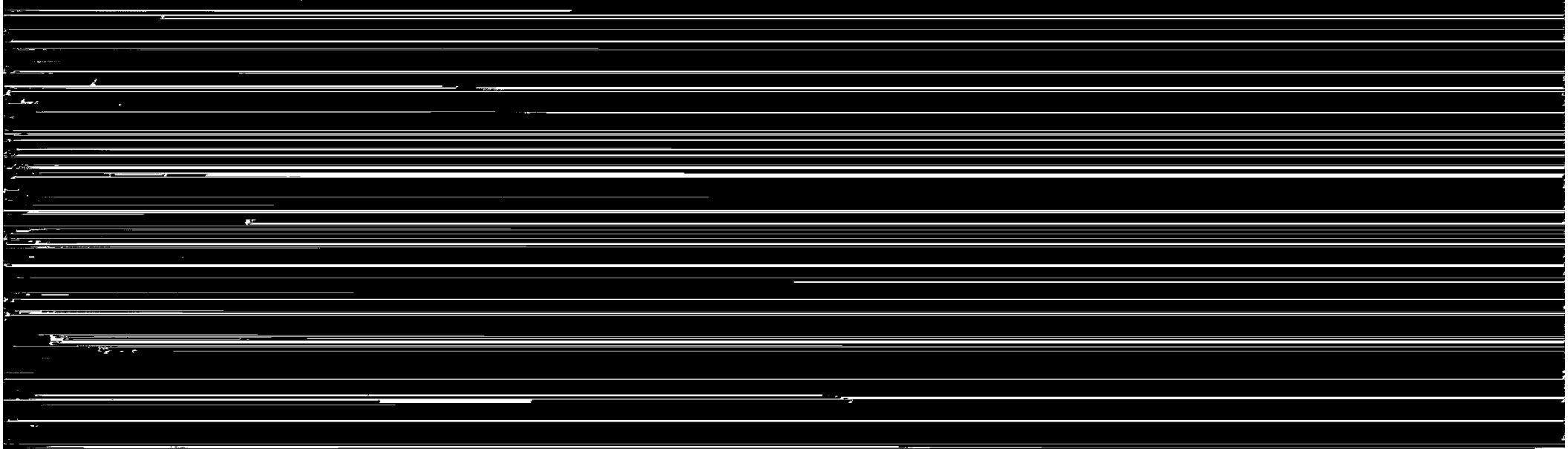


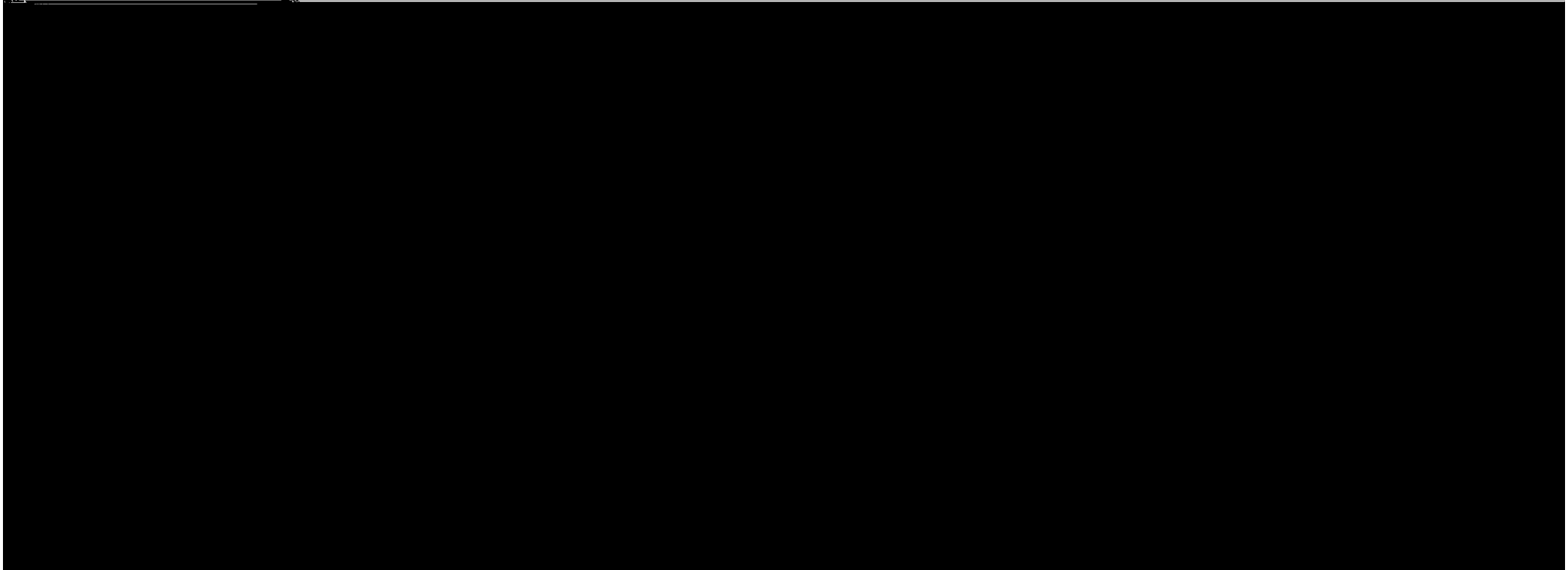










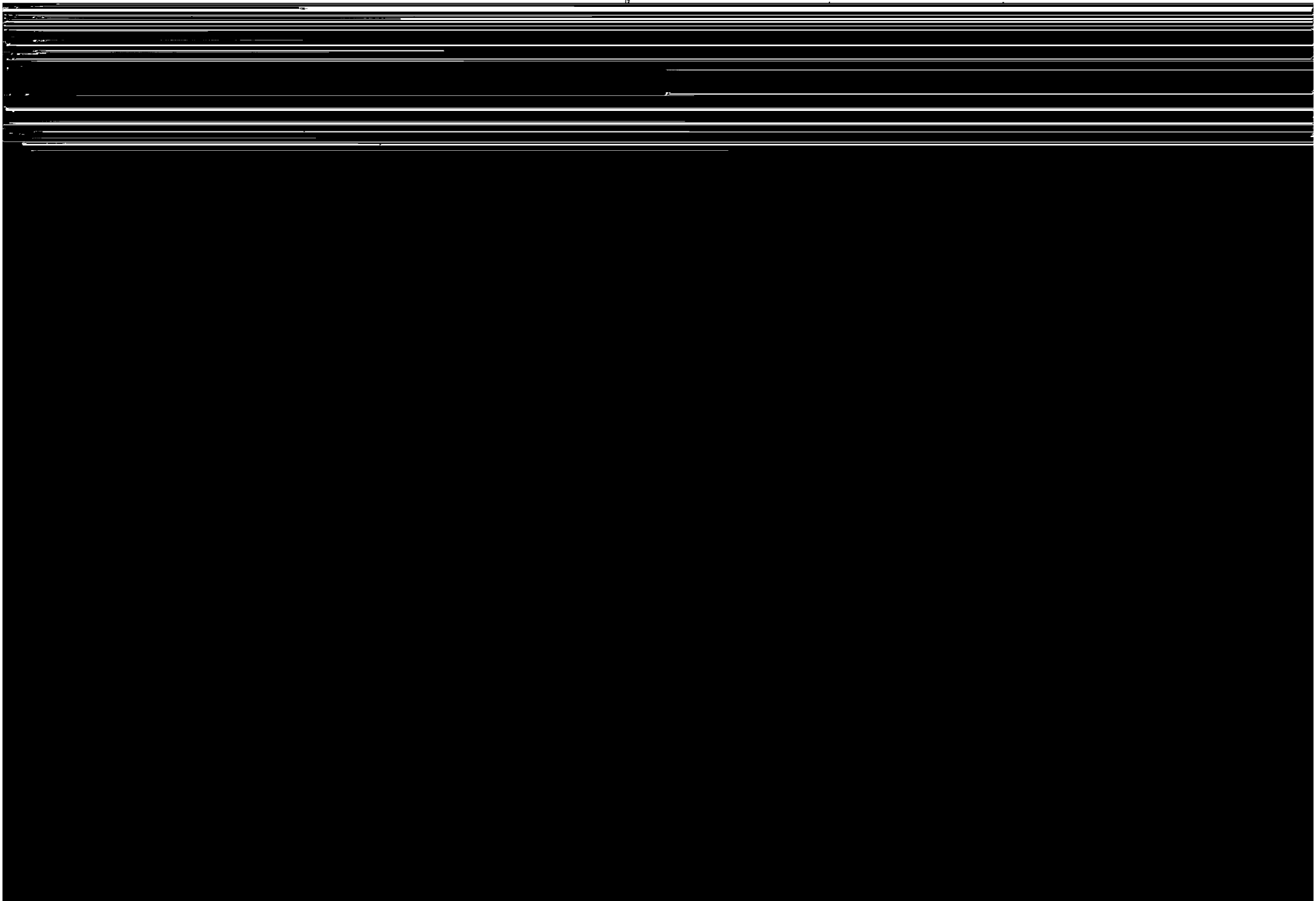




15.9. Let  $\bar{X}$  and  $S^2$  be the sample mean and sample variance, respectively, of a random sample of size  $n$  from a normal distribution with mean  $\mu$  and variance  $\sigma^2$ . If these statistics have been delivered to a

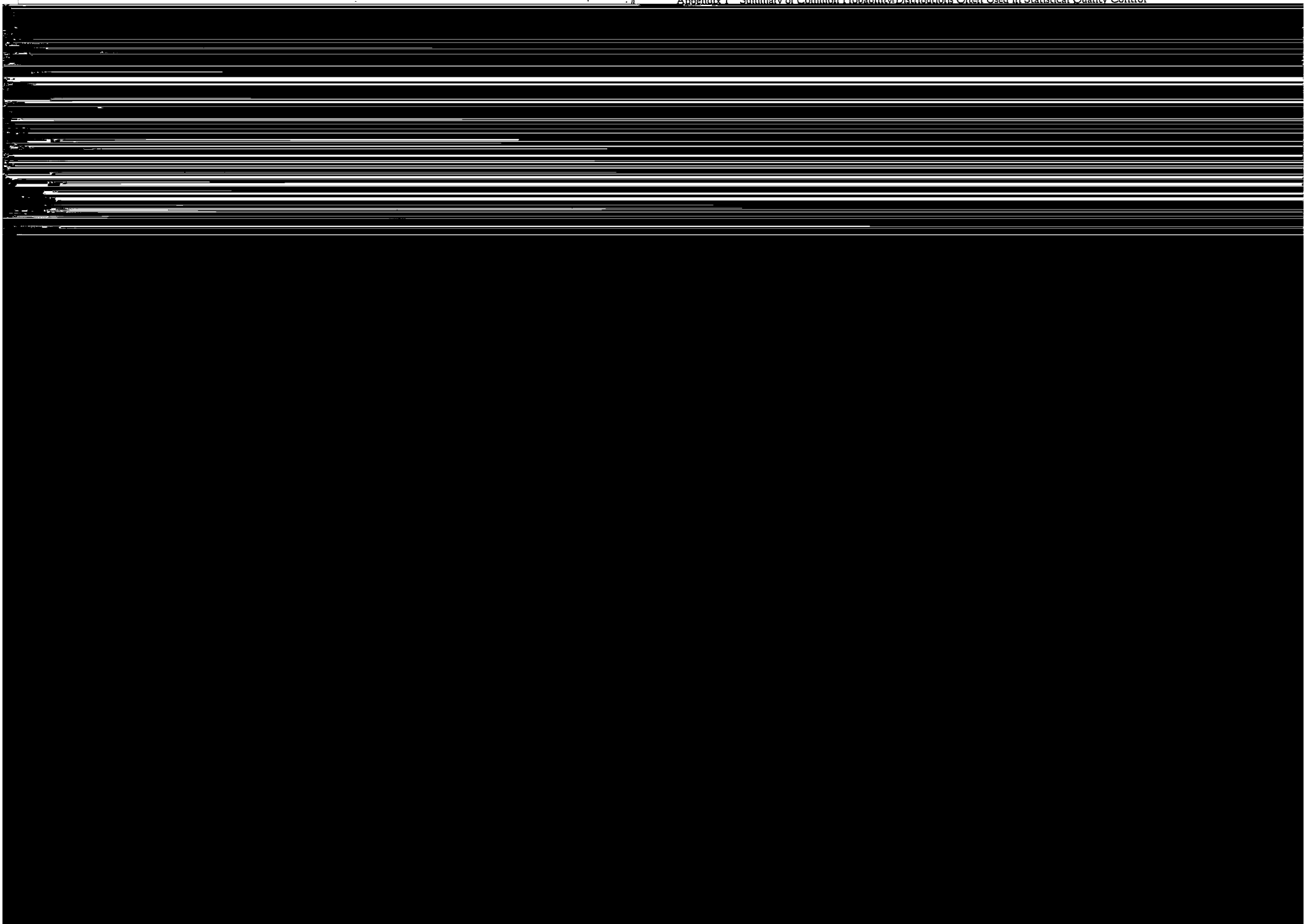
15.10. Consider a single sampling plan with  $n = 100$ ,  $c = 1$ , and  $AQL = 0.05$ . 15.11. A chain sampling plan is used for the

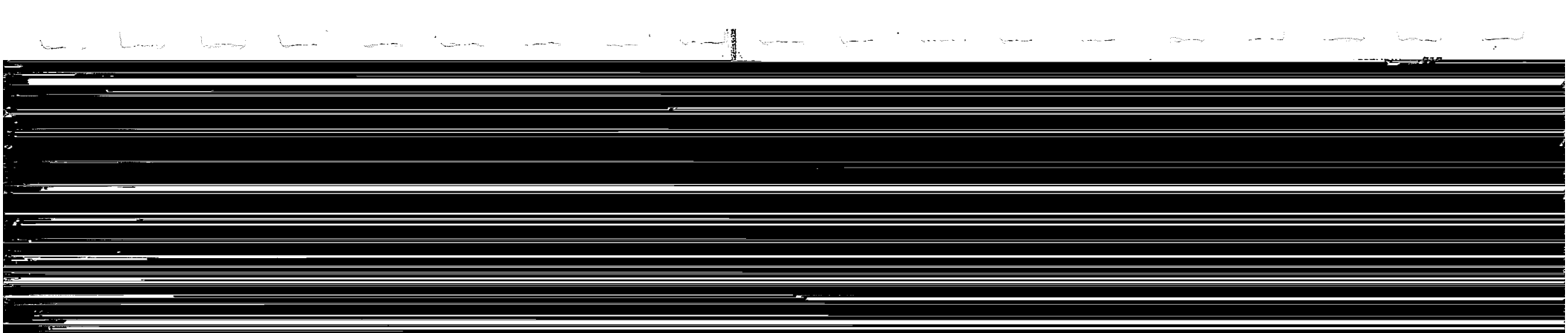
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Appendix I Summary of Common Probability Distributions Often Used in Statistical Quality Control



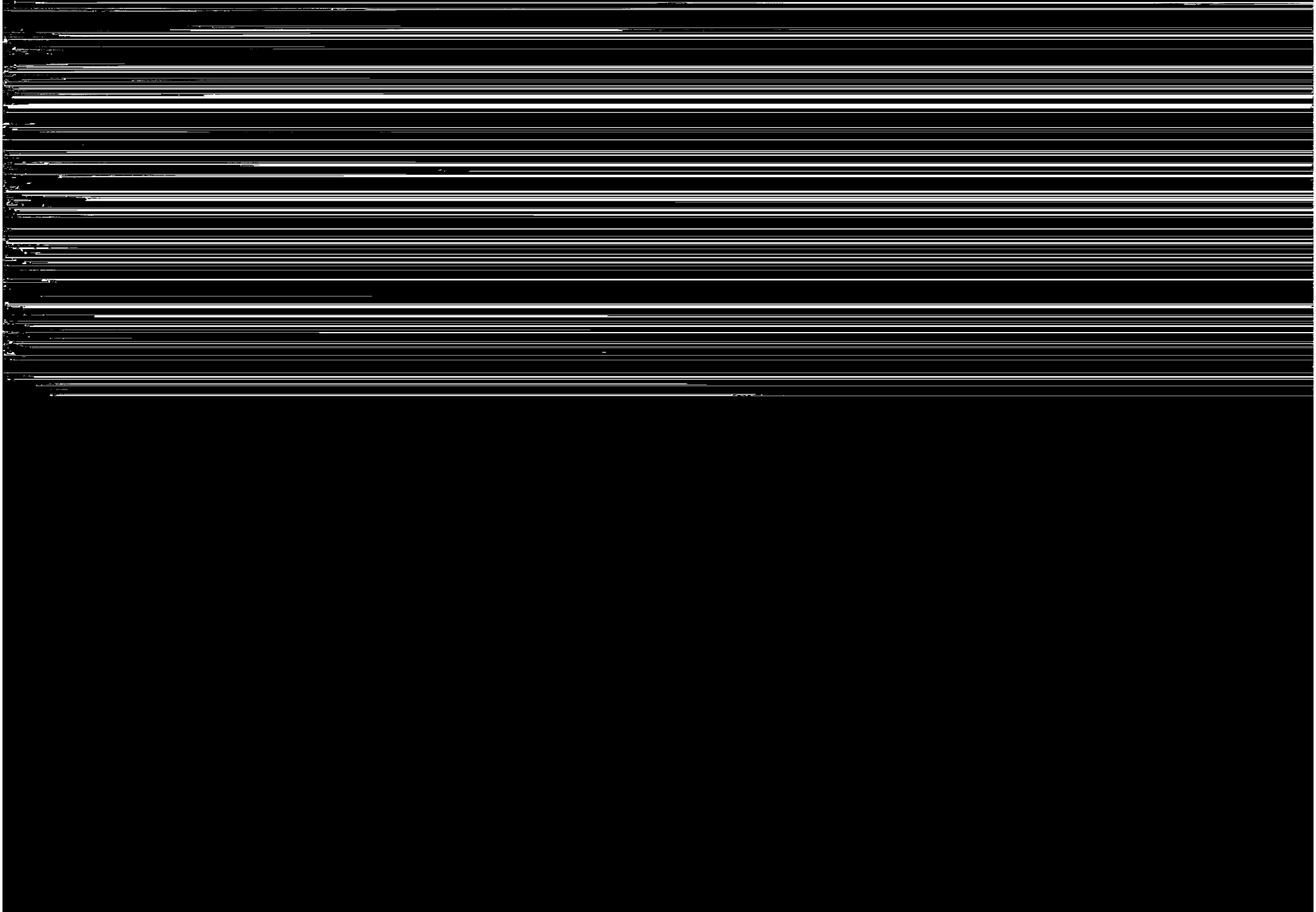


Appendix IV Percentage Points of the  $t$  Distribution<sup>a</sup>

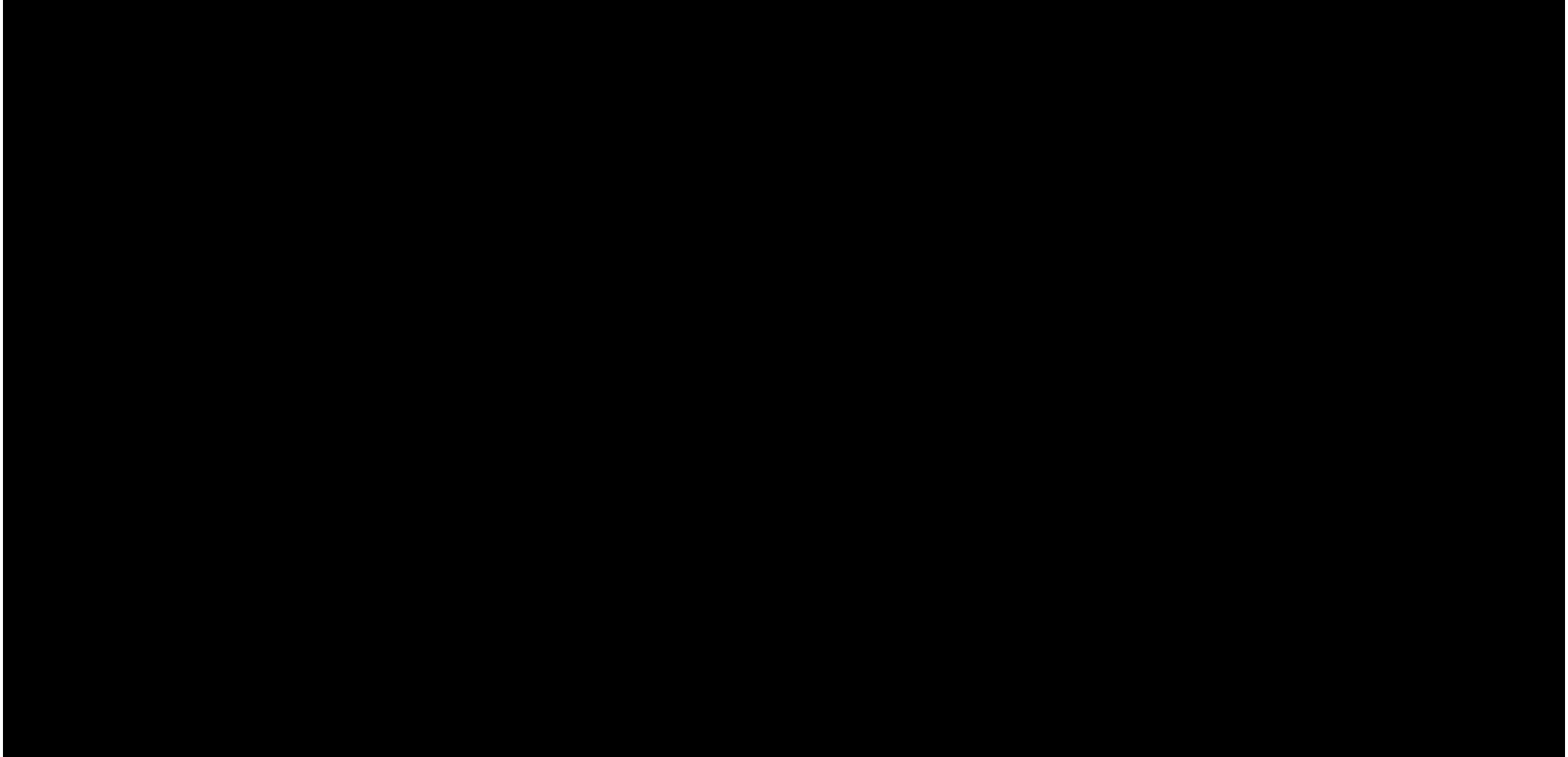
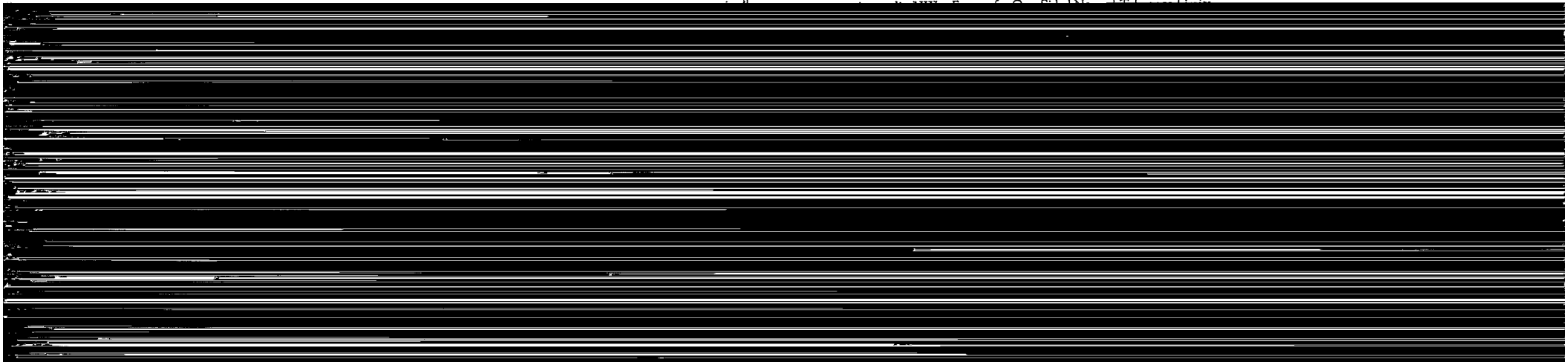
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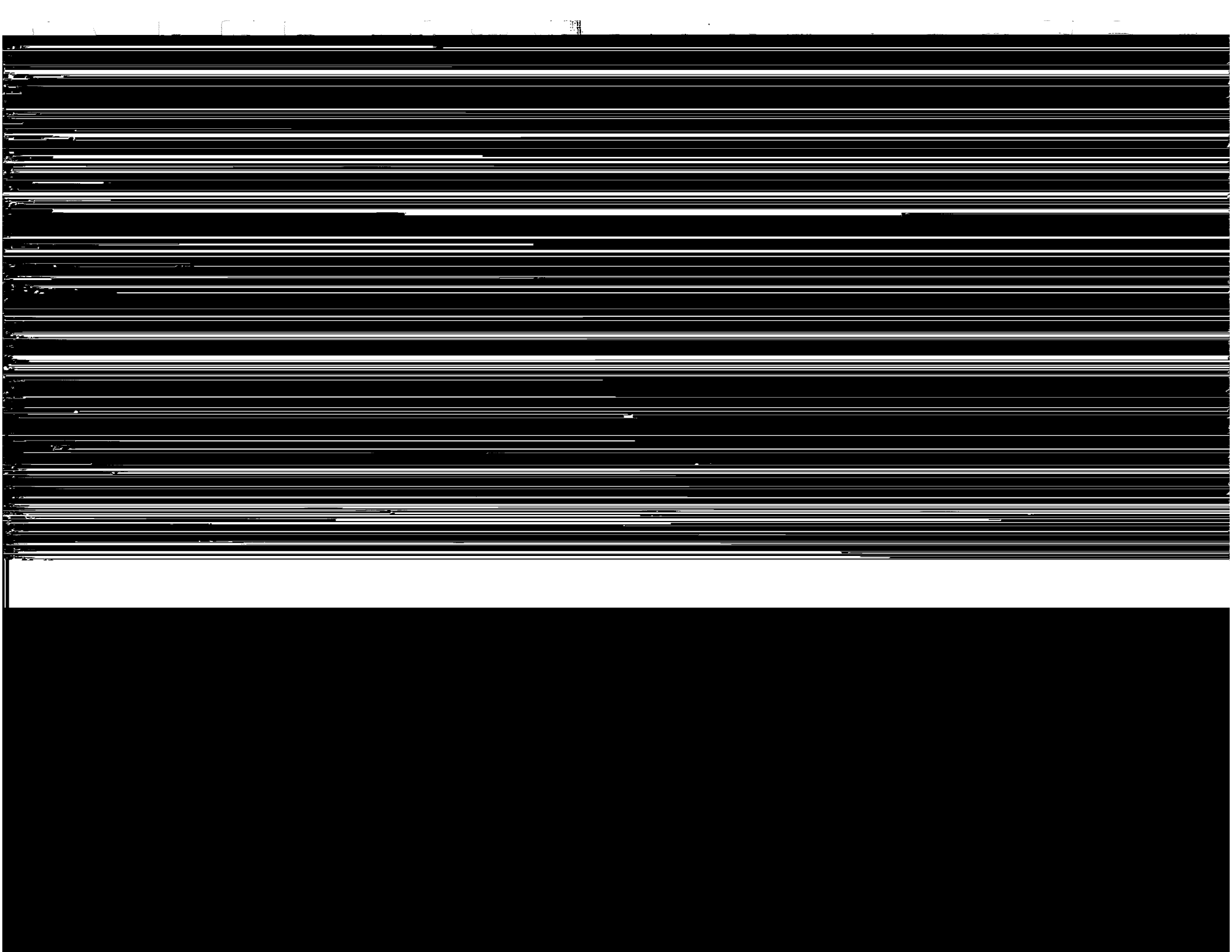
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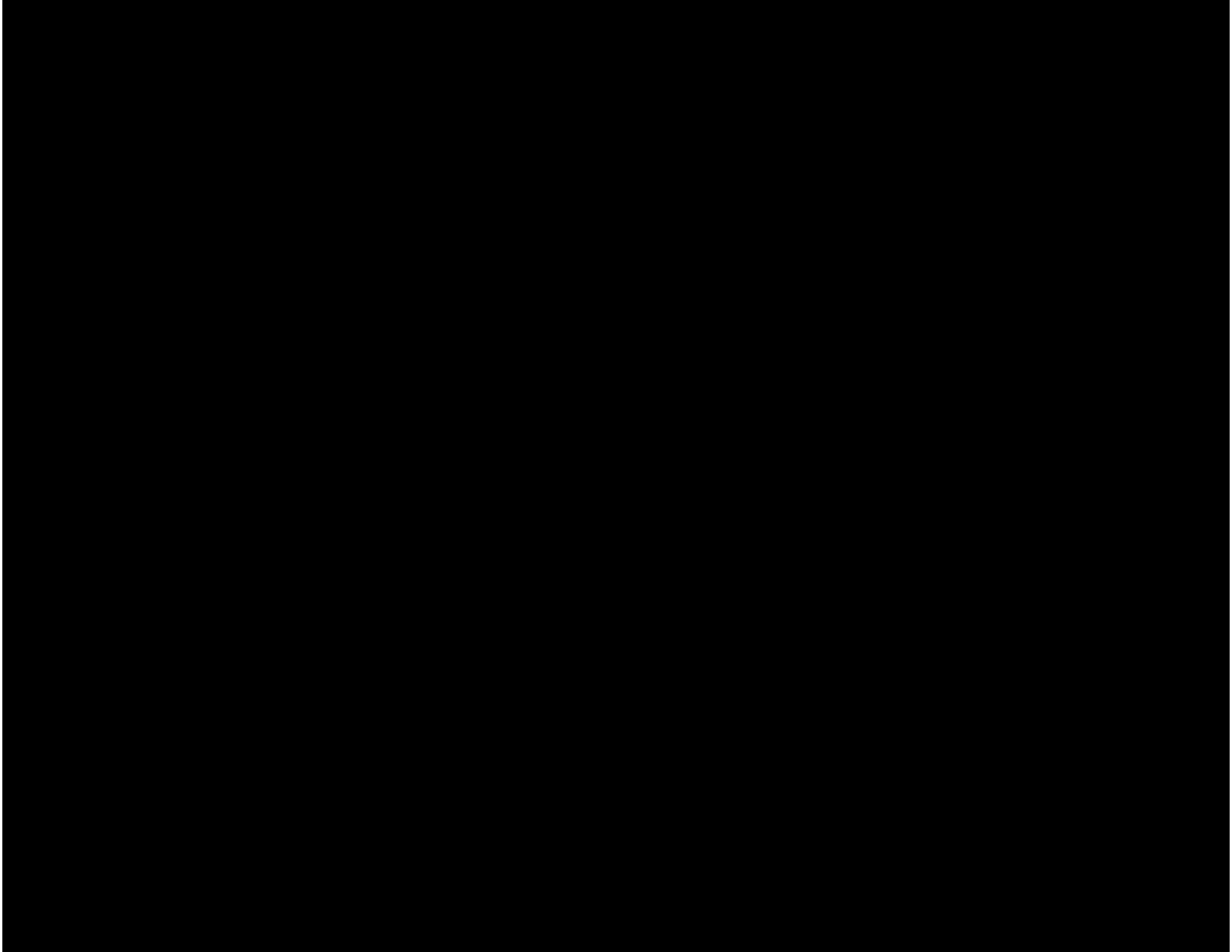


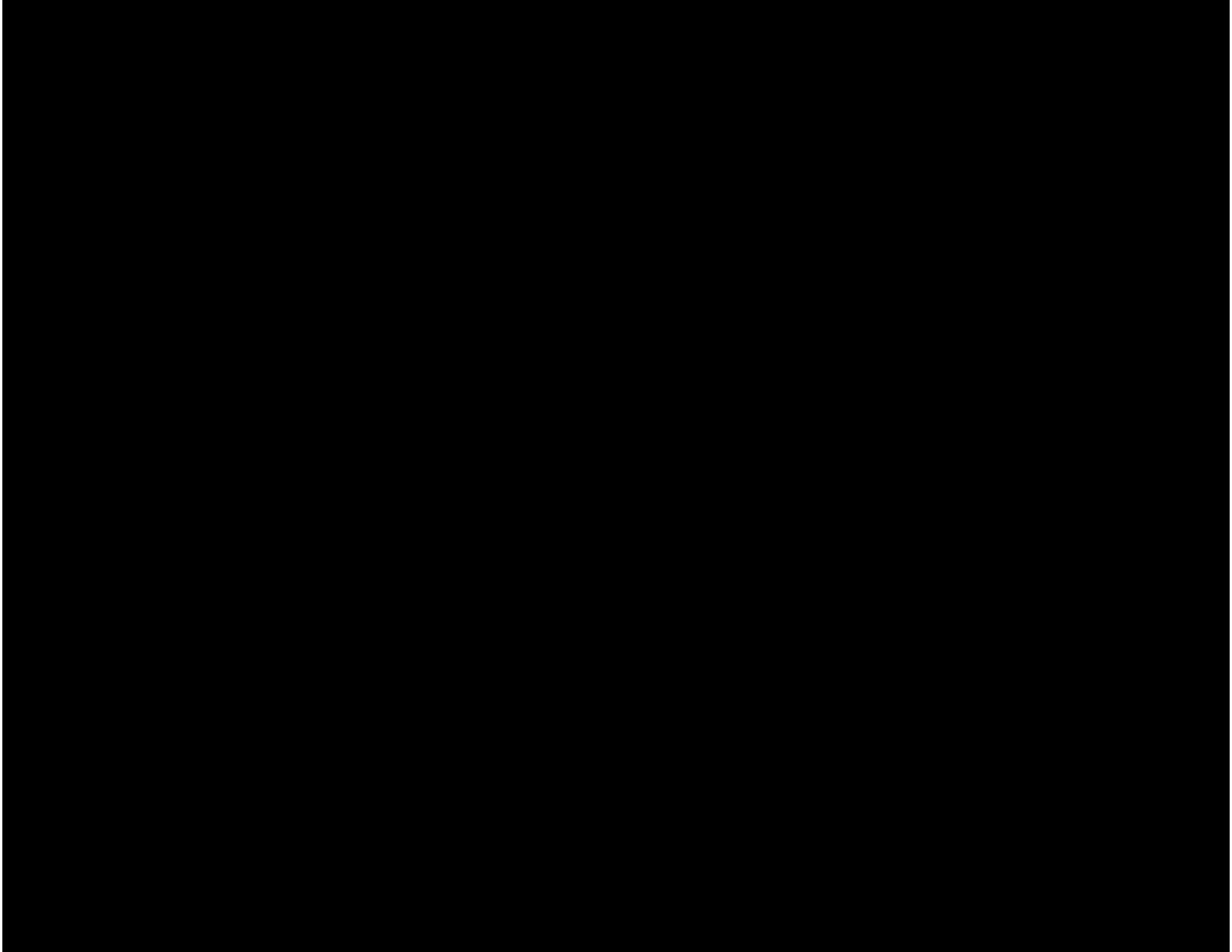






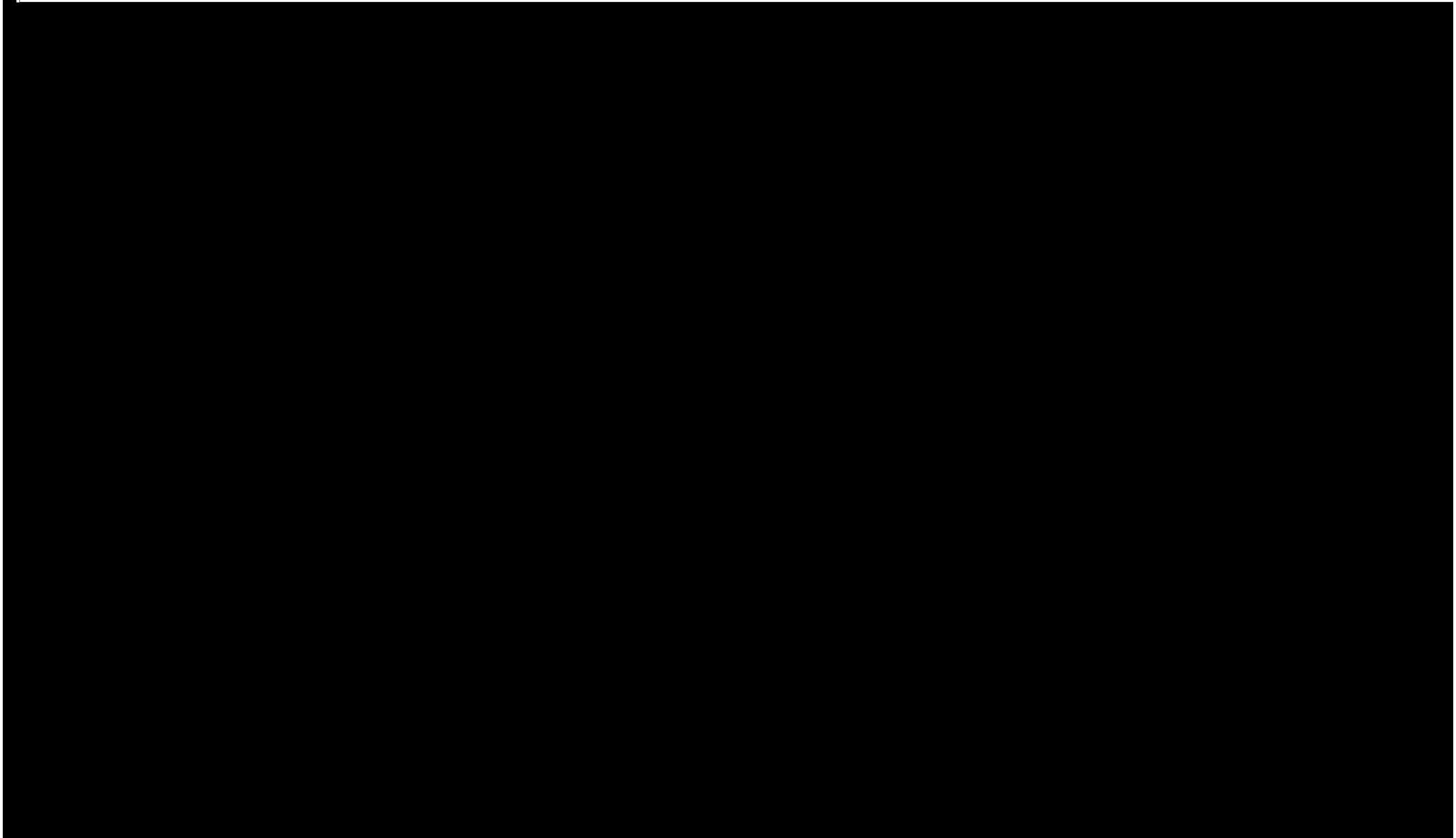
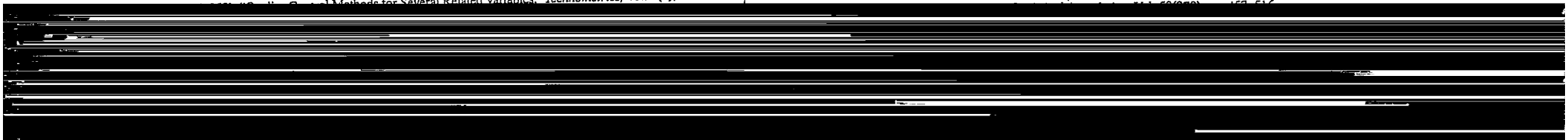


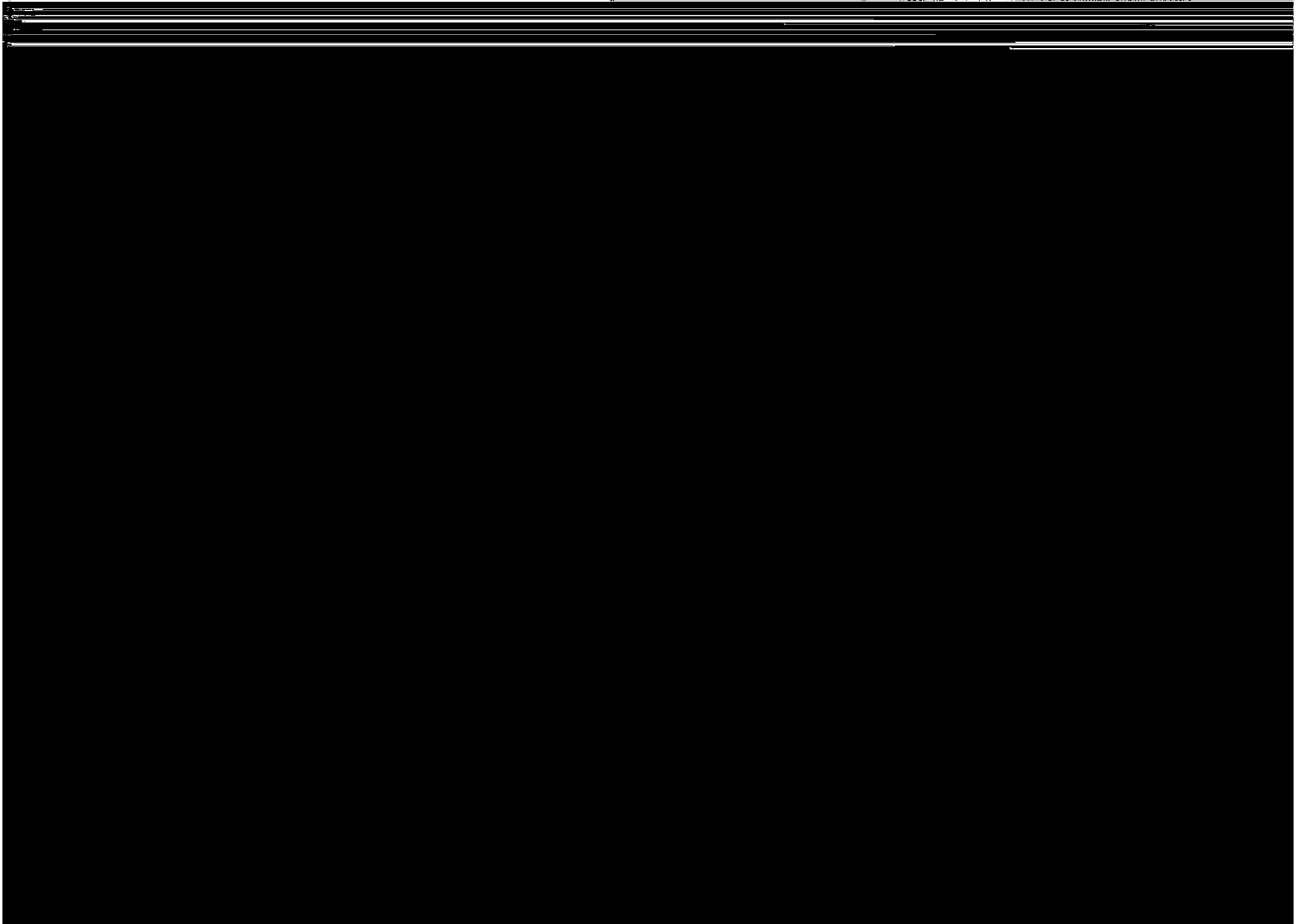




... "General Methods for Several Related Variables." *Technometrics*, Vol. 1(4),

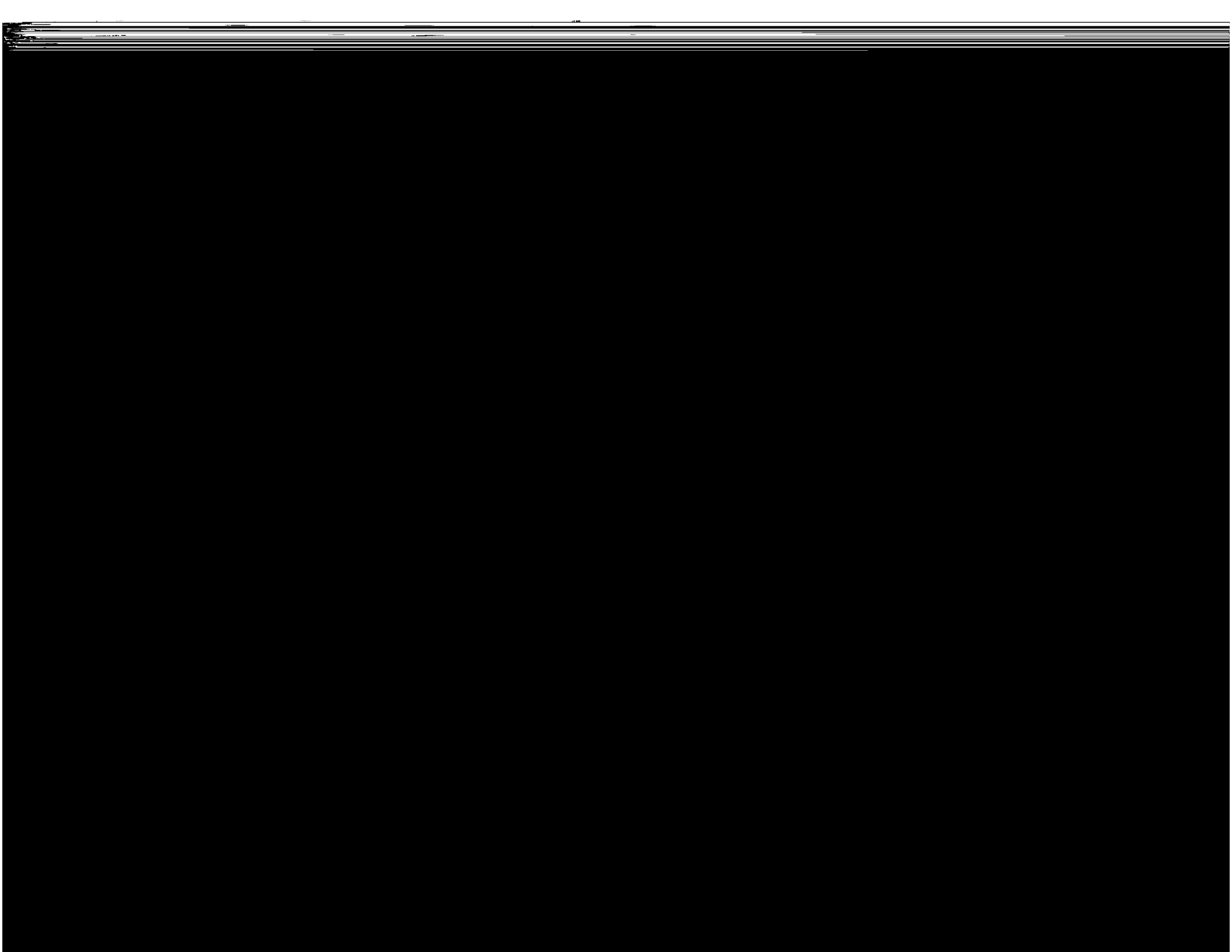
Lieberman, G. J., and G. J. Resnikoff (1955). "Sampling Plans for Inspection by Variables," *Journal of*



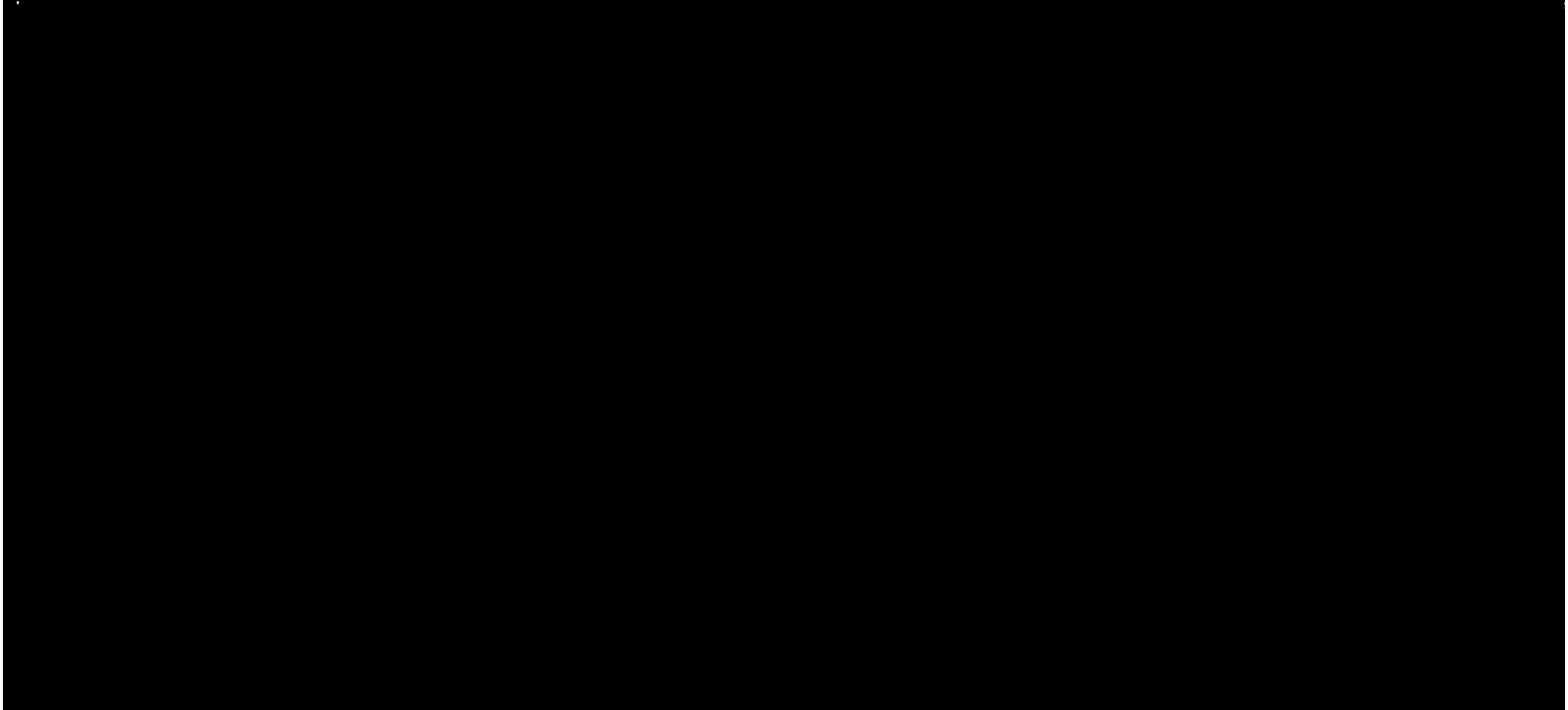


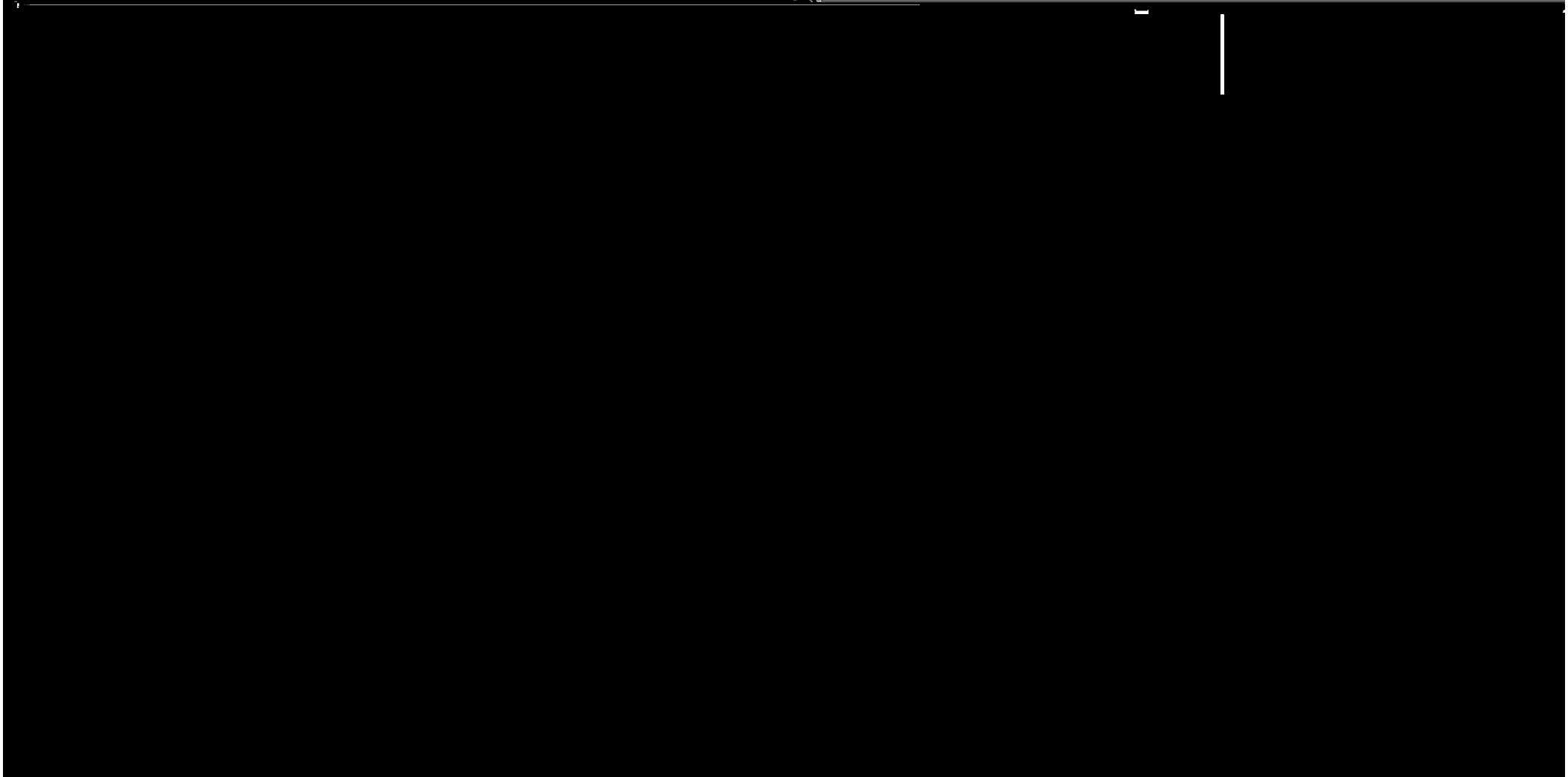
Schmidt, S. R., and J. R. Boudot (1989). "A Monte Carlo Simulation Study Comparing Effectiveness of



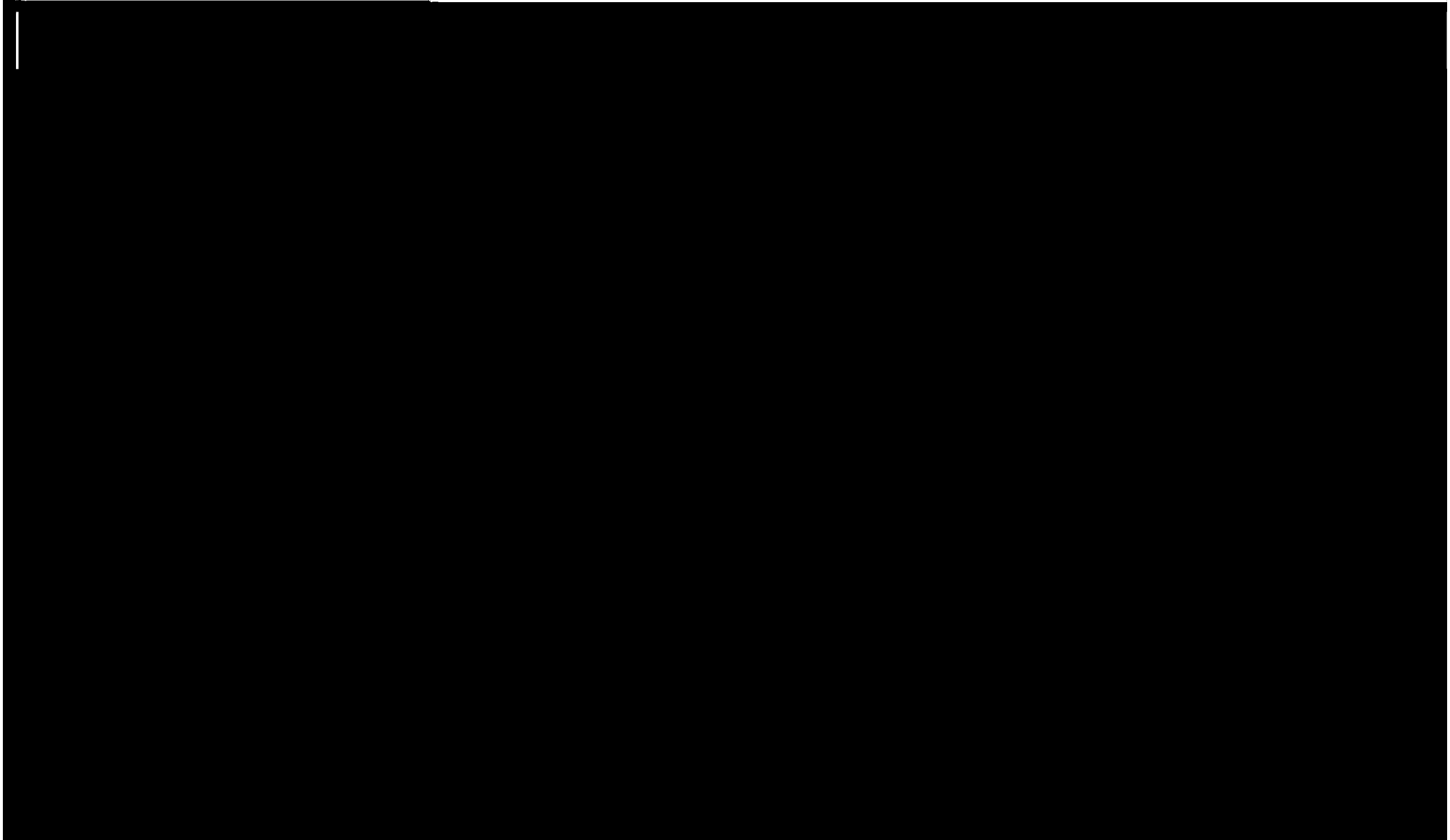
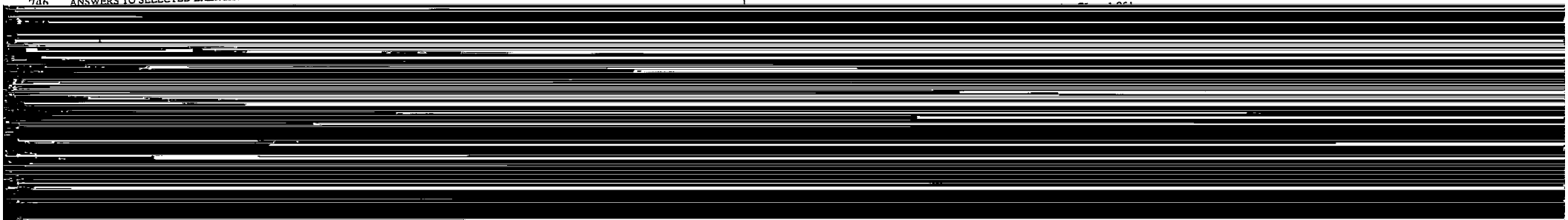


Answers to Selected Exercises











Control limits for  $y_1$  model MR chart: CL = 0.791, UCL = 2.586, LCL = 0

Control limits for  $y_2$  model MR chart: CL = 0.791, UCL = 2.586, LCL = 0



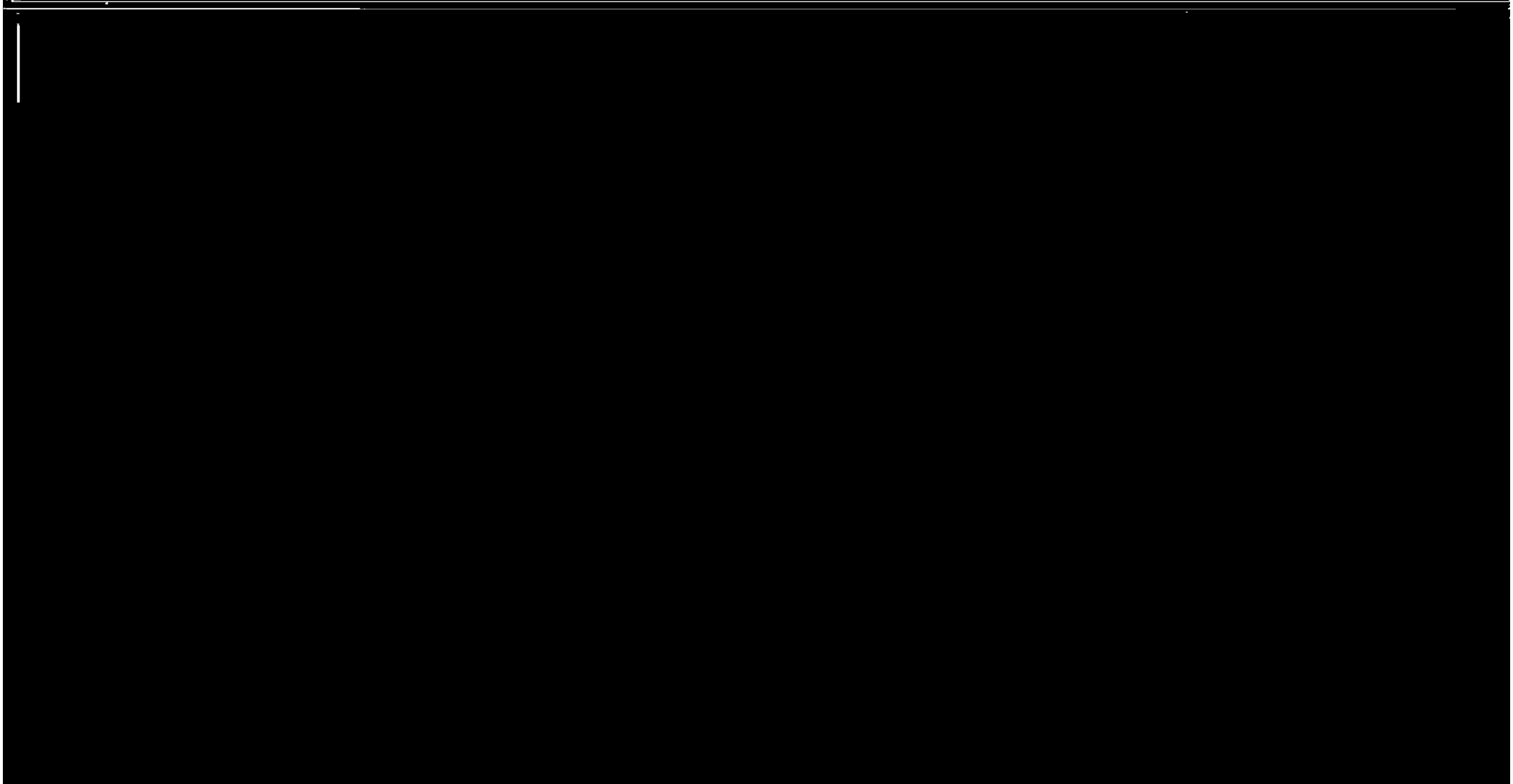
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X

Labert, see individuals control

