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# Research on Fire Rope Rescue Training System Based on IRATA and CMC Rope Rescue Techniques

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**ABSTRACT**
Rope rescue occupies a certain proportion in the fire emergency rescue. However, in China, rope rescue technique has a relatively later start. And technical rescue training is still in the stage of exploration. Therefore, it is particularly important to carry out systematic and professional rope rescue training to train rope rescue technicians for fire rescue teams, establish a rope rescue training system suitable for China fire service. This paper, through analysing the two major rope technical training systems of IRATA and CMC, comparing their respective characteristics, systematically analysing the suitable course content for the trainees, combining with the characteristics of fire rope rescue in China, this paper proposes to construct a fire rope rescue training system which contains three-level training courses for elementary, middle, and senior levels. At the same time, it puts forward suggestions on the normalized training of rope rescue in the fire station and the introduction and learning of the latest techniques for the reference of the fire rescue team.

***Keywords:*** *fire service; technical rescue; rope rescue; training system*

## 1. INTRODUCTION

Rope rescue technique is one of the important rescue methods in high-altitude rescue, water rescue, flood rescue, earthquake rescue, mountain rescue and other emergency rescue operations. At present, the widely used rope rescue technique in the world mainly includes the European rope rescue technique system based on industrial rope operation techniques such as IRATA and the North American rope rescue technique system represented by CMC[1]. In recent years, the Chinese fire rescue teams have gradually realized the necessity of rope rescue and invited domestic and foreign rope rescue experts to conduct training, which has achieved certain results. There are also related scholars who have done a lot of researches on the technique, safety and popularity of rope rescue from different angles. Chen S.F pointed out that the rope rescue courses are the core of the fire rescue team, and the teaching objectives, teaching content, course assessment and other aspects have been systematically optimized, so that the students have the ability to obtain the corresponding professional certificate after completing the course[2]. J. Peter made a questionnaire survey involving rope rescue safety issues, it was shown that the equipment in rope rescue should meet the corresponding standards and specifications[3]. Through the analysis of the fire brigade's rope rescue training situation, Zhou X.Y. concluded that the fire rope rescue training lacks of professional training, and it is proposed to strengthen the construction of rope rescue training mode[4]. Lin J. analysed the rope rescue training in Europe and the United States, and proposed that the fire rope rescue training should be systematic and professional, and avoid mixing other rescue courses[5]. The Fire Command Department of the Chinese Armed Police Force Academy cooperated with the American CMC Rope Rescue School to introduce CMC rope rescue techniques into the classroom and achieved certain results[6]. In NFPA 1006, the National Fire Protection Association points out that the first-level technical rescue personnel or the second-level technical rescue personnel need to receive 13 rescue training subjects to meet the requirements, one of which is rope rescue. In Chapter 5 of the standard, the equipment, personnel composition and training time of rope rescue are requested clearly[7].

The use of ropes in foreign countries has been relatively extensive. Corresponding rope rescue training systems have been designed for different occupations and tasks. The training system is relatively mature, the training

 

purpose is clear, and the training stages are accurately divided, which conform to the physical and psychological growth characteristics of the participants. The development of domestic rope rescue training is later than that of foreign countries. Many training systems have been introduced from abroad. However, because the composition of firefighting teams in China is different from that of foreign countries, there are some adaptability problems in the practical application of foreign training systems, and firefighting teams are also continuously improving the introduced training system to meet the needs of domestic development, but at this stage, with the continuous advancement of professionalization, we need to further explore the rope rescue training system of domestic firefighting teams to improve the firefighting team's rope rescue application ability and enhance the team's combat effectiveness.

## 2. ANALYSIS OF THE STATUS QUO OF IRATA AND CMC ROPE RESCUE TECHNIQUE TRAINING SYSTEM

### *2.1. Overview of the two training systems*

#### *2.1.1. IRATA rope technique training system*

IRATA International Industrial Rope Technical Operation Association is the largest organization in the world for industrial rope technique, covering a wide range, mainly for technical training for industrial aerial workers and outdoor enthusiasts. The ratio of the training course instructors to participants is generally 2:8 or 1:6. The IRATA rope technique training course is divided into three levels, corresponding to the three levels of the first level technician, the second-level technician, and the third-level technician.

#### *2.1.2. CMC rope rescue technique training system*

CMC rope rescue technique follows the rope rescue technical standards of NFPA. It is a relatively mature and advanced rope rescue technique in the United States. The rescue scenarios used include high-altitude rescue, mountain rescue, confined space rescue, water rescue etc. The CMC Rescue School provides public enrolment courses around the world. The ratio of the training course instructors to participants is generally 1:5. These intensive teaching courses include rope rescue, confined space rescue, trench rescue etc. CMC school can also teach customized contract courses on site to meet the specific needs of trainees.

### *2.2. Analysis of technique points*

#### *2.2.1. Rope knots and anchor points technique*

As a basic skill, rope knotting technique plays an important role in rope rescue. It can connect ropes to ropes, or connect fixed ropes to anchor points. IRATA rope technique training is highly dependent on the combined usage of equipments, and uses less knots. Basic knots such as figure eight knots and butterfly knots are common. In CMC rope rescue training, the knots include basic knots, binding knots and connecting knots. Combining the principles of systematic and actual combat training, the learning of rope knotting technique can be divided into two stages, that is, first concentrate on teaching basic knots, binding types, and connecting basic knots, and then teaching special knots during the construction of each training scene, so as to highlight the applicability of knots.

In the establishment of anchor points, IRATA rope technique uses more shaped anchor point belts, which is convenient to operate. CMC rope rescue technique will explain the use of flat belts to make anchor points, focusing on the basic knowledge. Both systems regard the establishment of anchor points as the key technique.

#### *2.2.2. Individual and team skills*

Rope rescue is a team operation. Every rescuer has his or her role positioning and task division. At the same time, in their respective positions, rescuers need to have solid personal operation skills to ensure a safe and effective rescue. Rope rescue technique will be affected by equipments. IRATA rope technique training focuses on the individual's ability to operate equipment and has strict personal technical requirements for operators. The typical equipments are self-locking descent control device and fall arrester etc. In CMC rope rescue technique training, the difficulty of the technique for the trainee will be reduced, and more attention will be paid to the basic skills. The typical equipments are the figure 8 descender and the Prusik knot etc. Relatively speaking, CMC 's teamwork awareness is more obvious, and IRATA 's personal skill operation ability is stronger.

#### *2.2.3. Training site*

The IRATA training system is derived from industrial operations, and the training site continue the consistent industrial framework. Its training mode has been standardized. The CMC training system has no fixed site mode. Floors, mountains and other sites are selected for implementation according to the needs of trainees. Relatively speaking, the CMC training system will be more in line with the China firefighting team's rescue concept of "full disaster, major emergency".

### 2.3. Analysis of training process

#### 2.3.1. Training Course Level Setting

The IRATA and CMC training systems are divided into three levels, and the difficulty of rope skills increases step by step. IRATA training has stricter requirements for equipments. The first-level course focuses on personal rope work, the second-level course focuses on personal rescue on the rope, and the third-level course will add some typical scenarios of system construction based on personal skills. The training time of each level course is 5 days for skill operation and 1 day for assessment. CMC training equipments are more flexible and changeable. The first and second level courses focus on basic skills such as knotting and anchoring, lifting and descending, and rescue system construction. The third level will increase the difficulty. Some personal rope skills and complex systems' building will be added in different scenarios, the training time of each level is 40 hours.

Rope rescue technique training for firefighters should be combined with their professional characteristics. First, firefighters must be aware of the safety issues of rope rescue operations, master the self-rescue skills and basic rescue skills such as descending the trapped people from high places and lifting from low places. On this basis, firefighters continue to learn some typical rescue skills to deal with most rope rescue scenes and some special scenes to deal with complex rescue finally.

#### 2.3.2. Technical level promotion

For each level of IRATA training system, the trainees need to obtain a certificate of the previous level for one year and work visa for 1,000 hours. At the same time, the trainees must participate in the training of the next level within the validity period of the certificate for three years and pass the assessment finally. The CMC training system only needs to obtain the training qualification of the previous level for the promotion of the level.

Rope rescue is complex and flexible. The promotion of technical level should require time accumulation, that is, work experience. In China's daily firefighting training, rope rescue training is indispensable, and it is also useful in firefighting rescue. Firefighters who have participated in rope rescue training have accumulated experience in daily firefighting work. Therefore, the level promotion conditions for rope rescue training can be relatively simple, that is, obtain the qualification and work in the fire station for one year as the conditions for participating in the upper-level training.

## 3. PRINCIPLES OF BUILDING A ROPE RESCUE TRAINING SYSTEM

### 3.1. Safety principle

Most rope rescues are carried out in harsh environments such as high altitude, mountains, and water. The safety is particularly important during this process. The safety assessment of rope work is mainly based on three aspects. The first is Heinrich's accident causal chain theory on eliminating the unsafe conditions of the on-site environment, equipment, as well as preventing unsafe behaviors such as technical concepts and safety awareness. It is the fundamental way to prevent accidents. The second is double ropes and double points. It is also known as the scissor principle, it means that the operator on the rope must have two ropes and two points connected for safety. The third is the sudden death principle, that is, the movable components of the rope system must have the ability of self-lock, and the operator accidentally drops his hands or makes mistake, the system cannot collapse and fail, and personnel cannot cause large uncontrollable displacement.

### 3.2. Modularity principle

According to the key technique of rope rescue, interrelated and independent training modules are set up, and each knowledge point is structured to decompose larger and complex problems into several smaller simple problems, so that the entire rope rescue technique is very structured. And it is clear and easy to understand. It cannot only decompose the overall training task or goal into one piece of specific goals and specific tasks in space, but also decompose the long-term goal into one paragraph after another of specific goals and specific tasks in time. The decomposition of rope rescue technique training goals should be applied first, from basic to operation, and then from single to overall planning, so as to realize the operability of training.

### 3.3. Forward-looking principle

Forward-looking can also be understood as foresight. It is important to fully understand the systematic, procedural, and long-term characteristics of rope rescue technique training, and look at technical training from the perspective of development. At the same time, the technical concept of rope rescue will change with the function of the equipment and with different scenarios. During technical training, the applicable scenarios and equipment used must be accurately analysed and judged to cope with complex and changeable rescue scenes. .

### 3.4. Effectiveness principle

Rope rescue training is not a traditional teaching activity. It permeates every link in the training. Whether it

can be operated or implemented, it is very important, otherwise it is worthless. Whether the technique can be demonstrated and whether the goal can be implemented is based on the current environment, combined with their own conditions, and the trainees will do what, when, where, who, and how in the work now and in the future. In other words, the rope rescue training program is a series of specific, clear, direct, and interrelated instructions for the action plan. Once implemented, each trainee can clarify his own goals, tasks, responsibilities, accomplishments, ways and methods of tasks, and know how to collaborate with other peers to ensure the achievement of goals and tasks.

## 4. ESTABLISHMENT OF THE FIRE ROPE RESCUE TRAINING SYSTEM

### *4.1. Primary rope rescue training*

#### *4.1.1. Capability Positioning*

Primary rope rescue training is mainly to enable ordinary firefighters or newly recruited firefighters to master the basic rope rescue techniques, so as to obtain the qualification for high-altitude rope operation, and know how to carry out rope rescue work in operations. Firefighters who have participated in the primary rope rescue technique training will be awarded a primary certificate after passing the training. They mainly work in ordinary fire stations and can realize self-rescue and escape in fire-fighting and rescue, as well as the lowering and lifting in the simple scenes, and can assist intermediate technicians in rope rescue work.

#### *4.1.2. Training content*

The primary training time is four days, plus one day for assessment, 8 hours a day, mainly for new recruits or firefighters who have not systematically learned rope rescue. In order to ensure the quality of teaching, the ratio of instructors to trainees strictly follows 1:5. The training content design of the primary rope rescue technique courses are shown in Table 1.

**Table 1** Primary training content

| Training module | Specific contents |
|---|---|
| Theoretical study | Safety principles, basic knowledge of fall prevention, rope terminology |
| Equipment awareness | Fall prevention equipment (helmet, webbing, metal) |
| Knot technique | Basic knots, binding knots, connection knots |
| Anchor point | Simple anchor for webbing |
| Descend and hover | The self-locking descent control device descends, the figure-eight device descends, and the caribiner descends |
| Lifting system | Simple mechanical advantage system establishment and reset |
| Lowering system | Lowering of the figure-eight device, self-locking descent control device. locking and unlocking of the system |
| Protection System | Double Prusik knots protection system, Fall arrester protection system |
| Low angle rescue | Patient Tie-in system, Litter Set-up, and the gentle slope rescue operation. |

#### *4.1.3. Assessment standards*

Training assessment should be divided into two parts: theory exam and practical assessment, two parts must be passed, and one failure is regarded as failure of the assessment. The theory exam accounts for 20% of the entire assessment, and 15 points must be achieved to pass the theory. Practical operation assessment accounted for 80%, with a total of seven assessment contents. Errors in prohibited or mandatory items and errors in operating procedures are judged to be failed. There is no time limit for operation, and the examiner judges that the operation time is obviously exceeded. Trainee passes the training assessment and obtains the primary training qualification certificate. The certificate is valid for three years. Firefighters can participate in the intermediate rope training after one year of work in fire station. If firefighters cannot be promoted within three years, they need to take the training assessment again . The assessment consists of two independent examiners who have obtained intermediate qualification certificates.

### *4.2. Intermediate rope rescue training*

#### *4.2.1. Capability Positioning*

Intermediate rope rescue training is mainly to enable firefighters to master a higher level of personal rope rescue skills while consolidating their basic skills, so that they can directly participate in rope rescues in various environments and know how to carry out rescue work in rope rescue. Firefighters who participate in the intermediate rope rescue technique training will be issued intermediate certificates after passing the training. They are mainly the operators of the rope rescue team or the

rope technicians of the special team member of the ordinary fire station. They are responsible for high-altitude, confined space, water, mountain and other relatively difficult scenes. Intermediate rescue technician can participate in the development of primary rope rescue training and assessment, and can assist senior rope rescue technician in intermediate rope rescue training.

### *4.2.2. Training content*

Intermediate rope rescue training lasts for five days, of which one day is to revisit the technique of primary training, plus one day for assessment time. The ratio of instructors to participants is 1:4 . The training adopts small class teaching, the instructor explains and demonstrates, the group conducts exercises, and the instructor finds mistakes and gives guidance in time. The training content design of the intermediate rope rescue technique courses are shown in Table 2.

**Table 2** Intermediate training content

| Training module | Specific contents |
|---|---|
| Theoretical study | Awareness of fall prevention equipment standards and risk management |
| Knot technique | Special knots for typical rescue scenarios |
| Anchor point | Anchor system and force analysis |
| Rise and fall | Handled rope clamp, foot loop and self-locking descent control device cooperate with each other to rise and fall along the rope; Through knots during ascent and descent |
| System conversion technique | Conversion between lowering and lifting system, lowering and lifting through knots |
| Mechanical advantage system | Complex system, complex and equipped lifting system |
| Hook rescue | Lowering to save patient, rappelling to save patient |
| Litter rescue operation | Litter accompanying, litter horizontal transportation, litter vertical transportation |

### *4.2.3. Assessment standards*

Training assessment should be divided into two parts: theory exam and practical assessment, two parts must be passed, and one failure is regarded as failure of the assessment. The theory test accounts for 20% of the entire assessment, and 15 points must be achieved to pass the theory. Practical operation assessment accounted for 80%, with a total of eight assessment contents. Errors in prohibited or required items and errors in operating procedures are judged to be failed. There is no time limit for operation, and the examiner judges that the operation time is obviously exceeded. Trainee passes the training assessment and obtains the primary training qualification certificate. The certificate is valid for three years. Firefighters can participate in the advanced rope rescue technique training after one year of work in rope rescue team or the rope technicians of the special team member of the ordinary fire station. The assessment is determined by two independent examiners based on the operating time, technique proficiency and performance of the trainees.

## ***4.3. Advanced rope rescue training***

### *4.3.1. Capability Positioning*

The advanced training courses aim to cultivate more high-level talents for rope rescue teams, which will help promote the development of rope rescue technique for firefighting teams and promote the construction of rope rescue teams in China. Senior rope rescue technicians will obtain the corresponding advanced training certificate after passing the assessment. They are mainly engaged in the command position of the rope rescue scene and act as the commander in the rescue. They can coordinate and command the team to perform on-site rescue. In the fire station, they lead the rope rescue team, train and cultivate the team's ability. They can also engage in the research of rope rescue technique, acting as the main force in rope rescue training, in primary and intermediate training as the chief instructor.

### *4.3.2. Training content*

The study time for advanced rope rescue training is six days, of which one day is to revisit the basic and intermediate skills, plus two days of assessment time. The ratio of examiners to participants is 1:4 . The training can be mainly explained by the instructor, the trainees perform operations, and the team conducts exercises. The trainees can take turns to act as the team commander to cultivate the commanding ability of the trainees. The situational rescue setting could be flexible for applying rescue techniques. The training content design of the advanced rope rescue technique course is shown in Table 3 .

**Table 3** Advanced training content

| Training module | Specific contents |
|---|---|
| Theoretical study | Team command, rescue plan formulation, selection and construction of rescue system |
| Rescue team | Basic task division, mobile communication, rescue environment risk assessment |
| Anchor system | Front anchor system, rear anchor system, emergency anchor system, offset anchor system |
| High fixed point | Simple high anchor points (A-frame, right-angle frame), assembling and use of rescue tripod |
| Large-span rescue | Construction of rescue systems for large spaces and multi-layer obstacle scenes such as mountains and floors |
| Cableway rescue | Construction of horizontal rescue and T-shaped rescue system |

### *4.3.3. Assessment Standard*

The advanced assessment also adopts theory exam and practical assessment, both of which must be passed, and one failure is regarded as failure of the assessment. The theory test accounts for 20% of the training assessment, and it must be 15 points to be considered as a theory pass. The theory test not only tests everything learned during advanced training, but should be the theory of the entire rope rescue system. The actual operation assessment uses situational rescue for assessment, mainly to assess the temporary response ability, on-site rescue command ability of the trainees etc. It depends on the efficiency and the applicability of the whole rescue system. The examiner should have an advanced certificate of three years or more and at least three members. The total score of the assessment is composed of the average score of the examiner and the theoretical score. After passing the training assessment, an advanced training certificate is obtained and can be used as an advanced rope rescue technician.

## 5. CONCLUSION

Fire rope rescue training should focus on the training of rope rescue technicians. Through the design of the course content, assessment form, level promotion, and allowable scope of work, determining the primary, intermediate, and advanced training courses, corresponding to the primary, intermediate, and advanced rope rescue technicians respectively, the development of rope rescue will be more and more professional.

Fire rope rescue technique is a complex, diverse, and highly professional rescue skill. Firefighters not only need to participate in systematic training, but also need to maintain daily rope rescue training in the fire station to better master rescue skills. The fire station should normalize the rope rescue training based on the rope rescue equipments and scenes in the station. Rope rescue training should be carried out once or twice a week. Junior technicians should participate in rope rescue training at least once a week. Intermediate or senior technicians should participate in rope rescue training appropriately. The fire station can also set up rescue scenes and carry out rope rescue training based on the characteristics of the jurisdiction of the fire station.

The establishment of a firefighting rope rescue training system can standardize firefighters' rope rescue skills, reduce accidental injuries of firefighters, improve the construction of firefighting rope rescue professional teams, and promote the development of the teams scientifically and systematically, so as to ensure the rescue efficiency and capability of firefighting and rescue operations.

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