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ESDU Ejectors and Jet Pumps

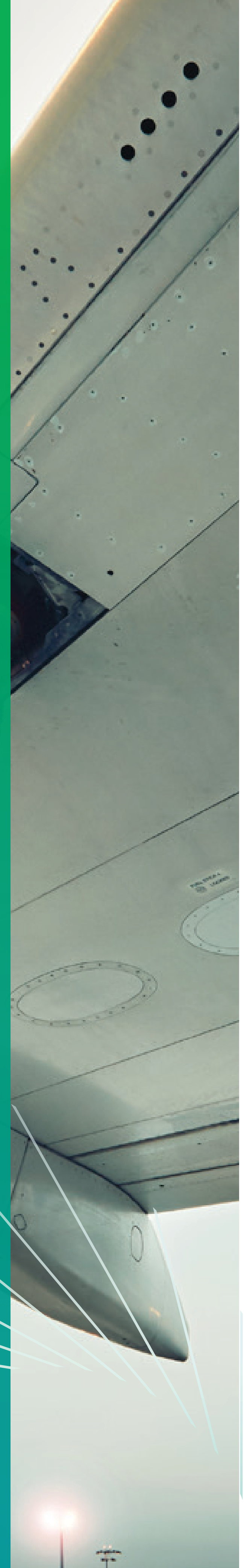
Ejectors and jet pumps are used in a wide range of engineering fields

ESDU Ejectors and Jet Pumps Overview

This brochure provides brief information on each Data Item in the group that treats the different combinations of working fluids (which can be gases, liquids or solids in suspension).

Analytical and semi-empirical methods and software are provided for plant engineers, design engineers and consultants in a wide range of industries (including petrochemical, process, power generation, nuclear, water supply and treatment, aircraft engine) for the design and performance evaluation of ejectors and jet pumps.

The performance prediction method calculates the flow conditions throughout the ejector given the dimensions, loss factors and entry flow conditions from appropriate performance characteristic curves.



Ejectors and Jet Pumps Introduction

The ESDU methods are based on the one-dimensional flow equations and include empirical coefficients that allow for losses in the different components. The working primary-secondary fluids may be non-reacting gases, liquids or steam in the following combinations:

- Gas-gas (ESDU 92042)
- Steam-gas (ESDU 94046 and ESDU 86030)
- Steam-liquid (ESDU 86030)
- Liquid-liquid (see ESDU 93022 and ESDU 85032)

Guidance is provided in each Data Item on the principles of operation, typical applications, various mechanical aspects, and use of annular- or multi-nozzle arrangements, and on the avoidance of cavitation.

The design methods provide an optimum design for a required duty. The performance evaluation method predicts performance of an existing ejector so that the effect of minor changes can be investigated.

Two design methods are provided:

- A 'quick' method based on experimental data for single-nozzle designs which requires a minimum of input data.
- A detailed design method which enables a more detailed assessment of the effects of internal losses and can be applied to multi-nozzle or annular-nozzle designs.

Each Data Item in the group treats the different combinations of working fluids (which can be gases, liquids or solids in suspension); their applicability is outlined below.

Fluid		Fluid Temperature	Mixing Chamber		Design Methods Application and Performance Prediction	Software / Active graphs
Primary Flow	Secondary Flow		Constant Area	Conical		
Gas	Gas	Any	✓	✓	92042	ESDUpac A9242 and Interactive graphs
Steam	Gas	Any (Saturated gas, saturated steam)	✓	✓	94046 and 86030	ESDUpac A9446
Steam	Liquid	Any (saturated steam)	✓	✓	86030	ESDUpac A9322 Interactive Graphs
Liquid	Liquid	N/A	✓	✓	93022 and 85032	93022 and 85032

The terms “ejector” and “jet pump” are synonymous, and the term “injector” is also commonly used. Guidance on the applications of ejectors (as pressure boosters, compressors, vacuum pumps or in ventilation and air conditioning, for example) and on the principles of operation is given in the Data Items within the group.

ESDU 92042

Ejectors and jet pumps: computer program for design and performance for compressible gas flow.

INTRODUCTION

ESDU 92042 is one of a group of ESDU Data Items concerned with the design and performance of ejectors and jet pumps. Such devices are characterised by the use of the kinetic energy of a fluid stream (the primary flow) to impart momentum to a second fluid stream (the secondary flow) by direct mixing.

ESDU 94046

Computer program for design and performance for steam/gas flow.

ESDU 94046 provides details of a computer program, ESDUpac A9446, for use in the design and performance evaluation of ejectors and jet pumps in which the working fluids are gases. A user-friendly version, referred to as VIEWpac 9446A, is also available, and is described in Section 4.

ESDUpac A9446 provides the following design and performance prediction procedures.

(i) Quick Design Procedure. Given a selection of entry and required exit pressures, temperatures, mass flow rates and dimensions, the program will calculate primary nozzle and exit dimensions, using empirical data for steam-air ejectors. Note that the scope of the Quick Design Method is restricted to ejectors with constant area mixing and air as the secondary fluid.

(ii) Detailed Design Procedure. Given a selection of entry and required exit pressures, temperatures, mass flow rates, dimensions and loss factors as well as four user defined constraints on the flow conditions, the program will calculate primary nozzle and exit dimensions and flow conditions throughout the ejector using the procedure outlined in Section A1 of Appendix A.

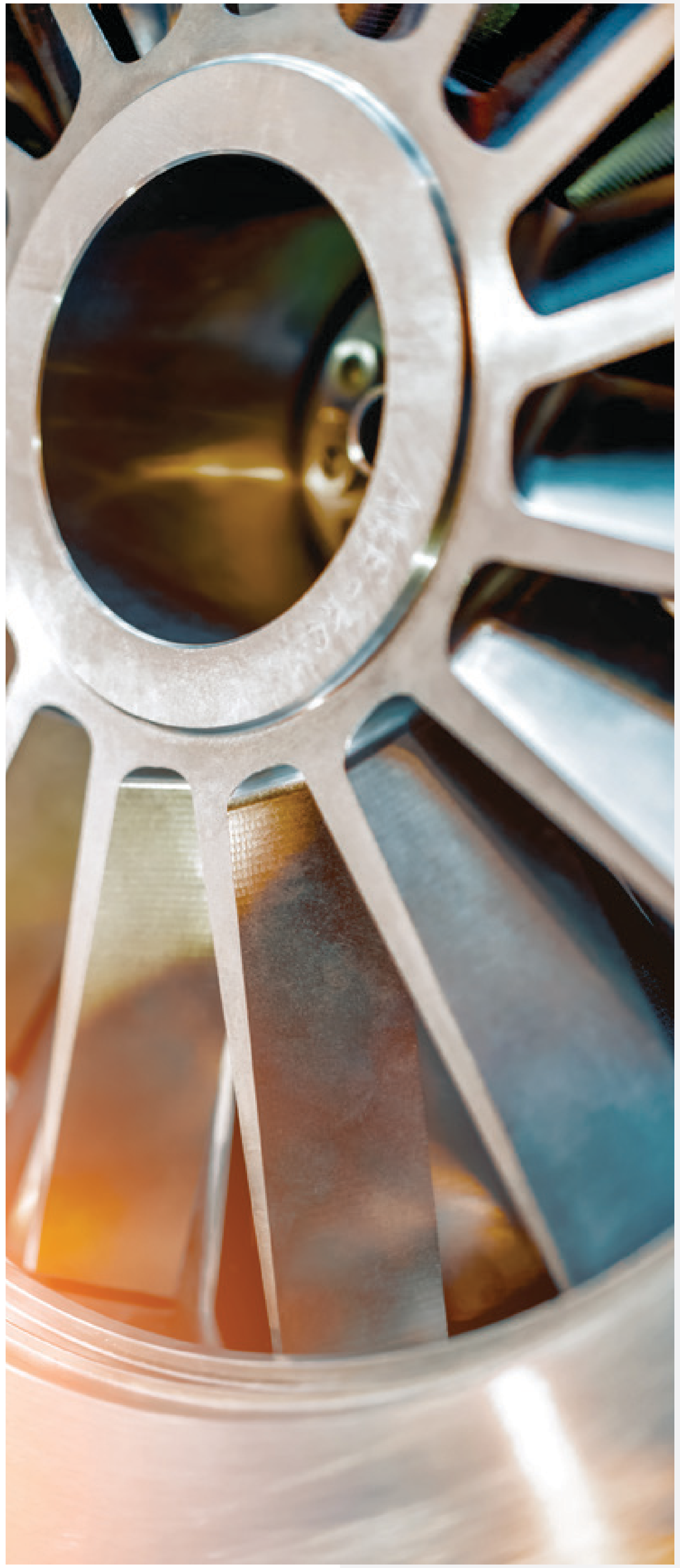
(i) Performance Prediction Calculation. Given the ejector dimensions, loss factors and a range of flow conditions at the entry, the program will calculate the outlet conditions and the flow conditions throughout the ejector, using the procedure outlined in Section A13 of Appendix A.

Section 5 describes the required input data. Section 6 provides notes on the design and operation of steam/gas ejectors. A number of examples that illustrate the use of the program are presented in Section 7. The full analysis for the computer program appears in Appendix A.

In many ejectors, the secondary inlet conditions are set by existing upstream pipework. In the design procedure, the program optimises for the shortest mixing duct length for complete mixing of the primary and secondary fluids and for the highest efficiency. The program allows a design requirement for a particular pressure and/or mass flow characteristic at the exit of the ejector to be met.

The ejector design procedures determine performance at the primary nozzle 'on-design' point. There are a number of situations in which this approach will be inadequate. The ejector may be required to operate over a range of primary pressures or secondary Mach numbers, in which case estimates of 'off-design' performance must be sought. Performance prediction is also necessary if an existing plant item, with all physical dimensions known, needs to be assessed for a particular application.

The performance prediction procedure calculates the flow conditions in an ejector of known physical dimensions. The calculation procedure presented in Appendix A is applicable to non-reacting gases that can be modelled as ideal and to ejectors with mixing ducts of circular (either cylindrical or conical) section. The methods are based on the equations of continuity and of momentum and energy conservation.



ESDU 86030

Design for steam driven flow.

This Item is one of a series of ESDU Data Items concerned with the design and performance of ejectors and jet pumps. Such devices are characterised by the use of the kinetic energy of one fluid stream (the primary, motive or driving flow) to drive a second fluid stream (the secondary, induced or driven flow) by direct mixing. The design parameters, requirements and methods vary considerably depending on whether the working fluids are gases, liquids, vapours or mixtures of these components. Each type is therefore considered in a separate Data Item. Derivation 25 considers ejectors in which the primary and secondary fluids are both air and Derivation 26 consider ejectors in which they are both liquids. This Item considers steam driven ejectors.

The terms “ejector” and “jet pump” are alternative names for the same device and the term “injector” is also used. Although common usage, it is not strictly correct to assume that the terms “ejector” and “injector” are used when the working fluids are gases and the term “jet pump” when they are liquids.

(ii) Purpose and Scope of this Item

This Data Item provides information for the design and performance evaluation of ejectors, jet pumps or injectors in which the primary fluid is steam and the secondary fluid is a liquid or a gas. The terms steam/liquid and steam/gas ejector are employed according to whether the secondary fluid is a liquid or gas. Techniques for the optimum design of a steam driven ejector are presented. The method for steam/liquid ejectors is based on a theoretical analysis that for steam/gas ejectors is based on experimental data obtained on a wide range of steam driven ejectors. A performance prediction method for steam/liquid ejectors is also presented, based on the same theoretical analysis as is used in the design method. A performance prediction method for steam/gas ejectors is discussed briefly.

(iii) Layout of this Item

Section 3 of this Item discusses some applications of steam driven ejectors.

Section 4 describes the principles of ejector operation and defines the different components. These may vary considerably with application and Section 4 considers some of the configurations possible.

Section 5 describes design methods that can be used to determine the on-design operating conditions and optimum dimensions of a steam driven ejector. Some considerations regarding mechanical design are given in Section 5.5.

Section 6 describes a method by which the performance of a steam/liquid ejector may be evaluated. Performance prediction for steam/gas ejectors is also discussed.

Section 7 describes designs such as multi-stage, annular nozzle and multi-nozzle ejectors and considers their advantages in certain situations.

Section 8 discusses some of the problems that may arise when an ejector is in operation.

Section 9 presents worked examples that illustrate the application of the Design and Performance Prediction Methods.

Section 10 lists sources of information used in the preparation of this Item together with further information.

Appendix A contains a glossary of terms used in describing ejector components, design parameters and performance.

Appendix B presents detailed theoretical analyses of the fluid flow through ejectors. These analyses are based on one-dimensional flow representations of mass, momentum and energy conservation.

ESDU 93022

Ejectors and jet pumps: computer program for design and performance for liquid flow.

PURPOSE AND SCOPE OF ESDUPAC A9322

ESDU 93022 provides details of a

computer program, ESDUpac A9322, for use in the design of ejectors and jet pumps in which both the working fluids are liquids. The program extends the scope of the calculation procedure of ESDU 85032 to include non-parallel-sided mixing ducts, and allows the user to model an ejector with pumps or constant pressure sources upstream of either the primary or secondary inlet. The program also extends the methods of ESDU 85032 to cases for which a volume change occurs during the mixing of primary and secondary flows.

ESDUpac A9322 provides the following design and performance prediction procedures.

(i) Design Procedure. Given a selection of entry and required exit pressures and flow rates, along with estimates of loss coefficients, the program calculates primary nozzle, secondary inlet and ejector exit dimensions, using the procedure outlined in Section A.3 of Appendix A.

(ii) Performance Prediction Procedure. Given the ejector dimensions, loss factors and a range of flow conditions at the entry, the program calculates the outlet conditions and the flow conditions throughout the ejector, using the procedure outlined in Section A.4 of Appendix A.

For both calculation procedures, the inlet conditions may be given either in terms of a pump characteristic (for centrifugal or mixed flow pumps) and flow rate or a pressure and flow rate.

An overview on the operational procedure for running the ESDUpacA9322 program is provided in Section 4. Section 5 describes the required input data. The program output is described in Section 6. A number of examples which illustrate the use of the program are presented in Section 7. The full analysis of the theoretical model used in the computer program is presented in Appendix A.

ESDU 85032

Design and performance for incompressible liquid flow

This Item is concerned with the design and performance of ejectors and jet pumps. Such devices are characterised by the use of the kinetic energy of one fluid stream (the primary flow) to drive a second fluid stream (the secondary flow) by direct mixing. The fluids may be gases or liquids and the secondary stream is not necessarily the same fluid as the primary.

For some applications the secondary steam and the primary steam also, may contain solid particles. The design parameters, requirements and methods vary considerably, depending on whether the working fluids are gases, liquids, solids-in-fluids or combinations of these, and each type is therefore considered in a separate Data Item. The terms “ejector” and “jet pump” are alternative names for the same device and the term “injector” is also used.

(i) Purpose and Scope of this Item

This Data Item provides information for design and performance evaluation of ejectors and jet pumps in which both working fluids are liquids. A technique for the optimum design of a jet pump or ejector is presented; the method is based on the equations of continuity and momentum conservation and includes empirical coefficients that allow for losses in the different components. The performance of an ejector or jet pump of given dimensions may be determined from an appropriate performance characteristic curve, which fully describes the operation of the device. A comprehensive series of such curves is presented, based on a large number of empirical and analytical data.

(ii) Layout of this Item

Section 3 of this Item discusses briefly some applications of ejectors and jet pumps. Section 4 describes the principles of ejector operation and defines the different components. These may vary considerably with application and Section 4 considers some of the possible configurations.

Section 5 describes a design method which will determine the on-design operating conditions and optimum dimensions for an ejector or jet pump when the primary and secondary working fluids are both liquids. The method is suitable for primary and secondary fluids of equal or differing densities. Mechanical design aspects are considered in Section 5.5.

Section 6 describes a method by which the performance of an existing ejector or jet pump may be evaluated. Performance charts are presented for the case when the working fluids are of equal density together with corrections allowing for differing densities.

Section 7 describes, briefly, more complicated ejector designs, such as multi-nozzle or annular ejectors or multi-stage configurations, and considers their advantages in certain situations.

Section 8 discusses the problem of cavitation and includes a definition for cavitation index. The index characterises the conditions under which cavitation occurs and may be used to predict the onset of this phenomenon. Methods for improving cavitation performance are also described.

Section 9 presents worked examples showing the application of both the design and the performance prediction methods.

Section 10 lists all the sources of information used in compiling this Data Item and includes further sources of reference which may be helpful to the engineer.

Appendix A contains a glossary of terms used in describing jet pump components, design parameters and performance.

Appendix B presents a detailed theoretical analysis of the flow through an ejector, based on one-dimensional flow representations of mass and momentum conservation, and includes the development of equations used to describe efficiency and the onset of cavitation.

Appendix C presents flow charts outlining the design and performance prediction procedures.