FOREWORD

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Norman H. Jackson

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interests in the specialized technical directions covered.
Stimulate the help of teachers and students who seek readily access
areas of industrial management and, usually, they are of
students and engineers concerned with nuclear energy.

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and technology development and research. The emphasis is on
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this book is published as one of a continuing series in the
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community and related fields authoritative information in many
fields. Authors and titles are selected to bring to print the
nucler energy.

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Foreword
The placement of the plasma must transport sufficient plasma energy to sustain the unlimited plasma in an efficient manner.

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The attainment of the plasma must transport sufficient plasma energy to sustain the unlimited plasma in an efficient manner.

To explain the point, the reactor chamber region, the plasma energy would probably be extracted via the exhaust from the fusion core.

Figure 6.1 shows a normal fusion core design. For high relevance, some source where the nuclear power reactor and reactor also nuclear reactor is shown over a fusion core system. However, power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system. Because of their small size, these reactor types have less yield than higher reaction systems. Therefore, these reactors cannot be used for fusion core systems. Power density, low-yield systems generally feature lower yield energy than a fusion core system.
6.3 Radiation Extinction

The position of the intersection of two of the lines is the intersection point of two of the lines. If the point is not at the intersection of two of the lines, then the intersection point is considered to be at the intersection of two of the lines.

In the upper right, the intersection point is where the two lines intersect. From there to the right, the point is considered to be at the intersection of two of the lines.

**Figure 6.2** Requirements for shock wave and detonation in the intersection region of a fusion product.

**Figure 6.3** Fusion zone conversion (from external and internal).
6.1.4 Energy-Consuming Units (Source Term)

The preceding remarks assume that a self-sustaining fusion reactor is to be utilized; this is not required, however, if we assume that the reactor is to be utilized. This is not required, however, if we assume a self-sustaining fusion reactor to be utilized. The preceding remarks apply to a self-sustaining fusion reactor. The preceding remarks apply to a self-sustaining fusion reactor.

1000 MWD reactor power plant. The power plant is a self-sustaining fusion reactor. Although the preceding remarks apply to a self-sustaining fusion reactor, the preceding remarks apply to a self-sustaining fusion reactor.

In summary, the selection of the reactor, its containment, and its fusion reactor, the selection of the reactor, its containment, and its fusion reactor.

\[
I = \frac{1}{\omega} \sum_{\omega} \left| \mathbf{E} \times \mathbf{B} \right| \left[ \mathbf{E} \cdot \mathbf{B} \right] \left[ \mathbf{E} \cdot \mathbf{v} \right]
\]
...CONCLUSION...
The connection region must also shield the interaction zone for practicality. The conduction processes extend in an open region, but the area is too restricted to produce an effect there. The conduction process takes place in a small region, but the size of this region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect. The connection region is too small to provide a significant effect.

TABLE 6.7

<table>
<thead>
<tr>
<th>Device</th>
<th>Input Energy</th>
<th>Plasma Power</th>
<th>Gas</th>
<th>Temperature (K)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torches</td>
<td>High-frequency RF wave</td>
<td>Fusion, possibly with sur.</td>
<td>Ar, N₂, Ar, or air</td>
<td>10⁷ to 10⁸</td>
<td>10¹⁶ to 10¹⁸</td>
</tr>
<tr>
<td>Torches</td>
<td>or electrical discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source of products:**
- Fusion, possibly with sur.
- Plasma power
- Gas
- Temperature (K)
- Density (kg/m³)
The high temperature involved favors the reactions, C and D.

\[ C + D = CD \]  \hspace{1cm} \text{(exothermic)}

However, in contrast with an exothermic reaction like the reverse of the reaction, the reaction tends to go to the right if the temperature is decreased.

Both the exothermic nature of the reaction and the reverse are possible, but some general observations can be made in the case of the reaction. The net reaction is complex, and some general observations about the temperature are possible, but the overall reaction is complex, and some general observations are possible.

The net reaction is complex, and some general observations are possible, but the overall reaction is complex, and some general observations are possible.

- In certain reactions, the net reaction is complex, and some general observations are possible, but the overall reaction is complex, and some general observations are possible.

The net reaction is complex, and some general observations are possible, but the overall reaction is complex, and some general observations are possible.

Only a few of the reactions have been described, and the rest are complex. The net reaction is complex, and some general observations are possible, but the overall reaction is complex, and some general observations are possible. The net reaction is complex, and some general observations are possible, but the overall reaction is complex, and some general observations are possible.

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**TABLE 6.8**

Some Chemical Reactions Carried Out In Plasma Jets and Arcs

<table>
<thead>
<tr>
<th>Product</th>
<th>Reaction</th>
<th>Overall</th>
<th>Synthesis Reactions</th>
<th>Decomposition Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen cyanide</td>
<td>2Al + 3H₂ → Al₂C₃ + 3H₂</td>
<td>Feed combustible C</td>
<td>Inject Al₂O₃ pellets into Ar plasma jet</td>
<td>Low yield</td>
</tr>
<tr>
<td>Ammonia</td>
<td>2H₂ + N₂ → 2NH₃</td>
<td>Nitrogen</td>
<td>Inject Al₂O₃ into Ar plasma jet and decompose in water</td>
<td>Up to 69 % yield</td>
</tr>
<tr>
<td>Diatomic nitrogen</td>
<td>N₂ + 3H₂ → 2NH₃</td>
<td>Nitrogen plasma jet</td>
<td>Inject Al₂O₃ into Ar plasma jet</td>
<td>40 % NH₃ yield</td>
</tr>
<tr>
<td>Acetylene</td>
<td>2C₂H₂ + 2H₂ → 2C₂H₄</td>
<td>Nitrogen plasma jet</td>
<td>Inject Al₂O₃ into Ar plasma jet</td>
<td>Over 85 % of C₂H₄ yield</td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>Al₂O₃ + 3H₂ → 2Al + 3H₂O</td>
<td>Nitrogen plasma jet</td>
<td>Inject Al₂O₃ into Ar plasma jet</td>
<td>0 % yield</td>
</tr>
</tbody>
</table>

**Chemical Conversion**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Approximate Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂ + 3H₂ → 2NH₃</td>
<td>67 % yield</td>
</tr>
<tr>
<td>Al₂O₃ + 3H₂ → 2Al + 3H₂O</td>
<td>40 % NH₃ yield</td>
</tr>
<tr>
<td>2C₂H₂ + 2H₂ → 2C₂H₄</td>
<td>Over 85 % of C₂H₄ yield</td>
</tr>
</tbody>
</table>

**Fusion Energy Conversion**

- N₂ + 3H₂ → 2NH₃
- Al₂O₃ + 3H₂ → 2Al + 3H₂O
- 2C₂H₂ + 2H₂ → 2C₂H₄

**Non-electrical Conversion**

- Electrochemical and have been achieved in a plasma arc.
- "Corrosive" reactions leading to corrosion
- "Corrosive" reactions causing damage to the reaction vessel.

**Diagram Description**

- The diagram illustrates the steps of plasma chemical processes and includes a flowchart for the reaction.
- The reactions shown are: N₂ + 3H₂ → 2NH₃, Al₂O₃ + 3H₂ → 2Al + 3H₂O, and 2C₂H₂ + 2H₂ → 2C₂H₄.
separation, the carrier gas provides a flowing low-temperature plasma analogous to electrically driven jet and arc plasmas. Its flow rate and the chemical injection rate are selected to provide the desired ionization of the chemicals.

The reaction zone in Fig. 6.12 provides conditions that promote the formation of the intermediate free radicals. The temperature is reduced at a rapid rate that favors recombination of the radicals to form the desired products in the quench zone.* Adequate quenching is a key step, and existing small-scale plasma-jet processes typically achieve quench rates of from \(10^5\) to \(10^6\) K/sec using one of three techniques:

1. The plasma is directed onto a cold surface, e.g., water-cooled tubes.
2. The plasma is entrained (“dumped”) into a cold, high-density inert gas.
3. The plasma is injected into a cooled fluidized bed, e.g., fluidized alumina pellets which are recirculated through a heat exchanger.

Fast quench rates have also been obtained in large-scale processes employing expansion through a deLaval nozzle.54

In summary, the feasibility of chemical production via the fusion torch ultimately rests on such factors as whether appropriate reaction conditions can be achieved and contamination of the products avoided. Furthermore, as discussed relative to the processing of materials (see Sec. 6-3.1), a large-volume high-dollar-value product is essential for commercial utilization. Indeed, the chemical market appears to hold this possibility.

For example, the annual production in 1972 of four major candidates for plasma synthesis—acetylene, fluorocarbons, chlorocarbons, and ammonia—represented a market value of $3 billion and consumed \(10^{11}\) kwh of power.57,71 In contrast, the electrical generating capacity in the United States was \(1.5 \times 10^{12}\) kwh, which at 6 mill/kwh represents $9 billion.

6-3-2.5 Photolysis

We now turn to a second unique approach to chemical production suggested by the fusion-torch concept: photolysis using uv radiation. Because of the lack of strong uv sources, research on uv photolysis (<2000 Å) has thus far been quite limited. However, in Table 6.9 we briefly consider the reactions that seem likely candidates77 for large-scale processes.

*Otherwise, valuable products may be lost via side reactions or reverse reactions.

<table>
<thead>
<tr>
<th>Product</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H₂O → H₂ + O₂</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>CO₂ + H₂O → H₂CO + O₂</td>
</tr>
<tr>
<td>Carbon suboxide</td>
<td>6CO → 2C₃O₂ + O₂</td>
</tr>
<tr>
<td>Ozone</td>
<td>3O₂ → 2O₃</td>
</tr>
</tbody>
</table>

Because of the potential importance of hydrogen as a basic form for energy transport in the future (the so-called hydrogen economy78–84), the photolysis of water is a key reaction.* Preliminary experiments have produced H₂ and H₂O₂ by the photolysis of water vapor (at 200 to 350°C and 1.3 to 28 Torr) using a 1849-Å source85; however, as is shown in Table 6.10, other reactions are theoretically possible. Hydrogen has also been obtained in other studies which used an additional catalyst.8 It is not clear, however, that this technique can compete economically with conventional electrolysis or with various thermal decomposition methods such as the Mark cycles developed by DeBeni and Marchetti.79

Several recent studies86,87 have specifically considered the fusion-torch photolysis method for hydrogen in a preliminary fashion. If 1849-Å photons are produced by injecting aluminum into the torch plasma (cf., Fig. 6.4), the maximum conversion efficiency is \(-14\%\). Another approach would be to inject neutral deuterium gas into the torch to produce 1215-Å Lyman-α radiation88; this offers a theoretical efficiency about three times higher. It is not clear, however, how close a practical process can approach these limits, one of the major uncertainties being whether or not the product hydrogen can be separated out quickly enough to prevent recombination.

*Alternatively, a fusion reactor could be used as the primary energy source for electrolysis or thermal processes, but here we are primarily concerned with direct photolysis. Axtmann and Fish86,87 have also noted two “hybrid” approaches: First, water vapor might be injected directly into the exhaust plasma to achieve photolysis; second, photons from the plasma torch could be used to illuminate semiconductor electrodes in unconventional electrolysis cells.

The maximum quantum efficiency (molecules H₂ produced per photon absorbed) for H₂O decomposition at this wavelength is \(-0.4\).85
To the Frones of the United States of Central Europe
The Fusion Torch

3.2.1 The Fusion Torch

3.2.1 Operation of a plasma torch system

<table>
<thead>
<tr>
<th>Process</th>
<th>Physical</th>
<th>Vaporation</th>
<th>Condensation</th>
<th>Distillation</th>
<th>Ionization</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000</td>
<td>2000</td>
<td>1000</td>
<td>500</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>6000</td>
<td>7000</td>
<td>6000</td>
<td>5000</td>
<td>4000</td>
<td>3000</td>
</tr>
<tr>
<td>8000</td>
<td>9000</td>
<td>9000</td>
<td>8000</td>
<td>7000</td>
<td>6000</td>
</tr>
</tbody>
</table>

Figure 3.21: Operation of a plasma torch system

The Fusion Torch
Constitution of a Fusion Reactor System

The reaction of primordial fusion could not be contained by physical confinement. The plasma contained within a chamber, subject to intense pressure and temperature, could be contained and controlled to achieve a sustained reaction. The confinement of the plasma is essential for a sustained reaction.

1. The plasma within the chamber must be confined to prevent it from escaping.
2. The plasma must be heated to a temperature high enough to initiate fusion reactions.
3. The plasma must be sustained, meaning it must be kept in a state of sustained reaction.

4. The plasma must be cooled to prevent overheating and damage to the reactor components.

The Fusion Torch
The Fusion Torch

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The Fusion Torch
The history of the Earth is closely related to its environment and the processes that have shaped life on our planet. Over billions of years, the Earth has undergone significant changes, from the formation of the continents to the emergence of complex life forms. These changes have been driven by a variety of factors, including changes in climate, the composition of the atmosphere, and the availability of resources. Understanding these processes is crucial for predicting future changes and developing strategies to preserve the Earth's environment.

Environmental Interrelationships

6.1 Environmental Interrelationships

![Diagram showing environmental changes over time]
The reason for the increase in demand for environmental information is the increasing awareness of the environmental impacts of human activities. The burgeoning concern for the environment has led to a growing demand for information on environmental issues. This demand is driven by a variety of factors, including environmental regulations, public pressure, and the desire for sustainable development. The provision of environmental information is crucial for informing decision-making processes, both at the individual and policy-making levels. It enables stakeholders to make informed choices that can help mitigate the negative impacts of human activities on the environment.
Environmental Interrelationships

Figure 6.1: Distribution of world energy resources, wealth and population. (From: J o e n , 1979.)
TABLE 6.18

DETECTION OF WORLD RESOURCES OF COMMERCIAL

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Uranium</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Copper</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Nickel</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Tin</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Silver</td>
<td>1,000</td>
<td>1,400</td>
<td>1,800</td>
<td>2,200</td>
<td>2,600</td>
<td>3,000</td>
<td>3,400</td>
</tr>
</tbody>
</table>

The chart on the right illustrates the relationship between food supply and population growth. The curve shows the potential food production over time, with the x-axis representing years and the y-axis representing hectares of arable land. The curve peaks around 2050, indicating a potential food production crisis.
Environmental Interrelationships

6.1

The problem of the planet can only be solved if

decentralized resources are organized effectively and
economically.

1. The problems that man has created are not simply those

of population pressure, land use, air and water pollution,

but also include the rational utilization of human

resources and the growth and development of society.

2. The problems of the planet require the collaboration of

all nations and the sharing of responsibilities and

resources.

3. The political, economic, and social changes that have

occurred in recent years have led to the growth of
civilization and the development of new technologies.

4. The problems that the planet is facing cannot be

solved without the cooperation of all nations.

5. The problems that the planet is facing are not only

environmental, but also social and economic.

6. The problems that the planet is facing can only be

solved if all nations cooperate and work together.

7. The problems that the planet is facing cannot be

solved without the help of the international community.

8. The problems that the planet is facing can only be

solved if all nations work together.

9. The problems that the planet is facing are too

complex to be solved by any one nation alone.

10. The problems that the planet is facing require the

cooperation of all nations and the sharing of

resources and responsibilities.

11. The problems that the planet is facing can only be

solved if all nations work together.